

KARPAGAM ACADEMY OF HIGHER EDUCATION (Deemed to be University) (Established Under Section of UGC Act 1956) Coimbatore-641 021 For the Candidates admitted from 2016 Onwards DEPARTMENT OF CHEMISTRY

SUBJECT	:INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE				
SEMESTER	:V				
SUBJECT CODE	:16CHU503A	CLASS	: III B.Sc Chemistry		

Course Objectives

The course enables the students to

- 1. Understand about the different types of silicate materials like glass, ceramics and cement and their industrial importance.
- 2. Understand the different types of fertilizers and surface coatings and their industrial importance.
- 3. Understand about the different types of batteries and their industrial importance.
- 4. Understand about the types of catalysts and their industrial importance.
- 5. Understand about the types of explosives and their industrial importance.

Course Outcome

The students able to describe

- 1. The different types of silicate materials like glass, ceramics and cement and their industrial importance.
- 2. The different types of fertilizers and surface coatings and their industrial importance.
- 3. The different types of batteries and their industrial importance.
- 4. About the types of catalysts and their industrial importance.
- 5. Analyse the types of explosives and their industrial importance.

UNIT I

Silicate Industries

Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

Ceramics: Brief introduction to types of ceramics. Superconducting and semiconducting oxides, fullerenes, carbon nanotubes and carbon fibre.

Cements: Manufacture of cement and the setting process, quick setting cements.

UNIT II

Fertilizers:

Different types of fertilizers (N, P and K). Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates, and superphosphate of lime.

Surface Coatings:

Brief introduction to and classification of surface coatings. Paints and pigments - formulation, composition and related properties. Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, Metallic coatings (electrolytic and electroless), metal spraying and anodizing.

UNIT III

Batteries:

Working of the following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

UNIT IV

Catalysis:

General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrial applications, Deactivation or regeneration of catalysts. Application of zeolites as catalysts.

UNIT V

Chemical explosives:

Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX).Introduction to rocket propellants.

Suggested Readings:

Text Books:

- 1. Stocchi, E. (1990). Industrial Chemistry, Vol I. Ellis Horwood Ltd., UK.
- 2. Felder, R. M. & Rousseau, R.W. (2005). *Elementary Principles of Chemical Processes*. Wiley Publishers, New Delhi.
- 3. Kent, J. A. (1997). *Riegel's Handbook of Industrial Chemistry* (XI Edition). CBS Publishers, New Delhi.

Reference Books:

- 1. Jain, P. C. and Jain, M. (2015). *Engineering Chemistry*. Dhanpat Rai & Sons, New Delhi.
- 2. Gopalan, R., Venkappayya, D. & Nagarajan, S. (2010). *Engineering Chemistr* (I Edition). Vikas Publications, New Delhi.
- 3. Sharma, B. K. (2012). *Engineering Chemistry* (VI Edition). Goel Publishing House, Meerut.

WEBSITES

https://chem..libretexts.org https://study.com> academy pubs.rsc.org



KARPAGAM ACADEMY OF HIGHER EDUCATION (Deemed to be University) (Established Under Section of UGC Act 1956) Coimbatore-641 021 For the Candidates admitted from 2016 Onwards **DEPARTMENT OF CHEMISTRY**

SUBJECT :INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE SEMESTER :V **SUBJECT CODE** :16CHU503A CLASS : III B.Sc Chemistry ____

LECTURE PLAN

DEPARTMENT OF CHEMISTRY

S.No	Lecture Duration	Topics to be covered	Support Material/Page Nos
	Period	UNITI	
1	1	Glass:Glassy state and its properties, classification (silicate and non-silicate glasses)	T1:701-702
2	1	Manufacture and processing of glass	T2:702-703
3	1	Composition and properties of soda lime glass	T2:703-705
4	1	Composition and properties of lead glass	T2:703-705
5	1	Composition and properties of armoured, safety glass and borosilicate glass	T2:703-705
6	1	Composition and properties of flurorsilicate, coloured glass, photosensitive glass	T2:703-705
7	1	Brief introduction to types of ceramics. Superconducting oxides	T1:702-703
8	1	Fullerenes, carbon nanotubes and carbon fibre	T1:705-706
9	1	Manufacture of cement and the setting process	T2:10.1-10.2
10	1	Quick setting cements	T2:10.15-10.16
11	1	Revision and discussion of question papers	
	Total No of	hours planned for Unit I-11	

LECTURE PLAN

		UNIT-II	
1	1	Different types of fertilizers (N, P and K)	T1:116-117
2	1	Manufacture of urea, ammonium nitrate	W1
3	1	Manufacture of calcium ammonium nitrate, ammonium phosphates	W2
4	1	Manufacture of superphosphate of lime	T2:347-350
5	1	Brief introduction and classification of surface coatings	T2:347-350
6	1	Paints and pigments	T2:347-348
7	1	Formulation, composition and related properties of paints	T2:369-370
8	1	Fillers, thinners, enamels, emulsifying agents	T2:366-369
9	1	Special paints, dyes, wax polishing	T2:374-375
10	1	Water and oil paints, metallic coatings	T2:347-351
11	1	Metal spraying and anodizing	T2:355
12	1	Revision and discussion of question papers	
	Total No of	hours planned for Unit II-12	
		UNIT-III	
1	1	Working of lead acid battery	T1:5.3-5.4
2	1	Working of lithium battery	T1:5.8-5.10
3	1	Working of solid state electrolyte battery	T1:5.8-5.12
4	1	Fuel cells	T1:5.12-5.14
5	1	Solar cell	T2:657-658
6	1	Polymer cell	T2:659-661
7	1	Revision and discussion of question papers	
	Total No of	hours planned for Unit III-7	
		UNIT-IV	
1	1	General principles and properties of catalysts	W1

LECTURE PLAN

2	1	Homogeneous catalysis(catalytic steps)	W2
3	1	Heterogeneous catalysis(catalytic steps)	W2
4	1	Industrial applications of homogeneous catalysis and heterogeneous catalysis	W3
5	1	Deactivation or regeneration of catalysis	T1:21-22
6	1	Application of zeolites aa catalysts	T1:17-19
7	1	Application of zeolites aa catalysts	T1:17-19
8	1	Revision and discussion of question papers	
	Total No of	hours planned for Unit IV-8	
		UNIT-V	
1	1	Origin of explosive properties in organic compounds	T1:733-734
2	1	Preparation and explosive properties of lead azide	T1:739
3	1	Preparation and explosive properties of PETN	T1:740
4	1	Preparation and explosive properties of cyclonite(RDX)	T2:740
5	1	Preparation and explosive properties of cyclonite(RDX)	T2:740
6	1	Introduction to rocket propellants	T2:740-743
7	1	Revision and discussion of question papers	
8	1	ESE question paper discussion	
9	1	ESE question paper discussion	
10	1	ESE question paper discussion	
	Total No of	hours planned for Unit V-10	
Total planned hours	48		

SUGGESTED READINGS:

1. Jain, P.C and Jain, M. (2015), Engineering Chemistry, Delhi: Dhanpat Rai & Sons.

2. Gopalan, R., Venkappayya, D. and Nagarajan, S.(2010). *Engineering chemistry*,New Delhi: Vikas Publications

3.B.K.Sharma, (2012), 6th Edition, *Engineering Chemistry*, Krishna Prakashan Media (P) Ltd. **WEBSITES:**

1.https://chem..libretexts.org
2.https://study.com> academy
3.pubs.rsc.org



CLASS:III B.Sc CHEMISTRY

COURSE NAME:INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

COURSE CODE:16CHU503A

UNIT:I(Silicate Industries) BATCH

BATCH:2016-2019

<u>UNIT I</u>

SYLLABUS

Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

Ceramics: Brief introduction to types of ceramics. Superconducting and semiconducting oxides, fullerenes, carbon nanotubes and carbon fibre.

Cements: Manufacture of cement and the setting process, quick setting cements.

Silicate Industries

Glass

Glass is a non-crystalline amorphous solid that is often transparent and has widespread practical, technological, and decorative usage in, for example, window panes, tableware, and optoelectronics. The most familiar, and historically the oldest, types of glass are "silicate glasses" based on the chemical compound silica (silicon dioxide, or quartz), the primary constituent of sand. The term *glass*, in popular usage, is often used to refer only to this type of material, which is familiar from use as window glass and in glass bottles. Of the many silica-based glasses that exist, ordinary glazing and container glass is formed from a specific type called soda-lime glass, composed of approximately 75% silicon dioxide (SiO₂), sodium oxide (Na₂O) from sodium carbonate (Na₂CO₃), calcium oxide (CaO), also called lime, and several minor additives.

Many applications of silicate glasses derive from their optical transparency, giving rise to their primary use as window panes. Glass will transmit, reflect and refract light; these qualities can be enhanced by cutting and polishing to make optical lenses, prisms, fine glassware, and optical fibers for high speed data transmission by light. Glass can be coloured by adding metallic salts, and can also be painted and printed with vitreous enamels. These qualities have led to the extensive use of glass in the manufacture of art objects and in particular, stained glass windows. Although brittle, silicate glass is extremely durable, and many examples of glass fragments exist from early glass-making cultures. Because glass can be formed or moulded into any shape, it has been traditionally used for vessels: bowls, vases, bottles, jars and drinking glasses. In its most solid forms it has also been used for paperweights, marbles, and beads. When extruded as glass fiber and matted as glass wool in a way to trap air, it becomes a thermal insulating material, and



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when these glass fibers are embedded into an organic polymer plastic, they are a key structural reinforcement part of the composite material fiberglass. Some objects historically were so commonly made of silicate glass that they are simply called by the name of the material, such as drinking glasses and eyeglasses.

Scientifically, the term "glass" is often defined in a broader sense, encompassing every solid that possesses a non-crystalline (that is, amorphous) structure at the atomic scale and that exhibits a glass transition when heated towards the liquid state. Porcelains and many polymer thermoplastics familiar from everyday use are glasses. These sorts of glasses can be made of quite different kinds of materials than silica: metallic alloys, ionic melts, aqueous solutions, molecular liquids, and polymers. For many applications, like glass bottles or eyewear, polymer glasses (acrylic glass, polycarbonate or polyethylene terephthalate) are a lighter alternative than traditional glass.

Properties

Optical properties

Glass is in widespread use largely due to the production of glass compositions that are transparent to visible light. In contrast, polycrystalline materials do not generally transmit visible light. The individual crystallites may be transparent, but their facets (grain boundaries) reflect or scatter light resulting in diffuse reflection. Glass does not contain the internal subdivisions associated with grain boundaries in polycrystals and hence does not scatter light in the same manner as a polycrystalline material. The surface of a glass is often smooth since during glass formation the molecules of the supercooled liquid are not forced to dispose in rigid crystal geometries and can follow surface tension, which imposes a microscopically smooth surface. These properties, which give glass its clearness, can be retained even if glass is partially light-absorbing—i.e., colored.

Glass has the ability to refract, reflect, and transmit light following geometrical optics, without scattering it (due to the absence of grain boundaries). It is used in the manufacture of lenses and windows. Common glass has a refraction index around 1.5. This may be modified by adding low-density materials such as boron, which lowers the index of refraction (see crown glass), or increased (to as much as 1.8) with high-density materials such as (classically) lead oxide (see flint glass and lead glass), or in modern uses, less toxic oxides of zirconium, titanium, or barium. These high-index glasses (inaccurately known as "crystal" when used in glass vessels) cause more chromatic dispersion of light, and are prized for their diamond-like optical properties.

According to Fresnel equations, the reflectivity of a sheet of glass is about 4% per surface (at normal incidence in air), and the transmissivity of one element (two surfaces) is about 90%. Glass with high germaniumoxide content also finds application in optoelectronics—e.g., for light-transmitting optical fibers.





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Simple optical device: the magnifying glass

• Strand of optical glass fiber

Other properties

In the process of manufacture, silicate glass can be poured, formed, extruded and molded into forms ranging from flat sheets to highly intricate shapes. The finished product is brittle and will fracture, unless laminated or specially treated, but is extremely durable under most conditions. It erodes very slowly and can mostly withstand the action of water. It is mostly resistant to chemical attack, does not react with foods, and is an ideal material for the manufacture of containers for foodstuffs and most chemicals. Glass is also a fairly inert substance.

Corrosion

Main article: Corrosion § Corrosion of glasses

Although glass is generally corrosion-resistant and more corrosion resistant than other materials, it still can be corroded. The materials that make up a particular glass composition has an effect on how quickly the glass corrodes. A glass containing a high proportion of alkalis or alkali earths is less corrosion-resistant than other kinds of glasses.

Glass flakes have applications as anti-corrosive coating.

Strength

Glass typically has a tensile strength of 7 megapascals (1,000 psi), however theoretically it can have a strength of 17 gigapascals (2,500,000 psi) due to glass's strong chemical bonds. Several factors such as imperfections like scratches and bubblesand the glass's chemical composition impact the tensile strength of glass. Several processes such as toughening can increase the strength of glass.

Classification

Silicate glass

Ingredients

Silica (SiO_2) is a common fundamental constituent of glass. In nature, vitrification of quartz occurs when lightning strikes sand, forming hollow, branching rootlike structures called fulgurites.



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Fused quartz is a glass made from chemically-pure silica. It has excellent resistance to thermal shock, being able to survive immersion in water while red hot. However, its high melting temperature (1723 °C) and viscosity make it difficult to work with. Normally, other substances are added to simplify processing. One is sodium carbonate (Na₂CO₃, "soda"), which lowers the glass-transition temperature. The soda makes the glass water-soluble, which is usually undesirable, so lime (CaO, calcium oxide, generally obtained from limestone), some magnesium oxide (MgO) and aluminium oxide (Al₂O₃) are added to provide for a better chemical durability. The resulting glass contains about 70 to 74% silica by weight and is called a soda-lime glass. Soda-lime glasses account for about 90% of manufactured glass.

Most common glass contains other ingredients to change its properties. Lead glass or flint glass is more "brilliant" because the increased refractive index causes noticeably more specular reflection and increased optical dispersion. Adding barium also increases the refractive index. Thorium oxide gives glass a high refractive index and low dispersion and was formerly used in producing high-quality lenses, but due to its radioactivity has been replaced by lanthanum oxide in modern eyeglasses. Iron can be incorporated into glass to absorb infrared radiation, for example in heat-absorbing filters for movie projectors, while cerium(IV) oxide can be used for glass that absorbs ultraviolet wavelengths.

The following is a list of the more common types of silicate glasses and their ingredients, properties, and applications:

- **Fused quartz**, also called **fused-silica glass**, **vitreous-silica glass**: silica (SiO₂) in vitreous, or glass, form (i.e., its molecules are disordered and random, without crystalline structure). It has very low thermal expansion, is very hard, and resists high temperatures (1000–1500 °C). It is also the most resistant against weathering (caused in other glasses by alkali ions leaching out of the glass, while staining it). Fused quartz is used for high-temperature applications such as furnace tubes, lighting tubes, melting crucibles, etc.
- Soda-lime-silica glass, window glass: silica + sodium oxide (Na₂O) + lime (CaO) + magnesia (MgO) + alumina (Al₂O₃). Is transparent, easily formed and most suitable for window glass (see flat glass). It has a high thermal expansion and poor resistance to heat (500–600 °C). It is used for windows, some low-temperature incandescent light bulbs, and tableware. Container glass is a soda-lime glass that is a slight variation on flat glass, which uses more alumina and calcium, and less sodium and magnesium, which are more water-soluble. This makes it less susceptible to water erosion.
- Sodium borosilicate glass, Pyrex: silica + boron trioxide (B₂O₃) + soda (Na₂O) + alumina (Al₂O₃). Stands heat expansion much better than window glass. Used for chemical glassware, cooking glass, car head lamps, etc. Borosilicate glasses (e.g. Pyrex, Duran) have as main constituents silica and boron trioxide. They have fairly low coefficients of thermal expansion (7740 Pyrex CTE is 3.25×10^{-6} /°C as compared to about 9×10^{-6} /°C for a typical soda-lime glass), making them more dimensionally stable. The lower coefficient of thermal expansion (CTE) also makes them less subject to stress caused by thermal expansion, thus less vulnerable to cracking from thermal shock. They are commonly used for reagent bottles, optical components and household cookware.



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- Lead-oxide glass, crystal glass, lead glass: silica + lead oxide (PbO) + potassium oxide (K_2O) + soda (Na_2O) + zinc oxide (ZnO) + alumina. Because of its high density (resulting in a high electron density), it has a high refractive index, making the look of glassware more brilliant (called "crystal", though of course it is a glass and not a crystal). It also has a high elasticity, making glassware "ring". It is also more workable in the factory, but cannot stand heating very well. This kind of glass is also more fragile than other glasses and is easier to cut.
- Aluminosilicate glass: silica + alumina + lime + magnesia + barium oxide (BaO) + boric oxide (B₂O₃). Extensively used for fiberglass, used for making glass-reinforced plastics (boats, fishing rods, etc.) and for halogen bulb glass.^[11] Aluminosilicate glasses are also resistant to weathering and water erosion.
- Germanium-oxide glass: alumina + germanium dioxide (GeO₂). Extremely clear glass, used for fiber-optic waveguides in communication networks. Light loses only 5% of its intensity through 1 km of glass fiber.

Another common glass ingredient is crushed alkali glass or 'cullet' ready for recycled glass. The recycled glass saves on raw materials and energy. Impurities in the cullet can lead to product and equipment failure. Fining agents such as sodium sulfate, sodium chloride, or antimony oxide may be added to reduce the number of air bubbles in the glass mixture.^[4] Glass batch calculation is the method by which the correct raw material mixture is determined to achieve the desired glass composition.^[27]



Moldavite, a natural glass formed by meteorite impact, from Besednice, Bohemia



Tube fulgurites



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Quartz sand (silica) is the main raw material in commercial glass production



Trinitite, a glass made by the Trinity nuclear-weapon test



Lead glass a glass made by adding lead oxide to glass



A borosilicate glassguitar slide

Manufacture and processing of glass

Batch processing system (batch house)

Batch processing is one of the initial steps of the glass-making process. The batch house simply houses the raw materials in large silos (fed by truck or railcar) and holds anywhere from 1-5 days of material. Some batch systems include material processing such as raw material screening/sieve, drying, or pre-heating (i.e. cullet). Whether automated or manual, the batch house measures, assembles, mixes, and delivers the glass raw material recipe (batch) via an array of chutes, conveyors, and scales to the furnace. The batch enters the furnace at the 'dog house' or



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'batch charger'. Different glass types, colors, desired quality, raw material purity / availability, and furnace design will affect the batch recipe.

Furnace



Batch feed (doghouse) of a glass furnace

The *hot end* of a glassworks is where the molten glass is formed into glass products, beginning when the batch is fed into the furnace at a slow, controlled rate by the batch processing system (batch house). The furnaces are natural gas- or fuel oil-fired, and operate at temperatures up to 1,575 °C (2,867 °F).^[3] The temperature is limited only by the quality of the furnace's superstructure material and by the glass composition. Types of furnaces used in container glass making include 'end-port' (end-fired), 'side-port', and 'oxy-fuel'. Typically, furnace "size" is classified by metric tons per day (MTPD) production capability.

Forming process



Glass container forming

There are currently two primary methods of making glass containers: the blow & blow method for narrow-neck containers only, and the press & blow method used for jars and tapered narrowneck containers.





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Figure 1: Steps during Blow&Blow container forming process

In both methods, a stream of molten glass, at its plastic temperature (1,050-1,200 °C [1,920-2,190 °F]), is cut with a shearing blade to form a solid cylinder of glass, called a *gob*. The gob is of predetermined weight just sufficient to make a bottle. Both processes start with the gob falling, by gravity, and guided, through troughs and chutes, into the blank moulds, two halves of which are clamped shut and then sealed by the "baffle" from above.

In the **blow and blow** process, the glass is first blown through a valve in the baffle, forcing it down into the three-piece "ring mould" which is held in the "neckring arm" below the blanks, to form the "finish", [The term "finish" describes the details (such as cap sealing surface, screw threads, retaining rib for a tamper-proof cap, etc.) at the open end of the container.] The compressed air is blown through the glass, which results in hollow and partly formed container. Compressed air is then blown again at the second stage to give final shape.

Containers are made in two major stages. The first stage moulds all the details ("finish") around the opening, but the body of the container is initially made much smaller than its final size. These partly manufactured containers are called **parisons**, and quite quickly, they are blow-molded into final shape.

Referring to the mechanism, the "rings" are sealed from below by a short plunger. After the "settleblow" finishes, the plunger retracts slightly, to allow the skin that's formed to soften. "Counterblow" air then comes up through the plunger, to create the parison. The baffle rises and the blanks open. The parison is inverted in an arc to the "mould side" by the "neckring arm", which holds the parison by the "finish".

As the neckring arm reaches the end of its arc, two mould halves close around the parison. The neckring arm opens slightly to release its grip on the "finish", then reverts to the blank side. *Final blow*, applied through the "blowhead", blows the glass out, expanding into the mould, to make the final container shape.

In the **press and blow** process, the parison is formed by a long metal plunger which rises up and presses the glass out, in order to fill the ring and blank moulds. The process then continues as before, with the parison being transferred to the final-shape mould, and the glass being blown out into the mould.

The container is then picked up from the mould by the "take-out" mechanism, and held over the "deadplate", where air cooling helps cool down the still-soft glass. Finally, the bottles are swept onto a conveyor by the "push out paddles" that have air pockets to keep the bottles standing after landing on the "deadplate"; they're now ready for annealing.

Forming machines



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IS machine during bottle production

The forming machines hold and move the parts that form the container. The machine consist of basic 19 mechanisms in operation to form a bottle and generally powered by compressed air (high pressure - 3.2 bar and low pressure - 2.8 bar), the mechanisms are electronically timed to coordinate all movements of the mechanisms. The most widely used forming machine arrangement is the *individual section* machine (or IS machine). This machine has a bank of 5–20 identical sections, each of which contains one complete set of mechanisms to make containers. The sections are in a row, and the gobs feed into each section via a moving chute, called the *gob distributor*. Sections make either one, two, three or four containers simultaneously. (Referred to as *single, double, triple* and *quad* gob). In the case of multiple gobs, the *shears* cut the *gobs* simultaneously, and they fall into the blank moulds in parallel.

Internal treatment

After the forming process, some containers—particularly those intended for alcoholic spirits undergo a treatment to improve the chemical resistance of the inside, called *internal treatment* or dealkalization. This is usually accomplished through the injection of a sulfur- or fluorine-containing gas mixture into bottles at high temperatures. The gas is typically delivered to the container either in the air used in the forming process (that is, during the final blow of the container), or through a nozzle directing a stream of the gas into the mouth of the bottle after forming. The treatment renders the container more resistant to alkali extraction, which can cause increases in product pH, and in some cases container degradation.

Annealing

As glass cools, it shrinks and solidifies. Uneven cooling causes weak glass due to stress. Even cooling is achieved by annealing. An annealing oven (known in the industry as a Lehr) heats the container to about 580 °C (1,076 °F), then cools it, depending on the glass thickness, over a 20 - 60 minute period.

Cold end

The role of the *cold end* is to spray on a polyethylene coating for abrasion resistance and increased lubricity, *inspect* the containers for defects, *package* the containers for shipment, and *label* the containers.

Inspection equipment



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Glass containers are 100% inspected; automatic machines, or sometimes persons, inspect every container for a variety of faults. Typical faults include small cracks in the glass called checks and foreign inclusions called stones which are pieces of the refractory brick lining of the melting furnace that break off and fall into the pool of molten glass, or more commonly oversized silica granules (sand) that have failed to melt and which subsequently are included in the final product. These are especially important to select out due to the fact that they can impart a destructive element to the final glass product. For example, since these materials can withstand large amounts of thermal energy, they can cause the glass product to sustain thermal shock resulting in explosive destruction when heated. Other defects include bubbles in the glass called *blisters* and excessively thin walls. Another defect common in glass manufacturing is referred to as a *tear*. In the press and blow forming, if a plunger and mould are out of alignment, or heated to an incorrect temperature, the glass will stick to either item and become torn. In addition to rejecting faulty containers, inspection equipment gathers statistical information and relays it to the forming machine operators in the hot end. Computer systems collect fault information and trace it to the mould that produced the container. This is done by reading the mould number on the container, which is encoded (as a numeral, or a binary code of dots) on the container by the mould that made it. Operators carry out a range of checks manually on samples of containers, usually visual and dimensional checks.

Secondary processing

Sometimes container factories will offer services such as **labelling**. Several labelling technologies are available. Unique to glass is the *Applied Ceramic Labelling* process (ACL). This is screen-printing of the decoration onto the container with a vitreous enamel paint, which is then baked on. An example of this is the original Coca-Cola bottle. Absolut Vodka Bottles have various added services such as: Etching (Absolut Citron/) Coating (Absolut Raspberry/Ruby Red) and *Applied Ceramic Labelling* (Absolut Blue/Pears/Red/Black).

Packaging

Glass containers are packaged in various ways. Popular in Europe are bulk pallets with between 1000 and 4000 containers each. This is carried out by automatic machines (palletisers) which arrange and stack containers separated by layer sheets. Other possibilities include boxes and even hand-sewn sacks. Once packed, the new "stock units" are labelled and warehoused.

Coatings

Glass containers typically receive two surface coatings, one at the *hot end*, just before annealing and one at the *cold end* just after annealing. At the *hot end* a very thin layer of tin(IV) oxide is applied either using a safe organic compound or inorganic stannic chloride. Tin based systems are not the only ones used, although the most popular. Titanium tetrachloride or organo titanates can also be used. In all cases the coating renders the surface of the glass more adhesive to the *cold end* coating. At the *cold end* a layer of typically, polyethylene wax, is applied via a water based emulsion. This makes the glass slippery, protecting it from scratching and stopping containers from sticking together when they are moved on a conveyor. The resultant invisible combined coating gives a virtually unscratchable surface to the glass. Due to reduction of in-



service surface damage, the coatings often are described as strengtheners, however a more correct definition might be strength-retaining coatings.

Ancillary processes – compressors and cooling

Forming machines are largely powered by compressed air and a typical glass works will have several large compressors (totaling 30k–60k cfm) to provide the needed compressed air. Furnaces, compressors and forming machine generate quantities of waste heat which is generally cooled by water. Hot glass which is not used in the forming machine is diverted and this diverted glass (called *cullet*) is generally cooled by water, and sometimes even processed and crushed in a water bath arrangement. Often cooling requirements are shared over banks of cooling towers arranged to allow for backup during maintenance.

Marketing

Glass container manufacture in the developed world is a mature market business. World demand for flat glass was approximately 52 million tonnes in 2009.^[7] The United States, Europe and China account for 75% of demand, with China's consumption having increased from 20% in the early 1990s to 50%.^[7] Glass container manufacture is also a geographical business; the product is heavy and large in volume, and the major raw materials (sand, soda ash and limestone) are generally readily available, therefore production facilities need to be located close to their markets. A typical glass furnace holds hundreds of tonnes of molten glass, and so it is simply not practical to shut it down every night, or in fact in any period short of a month. Factories therefore run 24 hours a day 7 days a week. This means that there is little opportunity to either increase or decrease production rates by more than a few percent. New furnaces and forming machines cost tens of millions of dollars and require at least 18 months of planning. Given this fact, and the fact that there are usually more products than machine lines means that products are sold from stock. The marketing/production challenge is therefore to be able to predict demand both in the short 4to 12-week term and over the 24- to 48-month-long term. Factories are generally sized to service the requirements of a city; in developed countries there is usually a factory per 1-2 million people. A typical factory will produce 1–3 million containers a day. Despite its positioning as a mature market product, glass does enjoy a high level of consumer acceptance and is perceived as a "premium" quality packaging format.

Composition and properties of the following glasses

Soda lime glass

Soda–lime glass, also called **soda–lime–silica glass**, is the most prevalent type of glass, used for windowpanes and glass containers (bottles and jars) for beverages, food, and some commodity items. Glass bakeware is often made of tempered soda–lime glass.^[1] Soda–lime glass accounts for about 90% of manufactured glass.

Soda–lime glass is relatively inexpensive, chemically stable, reasonably hard, and extremely workable. Because it can be resoftened and remelted numerous times, it is ideal for glass recycling.^[2]



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Soda–lime glass is prepared by melting the raw materials, such as sodium carbonate (Na₂CO₃), lime (Ca(OH)₂), dolomite (CaMg(CO₃)₂), silicon dioxide (silica, SiO₂), aluminium oxide (alumina, Al₂O₃), and small quantities of fining agents (e.g., sodium sulfate (Na₂SO₄), sodium chloride (NaCl), etc.) in a glass furnace at temperatures locally up to 1675 °C. The temperature is only limited by the quality of the furnace superstructure material and by the glass composition. Relatively inexpensive minerals such as trona, sand, and feldspar are usually used instead of pure chemicals. Green and brown bottles are obtained from raw materials containing iron oxide. The mix of raw materials is termed batch.

Soda–lime glass is divided technically into glass used for windows, called flat glass, and glass for containers, called container glass. The two types differ in the application, production method (float process for windows, blowing and pressing for containers), and chemical composition. Flat glass has a higher magnesium oxide and sodium oxidecontent than container glass, and a lower silica, calcium oxide, and aluminium oxide content. From the lower content of highly water-soluble ions (sodium and magnesium) in container glass comes its slightly higher chemical durability against water, which is required especially for storage of beverages and food.

Lead glass

Lead glass, commonly called **crystal**, is a variety of glass in which lead replaces the calcium content of a typical potash glass. Lead glass contains typically 18–40% (by weight) lead(II) oxide (PbO), while modern **lead crystal**, historically also known as flint glass due to the original silica source, contains a minimum of 24% PbO. Lead glass is desirable owing to its decorative properties.

Originally discovered by Englishman George Ravenscroft in 1674, the technique of adding lead oxide (in quantities of between 10 and 30%) improved the appearance of the glass and made it easier to melt using sea-coal as a furnace fuel. This technique also increased the "working period" making the glass easier to manipulate.

The term *lead crystal* is, by technicality, not an accurate term to describe *lead glass*, as glass, an amorphous solid, lacks a crystalline structure. The use of the term *lead crystal* remains popular for historical and commercial reasons. It is retained from the Venetian word *cristallo* to describe the rock crystal imitated by Murano glassmakers. This naming convention has been maintained to the present day to describe decorative hollow-ware.

Lead crystal glassware was formerly used to store and serve drinks, but due to the potential health risks of lead, this has become rare. One alternative material is **crystal glass**, in which barium oxide, zinc oxide, or potassium oxide are employed instead of lead oxide. Lead-free crystal has a similar refractive index to lead crystal, but it is lighter and it has less dispersive power.

In the European Union, labeling of "crystal" products is regulated by Council Directive 69/493/EEC, which defines four categories, depending on the chemical composition and properties of the material. Only glass products containing at least 24% of lead oxide may be



referred to as "lead crystal". Products with less lead oxide, or glass products with other metal oxides used in place of lead oxide, must be labeled "crystallin" or "crystal glass".

Safety glass

Safety glass is glass with additional safety features that make it less likely to break, or less likely to pose a threat when broken. Common designs include toughened glass (also known as tempered glass), laminated glass, wire mesh glass (also known as wired glass) and engraved glass. Wire mesh glass was invented by Frank Shuman. Laminated glass was invented in 1903 by the French chemist Édouard Bénédictus (1878–1930).

These four approaches can easily be combined, allowing for the creation of glass that is at the same time toughened, laminated, and contains a wire mesh. However, combination of a wire mesh with other techniques is unusual, as it typically betrays their individual qualities

Borosilicate glass

Borosilicate glass is a type of glass with silica and boron trioxide as the main glass-forming constituents. Borosilicate glasses are known for having very low coefficients of thermal expansion ($\sim 3 \times 10^{-6}$ K⁻¹ at 20 °C), making them resistant to thermal shock, more so than any other common glass. Such glass is less subject to thermal stress and is commonly used for the construction of reagent bottles. Borosilicate glass is sold under such trade names as Borcam, Borosil, DURAN, Suprax, Simax, BSA 60, BSC 51 (By NIPRO), Heatex, Endural, Schott, Refmex, Kimble, MG(India) and some (but not all) items sold under the trade name Pyrex.

Photosensitive glass

Photosensitive glass is a crystal-clear glass that belongs to the lithium-silicate family of glasses, in which an image of a mask can be captured by microscopic metallic particles in the glass when it is exposed to short wave radiations such as ultraviolet light. Photosensitive glass was first discovered by S. Donald Stookey in 1937.

Ceramics

A **ceramic** is a non-metallic solid material comprising an inorganic compound of metal, nonmetal or metalloid atoms primarily held in ionic and covalent bonds.

The crystallinity of ceramic materials ranges from highly oriented to semi-crystalline, vitrified, and often completely amorphous (e.g., glasses). Most often, fired ceramics are either vitrified or semi-vitrified as is the case with earthenware, stoneware, and porcelain. Varying crystallinity and electron consumption in the ionic and covalent bonds cause most ceramic materials to be good thermal and electrical insulators (extensively researched in ceramic engineering). With such a large range of possible options for the composition/structure of a ceramic (e.g. nearly all



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of the elements, nearly all types of bonding, and all levels of crystallinity), the breadth of the subject is vast, and identifiable attributes (e.g. hardness, toughness, electrical conductivity, etc.) are hard to specify for the group as a whole. General properties such as high melting temperature, high hardness, poor conductivity, high moduli of elasticity, chemical resistance and low ductility are the norm,^[1] with known exceptions to each of these rules (e.g. piezoelectric ceramics, glass transition temperature, superconductive ceramics, etc.). Many composites, such as fiberglass and carbon fiber, while containing ceramic materials, are not considered to be part of the ceramic family.

The earliest ceramics made by humans were pottery objects (i.e. *pots* or *vessels*) or figurines made from clay, either by itself or mixed with other materials like silica, hardened, sintered, in fire. Later ceramics were glazed and fired to create smooth, colored surfaces, decreasing porosity through the use of glassy, amorphous ceramic coatings on top of the crystalline ceramic substrates. Ceramics now include domestic, industrial and building products, as well as a wide range of ceramic art. In the 20th century, new ceramic materials were developed for use in advanced ceramic engineering, such as in semiconductors.

The word "*ceramic*" comes from the Greek word κεραμικός (*keramikos*), "of pottery" or "for pottery", from κέραμος (*keramos*), "potter's clay, tile, pottery". The earliest known mention of the root "ceram-" is the Mycenaean Greek *ke-ra-me-we*, "workers of ceramics", written in Linear B syllabic script. The word "ceramic" may be used as an adjective to describe a material, product or process, or it may be used as a noun, either singular, or, more commonly, as the plural noun "ceramics".

Electrical properties

Semiconductors

Some ceramics are semiconductors. Most of these are transition metal oxides that are II-VI semiconductors, such as zinc oxide.

While there are prospects of mass-producing blue LEDs from zinc oxide, ceramicists are most interested in the electrical properties that show grain boundary effects.

One of the most widely used of these is the varistor. These are devices that exhibit the property that resistance drops sharply at a certain threshold voltage. Once the voltage across the device reaches the threshold, there is a breakdown of the electrical structure in the vicinity of the grain boundaries, which results in its electrical resistance dropping from several megohms down to a few hundred ohms. The major advantage of these is that they can dissipate a lot of energy, and they self-reset – after the voltage across the device drops below the threshold, its resistance returns to being high.

This makes them ideal for surge-protection applications; as there is control over the threshold voltage and energy tolerance, they find use in all sorts of applications. The best demonstration of their ability can be found in electrical substations, where they are employed to protect the infrastructure from lightning strikes. They have rapid response, are low maintenance, and do not appreciably degrade from use, making them virtually ideal devices for this application.



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Semiconducting ceramics are also employed as gas sensors. When various gases are passed over a polycrystalline ceramic, its electrical resistance changes. With tuning to the possible gas mixtures, very inexpensive devices can be produced.

Superconductivity



The Meissner effect demonstrated by levitating a magnet above a cuprate superconductor, which is cooled by liquid nitrogen

Under some conditions, such as extremely low temperature, some ceramics exhibit hightemperature superconductivity. The exact reason for this is not known, but there are two major families of superconducting ceramics.

Fullerenes

A **fullerene** is a molecule of carbon in the form of a hollow sphere, ellipsoid, tube, and many other shapes. Spherical fullerenes, also referred to as Buckminsterfullerenes or buckyballs, resemble the balls used in association football. Cylindrical fullerenes are also called carbon nanotubes(buckytubes). Fullerenes are similar in structure to graphite, which is composed of stacked graphene sheets of linked hexagonal rings. Unless they are cylindrical, they must also contain pentagonal (or sometimes heptagonal) rings.

The first fullerene molecule to be discovered, and the family's

namesake, buckminsterfullerene (C_{60}), was manufactured in 1985 by Richard Smalley, Robert Curl, James Heath, Sean O'Brien, and Harold Kroto at Rice University. The name was an homage to Buckminster Fuller, whose geodesic domes it resembles. The structure was also identified some five years earlier by Sumio Iijima, from an electron microscope image, where it formed the core of a "bucky onion". Fullerenes have since been found to occur in nature. More recently, fullerenes have been detected in outer space. According to astronomer Letizia Stanghellini, "It's possible that buckyballs from outer space provided seeds for life on Earth."

The discovery of fullerenes greatly expanded the number of known carbon allotropes, which had previously been limited to graphite, graphene, diamond, and amorphous carbon such as soot and charcoal. Buckyballs and buckytubes have been the subject of intense research, both



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for their chemistry and for their technological applications, especially in materials science, electronics, and nanotechnology.

Carbon nanotubes



This rotating model of a carbon nanotubeshows its 3D structure

Nanotubes are cylindrical fullerenes. These tubes of carbon are usually only a few nanometres wide, but they can range from less than a micrometer to several millimeters in length. They often have closed ends, but can be open-ended as well. There are also cases in which the tube reduces in diameter before closing off. Their unique molecular structure results in extraordinary macroscopic properties, including high tensile strength, high electrical conductivity, high ductility, high heat conductivity, and relative chemical inactivity (as it is cylindrical and "planar" — that is, it has no "exposed" atoms that can be easily displaced). One proposed use of carbon nanotubes is in paper batteries, developed in 2007 by researchers at Rensselaer Polytechnic Institute. Another highly speculative proposed use in the field of space technologies is to produce high-tensile carbon cables required by a space elevator.

Carbon nanobuds

Nanobuds have been obtained by adding buckminsterfullerenes to carbon nanotubes.

Cements

A cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.

Cements used in construction are usually inorganic, often lime or calcium silicate based, and can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Non-hydraulic cement will not set in wet conditions or under water; rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.



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Hydraulic cements (e.g., Portland cement) set and become adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet conditions or under water and further protects the hardened material from chemical attack. The chemical process for hydraulic cement found by ancient Romans used volcanic ash (pozzolana) with added lime (calcium oxide).

The word "cement" can be traced back to the Roman term *opus caementicium*, used to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick supplements that were added to the burnt lime, to obtain a hydraulic binder, were later referred to as *cementum*, *cimentum*, *cäment*, and *cement*. In modern times, organic polymers are sometimes used as cements in concrete.

Cement is widely used material in building construction for making cement mortar and concrete. As we know that cement start hydrates when it is mixed with water. In presence of water, cement has a property to achieve strength and get hardened within a short period. So its mandate to place the cement in position without losing its plasticity. To achieve this, the setting time of cement is calculated.

Initial Setting time of Cement:-

The time to which cement can be moulded in any desired shape without losing it strength is called Initial setting time of cement

Or

The time at which cement starts hardens and completely loses its plasticity is called Initial setting time of cement.

Or

The time available for mixing the cement and placing it in position is an Initial setting time of cement. If delayed further, cement loses its strength.

For Ordinary Portland Cement, The initial Setting Time is 30 minutes.

Final setting time of Cement:-

The time at which cement completely loses its plasticity and became hard is a final setting time of cement.

Or

The time taken by cement to gain its entire strength is a Final setting time of cement. For Ordinary Portland Cement, The Final Setting Time is 600 minutes (10hrs).

Quick setting cements

This type of cement sets very quickly and is used where quick setting is required. Its initial setting time is 5 minutes and final setting time is 30 minutes. It cannot be used in normal construction projects but is used in special conditions such as construction in running water.



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POSSIBLE QUESTIONS

UNIT I

PART-A(20 MARKS)

(Q NO:1 TO 20 Online Examination)

PART-B(2 MARKS)

1.Write down few properties of glass

2. What are silicate and non-silicate glass.

3. Write down the composition and properties of borosilicate glass.

4. Write down the composition and properties of photosensitive glass.

5. Write down the composition and properties of coloured glass.

6.Write down the composition and properties of soda lime glass.

7.Write a note on fullerenes.

8. What are quick setting cements?

PART-C(6 MARKS)

- 1.Explain the manufacturing process of glass.
- 2. What are carbon nanotubes. Mention properties and applications of carbon nanotubes.
- 3.Compare armoured glass and safety glass.
- 4. Explain the manufacturing process of cement.



(Deemed to be University Under Section 3 of UGC Act 1956)

COIMBATORE-641 021

(For the Canditates admitted from 2016 & onwards)

III B.Sc Chemistry

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE (16CHU503A)

Unit I (SILICATE INDUSTRIES)

S.No	Question	Option 1	Option 2	Option 3	Option 4	Answer
1	A super cooled					
	liquid possessing					
	no sharp melting					
	point is known as	Glass	ceramics	cement	refractory	Glass
2	The material					
	having no definite					
	melting point is	ceramics	Glass	cement	refractory	Glass
3	The material					
	having high					
	compressive					
	strength is	cement	refractory	ceramics	Glass	Glass
4	Porcelain is a				whitewares	
	type which comes		structural clay	chemical	and chemical	
	under	the whitewares	products	stonewares	stonewares	the whitewares
5	Refractaries are a					
	group under	cement	refractory	ceramics	Glass	ceramics
6	Certain earths,					
	which are highly					
	plastic, when wet					
	and which, when					
	heated to redness,					
	loses their					
	plasticity and are					
	converted into a					
	hard mass are					
	known as	cement	clay	ceramics	Glass	clay
7	Clays are formed					
	by the weathering					
	of igneous, and					
	telspathic rocks					
	by various	aluminium	aluminium	magnesium	magnesium	aluminium
	agencies through	nıtrate	silicates	nitrate	sulphate	silicates

	time and are					
	composed					
	essentially of					
	hydrated					
8	Kaolin is					
	otherwise known					
	as	cement	china clay	ceramics	Glass	china clay
9	A compound that					
	contains					
	limestone					
	powder, hydrated					
	oxides, mud and					
	organic impurities					
	are known as	primary clay	secondary clay	china clay	Glass	secondary clay
10	The main					
	constituent in soft					
	glass is	potassium	sodium	calcium	magnesium	sodium
11	The main					
	constituent in					
	hard glass is	potassium	sodium	calcium	magnesium	potassium
12	Flint glass are			lead and red	shock proof	lead and red
	nothing but	soft glass	hard glass	lead	glass	lead
13	Soft glasses are	window	combustion	cathode ray	electrical	
	widely used in	glasses	tubes	tubes	insulators	window glasses
14	Hard glass are	cooling	heating	thermal	electrical	heating
	used for	operations	operations	operations	operations	operations
15	The glass					
	borosilicate glass					
	are otherwise			toughened		
	known	silica glass	optical glass	glass	jena glass	jena glass
16	Borosilicate glass					
	contain virtually					
	only silica and	carbon	boron	aluminium	sulphur	boron
17	The glass which					
	is used for					
	pipelines for					
	corrosive liquids				insulating	
	are	glass wool	hard glass	jena glass	glass	jena glass
18	High lead content					
	glasses are used					
	tor extra dense					
	optical glasses for					
	windows and					
	shields to protect					
	personnel from	cosmic rays	UV rays	gamma rays	beta rays	gamma rays
19	Lead glass is	magnesium	calcium oxide	calcium	sodium	calcium oxide

	made by using lead oxide instead	oxide		hydroxide	hydroxide	
	of					
20	The word cement,					
	in the broadest					
	sense, means any					
	substance which			reducing		
	acts as a	bonding agent	oxidising agent	agent	catalyst	bonding agent
21	Glues are nothing	cementing		ceramic		cementing
	but	materials	glass materials	materials	emulsions	materials
22	The material					
	having a very					
	desirable					
	adhering property					
	and is used in					
	construction work					
	are known as	glass	ceramics	cements	emulsions	cements
23	The material					
	when mixed with					
	water forms a					r
	paste which binds					
	firmly the					
	aggregates such					
	as gravel, stone,					
	sand are known					
	as	glass	ceramics	cements	emulsions	cements
24	The cement					
	which is					
	produced by					
	calcining and					
	pulversing natural					
	cement rocks					
	consisting of clay			high	.1 1	
	and limestone are	pozzolanic		alumina	portland	. 1 .
25	Known as	cement	natural cement	cement	cement	natural cement
25	The most ancient			1.1.1		
	among the types			nign		
	of manufacture	pozzolanic		alumina	portiand	pozzolanic
26	Veleenie eel	cement	natural cement	cement	cement	cement
20	voicanic asn					
	consisting of					
	silicates of					
	aluminium when			high		
	mixed with lime	nozzolanie		alumina	nortland	nozzolanie
	and heated	pozzolallic	natural comont	aiuiiiiia	coment	
	and neared,	Cement	natural cement	Cement	Cement	Cement

	produces					
27	The quick setting					
	variety of high					
	alumina cement is					
	manufactured by					
	calcining					
	limestone and	iron	bauxite	aluminium	magnesium	bauxite
28	Super sulphate					
	cement is used in					
	the construction					
	of	houses	dams	roads	bridges	dams
29	Expanding					
	cement is formed					
	by mixing					
	portland cement					
	with an					
	expanding agent	aluminium				
	called	nitrate	sulphoaluminate	aluminate	boron	sulphoaluminate
30				high		
	Aspdin named his	pozzolanic		alumina	portland	
	product as	cement	natural cement	cement	cement	portland cement
31	The major raw					
	material required					
	for the					
	manufacture of					
	portland cement		calcium	ammonium		
	are	gypsum	sulphate	nitrate	dolomite	gypsum
32	The main					
	compounds					
	formed during					
	fusion and found					
	in the finished					
	product of cement	tricalcium	tricalcium	dicalcium	tetracalcium	tricalcium
	is	borate	silicate	silicate	silicate	silicate
33	Whe cement is					
	mixed with water,					
	various hydration					
	and hydrolysis					
	reactions of the					
	compounds take					
	place and the					
	compounds thus					
	formed are	final		initial		
	responsible for	hardening	setting	setting	final setting	setting
34	The setting time	quantity of	quality of	quantity of	quality of	quantity of
	depends on the	cement	cement	water	water	water

	composition of					
	cement,					
	temperature and					
35	The final setting					
	time should not					
	be more than	20 hours	30 hours	5 hours	10 hours	10 hours
36	Hardening is a			vigorous		
	relatively	fast process	slow process	process	gradually slow	slow process
37						
	depends upon the					
	chemical					
	combination of					
	cement and water					
	and will thus					
	continue with					
	great speed at					
	first and go on					
	reducing			initial		
	gradually	quick setting	hardening	setting	final setting	hardening
38	Which material					
	helps to retard the					
	speed of the					
	initial set as it					
	reacts with					
	tricalcium					
	aluminate					
	forming calcium					
	sulphoaluminate					
	which does not					
	show any					
	tendency to rapid		calcium	calcium	ammonium	
	hydration	gypsum	sulphate	nitrate	nitrate	gypsum
39	The tricalcium					
	silicate combines					
	with water	more fastly	more slowly	slowly	fastly	more slowly
40	When the heat					
	liberated in					
	setting and					
	hardening is not					
	dissipated					
	rapidly, as in					
	large concrete					
	constructions,					
	serious					
	- may occur	stress cracking	wearing	tearing	elasticity	stress cracking
41	Toughened glass	soft glass	hard glass	tempered	shock proof	tempered glass

	is otherwise			glass	glass	
	known as					
42	Photosensitive					
	glass is a crystal					
	clear glass that			magnesium-	calcium-	
	belongs to the	boro-silicate	lithium silicate	silicate	silicate	lithium silicate
43	The glass which					
	was discovered					
	by S.Donold	photosensitive		tempered	shock proof	photosensitive
	Stookey was	glass	hard glass	glass	glass	glass
44	A fullerene is a					
	molecule of	boron	sulphur	carbon	oxygen	carbon
45	Cyclindrical					
	fullerene is				-	
	otherwise known			boron	carbon	carbon
	as	mica	talc	nanotubes	nanotubes	nanotubes
46	The researches					
	Georg Bednorz					
	and Alex muller					
	who were					r
	awarded the 1987					
	nobel prize in					
	physics for their					
	important					
	breakthrough in					
	the discovery of					
	superconductivity		ceramic	cement	carbon	ceramic
	in	glass materials	materials	materials	nanotubes	materials
47	The percentage of					
	dicalclium silicate					
	obtained in the					
	manufacture of					
	portland cement					
	is	35	45	25	15	25
48	Hydration of	highly	highly			highly
	tricalcium hydrate	exothermic	endothermic	dark	pphotocatalytic	exothermic
	is a	reaction	reaction	reaction	reaction	reaction
49	Which reaction is					
	responsible for					
	the progressive					
	increase of					
	strength and	reaction of	reaction of	reaction of	reaction of	reaction of
	hardness in	dicalcium	tricalcium	dicalcium	tetracalcium	dicalcium
	setting and	silicate with	silicate with	borate with	silicate with	silicate with
	hardening?	water	water	water	water	water
50	The initimate	mode	batch	common	high grade	batch

	mixture in the			glass	glass	
	manufacture of					
F 1	glass is known as				•	
51	calcium carbonate			1 .	magnesium	
	reacts with silica	magnesium	11.	calcium	silicate and	1
	to form	silicate	sodium silicate	silicate	sodium silicate	calcium silicate
52	An example for	sodium	cacium	magnesium	manganese	manganese
	decolorizes are	hydroxide	hydroxide	hydroxide	dioxide	dioxide
53	In the					
	manufacture of					
	glass, the process			forming and		forming and
	next to melting is	shaping	forming	shaping	annealing	shaping
54	The process of					
	allowing the glass					
	articles to cool					
	gradually to room					
	temperature is			forming and		
	known as	shaping	forming	shaping	annealing	annealing
55	The last process					
	carried out in the					
	manufacture of					
	glass is	shaping	finishing	forming	annealing	finishing
56	A glass made					
	from chemically					
	pure silca is	quartz	fused quartz	soft glass	hard glass	fused quartz
57	The refractive					
	index of the flint					
	glass is increased					
	by addition of					
	which of the					
	following element	carbon	oxygen	boron	barium	barium
58	Oxide of which					
	element in the					
	glass gives high					
	refractive index					
	and low					
	dispersion	barium	thorium	oxygen	boron	thorium
59	Fused quartz are					
	otherwise known		fused silica			fused silica
	as	silica glass	glass	hard glass	soft glass	glass
60	A glass having	<u> </u>		Ŭ	Ŭ	Ĭ
	high thermal					
	expansion and					
	poor resistance to	soda lime	fused silica			
	heat is	glass	glass	silica glass	lead glass	soda lime glass
	heat is	glass	glass	silica glass	lead glass	soda lime glass



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COURSE CODE:16CHU503A

INDUSTRIAL IMPORTANCE UNIT:II(Fertilizers) BATCH:2016-2019

COURSE NAME: INORGANIC MATERIALS OF

<u>UNIT II</u> SYLLABUS

Fertilizers:

Different types of fertilizers (N, P and K). Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates, superphosphate of lime.

Surface Coatings:

Brief introduction to and classification of surface coatings. Paints and pigments - formulation, composition and related properties. Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, Metallic coatings (electrolytic and electroless), metal spraying and anodizing.

Fertilizers

A **fertilizer** (American English) or **fertiliser** (British English; see spelling differences) is any material of natural or synthetic origin (other than liming materials) that is applied to soils or to plant tissues to supply one or more plant nutrients essential to the growth of plants. Many sources of fertilizer exist, both natural and industrially produced.

Fertilizers enhance the growth of plants. This goal is met in two ways, the traditional one being additives that provide nutrients. The second mode by which some fertilizers act is to enhance the effectiveness of the soil by modifying its water retention and aeration. This article, like many on fertilizers, emphasises the nutritional aspect. Fertilizers typically provide, in varying proportions:

• three main macronutrients:

- Nitrogen (N): leaf growth
- Phosphorus (P): Development of roots, flowers, seeds, fruit;
- Potassium (K): Strong stem growth, movement of water in plants, promotion of flowering and fruiting;
- three secondary macronutrients: calcium (Ca), magnesium (Mg), and sulfur (S);
- micronutrients: copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), boro n (B). Of occasional significance are silicon (Si), cobalt (Co), and vanadium (V).

The nutrients required for healthy plant life are classified according to the elements, but the elements are not used as fertilizers. Instead compounds containing these elements are the basis of fertilizers. The macro-nutrients are consumed in larger quantities and are present in plant tissue



in quantities from 0.15% to 6.0% on a dry matter (DM) (0% moisture) basis. Plants are made up of four main elements: hydrogen, oxygen, carbon, and nitrogen. Carbon, hydrogen and oxygen are widely available as water and carbon dioxide. Although nitrogen makes up most of the atmosphere, it is in a form that is unavailable to plants. Nitrogen is the most important fertilizer since nitrogen is present in proteins, DNA and other components (e.g., chlorophyll). To be nutritious to plants, nitrogen must be made available in a "fixed" form. Only some bacteria and their host plants (notably legumes) can fix atmospheric nitrogen (N_2) by converting it to ammonia. Phosphate is required for the production of DNA and ATP, the main energy carrier in cells, as well as certain lipids.

Micronutrients are consumed in smaller quantities and are present in plant tissue on the order of parts-per-million (ppm), ranging from 0.15 to 400 ppm DM, or less than 0.04% DM. These elements are often present at the active sites of enzymes that carry out the plant's metabolism. Because these elements enable catalysts (enzymes) their impact far exceeds their weight percentage.

Classification

Fertilizers are classified in several ways. They are classified according to whether they provide a single nutrient (e.g., K, P, or N), in which case they are classified as "straight fertilizers." "Multinutrient fertilizers" (or "complex fertilizers") provide two or more nutrients, for example N and P. Fertilizers are also sometimes classified as inorganic (the topic of most of this article) versus organic. Inorganic fertilizers exclude carbon-containing materials except ureas. Organic fertilizers are usually (recycled) plant- or animal-derived matter. Inorganic are sometimes called synthetic fertilizers since various chemical treatments are required for their manufacture.

Single nutrient ("straight") fertilizers

The main nitrogen-based straight fertilizer is ammonia or its solutions. Ammonium nitrate (NH₄NO₃) is also widely used. Urea is another popular source of nitrogen, having the advantage that it is solid and non-explosive, unlike ammonia and ammonium nitrate, respectively. A few percent of the nitrogen fertilizer market (4% in 2007) has been met by calcium ammonium nitrate (Ca(NO₃)₂ · NH₄NO₃ · 10H₂O).

The main straight phosphate fertilizers are the superphosphates. "Single superphosphate" (SSP) consists of 14-18% P₂O₅, again in the form of Ca(H₂PO₄)₂, but

also phosphogypsum (CaSO₄ \cdot 2H₂O). Triple superphosphate (TSP) typically consists of 44-48% of P₂O₅ and no gypsum. A mixture of single superphosphate and triple superphosphate is called double superphosphate. More than 90% of a typical superphosphate fertilizer is water-soluble.

Multinutrient fertilizers

These fertilizers are the most common. They consist of two or more nutrient components.

Binary (NP, NK, PK) fertilizers

Major two-component fertilizers provide both nitrogen and phosphorus to the plants. These are called NP fertilizers. The main NP fertilizers are monoammonium phosphate (MAP)



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and diammonium phosphate (DAP). The active ingredient in MAP is $NH_4H_2PO_4$. The active ingredient in DAP is (NH_4)₂HPO₄. About 85% of MAP and DAP fertilizers are soluble in water.

NPK fertilizers

NPK fertilizers are three-component fertilizers providing nitrogen, phosphorus, and potassium.

NPK rating is a rating system describing the amount of nitrogen, phosphorus, and potassium in a fertilizer. NPK ratings consist of three numbers separated by dashes (e.g., 10-10-10 or 16-4-8) describing the chemical content of fertilizers.^{[7][8]} The first number represents the percentage of nitrogen in the product; the second number, P_2O_5 ; the third, K_2O . Fertilizers do not actually contain P_2O_5 or K_2O , but the system is a conventional shorthand for the amount of the phosphorus (P) or potassium (K) in a fertilizer. A 50-pound (23 kg) bag of fertilizer labeled 16-4-8 contains 8 lb (3.6 kg) of nitrogen (16% of the 50 pounds), an amount of phosphorus equivalent to that in 2 pounds of P_2O_5 (4% of 50 pounds), and 4 pounds of K_2O (8% of 50 pounds). Most fertilizers are labeled according to this N-P-K convention, although Australian convention, following an N-P-K-S system, adds a fourth number for sulfur, and uses elemental values for all values including P and K.

Micronutrients

The main micronutrients are molybdenum, zinc, and copper. These elements are provided as water-soluble salts. Iron presents special problems because it converts to insoluble (bio-unavailable) compounds at moderate soil pH and phosphate concentrations. For this reason, iron is often administered as a chelate complex, e.g., the EDTA derivative. The micronutrient needs depend on the plant. For example, sugar beets appear to require boron, and legumes require cobalt.

Manufacture of Urea







Urea plant using ammonium carbamate briquettes, Fixed Nitrogen Research Laboratory, ca. 1930

The basic process, developed in 1922, is also called the Bosch–Meiser urea process after its discoverers. Various commercial urea processes are characterized by the conditions under which



urea forms and the way that unconverted reactants are further processed. The process consists of two main equilibrium reactions, with incomplete conversion of the reactants. The first is **carbamate formation**: the fast exothermic reaction of liquid ammonia with gaseous carbon dioxide (CO₂) at high temperature and pressure to form ammonium carbamate (H₂N-COONH₄):

2 NH₃ + CO₂ \rightleftharpoons H₂N-COONH₄ (Δ H= -117kJ/mol at 110 atm and 160°C)

The second is **urea conversion**: the slower endothermic decomposition of ammonium carbamate into urea and water:

H_2N -COON $H_4 \rightleftharpoons (NH_2)_2CO + H_2O (\Delta H = +15.5 \text{ kJ/mol at } 160-180^{\circ}C)$

The overall conversion of NH₃ and CO₂ to urea is exothermic,^[41] the reaction heat from the first reaction driving the second. Like all chemical equilibria, these reactions behave according to Le Chatelier's principle, and the conditions that most favour carbamate formation have an unfavourable effect on the urea conversion equilibrium. The process conditions are, therefore, a compromise: the ill-effect on the first reaction of the high temperature (around 190 °C) needed for the second is compensated for by conducting the process under high pressure (140–175 bar), which favours the first reaction. Although it is necessary to compress gaseous carbon dioxide to this pressure, the ammonia is available from the ammonia plant in liquid form, which can be pumped into the system much more economically. To allow the slow urea formation reaction time to reach equilibrium a large reaction space is needed, so the synthesis reactor in a large urea plant tends to be a massive pressure vessel.

Because the urea conversion is incomplete, the product must be separated from unchanged ammonium carbamate. In early "straight-through" urea plants this was done by letting down the system pressure to atmospheric to let the carbamate decompose back to ammonia and carbon dioxide. Originally, because it was not economic to recompress the ammonia and carbon dioxide for recycle, the ammonia at least would be used for the manufacture of other products, for example ammonium nitrate or sulfate. (The carbon dioxide was usually wasted.) Later process schemes made recycling unused ammonia and carbon dioxide practical. This was accomplished by depressurizing the reaction solution in stages (first to 18–25 bar and then to 2–5 bar) and passing it at each stage through a steam-heated *carbamate decomposer*, then recombining the resultant carbon dioxide and ammonia in a falling-film *carbamate condenser* and pumping the carbamate solution into the previous stage.

Manufacture of Ammonium nitirate

The industrial production of ammonium nitrate entails the acid-base reaction of ammonia with nitric acid:

 $HNO_3 + NH_3 \rightarrow NH_4NO_3$

Ammonia is used in its anhydrous form (i.e., gas form) and the nitric acid is concentrated. This reaction is violent owing to its highly exothermic nature. After the solution is formed, typically at about 83% concentration, the excess water is evaporated to an ammonium nitrate (AN) content of 95% to 99.9% concentration (AN melt), depending on grade. The AN melt is then made into


"prills" or small beads in a spray tower, or into granules by spraying and tumbling in a rotating drum. The prills or granules may be further dried, cooled, and then coated to prevent caking. These prills or granules are the typical AN products in commerce.

The ammonia required for this process is obtained by the Haber process from nitrogen and hydrogen. Ammonia produced by the Haber process is oxidized to nitric acid by the Ostwald process. Another production method is a variant of the Odda process:

 $Ca(NO_3)_2 + 2 NH_3 + CO_2 + H_2O \rightarrow 2 NH_4NO_3 + CaCO_3$

The products, calcium carbonate and ammonium nitrate, may be separately purified or sold combined as calcium ammonium nitrate.

Ammonium nitrate can also be made via metathesis reactions:

 $\begin{aligned} (NH_4)_2SO_4 + Ba(NO_3)_2 &\rightarrow 2 \text{ } NH_4NO_3 + BaSO_4 \\ NH_4Cl + AgNO_3 &\rightarrow NH_4NO_3 + AgCl \end{aligned}$

Manufacture of Ammonium phosphate

Ammonium phosphate is the salt of ammonium and phosphate. It is a highly unstable compound with the formula $(NH_4)_3PO_4$. Because of its instability, it is elusive and of no commercial value. A related "double salt", $(NH_4)_3PO_4(NH_4)_2HPO_4$ is also recognized but is too unstable for practical use. Both triammonium salts evolve ammonia. In contrast to the fragile nature of the triammonium salts, diammonium phosphate $(NH_4)_2HPO_4$ is a valuable material, mainly as a fertilizer. Also of value is monoammonium salt $(NH_4)H_2PO_4$ which is also valued as a fertilizer. These two salts provide plants with fixed nitrogen and phosphorus.

Preparation of triammonium phosphate

Triammonium phosphate can be prepared in the laboratory by treating 85% phosphoric acid with 30% ammonium solution:

 $H_3PO_4 + 3 NH_3 \rightarrow (NH_4)_3PO_4$

 $(NH_4)_3PO_4$ is a colorless, crystalline solid. The solid, which has the odor of ammonia, is readily soluble in water. The salt converts to diammonium hydrogen $(NH_4)_2HPO_4$.

Preparation of diammonium hydrogen phosphate (DHP)

DAP is a simple salt and a complex fertilizer. It is also the source of nitrogen and phosphorus nutrients.

 $H_3PO_4 + 2 NH_3 \rightarrow (NH_4)_2 HPO_4$

On heating, $(NH_4)_2$ HPO₄ evolves ammonia, giving colorless crystals of the monoammonium salt.

(NH₄)₂ HPO₄ is a colorless, odorless, crystalline solid, which insoluble in water.



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Manufacture of Superphosphate of lime

The finely ground rock is mixed with sulphuric acid in the proportions required by the equations

$CaCO_3 + H_2SO_4 + H_2O = CaSO_4 + H_2O + CO_2$ $Ca_{3}P_{2}O_{8} + 2H_{2}SO_{4} + 5H_{2}O = CaH_{4}P_{2}O_{8}H_{2}O + 2[CaSO_{4} + 2H_{2}O]$

The evolution of carbon dioxide plays an important part in keeping the mass porous; if a sufficient proportion of carbonate is not present in the rock it may be supplied by blending. The heat evolved by the reaction is used to evaporate the surplus water. This heat depends 011 the composition of the rocks—those which contain much carbonate evolve more heat and may be treated with cold acid, while those which contain little may require hot acid. Chamber acid of density 1.53 to 1.61 is used; this is also the chief source of the water required. The hydrates retain their water when dried at 100° C., or even to a great extent up to 150° C. If artificial drying is used the temperature should not rise over 150° C. or else an undue proportion becomes insoluble. The loss in weight is 10 to 12¹/₂ per cent. The product hardens on cooling and is cut out and powdered by a mechanical disintegrator. It contains, when freshly made, 30 to 45 per cent, of phosphate (calculated as $Ca_3P_2O_8$) soluble in water, according to the composition of the rock used. A more concentrated form ("double superphosphate") is made by adding sulphuric acid sufficient in amount to set free all the phosphoric acid, which, after filtration, is concentrated to a syrup and used to decompose more phosphate according to the equation

$Ca_{3}P_{2}O_{8} + 4H_{3}PO_{4} + 3H_{2}O = 3(CaH_{4}P_{2}O_{8} + H_{2}O)$

The manufacture has been of great value as an outlet for surplus sulphuric acid, of which 11 cwt. (69 per cent, acid) is required for every ton of (ordinary) superphosphate.

"Retrogression"

Superphosphate may require to be stored for several months, and during this time insoluble CaHPO₄ is formed according from the small amount of undecomposed Ca₃ P_2O_8 . Even a week after manufacture the soluble phosphate may have diminished by about 2 to 4 per cent. This "retrogression" is particularly marked when the phosphatic material contains more than 2 per cent, of iron plus alumina. The excess of these bases reacts with the $CaH_4P_2O_8$ to give insoluble phosphates of iron and aluminium according to the equation

$CaH_4P_2O_8H_2O + Fe_2(SO_4)_3 + 5H_2O = 2[FePO_4A_2H_2O] + CaSO_4A_2H_2O + 2H_2SO_4$

The phosphates of iron and aluminium form gelatinous precipitates which are insoluble in weak acids, or in hydrolysed acid phosphates or sulphates. Ferric phosphate may be decomposed, using up more sulphuric acid, as in the equation



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$3FePO_4 + 3H_2SO_4 \Leftrightarrow FePO_{4.2}H_3PO_4 + Fe_{2}(SO_{4})_3$

or it may easily lose its water, becoming insoluble, thus:

$FePO_4.2H_2O + CaSO_4 = CaSO_4.2H_2O + FePO_4$

If the original rock contains up to 2 per cent, of iron oxide the resulting phosphate of iron is soluble, but with more than 4 per cent, of iron oxide the phosphate is insoluble—hence such a rock is considered unsuitable for the manufacture of superphosphate. The "regression" of the phosphate by the iron salt just described may be avoided if the rock is dissolved in ammonium sulphate solution and then treated with sulphur dioxide; the iron is then converted into $(\mathbf{NH}_4)_2\mathbf{SO}_4$. FeSO $_4$. $\mathbf{6H}_2\mathbf{O}$.

The Treatment of Special Ores

Alumina does not appear to induce "retrogression." It may be removed by caustic alkalies or hot alkali carbonate solutions. Redonda phosphate (AIPO4) may be made soluble by fusion with ammonium bisulphate, giving a dry powder which is a mixture of ammonium alum, ammonium bisulphate and biphosphate.

Rocks which contain calcium chloride or fluoride (apatites) are decomposed according to the equations

$CaCl_2 + H_2SO_4 = 2HCl + CaSO_4$ $CaF_2 + H_2SO_4 = 2HF + CaSO_4$

The corrosive gases which are liberated are absorbed in towers containing water and furnish solutions of hydrochloric or hydrofluosilicic acid by reaction with the silica of the phosphate rock. Thus

 $4HF + SiO_2 = SiF_4 + 2H_2O$ $SiF_4 + 2HF = H_2SiF_6$

By addition of common salt silicofluoride may be precipitated and the filtrate may be worked up for hydrochloric acid. Thus

 $H_2SiF_6 + 2NaCl = Na_2SiF_6 + 2HCl$



Apatite may be treated by the following process (Palmer):— Perchloric or chloric acid made by electrolysis of the sodium salts is mixed with the coarsely ground rock. The liquid, containing H_3PO_4 , is precipitated by the alkaline kathode liquors so as to give a slightly acid precipitate of the composition CaHPO₄.2H₂O, which is soluble to the extent of 95 per cent, in ammonium citrate.

Surface Coatings

Surface coating, any mixture of film-forming materials plus pigments, solvents, and other additives, which, when applied to a surface and cured or dried, yields a thin film that is functional and often decorative. Surface coatings include paints, drying oils and varnishes, synthetic clear coatings, and other products whose primary function is to protect the surface of an object from the environment. These products can also enhance the aesthetic appeal of an object by accentuating its surface features or even by concealing them from view.

Most surface coatings employed in industry and by consumers are based on synthetic polymers—that is, industrially produced substances composed of extremely large, often interconnected molecules that form tough, flexible, adhesive films when applied to surfaces. The other component materials of surface coatings are pigments, which provide colour, opacity, gloss, and other properties; solvents or carrier liquids, which provide a liquid medium for applying the film-forming ingredients; and additives, which provide a number of special properties. This article reviews the composition and film-forming properties of polymer-based surface coatings, beginning with the polymer ingredients and continuing through the pigments, liquids, and additives. The emphasis is on paints (by far the most common type of coating), though occasional reference is made to other types of coatings such as drying oils and varnishes. For a fuller understanding of polymeric compounds, which form the basis of surface coatings, the reader is advised to begin with the article industrial polymers, chemistry of. For an overview of the position of surface coatings within the broader field of industrial polymers, see Industrial Polymers: Outline of Coverage.

Paints and Pigments

Paint is any liquid, liquefiable, or mastic composition that, after application to a substrate in a thin layer, converts to a solid film. It is most commonly used to protect, color, or provide texture to objects. Paint can be made or purchased in many colors—and in many different types, such as watercolor, synthetic, etc. Paint is typically stored, sold, and applied as a liquid, but most types dry into a solid.

Components



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Vehicle

The vehicle is composed of the binder; or, if it is necessary to thin the binder with a diluent like solvent or water, it is the combination of binder and diluent. In this case, once the paint has dried or cured very nearly all of the diluent has evaporated and only the binder is left on the coated surface. Thus, an important quantity in coatings formulation is the "vehicle solids", sometimes called the "resin solids" of the formula. This is the proportion of the wet coating weight that is binder, i.e. the polymer backbone of the film that will remain after drying or curing is complete.

Binder or film former

The binder is the film-forming component of paint. It is the only component that is always present among all the various types of formulations. Many binders are too thick to be applied and must be thinned. The type of thinner, if present, varies with the binder.

The binder imparts properties such as gloss, durability, flexibility, and toughness.

Binders include synthetic or natural resins such as alkyds, acrylics, vinyl-acrylics, vinyl acetate/ethylene (VAE), polyurethanes, polyesters, melamine resins, epoxy, silanes or siloxanes or oils.

Binders can be categorized according to the mechanisms for film formation. Thermoplastic mechanisms include drying and coalescence. Drying refers to simple evaporation of the solvent or thinner to leave a coherent film behind. Coalescence refers to a mechanism that involves drying followed by actual interpenetration and fusion of formerly discrete particles. Thermoplastic film-forming mechanisms are sometimes described as "thermoplastic cure" but that is a misnomer because no chemical curing reactions are required to knit the film. Thermosetting mechanisms, on the other hand, are true curing mechanism that involve chemical reaction(s) among the polymers that make up the binder.

Thermoplastic mechanisms: Some films are formed by simple cooling of the binder. For example, encaustic or wax paints are liquid when warm, and harden upon cooling. In many cases, they resoften or liquify if reheated.

Paints that dry by solvent evaporation and contain the solid binder dissolved in a solvent are known as lacquers. A solid film forms when the solvent evaporates. Because no chemical crosslinking is involved, the film can re-dissolve in solvent; as such, lacquers are unsuitable for applications where chemical resistance is important. Classic nitrocellulose lacquers fall into this category, as do non-grain raising stains composed of dyesdissolved in solvent. Performance varies by formulation, but lacquers generally tend to have better UV resistance and lower corrosion resistance than comparable systems that cure by polymerization or coalescence.

The paint type known as Emulsion in the UK and Latex in the United States is a water-borne dispersion of sub-micrometer polymer particles. These terms in their respective countries cover all paints that use synthetic polymers such as acrylic, vinyl acrylic (PVA), styrene acrylic, etc. as binders. The term "latex" in the context of paint in the United States simply means an aqueous dispersion; latex rubber from the rubber tree is not an ingredient. These dispersions are prepared by emulsion polymerization. Such paints cure by a process called coalescence where first the



water, and then the trace, or coalescing, solvent, evaporate and draw together and soften the binder particles and fuse them together into irreversibly bound networked structures, so that the paint cannot redissolve in the solvent/water that originally carried it. The residual surfactants in paint, as well as hydrolytic effects with some polymers cause the paint to remain susceptible to softening and, over time, degradation by water. The general term of latex paint is usually used in the United States, while the term emulsion paint is used for the same products in the UK and the term latex paint is not used at all.

Thermosetting mechanisms: Paints that cure by polymerization are generally one- or twopackage coatings that polymerize by way of a chemical reaction, and cure into a crosslinked film. Depending on composition they may need to dry first, by evaporation of solvent. Classic two-package epoxies or polyurethanes would fall into this category.

The "drying oils", counter-intuitively, actually cure by a crosslinking reaction even if they are not put through an oven cycle and seem to simply dry in air. The film formation mechanism of the simplest examples involve first evaporation of solvents followed by reaction with oxygen from the environment over a period of days, weeks and even months to create a crosslinked network.^[5] Classic alkyd enamels would fall into this category. Oxidative cure coatings are catalyzed by metal complex driers such as cobalt naphthenate.

Recent environmental requirements restrict the use of volatile organic compounds (VOCs), and alternative means of curing have been developed, generally for industrial purposes. UV curing paints, for example, enable formulation with very low amounts of solvent, or even none at all. This can be achieved because of the monomers and oligomers used in the coating have relatively very low molecular weight, and are therefore low enough in viscosity to enable good fluid flow without the need for additional thinner. If solvent is present in significant amounts, generally it is mostly evaporated first and then crosslinking is initiated by ultraviolet light. Similarly, powder coatings contain little or no solvent. Flow and cure are produced by heating of the substrate after electrostatic application of the dry powder.

Combination mechanisms: So-called "catalyzed" lacquers" or "crosslinking latex" coatings are designed to form films by a combination of methods: classic drying plus a curing reaction that benefits from the catalyst. There are paints called plastisols/organosols, which are made by blending PVC granules with a plasticiser. These are stoved and the mix coalesces.

Diluent or solvent or thinner

The main purposes of the diluent are to dissolve the polymer and adjust the viscosity of the paint. It is volatile and does not become part of the paint film. It also controls flow and application properties, and in some cases can affect the stability of the paint while in liquid state. Its main function is as the carrier for the non volatile components. To spread heavier oils (for example, linseed) as in oil-based interior house paint, a thinner oil is required. These volatile substances impart their properties temporarily—once the solvent has evaporated, the remaining paint is fixed to the surface.

This component is optional: some paints have no diluent.



Water is the main diluent for water-borne paints, even the co-solvent types.

Solvent-borne, also called oil-based, paints can have various combinations of organic solvents as the diluent, including aliphatics, aromatics, alcohols, ketones and white spirit. Specific examples are organic solvents such as petroleum distillate, esters, glycol ethers, and the like. Sometimes volatile low-molecular weight synthetic resins also serve as diluents.

Pigment and filler

Pigments are granular solids incorporated in the paint to contribute color. Fillers are granular solids incorporate to impart toughness, texture, give the paint special properties, or to reduce the cost of the paint. Alternatively, some paints contain dyes instead of or in combination with pigments.

Pigments can be classified as either natural or synthetic. Natural pigments include various clays, calcium carbonate, mica, silicas, and talcs. Synthetics would include engineered molecules, calcined clays, blanc fixe, precipitated calcium carbonate, and synthetic pyrogenic silicas.

Hiding pigments, in making paint opaque, also protect the substrate from the harmful effects of ultraviolet light. Hiding pigments include titanium dioxide, phthalo blue, red iron oxide, and many others.

Fillers are a special type of pigment that serve to thicken the film, support its structure and increase the volume of the paint. Fillers are usually cheap and inert materials, such as diatomaceous earth, talc, lime, barytes, clay, etc. Floor paints that must resist abrasion may contain fine quartz sand as a filler. Not all paints include fillers. On the other hand, some paints contain large proportions of pigment/filler and binder.

Some pigments are toxic, such as the lead pigments that are used in lead paint. Paint manufacturers began replacing white lead pigments with titanium white (titanium dioxide), before lead was banned in paint for residential use in 1978 by the US Consumer Product Safety Commission. The titanium dioxide used in most paints today is often coated with silica/alumina/zirconium for various reasons, such as better exterior durability, or better hiding performance (opacity) promoted by more optimal spacing within the paint film.

Micaceous iron oxide (MIO) is another alternative to lead for protection of steel, giving more protection against water and light damage than most paints. When MIO pigments are ground into fine particles, most cleave into shiny layers, which reflect light, thus minimising UV degradation and protecting the resin binder. Most pigments used in paint tend to be spherical, but lamellar pigments, such as glass flake and MIO have overlapping plates, which impede the path of water molecules.^[15] For optimum performance MIO should have a high content of thin flake-like particles resembling mica. ISO 10601 sets two levels of MIO content. MIO is often derived from a form of hematite.

Additives



Besides the three main categories of ingredients, paint can have a wide variety of miscellaneous additives, which are usually added in small amounts, yet provide a significant effect on the product. Some examples include additives to modify surface tension, improve flow properties, improve the finished appearance, increase wet edge, improve pigment stability, impart antifreeze properties, control foaming, control skinning, etc. Other types of additives include catalysts, thickeners, stabilizers, emulsifiers, texturizers, adhesion promoters, UV stabilizers, flatteners (de-glossing agents), biocides to fight bacterial growth, and the like.

Additives normally do not significantly alter the percentages of individual components in a formulation.

Enamels

Enamel paint is paint that air dries to a hard, usually glossy, finish, used for coating surfaces that are outdoors or otherwise subject to hard wear or variations in temperature; it should not be confused with decorated objects in "painted enamel", where vitreous enamel is applied with brushes and fired in a kiln. The name is something of a misnomer, as in reality, most commercially available enamel paints are significantly softer than either vitreous enamel or stoved synthetic resins, and are totally different in composition; vitreous enamel is applied as a powder or paste and then fired at high temperature. There is no generally accepted definition or standard for use of the term enamel paint, and not all enamel-type paints may use it.

Typically the term "enamel paint" is used to describe oil-based covering products, usually with a significant amount of gloss in them, however recently many latex or water-based paints have adopted the term as well. The term today means "hard surfaced paint" and usually is in reference to paint brands of higher quality, floor coatings of a high gloss finish, or spray paints. Most enamel paints are alkyd resin based. Some enamel paints have been made by adding varnish to oil-based paint.

Although "enamels" and "painted enamel" in art normally refer to vitreous enamel, in the 20th century some artists used commercial enamel paints in art, including Pablo Picasso(mixing it with oil paint), Hermann-Paul, Jackson Pollock, and Sidney Nolan. *The Trial* (1947) is one of a number of works by Nolan to use enamel paint, usually Ripolin, a commercial paint not intended for art, also Picasso's usual brand. Some "enamel paints" are now produced specifically for artists.

Enamels paints can also refer to nitro-cellulose based paints, one of the first modern commercial paints of the 20th century. They have since been superceded by new synthetic coatings like alkyd, acrylic and vinyl (a type of "látex"), due to toxicity, safety, and conservation (tendency to age yellow) concerns.^[3] In art has been used also by Pollock with the commercial paint named Duco. The artist experimented and created with many types of commercial or house paints during his career . Other artists: "after discovering various types of industrial materials produced in the United States in the 1930s, Siqueiros' produced most of his easel works with uncommon materials which include Duco paint, a DuPont brand name for pyroxyline paint, a tough and resilient type of nitro-cellulose paint manufactured for the automotive industry".Nitro-cellulose enamels are also commonly known as modern lacquers.



CLASS:III B.Sc CHEMISTRY

COURSE NAME: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE **UNIT:II**(Fertilizers) BATCH:2016-2019

Emulsying agents

To understand emulsifying agents, it's important to understand that emulsion is the process of integrating two fluids that generally don't mix. So, an emulsifying agent describes a compound applied to a formula to mix two immiscible compounds together.

An emulsifying agent is a substance that helps oil or fat evenly disperse in a water-based substance. Such agents are soluble in both water and fats.

Emulsifying agents are common ingredients in pesticides and foliar sprays. For example, among gardening pesticides, oil-based pest control products are generally considered eco-friendly. Consequently, emulsifying agents act as a mixture agent for oil and water-based pesticides.

Given that emulsifying agents are required to mix oil and water in pesticides, they are considered an essential ingredient in eco-friendly gardening. Emulsifying agents came into greater use when people began to be more apprehensive about consuming pesticide-filled fruits.

Though fruits are prone to pests, it is important to make sure they are edible as they are often directly consumed. This paved way for the light spray pesticides that are effective, yet safe for consumption.

Emulsifying agents are ideal in eco-friendly gardening as they have the ability to dissolve in both fat and water and ensure even distribution of pest repellents across plants.

Despite the inception process of using emulsifying agents in gardening with vegetable oil and water, now people have started using specialized horticulture oil and water with emulsifying agents to ensure effective pest control after usage. With this method, it is important to follow instructions closely to avoid improper use and undesired effects.

Some generally utilized emulsifying agents include sodium lauryl sulfate, polymers such as spans and tweens, and sodium dioctyl sulfosuccinate. In the food industry, foods that contain emulsions include butter, salad dressings, ice cream, and more.

Special Paints

Heat retardant paints

Heat resistant paints available at Rawlins Paints are designed to withstand hightemperatures of up to 750°C on commercial and industrial metal/metallic surfaces and structures – ranging from heat treatment applications, including incinerators and furnace chimneys, to pipework and vessels in chemical processing plants. For very demanding inland/offshore environments, VHT (very-high-temperature) paints and coatings are also required to deliver high-performance humidity resistance and anti-corrosive protection against liquids including water, oil and gasoline/petrol, as well as salt, gas, rust and chemical solvents.

Heat resistant paints and coatings are not designed to deliver fire retardant properties, but can be used on industrial chimneys and steel melting applications. These high-temperature coatings will



not react to flames and cannot contain the surface spread of flames. The most commonly used heat resistant paint colours include black and silver (also referred to as aluminium). Some heat resistant coatings we stock are also available in white, grey, red oxide and orange.

Fire retardant paints

Fire Retardant and Flame Retardant Paint and Coatings are used to provide additional time in a fire situation to exit a building and extra time for fire fighters to do their job before the fire spreads. Fire Resistive coatings provide protection for structural steel so that buildings don't collapse in a fire. Our Flame Retardant Fabric coatings help protect drapes and tarps and other fabrics from fire. These coatings save lives.

Flame Control coatings comply with federal, state and local building and fire code requirements. They retard flame spread and penetration of heat through their intumescent -sublimative-ablative and synergistic flame suppressing action. On contact with flame or excessive heat, **Flame Control Intumescent Fire Retardant Coatings** decompose and puff up (intumesce) forming a thick, dense, spongy foam layer that checks flame spread and retards heat penetration.

Eco-friendly paints

The potent health effects of these paints have made paint companies reconsider the composition of their products. This has led to the development of a new range of Environmentally Friendly non-toxic paints. They aim to reinvent paints so that serious health and environment problems can be prevented.

Eco-friendly paints available in India can be classified into three types:

- 1. **Zero-VOC paints:** The level of VOCs in these paints is so low that they can be termed as 'zero-VOC paints'. As per the EPA* standard, the total VOC content should be less than 5 gram per liter of paint.
- 2. **Low-VOC paints:** As specified by the EPA, these paints can have VOC concentrations ranging from 5 to 200 gram per liter of paint.
- 3. **Natural paints:** These paints are made of natural compounds such as tree resins, water, plant oil, essential oil and natural dyes. They do not contain any VOCs. Waterbased paints do not have an odor, while oil-based paints have a smell.



*Since India does not have guidelines on such non-toxic paints, we have considered the standards formulated by the Green Seal Standard for Paints & Coatings and the US Environment Protection Agency (EPA).

It is important to note that most green certifications stand for VOC in the paint base. VOC in colouring agents in the paint, the biggest contributor of VOC, is often ignored. As a thumb rule, darker colours and glossier paints have more VOC. BIS has recently reduced the standard for lead in normal paints from 1,000 ppm to 90 ppm, following the example of the US and China. Paints in India can undergo testing for certification from the National Testing House too, like Nerolac Paints.

Tech Specs of Environmentally Friendly Paints

Parameters	Conventional Paints	Low/Zero VOC Paints
VOC content (gram per liter)	250-800	50 for Low VOC / 5 for Zero VOC
Color ranges	All colors	Lighter colors
Texture	Flat or Glossy	Flat only
Base	Oil or Latex	Latex (Oil in rare cases)
Odor	Suffocating	Less or None

Technical comparison between conventional and low VOC paints:



CLASS:III B.Sc CHEMISTRY

COURSE NAME: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

CADEMY OF HIGHER EDUCATION COURSE CODE:16	CHU503A UNIT:II(Fertilize	ers) BATCH:2016-2019
Parameters	Conventional Paints	Low/Zero VOC Paints
Cost per gallon	INR720-3,000	INR1,800-4,200
Performance over 20 years	4-5 coats needed	1 coat is enough

Source: EPA

The following suppliers sell eco-friendly and non-toxic paints in India:

Asian Paints

Asian Paints is India's largest paint company that provides paint products for personal, industrial and automotive needs. Asian Paints began its journey into non-toxic paints by removing lead and heavy metals from its paints. The company has also substantially reduced the VOC content in its paints to comply with international standards, as specified by the Green Seal Standard for Paints & Coatings. For example, its Ace Exterior Emulsion (White) has 22.22 grams of VOC per liter of paint, which is substantially less than the international standard of 50 grams of VOC.

Berger Paints

Berger Paints is another leading paint company that has a broad customer base in India. Through their Green Horizon endeavor, the company seeks to protect the environment by producing better products. Berger Paints has removed lead, mercury and chromium from its paints, which are toxic to the human body. The company has also greatly reduced VOCs (8.4 gram per liter in its Breathe Easy Emulsions) and decreased the content of aromatics so that their products have zero negative health impact. Berger Paints has also diversified into water-based paints, custom-made for the pharmaceutical industry. Their Breathe Easy Emulsions are also water-based.



Dulux India

Dulux is a UK-based multinational company that has several production units in India. The company complies with the highest environmental standards on paints, especially in the area of VOC content. Dulux promotes water-based substitutes actively through its website and other promotional activities. The company offers a wide variety of water-based products such as Paint Mixing Kitchen, Endurance Silk, Magic White Silk, Quick Dry Gloss, Watershield Exterior Satin, and many more.

Kansai Nerolac

Nerolac is now the second largest player in the paints market in India. The company had switched to lead-free paints years ago due to the several health hazards associated with lead. All its manufacturing plants are ISO-14001 certified, which helps the company to achieve sound environmental performance. Recently, Kansai Nerolac launched a line of water-based, low-VOC paints that has the National Test House (NTH) certification.

It is clear that eco-friendly and non-toxic varieties of paints come at a higher cost than regular paints, but that they do last long. They also benefit you and your family's health, as well as the environment.

The shift to low/zero-VOC paints is seen not only because of an environmentally conscious industry but with an industry that understands that consumers are increasingly buying green-labelled products. Thus, it is necessary that consumers understand what a green label means. Green Seal Certifications (International), EcoMark Scheme (in India) are standards prevalent in the market for green paints. The EcoMark, conferred by Bureau of Indian Standards (BIS), has the following standards for water-based coatings:

• 5% or less VOC



- Absence of metals like Mercury and its compounds, Lead, Cadmium, Chromium VI and their oxides
- Less than 10 milligrams per kilogram free formaldehyde
- Absence of chemicals like halogenated solvents, benzene, poly-aromatic hydrocarbons and other aromatic hydrocarbons

Plastic paints



While oil-based paints still are widely used, "latex" paints that typically combine water and plastics have increased dramatically in popularity, particularly with do-it-yourselfers. The term latex originally referred to the use of latex from rubber trees for the solid part of the paint that actually creates the paint film. Today various plastics are used such as polyvinyls, polyurethanes, polyesters and acrylics. ("Acrylic latex paint" is sometimes mistakenly used to refer to any water-based paints that use plastics.)

Benefits of Plastic Based Paint

These latex paints take advantage of various properties of plastics. These plastic based paints are quick to cure, durable and washable. They often cover in one coat and clean up with water for minimal fuss.

Plastic Based Paint Trends

Before you pick up your brush or roller, check out some of the latest trends in painting:

- Plastic Based Paint for Exteriors: If you're looking to brighten up the exterior color of your home, look for latex paints that stand up to harsh weather and contain solar reflectivity formulation technology to help reduce heat absorption in the walls. This reduces the temperature inside the house, helping cut down on those air conditioning bills in summer!
- Lighten Up with White Plastic Based Paint: Bright whites are still go-to colors because they can quickly lighten up a room. But if you're repainting with a similar shade of white, it can be tricky to see exactly where you've painted. Check out the new latex paints with



special additives that actually roll on pink, allowing you to easily see your progress. And then have fun watching the paint dry as the disappearing dye fades to reveal your fresh shade of white. Yes—watching paint dry can be fun!

- Plastic Based Paint for Wood Floors: One of the latest trends in interior design is something unexpected—painted floors. Instead of repairing dingy old hardwoods or installing new flooring, try refinishing hardwoods with a durable latex paint. It can help bring out the warmth in the room—and you can readily change the color as often as you like.
- Plastic Lightens the Load: Some brands have switched to plastic paint containers that feature twist-off lids, side handles and easy-pour spouts. The plastic cans are lightweight, won't rust and are easier to carry.

Dyes, Wax polishing, Water and Oil paints

Watercolor (American English) or **watercolour** (British English; see spelling differences), also *aquarelle* (French, diminutive of Latin *aqua* "water"), is a painting method in which the paints are made of pigments suspended in a water-based solution. *Watercolor* refers to both the medium and the resulting artwork. Aquarelles painted with water-soluble colored ink instead of modern water colors are called "aquarellum atramento" (Latin for "aquarelle made with ink") by experts. However, this term has been more and more passing out of use.

The traditional and most common *support*—material to which the paint is applied—for watercolor paintings is paper. Other supports include papyrus, bark papers, plastics, vellum, leather, fabric, wood and canvas. Watercolor paper is often made entirely or partially with cotton, which gives a good texture and minimizes distortion when wet. Watercolors are usually translucent, and appear luminous because the pigments are laid down in a pure form with few fillers obscuring the pigment colors. Watercolors can also be made opaque by adding Chinese white.

In East Asia, watercolor painting with inks is referred to as brush painting or scroll painting. In Chinese, Korean and Japanese painting it has been the dominant medium, often in monochrome black or browns. India, Ethiopia and other countries have long watercolor painting traditions as well.

Oil paint is a type of slow-drying paint that consists of particles of pigment suspended in a drying oil, commonly linseed oil. The viscosity of the paint may be modified by the addition of a solvent such as turpentine or white spirit, and varnish may be added to increase



the glossiness of the dried oil paint film. Oil paints have been used in Europe since the 12th century for simple decoration, but were not widely adopted as an artistic medium until the early 15th century. Common modern applications of oil paint are in finishing and protection of wood in buildings and exposed metal structures such as ships and bridges. Its hard-wearing properties and luminous colors make it desirable for both interior and exterior use on wood and metal. Due to its slow-drying properties, it has recently been used in paint-on-glass animation. Thickness of coat has considerable bearing on time required for drying: thin coats of oil paint dry relatively quickly.

Metallic Coatings

Metallic coatings contain a metallic element or alloy. Metallic coatings can be applied by using a sprayer, electrochemically, chemically or mechanically. These coatings are applied on equipment requiring a shiny or glossy appearance and protection from sunlight, corrosion and oxidation.

Electrolytic plating

Electroplating is a process that uses electric current to reduce dissolved metal cations so that they form a thin coherent metal coating on an electrode. The term is also used for electrical oxidation of anions on to a solid substrate, as in the formation of silver chloride on silver wire to make silver/silver-chloride electrodes. Electroplating is primarily used to change the surface properties of an object (such as abrasion and wear resistance, corrosion protection, lubricity, aesthetic qualities), but may also be used to build up thickness on undersized parts or to form objects by electroforming.

The process used in electroplating is called **electrodeposition**. It is analogous to a concentration cell acting in reverse. The part to be plated is the cathode of the circuit. In one technique, the anode is made of the metal to be plated on the part. Both components are immersed in a solution called an electrolyte containing one or more dissolved metal saltsas well as other ions that permit the flow of electricity. A power supply supplies a direct current to the anode, oxidizing the metal atoms that it comprises and allowing them to dissolve in the solution. At the cathode, the dissolved metal ions in the electrolyte solution are reduced at the interface between the solution and the cathode, such that they "plate out" onto the cathode. The rate at which the anode is dissolved is equal to the rate at which the cathode is plated, vis-à-vis the current through the circuit. In this manner, the ions in the electrolyte bath are continuously replenished by the anode.

Other electroplating processes may use a nonconsumable anode such as lead or carbon. In these techniques, ions of the metal to be plated must be periodically replenished in the bath as they are drawn out of the solution. The most common form of electroplating is used for creating coins, such as US pennies, which are made of zinc covered in a layer of copper.

he cations associate with the anions in the solution. This cations are reduced at the cathode to deposit in the metallic, zero valence state. For example, for copper plating, in an acid



solution, copper is oxidized at the anode to Cu^{2+} by losing two electrons. The Cu^{2+} associates with the anion SO^{2-}

 $_4$ in the solution to form copper(II) sulphate. At the cathode, the Cu²⁺ is reduced to metallic copper by gaining two electrons. The result is the effective transfer of copper from the anode source to a plate covering the cathode.

The plating is most commonly a single metallic element, not an alloy. However, some alloys can be electrodeposited, notably brass and solder.

Many plating baths include cyanides of other metals (such as potassium cyanide) in addition to cyanides of the metal to be deposited. These free cyanides facilitate anode corrosion, help to maintain a constant metal ion level and contribute to conductivity. Additionally, non-metal chemicals such as carbonates and phosphates may be added to increase conductivity.

When plating is not desired on certain areas of the substrate, stop-offs are applied to prevent the bath from coming in contact with the substrate. Typical stop-offs include tape, foil, lacquers, and waxes.

The ability of a plating to cover uniformly is called *throwing power*; the better the throwing power the more uniform the coating.

Strike

Initially, a special plating deposit called a *strike* or *flash* may be used to form a very thin (typically less than 0.1 μ m thick) plating with high quality and good adherence to the substrate. This serves as a foundation for subsequent plating processes. A strike uses a high current density and a bath with a low ion concentration. The process is slow, so more efficient plating processes are used once the desired strike thickness is obtained.

The striking method is also used in combination with the plating of different metals. If it is desirable to plate one type of deposit onto a metal to improve corrosion resistance but this metal has inherently poor adhesion to the substrate, a strike can be first deposited that is compatible with both. One example of this situation is the poor adhesion of electrolytic nickel on zinc alloys, in which case a copper strike is used, which has good adherence to both.

Electrochemical deposition

Electrochemical deposition is generally used for the growth of metals and conducting metal oxides because of the following advantages: the thickness and morphology of the nanostructure can be precisely controlled by adjusting the electrochemical parameters; relatively uniform and compact deposits can be synthesized in template-based structures; higher deposition rates are obtained; and the equipment is inexpensive due to the non-requirements of either a high vacuum or a high reaction temperature.

Pulse electroplating or pulse electrodeposition (PED)

A simple modification in electroplating is pulse electroplating. This process involves the swift alternating of the potential or current between two different values resulting in a series of pulses



of equal amplitude, duration and polarity, separated by zero current. By changing the pulse amplitude and width, it is possible to change the deposited film's composition and thickness.^[9]

The experimental parameters of pulse electroplating usually consist of peak current/potential, duty cycle, frequency and effective current/potential. Peak current/potential is the maximum setting of electroplating current or potential. Duty cycle is the effective portion of time in certain electroplating period with the current or potential applied. The effective current/potential is calculated by multiplying the duty cycle and peak value of current or potential. Pulse electroplating could help to improve the quality of electroplated film and release the internal stress built up during fast deposition. Combination of the short duty cycle and high frequency could decrease the surface cracks. However, in order to maintain the constant effective current or potential, a high performance power supply may be required to provide high peak current/potential and fast switch. Another common problem of pulse electroplating is that the anode material could get plated and contaminated during the reverse electroplating, especially for the high cost, inert electrode like platinum.

Other factors that could affect the pulse electroplating include temperature, anode-to-cathode gap and stirring. Sometimes the pulse electroplating can be performed in heated electroplating bath to increase the depositing rate since the rate of almost all the chemical reaction increases exponentially with temperature per Arrhenius law. The anode-to-cathode gap is related to the current distribution between anode and cathode. Small gap to sample area ratio may cause uneven distribution of current and affect the surface topology of plated sample. Stirring may increase the transfer/diffusion rate of metal ions from bulk solution to the electrode surface. Stirring setting varies for different metal electroplating processes.

Brush electroplating

A closely related process is brush electroplating, in which localized areas or entire items are plated using a brush saturated with plating solution. The brush, typically a stainless steel body wrapped with an absorbent cloth material that both holds the plating solution and prevents direct contact with the item being plated, is connected to the anode of a low voltage direct current power source, and the item to be plated connected to the cathode. The operator dips the brush in plating solution then applies it to the item, moving the brush continually to get an even distribution of the plating material.

Brush electroplating has several advantages over tank plating, including portability, ability to plate items that for some reason cannot be tank plated (one application was the plating of portions of very large decorative support columns in a building restoration), low or no masking requirements, and comparatively low plating solution volume requirements. Disadvantages compared to tank plating can include greater operator involvement (tank plating can frequently be done with minimal attention), and inability to achieve as great a plate thickness.

Electroless deposition

Usually an electrolytic cell (consisting of two electrodes, electrolyte, and external source of current) is used for electrodeposition. In contrast, electroless deposition uses only one electrode



and no external source of electric current. However, the solution for electroless deposition needs to contain a reducing agent so that the electrode reaction has the form:

 $M^{z+}{+}Red_{solution}{\rightarrow} M_{solid}{+}Oxy_{solution}$

In principle any hydrogen-based reducing agent can be used although the redox potential of the reducing half-cell must be high enough to overcome the energy barriers inherent in liquid chemistry. Electroless nickel plating uses hypophosphite as the reducer while plating of other metals like silver, gold and copper typically use low-molecular-weight aldehydes.

A major benefit of this approach over electroplating is that the power sources and plating baths are not needed, reducing the cost of production. This technique can also plate diverse shapes and types of surface. The downside is that plating is usually slower and cannot create thick plates of metal. As a consequence of these characteristics, electroless deposition is quite common in the decorative arts.

Metal spraying process

Metal or thermal spraying is a technology, which protects and greatly extends the life of a wide variety of products in the most hostile environments and in situations where coatings are vital for longevity. The variety of metallised coatings is vast but can be broken down into two main categories. These include finishing coatings, such as anti-corrosion or decorative coatings, and engineering coatings such as wear resistant and thermal barrier coatings. Metal spraying is carried out in a wide range of anti corrosion and engineering markets, including oil and gas, construction, petrochemical and marine. Corrosion is a major problem for these industries. There are four commonly used processes in thermal spraying; Flamespray,

Arcspray, Plasma Spray and High Velocity Oxygen Fuel (HVOF), but only two of these, Flamespray and Arcspray are normally used for finishing coatings.

Anodizing

Anodizing (spelled **anodising** outside USA) is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts.

The process is called *anodizing* because the part to be treated forms the anode electrode of an electrical circuit. Anodizing increases resistance to corrosion and wear, and provides better adhesion for paint primers and glues than bare metal does. Anodic films can also be used for a number of cosmetic effects, either with thick porous coatings that can absorb dyes or with thin transparent coatings that add interference effects to reflected light.

Anodizing is also used to prevent galling of threaded components and to make dielectric films for electrolytic capacitors. Anodic films are most commonly applied to protect aluminium alloys, although processes also exist for titanium, zinc, magnesium, niobium, zirconium, hafnium, and tantalum. Iron or carbon steel metal exfoliates when oxidized under neutral or alkaline microelectrolytic conditions; i.e., the iron oxide (actually ferric hydroxide or hydrated iron oxide, also known as rust) forms by anoxic anodic pits and large cathodic surface, these pits concentrate anions such as sulfate and chloride accelerating the underlying metal to corrosion. Carbon flakes or nodules in iron or steel with high carbon content (high-carbon steel, cast iron) may cause an



electrolytic potential and interfere with coating or plating. Ferrous metals are commonly anodized electrolytically in nitric acid or by treatment with red fuming nitric acid to form hard black ferric oxide. This oxide remains conformal even when plated on wire and the wire is bent.

Anodizing changes the microscopic texture of the surface and the crystal structure of the metal near the surface. Thick coatings are normally porous, so a sealing process is often needed to achieve corrosion resistance. Anodized aluminium surfaces, for example, are harder than aluminium but have low to moderate wear resistance that can be improved with increasing thickness or by applying suitable sealing substances. Anodic films are generally much stronger and more adherent than most types of paint and metal plating, but also more brittle. This makes them less likely to crack and peel from aging and wear, but more susceptible to cracking from thermal stress.

Anodizing was first used on an industrial scale in 1923 to protect Duralumin seaplane parts from corrosion. This early chromic acid–based process was called the Bengough–Stuart process and was documented in British defence specification DEF STAN 03-24/3. It is still used today despite its legacy requirements for a complicated voltage cycle now known to be unnecessary. Variations of this process soon evolved, and the first sulfuric acid anodizing process was patented by Gower and O'Brien in 1927. Sulfuric acid soon became and remains the most common anodizing electrolyte.

Oxalic acid anodizing was first patented in Japan in 1923 and later widely used in Germany, particularly for architectural applications. Anodized aluminium extrusion was a popular architectural material in the 1960s and 1970s, but has since been displaced by cheaper plastics and powder coating. The phosphoric acid processes are the most recent major development, so far only used as pretreatments for adhesives or organic paints. A wide variety of proprietary and increasingly complex variations of all these anodizing processes continue to be developed by industry, so the growing trend in military and industrial standards is to classify by coating properties rather than by process chemistry.

Anodized aluminum

Aluminum alloys are anodized to increase corrosion resistance and to allow dyeing (coloring), improved lubrication, or improved adhesion. However, anodizing does not increase the strength of the aluminium object. The anodic layer is non-conductive.

When exposed to air at room temperature, or any other gas containing oxygen, pure aluminum self-passivates by forming a surface layer of amorphous aluminum oxide 2 to 3 nm thick, which provides very effective protection against corrosion. Aluminum alloys typically form a thicker oxide layer, 5–15 nm thick, but tend to be more susceptible to corrosion. Aluminum alloy parts are anodized to greatly increase the thickness of this layer for corrosion resistance. The corrosion resistance of aluminum alloys is significantly decreased by certain alloying elements or impurities: copper, iron, and silicon, so 2000-, 4000-, and 6000-series Al alloys tend to be most susceptible.



Although anodizing produces a very regular and uniform coating, microscopic fissures in the coating can lead to corrosion. Further, the coating is susceptible to chemical dissolution in the presence of high- and low-pHchemistry, which results in stripping the coating and corrosion of the substrate. To combat this, various techniques have been developed either to reduce the number of fissures, to insert more chemically stable compounds into the oxide, or both. For instance, sulfuric-anodized articles are normally sealed, either through hydro-thermal sealing or precipitating sealing, to reduce porosity and interstitial pathways that allow corrosive ion exchange between the surface and the substrate. Precipitating seals enhance chemical stability but are less effective in eliminating ion exchange pathways. Most recently, new techniques to partially convert the amorphous oxide coating into more stable micro-crystalline compounds have been developed that have shown significant improvement based on shorter bond lengths.

Some aluminium aircraft parts, architectural materials, and consumer products are anodized. Anodized aluminium can be found on MP3 players, smartphones, multitools, flashlights, cookware, cameras, sporting goods, firearms, window frames, roofs, in electrolytic capacitors, and on many other products both for corrosion resistance and the ability to retain dye. Although anodizing only has moderate wear resistance, the deeper pores can better retain a lubricating film than a smooth surface would.

Anodized coatings have a much lower thermal conductivity and coefficient of linear expansion than aluminium. As a result, the coating will crack from thermal stress if exposed to temperatures above 80 °C (353 K). The coating can crack, but it will not peel. The melting point of aluminium oxide is 2050 °C (2323 K), much higher than pure aluminium's 658 °C (931 K). This and the non-conductivity of aluminum oxide can make welding more difficult.

In typical commercial aluminium anodizing processes, the aluminium oxide is grown down into the surface and out from the surface by equal amounts. So anodizing will increase the part dimensions on each surface by half the oxide thickness. For example, a coating that is 2 μ m thick will increase the part dimensions by 1 μ m per surface. If the part is anodized on all sides, then all linear dimensions will increase by the oxide thickness. Anodized aluminium surfaces are harder than aluminium but have low to moderate wear resistance, although this can be improved with thickness and sealing.



CLASS:III B.Sc CHEMISTRY COURSE CODE:16CHU503A COURSE NAME:INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE UNIT:II(Fertilizers) BATCH:2016-2019

POSSIBLE QUESTIONS

UNIT II

PART A(20 MARKS)

(Q.NO 1 to 20 Online Examination)

PART-B(2 MARKS)

1. Mention different types of fertilizers.

2. Write down the manufacture process of urea

3. Write down the manufacture process of ammonium nitrate

4. What are paints?

5.Compare oil and water paints.

6.Write a note on metal spraying.

7. What is the role of fillers in paints?

PART-C(6 MARKS)

1. Explain the manufacture process of superphosphate of lime and ammonium phosphates.

2.How will you classify surface coatings. Explain various consitutents present in paints and mention its function.

3.Differentiate electroless and electroplating.

4. Write a note on plastic plaint and eco friendly paint.

(Deemed to be University Under Section 3 of UGC Act 1956)

COIMBATORE-641 021

(For the Canditates admitted from 2016 & onwards)

III B.Sc Chemistry

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE (16CHU503A)

Unit II (FERTILIZERS AND SURFACE COATINGS)

S.NO	Question	Option 1	Option 2	Option 3	Option 4	Answer
1	Which among these					
	is not the natural	chile	Ammonium	Rock		
	inorganic fertilizers	saltpeter	nitrate	phosphate	potassium salt	fuel gas
2	Ammonium nitrate	hydropho				
	is	bic	hydrosco pic	hydrogenous	hydrated	hydrosco pic
3				ammonium		
	21% of nitrogen	Ammoniu	ammonium	sulphate		ammonium
	present in	m nitrate	sulphate	nitrate	urea	sulphate
4	which one of the		ammonium			
	following is called	ammoniu	sulphate		triple super	ammonium
	double salt.	m nitrate	nitrate	urea	phosphate	sulphate nitrate
5	urea have%					
	of nitrogen in it.	50%	48%	45-47 %	46-50%	45-47 %
6	urea is used in					
	citrous crops it	healthy	high			
	cause	grow	production	plant toxicity	plant strength	plant toxicity
7	ammonium nitrate					
	contains%					
	of nitrogen	31-34	23-26	30-32	32-35	32-35
8	the bamag process					
	is carried out	100degre	200 degree	300 degree	150 degree	150 degree
	temperature	e celcious	celcious	celcious	celcious	celcious
9	the raw material for	ammoniu				
	ammonium nitrate	m and	ammonium	NH3 and	NH3 and	ammonium and
	are	NO2	and HNO3	NH4OH	NaNO3	HNO3
10	which one of the					
	following is belongs	fuel gas	fuel	nitric oxide	basic salt	fuel gas



	to ammonium					
11	the calcium					
11	nhosphate derived					
	from rock					
	nhosphate and	triple				
	sulphuric acid is	super	nhosnhate	super	commercial	
	called as	phosphate	fertilizers	phosphate	fertilizers	super phosphate
12	The is	prospriate		phosphate		
	known as					
	superphosphate	Ca3(PO4)	Ca(HPO4)2	Ca2(PO4)	Ca(H2PO4)	Ca(H2PO4)
13	Commercial super					
	phosphate is a	Ca3(PO4)2	Ca(H2PO4)2+C	CaSO4+Ca(PO	CaH(PO4)2+HN	
	combination of	+H2SO4	aSO4.2H2O	4)2	03	CaH(PO4)2+HNO3
14	The rock containing					
	% available					
	P_2O_5 for super					
	phosphate					
	manufactured	10%	5%	20%	50	20%
15	Triple phosphate					
	contains about 44 -					
	47 %content	PO4	(PO4)2	P2O5	НРОЗ	P2O5
16	which of the					
	potassium fertilizer					
	is known as muriate			1/252.4		
17	of potasn	KCI	KNU3	K2SO4	KBr	KCI
1/	In K_2SO_4 refuilzer,					
	%	65%	0.75%	0.45%	0.54%	0.54%
18	indicates the	0378	0.7570	0.4578	0.5476	0.54%
10	nhosphate contents	BIP	BIP	BTP	BIT	BLP
19	The following			DI		
17	fertilizers which					
	does not harmful to					
	the crops in				Supper	
	excessive amount.	Urea	Bone meal	N P K fertilizer	phosphate	Bone meal
20	Muriate is belongs	. Nitrate	.Phosphate		.Complex	
	to fertilizer	fertilizer	fertilizer	.Mixed	fertilizer	.Mixed
21	In atmosphere					
	,causes first step of					
	electrics discharge					
	nitrogen is					
	converted in to	NO	NO2	NO3	NO3 and HNO2	NO
22	In the atmosphere -					
	tonnes of					
	nitric acid are					
	produced daily	250,000	350,000	0.25	112,500	250,000

23	.Which is the					
	bacteria used for	symbiotic				
2.4	the nitrogen fixation	bacteria	streptococcus	E.coli	staphylococcus	symbiotic bacteria
24	The temperature	200-210		220 -		
	maintain in urea	degree	150 degree	250degree	150-200	200-210 degree
	synthesis is	Celsius	Celsius	Celsius	degree celcius	Celsius
25	The sensitivity of					
	ammonium nitrate					
	is removed by the	<i>c</i> :0	6.602	NO2	(004)2	
26	addition of	SIO ₂	CacO3	NOZ	(PO4)2	S
26	which is the primary					
	following	D	C		7	D
27	10110Wing	P	3	В	20	۲
27	which nutrient is the					
	in the plant growth	D	Нα		AL	N
28	which of the	Г	Пġ	Ca		
20	following nutrient is					
	used to strengthen					
	the roots and leaves	Ca	Mg	C	Zn	Ca
29	the pair which is	Cu	1118			Cu
27	belongs to micro					
	nutrient in given					
	below	Ca&P	N&K	S&K	Zn&Mb	Zn&Mb
30	how many essential					
	nutrient is present					
	in the plant					
	development	14	18	6	16	18
31	calcium gives					
	-to thee plants	strength	odour	colour	food	strength
32	the synonymous of	insectiside				
	pesticides is	5	fertilizers	nutrient	capsuls	insectisides
33	phosphate					
	preparation &					
	phosphate in oils	nematoci				
	are used as	de	miticides	herbicides	fungicides	herbicides
34	Surface coating is	metallic	protecting		ceramic	
25	otherwise known as	coating	coating	glass coating	coating	protecting coating
35	The first step in					
	applying a coating is					
	the of the					
	surface of the base	alaanin -	washing	druine	wasning and	alaanina
26	The vigerous	cleaning	wasning	urying	urying	cleaning
30	ine vigorous					
	evolution of					
	speeds up the	nitrogen	000000	budrogon	carbon	hydrogon
	process of cleaning	nitrogen	oxygen	nyarogen	Carbon	nyarogen

37	Immersion in hot					
	solution is the					
	most common					
	cleaning method	acid	alkaline	ethanol	methanol	alkaline
38	An example for					
	inorganic surface					
	coating is	paints	varnishes	enamels	wax polishes	enamels
39	An example for	-				
	organic surface				surface	
	coating is	enamels	metal coatings	lacquers	conversions	lacquers
40	oil paint is a type of	varnishes	lacquers	paints	spirit varnish	paints
41	Coating of zinc on		·			
	iron is known as	tinning	plating	galvanising	hot dipping	galvanising
42	coating of tin on	-				
	iron is called					
		tinning	plating	galvanising	hot dipping	tinning
43	In	-				
	molten metal coat					
	droplets are					
	atomised and blown					
	on the surface of					
	the base metal with					
	compressed air	cementati				
	using a spray gun	on	metal spraying	metal cladding	electroplating	metal spraying
44	is coated					
	using metal spraying					
	on air craft steel	aluminiu				
	parts	m	platinum	sodium	magnesium	aluminium
45	The disadvantages					
	of are					
	that the sprayed					
	coatings are					
	generally more					
	porous, rougher,					
	less adherent and					
	harder than the					
	coatings provided	cementati				
	by other methods.	on	metal spraying	metal cladding	electroplating	metal spraying
46	Metals zinc, nickel					
	are capable of					
	forming a self					
	protective layer of					
	their respective					
	oxides. But					
	coated					
	surfaces require					
	oxidation to convert	chromium	tin	aluminium	magnesium	aluminium

	the metal to its inert					
	oxide					
47	In anodising the					
	cathode can be				insulting or	
	made of any inert			semiconductin	semiconductin	
	material	insulating	conducting	g	g	conducting
48	The expansion of					
	the film in anodising					
	technique decreases					
	the					
	and consequently					
	the corrosion					
	resistance is	conductivi				
	increased.	ty	porosity	temperature	pressure	porosity
49	is a main					
	ingredient of an oil					
	paint	pigment	varnishes	water	oil	pigment
50	Special ingredients					
	such as extenders,					
	antiskinning agents					
	and are					
	required for					
	formulating paints	varnishes	water	oil	plastisizers	plastisizers
51	Extenders are	antiskinni				
50	otherwise known as	ng agents	fillers	vehicle	binder	fillers
52	Electroplating is					
	otherwise known as	electrode	electroless	and dising	vacuum	
52		position	plating	anodising	metallising	electrodeposition
55	the most important					
	the most important					
	nethou for applying	alactrada	alactrolocs		Vacuum	
	protective metaline	position	electroless	anodicing	motallicing	alactrodoposition
54	Diating in abconce of	position	plating	anouising	metanising	electiodeposition
54	current but					
	nresence of					
	reducing agent is	electrode	alectroless		vacuum	
	known as	nosition	plating	anodising	metallising	electroless plating
55	Wax polishes is	antiskinni	plating	anousing	metanising	cicculoress plating
55	otherwise known as	ng agents	fillers	paraffin coats	binder	paraffin coats
56	Wax polishes are					
	pastes of solid					
	waxes or semisolid					
	greases with a	organic			organic solvent	
	volatile	solvent	liguid wax	semi solid wax	and liquid wax	organic solvent
57		-				
37	The composition of	organic			organic solvent	

	or grease +					
58	paints			water		
	are fire-retardant	silicone	antifouling	repellant	luminous	silicone
59	are					
	used in silicone	liquid		semisolid	semiliquid	
	paints	silicones	soild silicones	silicones	silicones	soild silicones
60						
	are used as	liquid		semisolid	semiliquid	
	lubricants	silicones	soild silicones	silicones	silicones	liquid silicones





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UNIT III SYLLABUS

Batteries:

Working of the following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

Batteries

Lead acid battery

The **lead–acid battery** was invented in 1859 by French physicist Gaston Planté and is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by automobile starter motors.

As they are inexpensive compared to newer technologies, lead-acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Large-format lead-acid designs are widely used for storage in backup power supplies in cell phone towers, high-availability settings like hospitals, and stand-alone power systems. For these roles, modified versions of the standard cell may be used to improve storage times and reduce maintenance requirements. *Gel-cells* and *absorbed glass-mat* batteries are common in these roles, collectively known as VRLA (valve-regulated lead-acid) batteries.

In 1999 lead–acid battery sales accounted for 40–45% of the value from batteries sold worldwide excluding China and Russia, and a manufacturing market value of about \$15 billion.

Discharge



Futige discharged state betwither pasitive rand pages tive plates become lead(II) sulfate (PbSO 4), and the electrolyte loses much of its dissolved sulfuric acid and becomes primarily water. The discharge process is driven by the conduction of electrons from the negative plate back into the cell at the positive plate in the external circuit.

Negative plate reaction



Release of two conducting electrons gives lead electrode a net negative charge

As electrons accumulate they create an electric field which attracts hydrogen ions and repels sulfate ions, leading to a double-layer near the surface. The hydrogen ions screen the charged electrode from the solution which limits further reactions unless charge is allowed to flow out of electrode.

Positive plate reaction

 $PbO_2(s) + HSO_4(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

The total reaction can be written as

 $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

The sum of the molecular masses of the reactants is 642.6 g/mol, so theoretically a cell can produce two faradays of charge (192,971 coulombs) from 642.6 g of reactants, or 83.4 ampere-hours per kilogram (or 13.9 ampere-hours per kilogram for a 12-volt battery). For a 2 volts cell, this comes to 167 watt-hours per kilogram of reactants, but a lead–acid cell in practice gives only 30–40 watt-hours per kilogram of battery, due to the mass of the water and other constituent parts. .

Charging



Fully recharged: Lead negative plate, Lead dioxide positive plate and sulfuric acid electrolyte

In the fully charged state, the negative plate consists of lead, and the positive plate lead dioxide, with the electrolyte of concentrated sulfuric acid.

Overcharging with high charging voltages generates oxygen and hydrogen gas by electrolysis of water, which is lost to the cell. The design of some types of lead-acid battery allow the electrolyte level to be inspected and topped up with any water that has been lost.

Due to the freezing-point depression of the electrolyte, as the battery discharges and the concentration of sulfuric acid decreases, the electrolyte is more likely to freeze during winter weather when discharged.

Ion motion

During discharge, H⁺

produced at the negative plates moves into the electrolyte solution and then is consumed into the positive plates, while HSO^-

4 is consumed at both plates. The reverse occurs during charge. This motion can be by





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electrically driven proton flow or Grotthuss mechanism, or by diffusion through the medium, or by flow of a liquid electrolyte medium. Since the density is greater when the sulfuric acid concentration is higher, the liquid will tend to circulate by convection. Therefore, a liquidmedium cell tends to rapidly discharge and rapidly charge more efficiently than an otherwise similar gel cell.

Lithium battery

A lithium-ion battery or Li-ion battery (abbreviated as LIB) is a type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging. Li-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in a non-rechargeable lithium battery. The electrolyte, which allows for ionic movement, and the two electrodes are the constituent components of a lithium-ion battery cell.

Lithium-ion batteries are common in home electronics. They are one of the most popular types of rechargeable batteries for portable electronics, with a high energy density, tiny memory effect and low self-discharge. LIBs are also growing in popularity for military, battery electric vehicle and aerospace applications.

Chemistry, performance, cost and safety characteristics vary across LIB types. Handheld electronics mostly use LIBs based on lithium cobalt oxide (LiCoO₂), which offers high energy density but presents safety risks, especially when damaged. Lithium iron phosphate (LiFePO₄), lithium ion manganese oxide battery (LiMn₂O₄, Li₂MnO₃, or LMO), and lithium nickel manganese cobalt oxide (LiNiMnCoO₂ or NMC) offer lower energy density but longer lives and less likelihood of unfortunate events in real-world use (e.g., fire, explosion, etc.). Such batteries are widely used for electric tools, medical equipment, and other roles. NMC in particular is a leading contender for automotive applications. Lithium nickel cobalt aluminum oxide (LiNiCoAlO₂ or NCA) and lithium titanate (Li₄Ti₅O₁₂ or LTO) are specialty designs aimed at particular niche roles. The newer lithium-sulfur batteries promise the highest performance-toweight ratio.

Lithium-ion batteries can pose unique safety hazards since they contain a flammable electrolyte and may be kept pressurized. A battery cell charged too quickly could cause a short circuit, leading to explosions and fires. Because of these risks, testing standards are more stringent than those for acid-electrolyte batteries, requiring both a broader range of test conditions and additional battery-specific tests. There have been battery-related recalls by some companies, including the 2016 SamsungGalaxy Note 7 recall for battery fires.

Research areas for lithium-ion batteries include life extension, energy density, safety, cost reduction, and charging speed, among others.

The reactants in the electrochemical reactions in a lithium-ion battery are the negative and positive electrodes and the electrolyte providing a conductive medium for lithium ions to move between the electrodes. Electrical energy flows out from or in to the battery when electrons flow through an external circuit during discharge or charge, respectively.

Both electrodes allow lithium ions to move in and out of their structures with a process called insertion (intercalation) or extraction (deintercalation), respectively. During discharge,



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the (positive) lithium ions move from the negative electrode to the positive electrode (forming a lithium compound) through the electrolyte while the electrons flow through the external circuit in the same direction.^[83] When the cell is charging, the reverse occurs with the lithium ions and electrons moved back into the negative electrode in a net higher energy state. The following equations exemplify the chemistry.

The positive (cathode) electrode half-reaction in the lithium-doped cobalt oxide substrate is:

 $CoO_2 + Li^+ + e^- \leftrightarrow LiCoO_2$

The negative (anode) electrode half-reaction for the graphite is:

 $LiC_6 \leftrightarrow C_6 + Li^+ + e^-$

The full reaction (left: charged, right: discharged) being:

 $LiC_6+CoO_2\leftrightarrow C_6+LiCoO_2$

The overall reaction has its limits. Overdischarge supersaturates lithium cobalt oxide, leading to the production of lithium oxide, possibly by the following irreversible reaction:

Li⁺+e⁻LiCoO₂→Li₂O+CoO

Overcharge up to 5.2 volts leads to the synthesis of cobalt(IV) oxide, as evidenced by x-ray diffraction:

$$LiCoO_2 \rightarrow Li^+ + e^- + CoO_2$$

In a lithium-ion battery the lithium ions are transported to and from the positive or negative electrodes by oxidizing the transition metal, cobalt (Co), in $Li_{1-x}CoO_2$ from Co^{3+} to Co⁴⁺ during charge, and reducing from Co⁴⁺ to Co³⁺ during discharge. The cobalt electrode reaction is **only** reversible for x < 0.5 (x in mole units), limiting the depth of discharge allowable. This chemistry was used in the Li-ion cells developed by Sony in 1990.

The cell's energy is equal to the voltage times the charge. Each gram of lithium represents Faraday's constant/6.941 or 13,901 coulombs. At 3 V, this gives 41.7 kJ per gram of lithium, or 11.6 kWh per kg. This is a bit more than the heat of combustion of gasoline, but does not consider the other materials that go into a lithium battery and that make lithium batteries many times heavier per unit of energy.

Electrolytes

The cell voltages given in the Electrochemistry section are larger than the potential at which aqueous solutions will electrolyze.

Liquid Electrolytes

Liquid electrolytes in lithium-ion batteries consist of lithium salts, such

as LiPF₆, LiBF₄ or LiClO₄ in an organic solvent, such as ethylene carbonate, dimethyl carbonate, and diethyl carbonate. A liquid electrolyte acts as a conductive pathway for the movement of cations passing from the negative to the positive electrodes during discharge. Typical conductivities of liquid electrolyte at room temperature (20 °C (68 °F)) are in the range of





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10 mS/cm, increasing by approximately 30–40% at 40 °C (104 °F) and decreasing slightly at 0 °C (32 °F).

The combination of linear and cyclic carbonates (e.g., ethylene carbonate (EC) and dimethyl carbonate (DMC)) offers high conductivity and SEI-forming ability. A mixture of a high ionic conductivity and low viscosity carbonate solvents is needed, because the two properties are mutually exclusive in a single material.

Organic solvents easily decompose on the negative electrodes during charge. When appropriate organic solvents are used as the electrolyte, the solvent decomposes on initial charging and forms a solid layer called the solid electrolyte interphase (SEI), which is electrically insulating yet provides significant ionic conductivity. The interphase prevents further decomposition of the electrolyte after the second charge. For example, ethylene carbonate is decomposed at a relatively high voltage, 0.7 V vs. lithium, and forms a dense and stable interface.

Composite electrolytes based on POE (poly(oxyethylene)) provide a relatively stable interface. It can be either solid (high molecular weight) and be applied in dry Li-polymer cells, or liquid (low molecular weight) and be applied in regular Li-ion cells.

Room temperature ionic liquids (RTILs) are another approach to limiting the flammability and volatility of organic electrolytes.

Solid Electrolytes

Recent advances in battery technology involve using a solid as the electrolyte material. The most promising of these being ceramics.

Solid ceramic electrolytes are mostly lithium metal oxides which allow lithium ion transport through the solid more readily due to the intrinsic lithium. The main benefit of solid electrolytes is that there is no risk of leaks, which is a serious safety issue for batteries with liquid electrolytes.

Solid ceramic electrolytes can be further broken down into two main categories: ceramic and glassy. Ceramic solid electrolytes are highly ordered compounds with crystal structures that usually have ion transport channels. Common ceramic electrolytes are lithium super ion conductors (LISICON) and perovskites. Glassy solid electrolytes are amorphous atomic structures made up of similar elements to ceramic solid electrolytes, but have higher conductivities overall due to higher conductivity at grain boundaries.

Both glassy and ceramic electrolytes can be made more ionically conductive by substituting sulfur for oxygen. The larger radius of sulfur and its higher ability to be polarized allow for higher conductivity of lithium. This contributes to conductivities of solid electrolytes are nearing parity with their liquid counterparts, with most on the order of 0.1 mS/cm and the best at 10 mS/cm.



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Charge and discharge

During discharge, lithium ions (Li⁺) carry the current within the battery from the negative to the positive electrode, through the non-aqueous electrolyte and separator diaphragm.

During charging, an external electrical power source (the charging circuit) applies an overvoltage (a higher voltage than the battery produces, of the same polarity), forcing a charging current to flow within the battery from the positive to the negative electrode, i.e. in the reverse direction of a discharge current under normal conditions. The lithium ions then migrate from the positive to the negative electrode, where they become embedded in the porous electrode material in a process known as intercalation.

Procedure

The charging procedures for single Li-ion cells, and complete Li-ion batteries, are slightly different.

- A single Li-ion cell is charged in two stages:
 - 1. Constant current (CC)
 - 2. Constant Voltage (CV)
- A Li-ion battery (a set of Li-ion cells in series) is charged in three stages:
 - 1. Constant current
 - 2. Balance (not required once a battery is balanced)
 - 3. Constant Voltage

During the **constant current** phase, the charger applies a constant current to the battery at a steadily increasing voltage, until the voltage limit per cell is reached.

During the **balance** phase, the charger reduces the charging current (or cycles the charging on and off to reduce the average current) while the state of charge of individual cells is brought to the same level by a balancing circuit, until the battery is balanced. Some fast chargers skip this stage. Some chargers accomplish the balance by charging each cell independently.

During the **constant voltage** phase, the charger applies a voltage equal to the maximum cell voltage times the number of cells in series to the battery, as the current gradually declines towards 0, until the current is below a set threshold of about 3% of initial constant charge current.

Periodic topping charge about once per 500 hours. Top charging is recommended to be initiated when voltage goes below 4.05 V/cell.

Failure to follow current and voltage limitations can result in an explosion.

Fuel cells

A **fuel cell** is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or



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another oxidizing agent. Fuel cells are different from batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy comes from chemicals already present in the battery. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

The first fuel cells were invented in 1838. The first commercial use of fuel cells came more than a century later in NASA space programmes to generate power for satellite sand space capsules. Since then, fuel cells have been used in many other applications. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are also used to power fuel cell vehicles, including forklifts, automobiles, buses, boats, motorcycles and submarines.

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (protons) to move between the two sides of the fuel cell. At the anode a catalyst causes the fuel to undergo oxidation reactions that generate protons (positively charged hydrogen ions) and electrons. The protons flow from the anode to the cathode through the electrolyte after the reaction. At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, another catalyst causes hydrogen ions, electrons, and oxygen to react, forming water. Fuel cells are classified by the type of electrolyte they use and by the difference in startup time ranging from 1 second for proton exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC). A related technology is flow batteries, in which the fuel can be regenerated by recharging. Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are "stacked", or placed in series, to create sufficient voltage to meet an application's requirements.^[2] In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40-60%; however, if waste heat is captured in a cogeneration scheme, efficiencies up to 85% can be obtained.

The fuel cell market is growing, and in 2013 Pike Research estimated that the stationary fuel cell market will reach 50 GW by 2020.

Types of fuel cells; design

Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three adjacent segments: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electric current is created, which can be used to power electrical devices, normally referred to as the load.

At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide.

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A block diagram of a fuel cell

Design features in a fuel cell include:

- The electrolyte substance, which usually defines the *type* of fuel cell, and can be made from a number of substances like potassium hydroxide, salt carbonates, and phosphoric acid.
- The anode catalyst, usually fine platinum powder, breaks down the fuel into electrons and ions.
- The cathode catalyst, often nickel, converts ions into waste chemicals, with water being the most common type of waste.
- Gas diffusion layers that are designed to resist oxidization.

A typical fuel cell produces a voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors:

- Activation loss
- Ohmic loss (voltage drop due to resistance of the cell components and interconnections)
- Mass transport loss (depletion of reactants at catalyst sites under high loads, causing rapid loss of voltage).

To deliver the desired amount of energy, the fuel cells can be combined in series to yield higher voltage, and in parallel to allow a higher current to be supplied. Such a design is called a *fuel cell stack*. The cell surface area can also be increased, to allow higher current from each cell. Within the stack, reactant gases must be distributed uniformly over each of the cells to maximize the power output.

Proton exchange membrane fuel cells (PEMFCs)

In the archetypical hydrogen–oxide proton exchange membrane fuel cell design, a protonconducting polymer membrane (typically nafion) contains the electrolyte solution that separates




the anode and cathodesides. This was called a "solid polymer electrolyte fuel cell" (SPEFC) in the early 1970s, before the proton exchange mechanism was well understood. (Notice that the synonyms "polymer electrolyte membrane" and "proton exchange mechanism" result in the same acronym.)

On the anode side, hydrogen diffuses to the anode catalyst where it later dissociates into protons and electrons. These protons often react with oxidants causing them to become what are commonly referred to as multi-facilitated proton membranes. The protons are conducted through the membrane to the cathode, but the electrons are forced to travel in an external circuit (supplying power) because the membrane is electrically insulating. On the cathode catalyst, oxygen molecules react with the electrons (which have traveled through the external circuit) and protons to form water.

In addition to this pure hydrogen type, there are hydrocarbon fuels for fuel cells, including diesel, methanol (*see:* direct-methanol fuel cells and indirect methanol fuel cells) and chemical hydrides. The waste products with these types of fuel are carbon dioxide and water. When hydrogen is used, the CO2 is released when methane from natural gas is combined with steam, in a process called steam methane reforming, to produce the hydrogen. This can take place in a different location to the fuel cell, potentially allowing the hydrogen fuel cell to be used indoors—for example, in fork lifts.



Construction of a high-temperature PEMFC: Bipolar plate as electrode with in-milled gas channel structure, fabricated from conductive composites (enhanced with graphite, carbon black, carbon fiber, and/or carbon nanotubes for more conductivity); Porous carbon papers; reactive layer, usually on the polymer membrane applied; polymer membrane.



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Condensation of water produced by a PEMFC on the air channel wall. The gold wire around the cell ensures the collection of electric current.

The different components of a PEMFC are

- 1. bipolar plates,
- 2. electrodes,
- 3. catalyst,
- 4. membrane, and
- 5. the necessary hardware such as current collectors and gaskets.

The materials used for different parts of the fuel cells differ by type. The bipolar plates may be made of different types of materials, such as, metal, coated metal, graphite, flexible graphite, C– C composite, carbon–polymer composites etc.^[26] The membrane electrode assembly (MEA) is referred as the heart of the PEMFC and is usually made of a proton exchange membrane sandwiched between two catalyst-coated carbon papers. Platinum and/or similar type of noble metals are usually used as the catalyst for PEMFC. The electrolyte could be a polymer membrane.

Proton exchange membrane fuel cell design issues

- Cost. In 2013, the Department of Energy estimated that 80-kW automotive fuel cell system costs of US\$67 per kilowatt could be achieved, assuming volume production of 100,000 automotive units per year and US\$55 per kilowatt could be achieved, assuming volume production of 500,000 units per year. Many companies are working on techniques to reduce cost in a variety of ways including reducing the amount of platinum needed in each individual cell. Ballard Power Systems has experimented with a catalyst enhanced with carbon silk, which allows a 30% reduction (1 mg/cm² to 0.7 mg/cm²) in platinum usage without reduction in performance. Monash University, Melbourne uses PEDOT as a cathode. A 2011 published study doi: 10.1021/ja1112904^[30] documented the first metal-free electrocatalyst using relatively inexpensive doped carbon nanotubes, which are less than 1% the cost of platinum and are of equal or superior performance. A recently published article demonstrated how the environmental burdens change when using carbon nanotubes as carbon substrate for platinum.
- Water and air management (in PEMFCs). In this type of fuel cell, the membrane must be hydrated, requiring water to be evaporated at precisely the same rate that it is produced. If





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water is evaporated too quickly, the membrane dries, resistance across it increases, and eventually it will crack, creating a gas "short circuit" where hydrogen and oxygen combine directly, generating heat that will damage the fuel cell. If the water is evaporated too slowly, the electrodes will flood, preventing the reactants from reaching the catalyst and stopping the reaction. Methods to manage water in cells are being developed like electroosmotic pumps focusing on flow control. Just as in a combustion engine, a steady ratio between the reactant and oxygen is necessary to keep the fuel cell operating efficiently.

- Temperature management. The same temperature must be maintained throughout the cell in order to prevent destruction of the cell through thermal loading. This is particularly challenging as the $2H_2 + O_2 \rightarrow 2H_2O$ reaction is highly exothermic, so a large quantity of heat is generated within the fuel cell.
- Durability, service life, and special requirements for some type of cells. Stationary fuel cell applications typically require more than 40,000 hours of reliable operation at a temperature of -35 °C to 40 °C (-31 °F to 104 °F), while automotive fuel cells require a 5,000-hour lifespan (the equivalent of 240,000 km (150,000 mi)) under extreme temperatures. Current service life is 2,500 hours (about 75,000 miles).^[34] Automotive engines must also be able to start reliably at $-30 \,^{\circ}\text{C}$ ($-22 \,^{\circ}\text{F}$) and have a high power-to-volume ratio (typically 2.5 kW per liter).
- Limited carbon monoxide tolerance of some (non-PEDOT) cathodes.

Phosphoric acid fuel cell (PAFC)

Phosphoric acid fuel cells (PAFC) were first designed and introduced in 1961 by G. V. Elmore and H. A. Tanner. In these cells phosphoric acid is used as a non-conductive electrolyte to pass positive hydrogen ions from the anode to the cathode. These cells commonly work in temperatures of 150 to 200 degrees Celsius. This high temperature will cause heat and energy loss if the heat is not removed and used properly. This heat can be used to produce steam for air conditioning systems or any other thermal energy consuming system. Using this heat in cogeneration can enhance the efficiency of phosphoric acid fuel cells from 40-50% to about 80%.^[35] Phosphoric acid, the electrolyte used in PAFCs, is a non-conductive liquid acid which forces electrons to travel from anode to cathode through an external electrical circuit. Since the hydrogen ion production rate on the anode is small, platinum is used as catalyst to increase this ionization rate. A key disadvantage of these cells is the use of an acidic electrolyte. This increases the corrosion or oxidation of components exposed to phosphoric acid.

Solid acid fuel cell (SAFC)

Solid acid fuel cells (SAFCs) are characterized by the use of a solid acid material as the electrolyte. At low temperatures, solid acids have an ordered molecular structure like most salts. At warmer temperatures (between 140 and 150 degrees Celsius for CsHSO₄), some solid acids undergo a phase transition to become highly disordered "superprotonic" structures, which increases conductivity by several orders of magnitude. The first proof-of-concept SAFCs were developed in 2000 using cesium hydrogen sulfate (CsHSO₄).^[37] Current SAFC systems use cesium dihydrogen phosphate (CsH₂PO₄) and have demonstrated lifetimes in the thousands of hours.

Alkaline fuel cell (AFC)





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The alkaline fuel cell or hydrogen-oxygen fuel cell was designed and first demonstrated publicly by Francis Thomas Bacon in 1959. It was used as a primary source of electrical energy in the Apollo space program. The cell consists of two porous carbon electrodes impregnated with a suitable catalyst such as Pt, Ag, CoO, etc. The space between the two electrodes is filled with a concentrated solution of KOH or NaOH which serves as an electrolyte. H₂ gas and O₂ gas are bubbled into the electrolyte through the porous carbon electrodes. Thus the overall reaction involves the combination of hydrogen gas and oxygen gas to form water. The cell runs continuously until the reactant's supply is exhausted. This type of cell operates efficiently in the temperature range 343 K to 413 K and provides a potential of about 0.9 V. AAEMFC is a type of AFC which employs a solid polymer electrolyte instead of aqueous potassium hydroxide (KOH) and it is superior to aqueous AFC.

Solar cell

A **solar cell**, or **photovoltaic cell**, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemicalphenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices can be combined to form modules, otherwise known as solar panels. In basic terms a single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts.

Solar cells are described as being photovoltaic, irrespective of whether the source is sunlight or an artificial light. They are used as a photodetector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating either electron-hole pairs or excitons.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

In contrast, a solar thermal collector supplies heat by absorbing sunlight, for the purpose of either direct heating or indirect electrical power generation from heat. A "photoelectrolytic cell" (photoelectrochemical cell), on the other hand, refers either to a type of photovoltaic cell (like that developed by Edmond Becquerel and modern dye-sensitized solar cells), or to a device that splits water directly into hydrogen and oxygen using only solar illumination.

The solar cell works in several steps:

- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
- Electrons are excited from their current molecular/atomic orbital. Once excited an electron can either dissipate the energy as heat and return to its orbital or travel through the cell until it reaches an electrode. Current flows through the material to cancel the potential and this electricity is captured. The chemical bonds of the material are vital for this process to work, and usually silicon is used in two layers, one layer being doped with boron, the



other phosphorus. These layers have different chemical electric charges and subsequently both drive and direct the current of electrons.

- An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.
- An inverter can convert the power to alternating current (AC).

The most commonly known solar cell is configured as a large-area p–n junction made from silicon. Other possible solar cell types are organic solar cells, dye sensitized solar cells, perovskite solar cells, quantum dot solar cells etc. The illuminated side of a solar cell generally have a transparent conducting film for allowing light to enter into active material and to collect the generated charge carriers. Typically, films with high transmittance and high electrical conductance such as indium tin oxide, conducting polymers or conducting nanowire networks are used for the purpose.

Polymer cell

A lithium polymer battery, or more correctly lithium-ion polymer battery (abbreviated as LiPo, LIP, Li-poly, lithium-poly and others), is a rechargeable batteryof lithiumion technology using a polymer electrolyte instead of a liquid electrolyte. High conductivity semisolid (gel) polymers form this electrolyte. These batteries provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature, like tablet computers, cellular telephonehandsets and radio-controlled aircraft.

Working principle

Just as with other lithium-ion cells, LiPos work on the principle of intercalation and deintercalation of lithium ions from a positive electrode material and a negative electrode material, with the liquid electrolyte providing a conductive medium. To prevent the electrodes from touching each other directly, a microporous separator is in between which allows only the ions and not the electrode particles to migrate from one side to the other.

Charging

The voltage of a LiPo cell depends on its chemistry and varies from about 2.7-3.0 V (discharged) to about 4.2 V (fully charged), for cells based on lithium-metal-oxides (such as LiCoO₂), and around 1.8-2.0 V (discharged) to 3.6-3.8 V (charged) for those based on lithium-iron-phosphate (LiFePO₄).

The exact voltage ratings should be specified in product data sheets, with the understanding that the cells should be protected by an electronic circuit that won't allow them to overcharge nor over-discharge under use.

For LiPo battery packs with cells connected in series, a specialised charger may monitor the charge on a per-cell basis so that all cells are brought to the same state of charge (SOC).



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Applying pressure on LiPo cells



An experimental lithium-ion polymer battery made by Lockheed-Martin for NASA

Unlike lithium-ion cylindrical and prismatic cells, which have a rigid metal case, LiPo cells have a flexible, foil-type (polymer laminate) case, so they are relatively unconstrained. By themselves the cells are over 20% lighter than equivalent cylindrical cells of the same capacity.

Being lightweight is an advantage when the application requires minimum weight, as in the case of radio controlled aircraft. However, it has been established that moderate pressure on the stack of layers that compose the cell results in increased capacity retention, because the contact between the components is maximised and delamination and deformation is prevented, which is associated with increase of cell impedance and degradation.

Applications

Six edge shaped Lithium-Polymer-Battery for Underwater Vehicles made by Custom Cells Itzehoe GmbH

LiPo cells provide manufacturers with compelling advantages. They can easily produce batteries of almost any desired shape. For example, the space and weight requirements of mobile phones and notebook computers can be completely satisfied. Also, they have low-self discharge rate, which is about 5% per month.

Radio controlled equipment and airsoft



3-Cell LiPo battery for RC-models



LiPo batteries have just about taken over in the world of radio-controlled aircraft, radiocontrolled cars and large scale model trains, where the advantages of lower weight and increased capacity and power delivery justify the price. Test reports warn of the risk of fire when the batteries are not used in accordance with the instructions.

As of mid 2016, LiPo packs of 1.3 Ah exist, providing 95C continuous discharge, and shorttime 190C bursts. In March 2017, LiPo packs were available in various configurations, most commonly up to 6400mAh, achieving a maximum 4.2V/cell, for powering certain R/C vehicles and helicopters or drones.^[13] Some test reports warn of the risk of fire when the batteries are not used in accordance with the instructions.

LiPo packs also see widespread use in airsoft, where their higher discharge currents and better energy density compared to more traditional NiMH batteries has very noticeable performance gain (higher rate of fire). The high discharge currents do damage the switch contacts due to arcing (causing the contacts to oxidize and often deposit carbon), so it is advised to either use a solid-state MOSFET switch or clean the trigger contacts regularly.

Personal electronics

LiPo batteries are pervasive in mobile phones, tablet computers, power banks, very thin laptop computers, portable media players, wireless controllers for video game consoles, electronic cigarettes, and other applications where small form factors are sought and the high energy density outweighs cost considerations.

Electric vehicles

Lithium-ion cells in pouch format are being investigated to power battery electric vehicles. While it is possible to use a large number of cells of small capacity to obtain required levels of power and energy to drive a vehicle, some manufacturers and research centres are looking into large-format lithium-ion cells of capacities exceeding 50 Ah for this purpose. With higher energy content per cell, the number of cells and electrical connections in a battery pack would certainly decrease but the danger associated with individual cells of such high capacity might be greater.

Hyundai Motor Company uses this type of battery in some of their hybrid vehicles, as well as Kia Motors in their battery electric Kia Soul. The Bolloré Bluecar, which is used in car sharing schemes in several cities, also uses this type of battery.

Light aircraft and self-launching gliders are being produced such as the Alisport Silent 2 Electro and the Pipistrel WATTsUP. Some larger gliders such as Schempp-Hirth Ventus-2 use the technology for self-sustaining motors



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COURSE CODE:16CHU503A

COURSE NAME:INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE UNIT:III(Bottories) BATCH:2016-2010

UNIT:III(Batteries)

BATCH:2016-2019

POSSIBLE OUESTIONS

UNIT III

PART A(20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B(2 MARKS)

1. How density of sulphuric acid be raised in leade acid battery.

2. Write down discharging and recharging reactions in lead acid battery.

3.Write down discharging and recharging reactions in lithium battery.

4. Mention different types of fuel cells.

5.Write a note on polymer cell.

PART-C(6 marks)

1.Explain the construction and working of lead acid battery.

2.Explain the construction and working of solid state battery.

3. Why lithium battery is known as battery of future. How lithium battery differs with other batteries.

4. Write a note on hydrogen-oxygen fuel cell.





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(Deemed to be University Under Section 3 of UGC Act 1956)

COIMBATORE-641 021

(For the Canditates admitted from 2016 & onwards)

III B.Sc Chemistry

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE (16CHU503A)

Unit III (BATTERIES)

S.NO	Question	Option 1	Option 2	Option 3	Option 4	Answer
1	Persian artisans of					r
	the second					
	century B.C were				_	
	believed to have					
	used a form of			Copper	Platinum	
	battery for	Gold plated	Silver plated	plated	plated	Gold plated
	preparing	jewellery	jewellery	jewellery	jewellery	jewellery
2	The modern					
	development of					
	batteries began					
	with the invention					
	of a crude battery					
	by Alessandro					
	volta in	1900	1800	1700	1600	1800
3						
	constructed a pile					
	consisting of a					
	Stock of					
	alternating zinc					
	and silver discs,					
	which wore					
	incorted paper					
	moistoned with an	Alossandro				
	acid	volta	Albert Finstein	Newton	Putherford	Alessandro volta
4		volla		NEWLOII	Numerioru	Alessaliul Vulla
4	A Dattery is a	mochanical	chomical	thormal	goothormal	chomical
		mechanical	chemical	ulennal	Reornennal	CHEIMICAI



	converts					
	energy into					
	electrical energy					
5	Electrolytic cell is					
	a device which					
	converts					
	electgrical energy	mechanical		chemical	geothermal	
6	into	energy	thermal energy	energy	energy	chemical energy
6	Electrochemical					
	cell is a device					
	which converts					
	chemical energy	electrical	mechanical	thermal	geothermal	ala atulaal ay ayay
7	Into	energy	energy	energy	energy	electrical energy
/	The tendency of					
	the donor to					
	aonate electrons					
					ſ	
	electrons is					
	individual	notontial	valtages	omf	amporor	voltagos
8	The difference	potential	Voltages	em	amperes	Voltages
0	hetween the two					
	voltages of the					
	donor accentor					
	pair is the	cell voltage	voltage	emf	potential	cell voltage
9	The battery	oxidation	reduction	nuclear	redox	
	reaction involves a	reaction	reaction	reaction	reaction	redox reaction
10				reversible		
	All primary			and		
	batteries are	irreversible	reversible	irreversible	rechargeable	irreversible
11				reversible		
	All secondary			and	non	
	batteries are	irreversible	reversible	irreversible	rechargeable	reversible
12				both		
	Alkaline battery is			primary and		
10	an example for	primary	secondary	secondary	rechargeable	primary
13						
	is an example for		lead acid			
1.4	irreversible	dry cell	battery	NiCad	lithium	dry cell
14				primary and		
	Cell reactions are	secondary		secondary	rechargeable	
15	irreversible in	pattery	primary battery	pattery	battery	primary battery
15	Coll reactions are	nrimani	cocondary	primary and	non	
	cell reactions are	primary	batton	battory	hattori	cocondary battary
16		drugell	pattery	battery	battery	secondary battery
10	is an	dry cell	alkalne battery	iead acid	ary cell and	lead acid battery

	example for			battery	lead acid	
	reversible battery					
17				both		
	NiCad battery is			primary and		
	an example for	primary	secondary	secondary	irreversible	secondary
18		increasing	decreasing			
	EMF of lead	concentration	concentration			increasing
	storage cell	of sulphuric	of sulphuric	increase in	decrease in	concentration of
	increases with	acid	acid	temperature	temperature	sulphuric acid
19	The negative					
	electrode of lead					
•	storage cell is	Pb, PbO ₂	Pb, H ₂ SO ₄	Pb	Pb, PbSO ₄	Pb, PbSO ₄
20	Lead storage cell					
01	electrolyte is	H ₂ SO ₄	PbO ₂	PbSO ₄	Pb	H ₂ SO ₄
21	In lead acid					
	accumulator, a					
	single cell	4.57	21/		1.1	2.1/
22	generates	4 V	2 V	8 V	1 V	2 V
22						
	doncity of the					
	electrolyte					
	decreases from					
	the initial value of					
	1.2 g/cm to	2 g/cm	1 g/cm	3 g/cm	4 g/cm	1 g/cm
23	The amount of	<u> </u>	5	<u>,</u>		
	water in a lead-					
	storage battery					
	can decrease due					
	to evaporation on			discharging	anodic	
	slight electrolysis			and	oxidation	
	during	discharging	recharging	recharging	reaction	recharging
24						
	 battery is known 					
	as battery of				alkaline	
25	tuture	lead acid	NiCad	Lithium	battery	Lithium
25				semi solid	liquid as well	
	Lithium battery is	liquid state	solid state	state	as solid state	
26	an example for	battery	battery	battery	battery	solid state battery
20	Anode used in	lithium	titonium	and mission	aulah	lithium
27		iitmum	titatium	titatium	suipnur	
21	lithium battory is	lithium	diculobido	diovido	diovido	diculphido
28	Lithium battery is		usuipilide	uloxide	uluxiue	usulpillue
20	produces a cell					
	voltage ofV	2	3	А	5	3
29			yoltaic cell	galvanic coll	daniel cell	galvanic cell
<i>L</i>)		Baivariic Cell		Salvaille Cell		gaivanic cen

30	In fuel cells the					
	chemical energy is			hu na saina		
	converted into	huunainen the	huun in a tha sall	by passing		
	electrical energy	burning the	directly	electric	oxidising the	burning the fuel
21	by Amount of	ruei	directly	current	cell	burning the fuel
51	Amount of					
	chemical energy is					
	converted into					
	by a fuel is	50%	80%	70%	75%	70%
32	Hydrogen- oxygen	5078	80%	7078	7570	7070
52	fuel cell is based					
	on the combusion					
	of	н	0	Ha	H2O	0
33	How many					•
	, electrodes are in					
	the hydrogen-					
	oxygen fuel cells	2	4	6	3	2
34	The EMF of					
	hydrogen-oxygen					
	fuel cell is about	2 volts	1.5 volts	1.2 volts	1 volts	1.2 volts
35	Hydrogen-oxygen					
	fuel cell is					
	operated at the					
26	temperature of	150°C	180°C	200°C	220°C	200°C
36	The catalyst used					
	in nydrocarbon-	silvor	Tinc	cold	platinum	silvor
37	In coal-fired fuel	Silver		golu	platilitutii	511761
57	cells the					
	gassification of					
	coal is achieved at					
	temperature of					
	about	560°C	650°C	700°C	660°C	650°C
38	Sodium carbonate					
	is used as an					
	electrolyte for					
	coal-fired fuel		_			
20	cells in its	liquid state	molten state	solid state	gas state	molten state
39	Which type of					
	reaction is					
	occurred during					
	anode nalf-cell					
	fired fuel cells	ovidation	roduction	compution	budration	roduction
40	Which of the	bydrocarban	hydrogen		nyuration	hydrocarbon
40	following fuel calls	nyurocarbon-	nyarogen-	colle	nickei	nyurocarbon-
	ronowing ruei cells	oxygen nuel	oxygen	CEIIS	cauiniun	oxygen nuel cells

	are used in space	cells			cells	
	flights					
41	Hydrocarbon-					
	oxygen fuel cells					
	are based on the		carbon and			
	combustion of	hydrogens	hydrogen	oxygen	hydrocarbon	hydrocarbon
42	The electrolyte					
	used in hydrogen-					
	oxygen fuel cell is					
	are	КОН	KCI	NaCl	H ₂ SO ₄	КОН
43	The number of					
	electrons released					
	in oxidation					
	reaction of					
	hydrogen-oxygen					
	fuel cell	2	3	4	1	2
44	To operate the					
	hydrogen- oxygen					
	fuel cell at 200°C,					
	the electrolyte	phosphorous		KOUL	sulphuric	
45	have to be used is	acid	phosphoric acid	КОН	acid	phosphoric acid
45	At 200°C, the					
	phosphoric acid	polyphosphoric	polyphosphorus	acrolain	docran	polyphosphoric
16	Hydrocarbon	aciu	aciu	acroiein	uacion	aciu
40						
	are based on the					
	combustion of	methane	hexene	pentene	heptane	methane
47	The catalyst used					
.,	in hydrogen-					
	oxygen fuel cell					
	are	platinum	chromium	vanadium	titanium	platinum
48	Combustion of		hydrogen	hydrogen	hydrogen	
	hydrogen gives	water	dioxide	sulphide	peroxide	water
49				eight	six	
		four molecules	three molecules	molecules of	molecules of	
	Combustion of	of carbon	of carbon	carbon	carbon	three molecules
	propane gives	dioxide	dioxide	dioxide	dioxide	of carbon dioxide
50	In fuel cells ,					
	usually electrons	oxidation	reduction	combustion	hydration	
	evolves during the	reaction	reaction	reaction	reaction	oxidation reaction
51	Solar battery					
	exploits solar					
	energy by					
	conversion to					
	electrical energy	photovoltaic				
	directly using	cell	daniel cell	dry cell	alkaline cell	photovoltaic cell

52	Si doped with					
	- is example for p-					
	type					
	semiconductor	Са	AI	Cu	В	В
53	doped with					
	P is an example					
	for n-type					
	semiconductor	Са	Si	Cu	В	Si
54	When a positive					
	hole leaves the p-					
	type					
	semiconductor, a					
	build -up of					
	negative charge			K		
	occurs, due to the					
	presence of					
	immobile					
	ions	Са	Si	Cu	В	В
55	In solar cell the					
	conduction of					
	electrons can					
	readily be					
	neutralised by					
	holes, so the					
	layer of p-type					
	semiconductor is			positive and		
	kept very thin	positive	negative	negative	electron	positive
56		non		primary and		
	Lithium polymer	rehargeable		secondary	rechargeable	rechargeable
	battery is a	battery	primary battery	battery	battery	battery
57	can					
	easily produce					
	batteries of				lithium	
	almost any			lead acid	polymer	lithium polymer
	desired shape	dry cell	alkaine battery	battery	battery	battery
58	cells					
	could be					
	considered to be					
	between a					
	traditional lithium-					
	ion battery (with					
	iiquia electrolyte)					
	and a completely					
	plastic, solid-state					
	hottom	prototyra	des	alkalina	danial	prototype
50	Dattery	ргосотуре	ury	aikaline	daniel	prototype
39	New Li-ion battery	silicon	graphene	silicon-	boron	silicon-graphene

	cell technology has introduced a			graphene		
	additive that helps to preserve the positive terminal during discharging					
60	The silicon- graphene additive helps reduce corrosion of the positive terminal when charged up to voltages of -V or more.	1.35	2.35	3.35	4.35	4.35



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COURSE NAME: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

COURSE CODE:16CHU503A

UNIT:IV(Catalysis) BATC

BATCH:2016-2019

<u>UNIT IV</u> SYLLABUS

Catalysis:

General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrial applications, Deactivation or regeneration of catalysts.

Application of zeolites as catalysts.

General principles and properties of catalysts

Catalysis is the increase in the rate of a chemical reaction due to the participation of an additional substance called a **catalyst**, which is not consumed in the catalyzed reaction and can continue to act repeatedly. Often only tiny amounts of catalyst are required in principle.

In general, the reactions occur faster with a catalyst because they require less activation energy. In catalyzed mechanisms, the catalyst usually reacts to form a temporary intermediate which then regenerates the original catalyst in a cyclic process.

Catalysts may be classified as either homogeneous or heterogeneous. A homogeneous catalyst is one whose molecules are dispersed in the same phase (usually gaseous or liquid) as the reactant molecules. A heterogeneous catalyst is one whose molecules are not in the same phase as the reactants, which are typically gases or liquids that are adsorbed onto the surface of the solid catalyst. Enzymes and other biocatalysts are often considered as a third category.

Technical perspective

In the presence of a catalyst, less free energy is required to reach the transition state, but the total free energy from reactants to products does not change. A catalyst may participate in multiple chemical transformations. The effect of a catalyst may vary due to the presence of other substances known as inhibitors or poisons (which reduce the catalytic activity) or promoters (which increase the activity and also affect the temperature of the reaction).

Catalyzed reactions have a lower activation energy (rate-limiting free energy of activation) than the corresponding uncatalyzed reaction, resulting in a higher reaction rate at the same temperature and for the same reactant concentrations. However, the detailed mechanics of catalysis is complex. Catalysts may affect the reaction environment favorably(like heat), or bind to the reagents to polarize bonds, e.g. acid catalysts for reactions of carbonyl compounds, or form specific intermediates that are not produced naturally, such as osmate esters in osmium tetroxide-catalyzed dihydroxylation of alkenes, or cause dissociation of reagents to reactive forms, such as chemisorbed hydrogen in catalytic hydrogenation.

Kinetically, catalytic reactions are typical chemical reactions; i.e. the reaction rate depends on the frequency of contact of the reactants in the rate-determining step. Usually, the catalyst



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participates in this slowest step, and rates are limited by amount of catalyst and its "activity". In heterogeneous catalysis, the diffusion of reagents to the surface and diffusion of products from the surface can be rate determining. A nanomaterial-based catalyst is an example of a heterogeneous catalyst. Analogous events associated with substrate binding and product dissociation apply to homogeneous catalysts.

Although catalysts are not consumed by the reaction itself, they may be inhibited, deactivated, or destroyed by secondary processes. In heterogeneous catalysis, typical secondary processes include coking where the catalyst becomes covered by polymeric side products. Additionally, heterogeneous catalysts can dissolve into the solution in a solid–liquid system or sublimate in a solid–gas system.

Homogeneous catalysis

Enzyme Catalysis

To live, grow, and reproduce, microorganisms undergo a variety of chemical changes. They alter nutrients so they can enter the cell and they change them once they enter in order to synthesize cell parts and obtain energy.

Metabolism refers to all of the organized chemical reactions in a cell. Reactions in which chemical compounds are broken down are called **catabolic reactions** while reactions in which chemical compounds are synthesized are termed **anabolic reactions**. All of these reactions are under the control of enzymes.

Enzymes are substances present in the cell in small amounts that function to **speed up or catalyze chemical reactions**. On the surface of the enzyme is usually a small crevice that functions as an **active site** or catalytic site to which one or two specific substrates are able to bind. (Anything that an enzyme normally combines with is called a **substrate**). The binding of the substrate to the enzyme causes the flexible enzyme to change its shape slightly through a process called **induced fit** to form a tempore intermediate called an **enzyme-substrate complex**.





Enzymes are substances present in the cell in small amounts which speed up or catalyze chemical reactions. Enzymes speed up the rate of chemical reactions because they lower the energy of activation, the energy that must be supplied in order for molecules to react with one another. Enzymes lower the energy of activation by forming an enzyme-substrate complex.

Enzymes speed up the rate of chemical reactions because they lower the energy of activation, the energy that must be supplied in order for molecules to react with one another. Like homogeneous catalysts discussed above, enzymes lower the energy of activation by forming an enzyme-substrate complex allowing products of the enzyme reaction to be formed and released



An enzyme speeds up a chemical reaction by lowering its energy of activation, the energy that must be supplied in order for molecules to react with one another.

ENZYME-SUBSTRATE REACTIONS

Enzymes are substances present in the cell in small amounts which speed up or catalyze chemical reactions. Enzymes speed up the rate of chemical reactions because they lower the energy of activation, the energy that must be supplied in order for molecules to react with one another. Enzymes lower the energy of activation by forming an enzyme-substrate complex.



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Many enzymes require a nonprotein **cofactor** to assist them in their reaction. In this case, the protein portion of the enzyme, called an **apoenzyme**, combines with the cofactor to form the whole enzyme or **haloenzyme**. Some cofactors are ions such as Ca^{++} , Mg^{++} , and K^+ ; other cofactors are organic molecules called **coenzymes** which serve as carriers for chemical groups or electrons. NAD⁺, NADP⁺, FAD, and coenzyme A (CoA) are examples of coenzymes.



An apoenzyme and cofactor combine to form a haloenzyme. If the cofactor is an organic molecule, it is called a coenzyme.

Enzymes are generally globular proteins. (Some RNA molecules called ribozymes can also be enzymes. These are usually found in the nuclear region of cells and catalyze the splitting of RNA molecules.). Enzymes are catalysts that breakdown or synthesize more complex chemical compounds. They allow chemical reactions to occur fast enough to support life. Enzymes speed up the rate of chemical reactions because they lower the energy of activation, the energy that must be supplied in order for molecules to react with one another. Anything that an enzyme normally combines with is called a substrate. Enzymes are very efficient with a typically enzyme generally able to catalyze between 1 and 10,000 molecules of substrate per second. The means that enzymes are only have to be present in small amounts in the cell since. They are not altered



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during their reaction and are highly specific for their substrate, with generally one specific enzyme dedicated for each specific chemical reaction.

FACTORS THAT AFFECT THE RATE OF ENZYME REACTIONS

Enzyme activity is affected by a number of factors including:

- a. **The concentration of enzyme**: Assuming a sufficient concentration of substrate is available, increasing enzyme concentration will increase the enzyme reaction rate.
- b. **The concentration of substrate**: At a constant enzyme concentration and at lower concentrations of substrates, the substrate concentration is the limiting factor. As the substrate concentration increases, the enzyme reaction rate increases. However, at very high substrate concentrations, the enzymes become saturated with substrate and a higher concentration of substrate does not increase the reaction rate.
- c. **Inhibitors:** inhibitors will inhibit the activity of enzyme and decrease the rate of reaction. Enzyme inhibitors will bind to enzyme active sites and could modify the chemistry of an active site which can stop a substrate from entering.
- d. **The temperature**: Each enzyme has an optimum temperature at which it works best. A higher temperature generally results in an increase in enzyme activity (Arrhenius kinetics). As the temperature increases, molecular motion increases resulting in more molecular collisions. If, however, the temperature rises above a certain point, the heat will denature the enzyme, causing it to lose its three-dimensional functional shape by denaturing its hydrogen bonds. Cold temperature, on the other hand, slows down enzyme activity by decreasing molecular motion.
- e. **The pH**: Each enzyme has an optimal pH that helps maintain its three-dimensional shape. Changes in pH may denature enzymes by altering the enzyme's charge. This alters the ionic bonds of the enzyme that contribute to its functional shape.
- f. **The salt concentration**: Each enzyme has an optimal salt concentration. Changes in the salt concentration may also denature enzymes.

Applications of Enzymes

Enzymes are essential to maintain homeostasis because any malfunction of an enzyme could lead to diseases. Therefore, pharmaceutical companies study enzyme to manipulate and synthesis new medicine. Besides their medicinal applications, enzymes in industry are important because enzymes help breaking down cellulose, wastes, etc. Enzymes are essential in the process of making new products in many industries such as pharmaceutical, food, paper, wine, etc

Heterogenous catalysis

In chemistry, **heterogeneous catalysis** refers to the form of catalysis where the phase of the catalyst differs from that of the reactants. Phase here refers not only to solid, liquid, vs gas,



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but also immiscible liquids, e.g. oil and water. The great majority of practical heterogeneous catalysts are solids and the great majority of reactants are gases or liquids.^[1]Heterogeneous catalysis is of paramount importance in many areas of the chemical and energy industries. Heterogeneous catalysis has attracted Nobel prizes for Fritz Haber in 1918, Carl Bosch in 1931, Irving Langmuir in 1932, and Gerhard Ertl in 2007.

Examples

• Reduction of nitriles for instance in a synthesis of phenethylamine with Raney nickel and ammonia:



The cracking, isomerisation and re-forming of hydrocarbons to form appropriate and useful blends of petrol.

Catalytic converters are often used in automobiles. Three main reactions are catalysed by catalytic converters.

The oxidation of carbon monoxide to carbon dioxide:

 $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

The reduction of nitrogen monoxide back to nitrogen:

 $2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$

The oxidation of hydrocarbons to water and carbon dioxide:

 $2 \text{ C}_6\text{H}_6 + 15 \text{ O}_2 \rightarrow 12 \text{ CO}_2 + 6 \text{ H}_2\text{O}$

This process can occur with any of the hydrocarbons, but most commonly is performed with petrol or diesel.

Asymmetric heterogeneous catalysis affords enantiomerically enriched compounds using chiral heterogeneous catalysts.

The vast majority of heterogeneous catalysts are based on metals or metal oxides, however, some chemical reactions can be catalyzed by carbon-based materials, e.g., oxidative dehydrogenations^[13] or selective oxidations.^[14] Ethylbenzene + $1/2 O_2 \rightarrow$ Styrene + H₂O Acrolein + $1/2 O_2 \rightarrow$ Acrylic acid



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Gas streams with strongly nonequilibrium gas phase concentrations can be achieved via epicatalysis

Application of zeolites as catalysts

Natural zeolite is a new and very good natural filter medium available for the filtration of water. It offers superior performance to sand and carbon filters, giving purer water and higher throughput rates with less maintenance required. It has many advantages over sand and can be used to directly replace sand in a normal sand filter.

There are three main uses of zeolites in industry: catalysis, gas separation and ion exchange.

Catalysis: Zeolites are extremely useful as catalysts for several important reactions involving organic molecules. The most important are cracking, isomerisation and hydrocarbon synthesis. Zeolites can promote a diverse range of catalytic reactions including acid-base and metal induced reactions. Zeolites can also be acid catalysts and can be used as supports for active metals or reagents.

Zeolites can be shape-selective catalysts either by transition state selectivity or by exclusion of competing reactants on the basis of molecular diameter. They have also been used as oxidation catalysts. The reactions can take place within the pores of the zeolite, which allows a greater degree of product control.

The main industrial application areas are: petroleum refining, synfuels production, and petrochemical production. Synthetic zeolites are the most important catalysts in petrochemical refineries.

Adsorption: Zeolites are used to adsorb a variety of materials. This includes applications in drying, purification, and separation. They can remove water to very low partial pressures and are very effective desiccants, with a capacity of up to more than 25% of their weight in water. They can remove volatile organic chemicals from air streams, separate isomers and mixtures of gases. A widely used property of zeolites is that of gas separation. The porous structure of zeolites can be used to "sieve" molecules having certain dimensions and allow them to enter the pores. This property can be fine tuned by variating the structure by changing the size and number of cations around the pores. Other applications that can take place within the pore include polymerisation of semi conducting materials and conducting polymers to produce materials having unusual physical and electrical attributes.

Ion exchange: Hydrated cations within the zeolite pores are bound loosely to the zeolite framework, and can readily exchange with other cations when in aqueous media. Applications of this can be seen in water softening devices, and the use of zeolites in detergents and soaps. The largest volume use for zeolites is in detergent formulations where they have replaced phosphates as water-softening agents. They do this by exchanging the sodium in the zeolite for the calcium and magnesium present in the water. It is even possible to remove radioactive ions from contaminated water.



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POSSIBLE OUESTIONS

UNIT IV

PART-A(20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B(2 MARKS)

- 1. What are catalyst.
- 2. Mention the types of catalyst.
- 3. What are homogeneous catalysis?
- 4. What are heterogeneous catalysis?
- 5. Mention application of zeolites as catalysts.

PART-C(6 MARKS)

- 1. Write down the general principles and properties of catalysts.
- 2. Explain the catalytic steps of homogeneous catalysis.
- 3. Explain the catalytic steps of heterogeneous catalysis.
- 4. Justify zeolites can be used as catalysts.



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COIMBATORE-641 021

(For the Canditates admitted from 2016 & onwards)

III B.Sc Chemistry

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE (16CHU503A)

Unit IV (CATALYSIS)

S.NO	Question	Option 1	Option 2	Option 3	Option 4	Answer		
1	A substance that							
	increases the							
	reaction rate							
	without itself							
	getting used up is				Activated			
	known as a	Buffer	Catalyst	Inhibitor	Complex	Catalyst		
2	In a reaction,a							
	positive catalyst							
	will decrease the					Activation		
	value of	Delta H	Activation energy	Delta S	rate constant	energy		
3	In the							
	hydrogenation of			r				
	vegetable oils,the							
	catalyst							
	commonly used is	Fe2O3	Activated charcoal	ZnO	Ni	Ni		
4	The catalyst and							
	the reactant are							
	in the same							
	phase which is							
	called	Heterogenous	Activation energy	Homogeneous	rate constant	Homogeneous		
5	The catalyst and							
	the reactant are							
	in the different							
	phase Which is				Activation			
	called	Heterogenous	Enzyme	Adsorption	energy	Heterogenous		
6	A catalyst is the							
	finely divided			More active	More energy	More active		
	form is most	Less surface area	Most surface area is	centres are	gets stored in	centres are		
	effective because	is available	available	formed	the catalyst	formed		



7	The effect of				Activation	
	catalyst in a			internal energy	energy	Activation
	, chemical reaction			of the	required for	energy required
	is to change	Heat of reaction	Equilibrium constant	reactants	the reaction	for the reaction
8	<u> </u>		-	The rate of	The rate of	
	When a catalyst	Equilibrium	Equilibrium	forward	backward	Equilibrium
	is added to a	concentrations are	concentrations are	reaction is	reaction is	concentrations
	system the	increased	unchanged	increased	decreased	are unchanged
9	Efficiency of a					
	catalyst depends			Molecular	Activation	
	on its	particle size	Solubility	weight	energy	particle size
10				Lowering the		
	Which of the			activation		
	following does			energies of the		
	not a apply to	Capability to		foreard as well	Constancy in	Capability to
	catalytic	infinite the non		as backward	value of delta	infinite the non
	reactions	feasible reaction	Specificity	reaction	Н	feasible reaction
11	Any substance					
	which completely					
	destroys or					
	reduces the					
	activity of the				Catalyst	
	catalyst is called	Catalyst	Inhibitor	Promotor	poison	Catalyst poison
12	Which of the					
	following types of					
	materials form			Alkaline earth	Radioactive	Radioactive
	effective catalysts	Alkali metals	Transition metals	metals	metals	metals
13	Which of the					A catalyst
	following			All kinds of	A catalyst	remains
	statements is	A catalyst remains		catalysts	physically	unchanged at
	universally	unchanged at the	A catalyst takes part	undergo	changes at the	the end of
	correct for	end of chemical	in a chemical	catalytic	end of the	chemical
1.4	catalyst	reaction	reaction	poisoning	reaction	reaction
14	which of the					
	tonowing is not	The establish and	unoffected ofter the	Ine calalyst	the calalyst	the calaryst
	hotorogonoous	the reactants are	completion of the	operation of		
	catalyst	in different states	reaction	activation	constant	constant
15	Catalyst		Teaction	Participates in	Does not	CONSTANT
15				the reaction	narticinate in	Does not
		Alters the	Is always in the	and provides	the reaction	narticinate in
	Δ catalyst is a	equilibrium in a	same nhace as the	nathway for	hut speeds it	the reaction but
	substance which	reaction	reactants	the same	un	sneeds it un
16	Platinised				чр	specusitup
10	ashestos used as					
	catalyst in the	Heterogenous			Induced	Heterogenous
	manufacture of	catalyst	Auto catalyst	Homo catalyst	catalyst	catalyst
		cataryst		nomo catalyst	cuturyst	cataryst

	H_2SO_4 is an					
17					Increases and	
17	adding a catalyst			Does not affect	decreases the	Does not affect
	to a reacting	Increases the vield	Decreases the vield	the vield of the	vield	the vield of the
	system	of the product	of the product	product	irregularly	product
18	In homogeneous			p. 0	Depends upon	Depends upon
10	catalvtic	Depends upon the	Independent upon	Depends upon	the physical	the
	, reactions,the rate	concentration of	the concentration of	the free energy	state of the	concentration of
	of reaction	catalyst	catalyst	change	catalyst	catalyst
19	V ₂ O ₅ has replaced					
	Pt as catalyst in					
	the contact		It is not easily	Both are	None is	
	process because	It is cheap	poisoned	correct	correct	Both are correct
20	When a catalyst					
	increases the rate					
	of a chemical					
	reaction,the rate			Remains	Becomes	
1	constant	Increases	Decreases	constant	infinite	Increases
21	A substance					
	which promotes					
	the activity of a					
		Initiator	Catalyst	Promotor	Autocatalyst	Promotor
22	Which is the	Initiator	Catalyst		Hydrogenatio	riomotor
22	following is an	Decomposition of			n of vegetable	The
	example of	KCIO3 + MnO2	The decomposition	Breakdown of	oil using Ni	decomposition
	autocatalysis	mixt.	of nitroglycerine	6C14	catalyst	of nitroglycerine
23				One of the		C /
				products of the		One of the
				reaction which	Which retards	products of the
	An auto catalyst	Catalyst for	One which starts a	acts as a	a chemical	reaction which
	is	catalyst	reaction	catalyst	reaction	acts as a catalyst
24				Getting	Chemical	
				adsorbed on	combination	Getting
		Chemically		the active	with anyone	adsorbed on the
	Catalytic poison	combining with	Coagualting the	centres on the	of the	active centres
25	acts by		catalyst	surraces	reactants	on the surfaces
23			Chamical		detting	Cotting
	In temporary		combination with	Chemically	the active	adsorbed on the
	noisoning catalyti	Coagualting the	anyone of the	combining with	centres on the	active centres
	c poison acts by	catalvst	reactants	catalvst	catalvst	on the catalyst
26	A substance like					
	CO,As ₂ O ₃ ,HCN					
	etc,which					
	paralyses the	A negative catalyst	Auto catalyst	A Promotor	Poison	Poison

	catalytic activity					
	called					
27	Catalytic					
	, poisoners are					
	usually the same	Poison for human	Enzyme for human	Vitamins for	proteins for	Poison for
	as	body	body	human body	human body	human body
28			Takes the reaction			Which retards
	Negative catalyt	Which retards the	in the backward	Promotes the	Coagualting	the rate of
	is that	rate of reaction	direction	side reaction	the catalyst	reaction
29	Which of the	Lead tetraethyl as	Glycerol in	Ethanol in		
	following acts as	antiknock	decomposition of	oxidation of		
	negative catalyst	compound	H2O2	chloroform	All are correct	All are correct
30	The efficiency of				To decrease	
	an enzyme in			To lower the	the bond	To lower the
	catalysing a	To form a strong	To change the shape	activation	energy of all	activation
	reaction is due to	enzyme substrate	of the substrate	energy of the	substrate	energy of the
21	its capacity	molecule	molecule	rection	molecules	rection
31		substance made				
		by chemist to	vonuactivo	catalysts found	synthotic	catalysts found
	enzymes are	nowder	vegetable catalysts	in organisms	catalysts	in organisms
32	The efficiency of	powder	Vegetable catalysts		catalysts	in organisms
52	an enzyme in		To decrease the	To change the	To lower the	To lower the
	catalysing a	To form a strong	bond energies of	shape of the	activation	activation
	reaction is due to	enzyme substrate	the substrate	substrate	energy of the	energy of the
	its capacity	molecule	molecule	molecule	reaction	reaction
33	enzymes take					
	part in reaction	Decreases the rate	Increases the rate of			Increases the
	and	of reaction	reaction	Both (a) and (b)	None	rate of reaction
34	When a catalyst					
	is introduced into	Equilibrium			Equilibrium is	
	a reversible	reaction rate	Backward reaction	Equilibrium is	attained	Equilibrium is
	reaction	increases	rate increases	not changed	quickly	attained quickly
35	A biological					
	catalyst is				A nitrogen	
26	essentially	An amino acid	An enzyme	A carbohydrate	molecule	An enzyme
36	which of the			The establish	Thora is no	Thora is no
	following is not	The catalyst	The curface of	The Catalyst	change in the	there is no
	botorogonous	operate of	catalyst plays ap	actually forms	change in the	change in the
	catalyst	activation	important role	with reactants	activation	activation
37	ταταιγστ	The catalyst		with reactants		
57		altered during the		It lowers the		
	Which is true in	reaction is	It does not alter the	energy of		
	case of catalyst	regenerated	equilibrium	activation	All the above	All the above
38	A catalyst in a	Does not initiate a	Increases the	Changes the	Does not	Does not initiate
38	A catalyst in a	Does not initiate a	Increases the	Changes the	Does not	Does not initiate

	chemical reaction	reaction	activation energy of the reaction	equilibrium constant of a reaction	change the rate of reaction	a reaction
39	The enzyme					
	which can					
	catalyze the					
	conversion of					
	glucose to					
	ethanol is	Zymase	Invertase	Maltase	Diastate	Zymase
40				Only for		
		Only for increasing	For altering the	decreasing the		For altering the
		the velocity of the	velocity of the	velocity of the		velocity of the
	A catalyst is used	reaction	reaction	reaction	All are correct	reaction
41	A catalyst				increasing	Decreasing
	increases the rate	Decreasing	Decreasing internal	Decreasing	activation	activation
	of reaction by	activation energy	energy	enthalpy	energy	energy
42	The ability of					
	catalyst to					
	accelerate the					
	chemical reaction	_		Negative		
10	is known as	Selectivity	Activity	catalyst	None of these	Activity
43	The process					
	which is catalysed				_	
	one of the			Negative	Positive	
4.4	product is called	Acid-base catalysis	Auto catalysis	catalyst	catalysis	Auto catalysis
44	When the					
	catalyst is added					
	to the reversible					
	reaction in					
	equilbrium					
	state, the value of				Descret	Dessat
	equilorium		Deersees	December Jore	Does not	Does not
15	CONSTANT	Increases	Decleases	Becomes zero		change
43					neal	
	In the case of			Peactant	the reaction	Product
	auto catalysis	Solvent catalysis	Product catalyses	catalyses	catalyses	catalyses
46	which of the	Solvent edulysis	Troduct catalyses	cataryses	It increase	catalyses
10	following is true	-	It changes	It alters the	average	It alters the rate
	about the catalyst	It initiates reaction	equlibrium point	rate of reaction	kinetic energy	of reaction
47		The active site of	The active site of an	The active site	The active site	The active site
	Which of the	an enzyme binds	enzyme binds the	of an enzyme	of an enzyme	of an enzyme
	following	the substrate of	substrate of the	binds the	is	binds the
	statements about	the reaction it	reaction it catalyses	product of the	complementa	substrate of the
	the active site of	catalyses more	less tightly than it	reaction it	rv to the	reaction it
	an enzyme is	tightly than it does	does the transition	catalyses more	substrate of	catalyses less
	correct?	the transition	state intermediate.	tightly than it	the reaction it	tightly than it

		state intermediate.		does the transition state intermediate.	catalyses.	does the transition state intermediate.
48	are					
	essential in the					
	process of					
	making new					
	products in many					
	industries such as					
	pharmaceutical,					
	food, paper and	D ((Activated	
40	wine.	Buffer	enzymes	Inhibitor	Complex	enzymes
49	The company					
	enzyme to					
	maninulate and					
	synthesis new					
	medicine is	Pharmaceutical	food	wine	food and wine	Pharmaceutical
50	A compound					
	having very good					
	natural filter					
	medium available					
	for the filtration					
	of water is	Buffer	enzymes	Inhibitor	zeolite	zeolite
51	A compound					
	having					
	advantages over					
	sand and can be					
	roplace cand in a					
	normal sand		Ĭ			
	filter.	Buffer	enzymes	Inhibitor	zeolite	zeolite
52	Synthetic zeolites				200110	200110
	are the most					
	important					
	catalysts in	Pharmaceutical			petrochemical	petrochemical
		industry	food industry	wine industry	refineries	refineries
53	A material having					
	applications in					
	separation is	zeolite	inhibitor	enzymes	catalyst	zeolite
54	Zeolite finds		detergents and			detergents and
	application in	pharmaceutical	soaps	tood	paper	soaps
22	ine other name	dominaralianting			limo codo	dominanalis-ti-
	for ion exchange	aemineralisation	Haber's process	zeolito procoss	nme soda	uemineralisatio
56	Activity of	process	Habel S PIOCESS	zeonie process	concentration	ii process
50	catalyst	time	volume	concentration	and time	time
	cataryst	une	volume	concentration		une

	decreases with					
57				increase in		
	A catalyst can be	increase in particle	increase in	activation		
	deactivated by	size	molecular weight	energy	fouling	fouling
58	Sintering is					
	otherwise known			phase		phase
	as	fouling	poisoning	transformation	inhibitor	transformation
59	Catalyst					
	regeneration					
	processes utilize					
	different types of					
	batch and					
	continuous-flow					
	equipment to					
	remove which of					
	the following					
	elements from			barium and	nitrogen and	carbon and
	spent catalyst	carbon and boron	carbon and sulphur	nitrogen	sulphur	sulphur
60	Catalyst mortality					
	may be on the					
	order of seconds,					
	while in ammonia					
	synthesis the iron				-	
	catalyst may last					
	for	5-10 years	10-15 years	20-25 years	25-30 years	5-10 years

Prepared by H.Revathi, Asst Prof, Department of Chemistry, KAHE



CLASS:III B.Sc CHEMISTRY

COURSE NAME:INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

COURSE CODE:16CHU503A

UNIT:V(Chemical Explosives)

BATCH:2016-2019

<u>UNIT V</u> SYLLABUS

Chemical explosives:

Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX). Introduction to rocket propellants.

Origin of explosives properties in organic compounds

An **explosive material**, also called an **explosive**, is a reactive substance that contains a great amount of potential energy that can produce an explosion if released suddenly, usually accompanied by the production of light, heat, sound, and pressure. An **explosive charge** is a measured quantity of explosive material, which may be composed of a single ingredient or a combination of two or more.

The potential energy stored in an explosive material may, for example, be

- chemical energy, such as nitroglycerin or grain dust
- pressurized gas, such as a gas cylinder or aerosol can
- nuclear energy, such as in the fissile isotopes uranium-235 and plutonium-239

Explosive materials may be categorized by the speed at which they expand. Materials that detonate (the front of the chemical reaction moves faster through the material than the speed of sound) are said to be "high explosives" and materials that deflagrate are said to be "low explosives". Explosives may also be categorized by their sensitivity. Sensitive materials that can be initiated by a relatively small amount of heat or pressure are primary explosives and materials that are relatively insensitive are secondary or tertiary explosives.

A wide variety of chemicals can explode; a smaller number are manufactured specifically for the purpose of being used as explosives. The remainder are too dangerous, sensitive, toxic, expensive, unstable, or prone to decomposition or degradation over short time spans.

In contrast, some materials are merely combustible or flammable if they burn without exploding.

The distinction, however, is not razor-sharp. Certain materials—dusts, powders, gases, or volatile organic liquids—may be simply combustible or flammable under ordinary conditions, but become explosive in specific situations or forms, such as dispersed airborne clouds, or confinement or sudden release.

Preparation and explosive properties of Lead azide



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Lead azide $(Pb(N_3)_2)$ is an inorganic compound. More so than other azides, $Pb(N_3)_2$ is explosive. It is used in detonators to initiate secondary explosives. In a commercially usable form, it is a white to buff powder.

Preparation and handling

Lead azide is prepared by metathesis between sodium azide and lead nitrate. Dextrin can be added to the solution to stabilize the precipitated product. The solid is not very hygroscopic, and water does not reduce its impact sensitivity. It is normally shipped in a dextrinated solution that lowers its sensitivity. When protected from humidity, it is completely stable in storage. An alternative method involves dissolving lead acetate in a sodium azide solution.

Production history

Lead azide in its pure form was first prepared by Theodor Curtius in 1891. Due to sensitivity and stability concerns, the dextrinated form of lead azide (MIL-L-3055) was developed in the 1920s and 1930s with large scale production by DuPont Co beginning in 1932. Detonator development during World War II resulted in the need for a form of lead azide with a more brisant output. RD-1333 lead azide (MIL-DTL-46225), a version of lead azide with sodium carboxymethylcellulose as a precipitating agent, was developed to meet that need. The Vietnam War saw an accelerated need for lead azide and it was during this time that Special Purpose Lead Azide (MIL-L-14758) was developed; the US government also began stockpiling lead azide in large quantities. After the Vietnam War, the use of lead azide in the US ceased completely by the early 1990s. In the 2000s, concerns about the age and stability of stockpiled lead azide azide led the US government to investigate methods to dispose of its stockpiled lead azide and obtain new manufacturers.

Explosive characteristics

Lead azide is highly sensitive and usually handled and stored under water in insulated rubber containers. It will explode after a fall of around 150 mm (6 in) or in the presence of a static discharge of 7 millijoules. Its detonation velocity is around 5,180 m/s (17,000 ft/s).

Ammonium acetate and sodium dichromate are used to destroy small quantities of lead azide.

Lead azide has immediate deflagration to detonation transition (DDT) this means that even small amounts undergo full detonation(after being hit by flame or static electricity).

Lead azide reacts with copper, zinc, cadmium, or alloys containing these metals to form other azides. For example, copper azide is even more explosive and too sensitive to be used commercially.^{[10][citation needed]}



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Lead azide was a component of the six .22 caliber Devastator rounds fired from a Röhm RG-14 revolver by John Hinckley, Jr. in his assassination attempt on U.S. President Ronald Reagan on March 30, 1981. The rounds consisted of lead azide centers with lacquer-sealed aluminum tips designed to explode upon impact.

PETN

Pentaerythritol tetranitrate (**PETN**), also known as **PENT**, **PENTA**, **TEN**, **corpent**, or **penthrite** (or—rarely and primarily in German—as **nitropenta**), is an explosive material. It is the nitrate ester of pentaerythritol, and is structurally very similar to nitroglycerin. Penta refers to the five carbon atoms of the neopentane skeleton. PETN is one of the most powerful explosive materials known, with a relative effectiveness factor of 1.66. When mixed with a plasticizer, PETN forms a plastic explosive. Along with RDX it is the main ingredient of Semtex.

PETN is also used as a vasodilator drug to treat certain heart conditions, such as for management of angina.

Production is by the reaction of pentaerythritol with concentrated nitric acid to form a precipitate which can be recrystallized from acetone to give processable crystals.



Variations of a method first published in a US Patent 2,370,437 by Acken and Vyverberg (1945 to Du Pont) forms the basis of all current commercial production.

PETN is manufactured by numerous manufacturers as a powder, or together with nitrocellulose and plasticizer as thin plasticized sheets (e.g. Primasheet 1000 or Detasheet). PETN residues are easily detectable in hair of people handling it. The highest residue retention is on black hair; some residues remain even after washing.

Explosive use





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Pentaerythritol tetranitrate before crystallization from acetone

The most common use of PETN is as an explosive with high brisance. It is more difficult to detonate than primary explosives, so dropping or igniting it will typically not cause an explosion (at atmospheric pressure it is difficult to ignite and burns relatively slowly), but is more sensitive to shock and friction than other secondary explosives such as TNT or tetryl. Under certain conditions a deflagration to detonation transition can occur.

It is rarely used alone, but primarily used in booster and bursting charges of small caliber ammunition, in upper charges of detonators in some land mines and shells, and as the explosive core of detonation cord. PETN is the least stable of the common military explosives, but can be stored without significant deterioration for longer than nitroglycerin or nitrocellulose.

During World War II, PETN was most importantly used in exploding-bridgewire detonators for the atomic bombs. These exploding-bridgewire detonators gave more precise detonation, compared with primacord. PETN was used for these detonators because it was safer than primary explosives like lead azide: while it was sensitive, it would not detonate below a threshold amount of energy.^[22] Exploding bridgewires containing PETN remain used in current nuclear weapons. In spark detonators, PETN is used to avoid the need for primary explosives; the energy needed for a successful direct initiation of PETN by an electric spark ranges between 10–60 mJ.

Its basic explosion characteristics are:

- Explosion energy: 5810 kJ/kg (1390 kcal/kg), so 1 kg of PETN has the energy of 1.24 kg TNT.
- Detonation velocity: 8350 m/s (1.73 g/cm³), 7910 m/s (1.62 g/cm³), 7420 m/s (1.5 g/cm³), 8500 m/s (pressed in a steel tube)
- Volume of gases produced: 790 dm³/kg (other value: 768 dm³/kg)
- Explosion temperature: 4230 °C
- Oxygen balance: -6.31 atom -g/kg
- Melting point: 141.3 °C (pure), 140–141 °C (technical)
- Trauzl lead block test: 523 cm³ (other values: 500 cm³ when sealed with sand, or 560 cm³ when sealed with water)
- Critical diameter (minimal diameter of a rod that can sustain detonation propagation): 0.9 mm for PETN at 1 g/cm³, smaller for higher densities (other value: 1.5 mm)

In mixtures

PETN is used in a number of compositions. It is a major ingredient of the Semtex plastic explosive. It is also used as a component of pentolite, a 50/50 blend with TNT. The XTX8003 extrudable explosive, used in the W68 and W76 nuclear warheads, is a mixture of 80% PETN and 20% of Sylgard 182, a silicone rubber.^[23] It is often phlegmatized by addition of 5–40% of wax, or by polymers (producing polymer-bonded explosives); in this form it is used in some


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cannon shells up to 30 mm caliber, though it is unsuitable for higher calibers. It is also used as a component of some gun propellants and solid rocket propellants. Nonphlegmatized PETN is stored and handled with approximately 10% water content. PETN alone cannot be cast as it explosively decomposes slightly above its melting point, but it can be mixed with other explosives to form castable mixtures.

PETN can be initiated by a laser. A pulse with duration of 25 nanoseconds and 0.5–4.2 joules of energy from a Q-switched ruby laser can initiate detonation of a PETN surface coated with a 100 nm thick aluminium layer in less than half of a microsecond.

PETN has been replaced in many applications by RDX, which is thermally more stable and has a longer shelf life. PETN can be used in some ram accelerator types. Replacement of the central carbon atom with silicon produces Si-PETN, which is extremely sensitive.

Terrorist use

Ten kilograms of PETN was used in the 1980 Paris synagogue bombing.

In 1983, the "Maison de France" house in Berlin was brought to a near-total collapse by the detonation of 24 kilograms (53 lb) of PETN by terrorist Johannes Weinrich.

In 1999, Alfred Heinz Reumayr used PETN as the main charge for his fourteen improvised explosive devices that he constructed in a thwarted attempt to damage the Trans-Alaska Pipeline System.

In 2001, al-Qaeda member Richard Reid, the "Shoe Bomber", used PETN in the sole of his shoe in his unsuccessful attempt to blow up American Airlines Flight 63 from Paris to Miami.^{[18][30]} He had intended to use the solid triacetone triperoxide (TATP) as a detonator.

In 2009, PETN was used in an attempt by al-Qaeda in the Arabian Peninsula to murder the Saudi Arabian Deputy Minister of Interior Prince Muhammad bin Nayef, by Saudi suicide bomber Abdullah Hassan al Asiri. The target survived and the bomber died in the blast. The PETN was hidden in the bomber's rectum, which security experts described as a novel technique.

On December 25, 2009, PETN was found in the underwear of Umar Farouk Abdulmutallab, the "Underwear bomber", a Nigerian with links to al-Qaeda in the Arabian Peninsula.^[34] According to US law enforcement officials, he had attempted to blow up Northwest Airlines Flight 253 while approaching Detroit from Amsterdam. Abdulmutallab had tried, unsuccessfully, to detonate approximately 80 grams (2.8 oz) of PETN sewn into his underwear by adding liquid from a syringe; however, only a small fire resulted.

In the al-Qaeda in the Arabian Peninsula October 2010 cargo plane bomb plot, two PETN-filled printer cartridges were found at East Midlands Airport and in Dubai on flights bound for the US on an intelligence tip. Both packages contained sophisticated bombs concealed in computer printer cartridges filled with PETN. The bomb found in England contained 400 grams (14 oz) of PETN, and the one found in Dubai contained 300 grams (11 oz) of PETN. Hans Michels, professor of safety engineering at University College London, told a newspaper that 6

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grams (0.21 oz) of PETN—"around 50 times less than was used—would be enough to blast a hole in a metal plate twice the thickness of an aircraft's skin". In contrast, according to an experiment conducted by a BBC documentary team designed to simulate Abdulmutallab's Christmas Day bombing, using a Boeing 747 plane, even 80 grams of PETN was not sufficient to materially damage the fuselage.

On July 12, 2017, 150 grams of PETN was found in the Assembly of Uttar Pradesh, India's most populous state.

Detection

In the wake of terrorist PETN bomb plots, an article in Scientific American noted PETN is difficult to detect because it does not readily vaporize into the surrounding air. The Los Angeles Times noted in November 2010 that PETN's low vapor pressure makes it difficult for bomb-sniffing dogs to detect.

Many technologies can be used to detect PETN, including chemical sensors, X-rays, infrared, microwaves and terahertz, some of which have been implemented in public screening applications, primarily for air travel. PETN is one of the explosive chemicals typically of interest in that area, and it belongs to a family of common nitrate-based explosive chemicals which can often be detected by the same tests.

One detection system in use at airports involves analysis of swab samples obtained from passengers and their baggage. Whole-body imaging scanners that use radio-frequency electromagnetic waves, low-intensity X-rays, or T-rays of terahertz frequency that can detect objects hidden under clothing are not widely used because of cost, concerns about the resulting traveler delays, and privacy concerns.

Both parcels in the 2010 cargo plane bomb plot were x-rayed without the bombs being spotted. Qatar Airways said the PETN bomb "could not be detected by x-ray screening or trained sniffer dogs". The Bundeskriminalamt received copies of the Dubai x-rays, and an investigator said German staff would not have identified the bomb either. New airport security procedures followed in the U.S., largely to protect against PETN.

Medical use

Like nitroglycerin (glyceryl trinitrate) and other nitrates, PETN is also used medically as a vasodilator in the treatment of heart conditions. These drugs work by releasing the signaling gas nitric oxide in the body. The heart medicine Lentonitrat is nearly pure PETN.

Monitoring of oral usage of the drug by patients has been performed by determination of plasma levels of several of its hydrolysis products, pentaerythritol dinitrate, pentaerythritol mononitrate and pentaerythritol, in plasma using gas chromatography-mass spectrometry.

Cyclonite

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RDX is the organic compound with the formula $(O_2NNCH_2)_3$. It is a white solid without smell or taste, widely used as an explosive. Chemically, it is classified as a nitramide, chemically similar to HMX. A more energetic explosive than TNT, it was used widely in World War II.

It is often used in mixtures with other explosives

and plasticizers or phlegmatizers (desensitizers). RDX is stable in storage and is considered one of the most energetic and brisant of the military high explosives.

Name

RDX is also known, but less commonly, as cyclonite, hexogen (particularly in Russian, French, German and German-influenced languages), T4, and, chemically, as

cyclotrimethylenetrinitramine. In the 1930s, the Royal Arsenal, Woolwich, started investigating cyclonite to use against German U-boats that were being built with thicker hulls. The goal was having an explosive more energetic than TNT. For security reasons, Britain termed cyclonite as "Research Department Explosive" (R.D.X.). The term RDX appeared in the United States in 1946.^[6] The first public reference in the United Kingdom to the name RDX, or R.D.X., to use the official title, appeared in 1948; its authors were the managing chemist, ROF Bridgwater, the chemical research and development department, Woolwich, and the director of Royal Ordnance Factories, Explosives; again, it was referred to as simply RDX.

RDX is classified by chemists as a hexahydro-1,3,5-triazine derivative. The molecule adopts with a ruffled, cyclic structure similar to that of cyclohexane. The molecule has a high nitrogen content and a high O:C ratio, both of which indicate its explosive potential for formation of N_2 and CO_2 .

It is obtained by treating white fuming nitric acid (WFNA) with hexamine. This nitrolysis reaction produces RDX with methylene dinitrate and ammonium nitrate and water as byproducts, as described in the following idealized reactions:

Toxicity

The substance's toxicity has been studied for many years. RDX has caused convulsions (seizures) in military field personnel ingesting it, and in munition workers inhaling its dust during manufacture. At least one fatality was attributed to RDX toxicity in a European munitions manufacturing plant.

During the Vietnam War, at least 40 American soldiers were hospitalized with composition C-4 (which is 91% RDX) intoxication from December 1968 to December 1969. C-4 was frequently used by soldiers as a fuel to heat food, and the food was generally mixed by the same knife that was used to cut C-4 into small pieces prior to burning. Soldiers were exposed to C-4 either due to inhaling the fumes, or due to ingestion, made possible by many small particles adhering to the knife having been deposited into the cooked food. The symptom complex involved nausea, vomiting, generalized seizures, and prolonged postictal confusion and amnesia; which indicated toxic encephalopathy.

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Oral toxicity of RDX depends on its physical form; in rats, the LD50 was found to be 100 mg/kg for finely powdered RDX, and 300 mg/kg for coarse, granular RDX. A case has been reported of a human child hospitalized in status epilepticus following the ingestion of 84.82 mg/kg dose of RDX (or 1.23 g for the patient's body weight of 14.5 kg) in the "plastic explosive" form.

The substance has low to moderate toxicity with a possible human carcinogen classification. Further research is ongoing, however, and this classification may be revised by the United States Environmental Protection Agency (EPA). Remediating RDX-contaminated water supplies has proven to be successful.^[64] It is known to be a kidney toxin in humans and highly toxic to earthworms and plants, and thus army testing ranges where RDX was used heavily may need to undergo environmental remediation. Concerns have been raised by research published in late 2017 indicating that the issue has been not been addressed correctly by U.S. officials.

Introduction to rocket propellants

Rocket propellant is a material used either directly by a rocket as the reaction mass (propulsive mass) that is ejected, typically with very high speed, from a rocket engine to produce thrust, and thus provide spacecraft propulsion, or indirectly to produce the reaction mass in a chemical reaction. Each rocket type requires a different kind of propellant: chemical rockets require propellants capable of undergoing exothermic chemical reactions, which provide the energy to accelerate the resulting gases through the nozzle. Thermal rockets instead use inert propellants of low molecular weight that are chemically compatible with the heating mechanism at high temperatures, while cold gas thrusters use pressurized, easily stored inert gases. Electric propulsion requires propellants that are easily ionized or made into plasma, and in the extreme case of nuclear pulse propulsion the propellant consists of many small, non-weapon nuclear explosives of which the resulting shock wave propels the spacecraft away from the explosive, thereby creating propulsion. One such spacecraft was designed (but never built), being dubbed "Project Orion" (not to be confused with the NASA Orion spacecraft).

Solid rocket propellant was first developed during the 13th century under the Chinese Song dynasty, at a time when bows, arrows, and catapult-based projectile launchers were state-of-theart military technology in medieval Europe.^[1] The Song Chinese first used solid propellant (gunpowder fuel) in 1232 during the military siege of Kaifeng.

Chemical propellants

There are four main types of chemical rocket propellants: solid, storable liquid, cryogenic liquid, and a liquid monopropellant. Hybrid solid/liquid bi-propellant rocket engines are starting to see limited use as well.



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Solid propellants

Description

Solid propellants are either "composites" composed mostly of large, distinct macroscopic particles or single-, double-, or triple-bases (depending on the number of primary ingredients), which are homogeneous mixtures of one or more primary ingredients. Composites typically consist of a mixture of granules of solid oxidizer (examples: ammonium nitrate, ammonium dinitramide, ammonium perchlorate, potassium nitrate) in a polymer binder (binding agent) with flakes or powders of energetic compounds (examples: RDX, HMX), metallic additives (examples: aluminium, beryllium), plasticizers, stabilizers, and/or burn rate modifiers (iron oxide, copper oxide). Single-, double-, or triple-bases are mixtures of the fuel, oxidizer, binders, and plasticizers that are macroscopically indistinguishable and often blended as liquids and cured in a single batch. Often, the ingredients of a double-base propellant have multiple roles. For example, RDX is both a fuel and oxidizer while nitrocellulose is a fuel, oxidizer, and plasticizer. Further complicating categorization, there are many propellants that contain elements of doublebase and composite propellants, which often contain some amount of energetic additives homogeneously mixed into the binder. In the case of gunpowder (a pressed composite without a polymeric binder) the fuel is charcoal, the oxidizer is potassium nitrate, and sulphur serves as a catalyst. (Note: sulphur is not a true catalyst in gunpowder as it is consumed to a great extent into a variety of reaction products such as K₂S.) During the 1950s and 60s researchers in the United States developed ammonium perchlorate composite propellant (APCP). This mixture is typically 69-70% finely ground ammonium perchlorate(an oxidizer), combined with 16-20% fine aluminium powder (a fuel), held together in a base of 11-14% polybutadiene acrylonitrile (PBAN) or Hydroxyl-terminated polybutadiene (polybutadiene rubber fuel). The mixture is formed as a thickened liquid and then cast into the correct shape and cured into a firm but flexible load-bearing solid. Historically the tally of APCP solid propellants is relatively small. The military, however, uses a wide variety of different types of solid propellants some of which exceed the performance of APCP. A comparison of the highest specific impulses achieved with the various solid and liquid propellant combinations used in current launch vehicles is given in the article on solid-fuel rockets.

Advantages

Solid propellant rockets are much easier to store and handle than liquid propellant rockets. High propellant density makes for compact size as well. These features plus simplicity and low cost make solid propellant rockets ideal for military applications. In the 1970s and 1980s, the U.S. switched entirely to solid-fueled ICBMs: the LGM-30 Minuteman and LG-118A Peacekeeper (MX). In the 1980s and 1990s, the USSR/Russia also deployed solid-fueled ICBMs (RT-23, RT-2PM, and RT-2UTTH), but retains two liquid-fueled ICBMs (R-36 and UR-100N). All solid-fueled ICBMs on both sides had three initial solid stages, and those with multiple independently targeted warheads had a precision maneuverable bus used to fine tune the trajectory of the re-entry vehicles. U.S. Minuteman III ICBMs were reduced to a single warhead

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by 2011 in accordance with the START treaty leaving only the Navy's Trident sub-launched ICBMs with multiple warheads.

Their simplicity also makes solid rockets a good choice whenever large amounts of thrust are needed and the cost is an issue. The Space Shuttle and many other orbital launch vehicles use solid-fueled rockets in their boost stages (solid rocket boosters) for this reason.

Disadvantages

Relative to liquid fuel rockets, solid fuel rockets have lower specific impulse, a measure of propellant efficiency. The propellant mass ratios of solid propellant upper stages are usually in the .91 to .93 range which is as good as or better than that of most liquid propellant upper stages but overall performance is less than for liquid stages because of the solids' lower exhaust velocities. The high mass ratios possible with (unsegmented) solids is a result of high propellant density and very high strength-to-weight ratio filament-wound motor casings. A drawback to solid rockets is that they cannot be throttled in real time, although a programmed thrust schedule can be created by adjusting the interior propellant geometry. Solid rockets can be vented to extinguish combustion or reverse thrust as a means of controlling range or accommodating warhead separation. Casting large amounts of propellant requires consistency and repeatability which is assured by computer control. Casting voids in propellant can adversely affect burn rate so the blending and casting take place under vacuum and the propellant blend is spread thin and scanned to assure no large gas bubbles are introduced into the motor. Solid fuel rockets are intolerant to cracks and voids and often require post-processing such as X-ray scans to identify faults. Since the combustion process is dependent on the surface area of the fuel; voids and cracks represent local increases in burning surface area. This increases the local temperature, system pressure and radiative heat flux to the surface. This positive feedback loop further increases burn rate and can easily lead to catastrophic failure typically due to case failure or nozzle system damage.

Liquid propellants

Current types

The most common liquid propellants in use today:

- Liquid oxygen (LOX) and highly refined kerosene (RP-1). Used for the first stages of the Saturn V, Atlas V and Falcon, the Russian Soyuz, Ukrainian Zenit, and developmental rockets like Angara and Long March 6. Very similar to Robert Goddard's first rocket, this combination is widely regarded as the most practical for boosters that lift off at ground level and therefore must operate at full atmospheric pressure.
- LOX and liquid hydrogen, used in the Space Shuttle orbiter, the Centaur upper stage of the Atlas V, Saturn V upper stages, the newer Delta IV rocket, the H-IIA rocket, and most stages of the European Ariane 5rocket.



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- Dinitrogen tetroxide (N_2O_4) and hydrazine (N_2H_4), MMH, or UDMH. Used in military, orbital, and deep space rockets because both liquids are storable for long periods at reasonable temperatures and pressures. N₂O₄/UDMH is the main fuel for the Proton rocket, older Long March rockets (LM 1-4), PSLV, and Fregat and Briz-M upper stages. This combination is hypergolic, making for attractively simple ignition sequences. The major inconvenience is that these propellants are highly toxic, hence they require careful handling.
- Monopropellants such as hydrogen peroxide, hydrazine, and nitrous oxide are primarily used for attitude control and spacecraft station-keeping where their long-term storability, simplicity of use, and ability to provide the tiny impulses needed, outweighs their lower specific impulse as compared to bipropellants. Hydrogen peroxide is also used to drive the turbopumps on the first stage of the Soyuz launch vehicle.

Historical propellants

These include propellants such as the letter-coded rocket propellants used by Germany in World War II used for the Messerschmitt Me 163 Komet's Walter HWK 109-509 motor and the V-2 pioneer SRBM missile, and the Soviet/Russian utilized syntin, which is synthetic cyclopropane, C₁₀H₁₆ which was used on Soyuz U2 until 1995. Syntin develops about 10 seconds greater specific impulse than kerosene.

Advantages

Liquid-fueled rockets have higher specific impulse than solid rockets and are capable of being throttled, shut down, and restarted. Only the combustion chamber of a liquid-fueled rocket needs to withstand high combustion pressures and temperatures and they can be regeneratively cooled by the liquid propellant. On vehicles employing turbopumps, the propellant tanks are at very much lower pressure than the combustion chamber. For these reasons, most orbital launch vehicles use liquid propellants.

The primary performance advantage of liquid propellants is due to the oxidizer. Several practical liquid oxidizers (liquid oxygen, nitrogen tetroxide, and hydrogen peroxide) are available which have better specific impulse than the ammonium perchlorate used in most solid rockets, when paired with comparable fuels. These facts have led to the use of hybrid propellants: a storable oxidizer used with a solid fuel, which retains most virtues of both liquids (high ISP) and solids (simplicity). (The newest nitramine solid propellants based on CL-20 (HNIW) can match the performance of NTO/UDMH storable liquid propellants, but cannot be controlled as can the storable liquids.)

While liquid propellants are cheaper than solid propellants, for orbital launchers, the cost savings do not, and historically have not mattered; the cost of the propellant is a very small portion of the overall cost of the rocket.^[citation needed] Some propellants, notably oxygen and nitrogen, may be able to be collected from the upper atmosphere, and transferred up to low-Earth orbit for use in propellant depots at substantially reduced cost.



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Disadvantages

The main difficulties with liquid propellants are also with the oxidizers. These are generally at least moderately difficult to store and handle due to their high reactivity with common materials, may have extreme toxicity (nitric acid, nitrogen tetroxide), require moderately cryogenic storage (liquid oxygen), or both (FLOX, a fluorine/LOX mix). Several exotic oxidizers have been proposed: liquid ozone (O₃), ClF₃, and ClF₅, all of which are unstable, energetic, and toxic.

Liquid-fueled rockets also require potentially troublesome valves and seals and thermally stressed combustion chambers, which increase the cost of the rocket. Many employ specially designed turbopumps which raise the cost enormously due to difficult fluid flow patterns that exist within the casings.

Gas propellants

A gas propellant usually involves some sort of compressed gas. However, due to the low density of the gas and high weight of the pressure vessel required to contain it, gases see little current use but are sometimes used for vernier engines, particularly with inert propellants like nitrogen.

GOX (gaseous oxygen) was used as the oxidizer for the Buran program's orbital maneuvering system.

Hybrid propellants

A hybrid rocket usually has a solid fuel and a liquid or NEMA oxidizer. The fluid oxidizer can make it possible to throttle and restart the motor just like a liquid-fueled rocket. Hybrid rockets can also be environmentally safer than solid rockets since some high-performance solid-phase oxidizers contain chlorine (specifically composites with ammonium perchlorate), versus the more benign liquid oxygen or nitrous oxide often used in hybrids. This is only true for specific hybrid systems. There have been hybrids which have used chlorine or fluorine compounds as oxidizers and hazardous materials such as beryllium compounds mixed into the solid fuel grain. Because just one constituent is a fluid, hybrids can be simpler than liquid rockets depending motive force used to transport the fluid into the combustion chamber. Fewer fluids typically mean fewer and smaller piping systems, valves and pumps (if utilized).

Hybrid motors suffer two major drawbacks. The first, shared with solid rocket motors, is that the casing around the fuel grain must be built to withstand full combustion pressure and often extreme temperatures as well. However, modern composite structures handle this problem well, and when used with nitrous oxide and a solid rubber propellant (HTPB), relatively small percentage of fuel is needed anyway, so the combustion chamber is not especially large.

The primary remaining difficulty with hybrids is with mixing the propellants during the combustion process. In solid propellants, the oxidizer and fuel are mixed in a factory in carefully controlled conditions. Liquid propellants are generally mixed by the injector at the top of the combustion chamber, which directs many small swift-moving streams of fuel and oxidizer into one another. Liquid-fueled rocket injector design has been studied at great length and still resists

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reliable performance prediction. In a hybrid motor, the mixing happens at the melting or evaporating surface of the fuel. The mixing is not a well-controlled process and generally, quite a lot of propellant is left unburned,^[11] which limits the efficiency of the motor. The combustion rate of the fuel is largely determined by the oxidizer flux and exposed fuel surface area. This combustion rate is not usually sufficient for high power operations such as boost stages unless the surface area or oxidizer flux is high. Too high of oxidizer flux can lead to flooding and loss of flame holding that locally extinguishes the combustion. Surface area can be increased, typically by longer grains or multiple ports, but this can increase combustion chamber size, reduce grain strength and/or reduce volumetric loading. Additionally, as the burn continues, the hole down the center of the grain (the 'port') widens and the mixture ratio tends to become more oxidizer rich.

There has been much less development of hybrid motors than solid and liquid motors. For military use, ease of handling and maintenance have driven the use of solid rockets. For orbital work, liquid fuels are more efficient than hybrids and most development has concentrated there. There has recently been an increase in hybrid motor development for nonmilitary suborbital work:

- Several universities have recently experimented with hybrid rockets. Brigham Young University, the University of Utah and Utah State University launched a student-designed rocket called Unity IV in 1995 which burned the solid fuel hydroxy-terminated polybutadiene (HTPB) with an oxidizer of gaseous oxygen, and in 2003 launched a larger version which burned HTPB with nitrous oxide. Stanford University researches nitrous-oxide/paraffin wax hybrid motors. UCLA has launched hybrid rockets through an undergraduate student group since 2009 using HTPB.
- The Rochester Institute of Technology was building an HTPB hybrid rocket to launch small payloads into space and to several near-Earth objects. Its first launch was in the Summer of 2007.
- Scaled Composites SpaceShipOne, the first private manned spacecraft, was powered by a hybrid rocket burning HTPB with nitrous oxide: RocketMotorOne. The hybrid rocket engine was manufactured by SpaceDev. SpaceDev partially based its motors on experimental data collected from the testing of AMROC's (American Rocket Company) motors at NASA's Stennis Space Center's E1 test stand.
- The Dream Chaser spaceplane intends to use twin hybrid engines of similar design to SpaceShipOne for orbit raising, deorbiting, and emergency escape system.

Gel propellant

Some work has been done on gelling liquid propellants to give a propellant with low vapor pressure to reduce the risk of an accidental fireball. Gelled propellant behaves like a solid propellant in storage and like a liquid propellant in use.

Inert propellants

Prepared by H.Revathi, Asst Prof, Department of Chemistry, KAHE



CLASS:III B.Sc CHEMISTRY

COURSE NAME: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

COURSE CODE:16CHU503A

UNIT:V(Chemical Explosives)

BATCH:2016-2019

Some rocket designs have their propellants obtain their energy from non-chemical or even external sources. For example, water rockets use the compressed gas, typically air, to force the water out of the rocket.

Solar thermal rockets and nuclear thermal rockets typically propose to use liquid hydrogen for an I_{sp} (Specific Impulse) of around 600–900 seconds, or in some cases water that is exhausted as steam for an I_{sp} of about 190 seconds.

Additionally for low performance requirements such as attitude control jets, inert gases such as nitrogen have been employed.

Nuclear thermal rockets pass a propellant over a central reactor, heating the propellant and causing it to expand rapidly out a rocket nozzle, pushing the craft forward. The propellant itself is not directly interacting with the interior of the reactor, so the propellant is not irradiated.

Solar thermal rockets use concentrated sunlight to heat a propellant, rather than using a nuclear reactor.



CLASS:III B.Sc CHEMISTRY

INDUSTRIAL IMPORTANCE UNIT:V(Chemical Explosives)

BATCH:2016-2019

COURSE NAME: INORGANIC MATERIALS OF

COURSE CODE:16CHU503A

POSSIBLE QUESTIONS

UNIT V

PART-A(20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B(2 MARKS)

1.Write a note on origin of explosives.

2.Write down preparation and explosive properties of lead azide.

3. Write down preparation and explosive properties of PETN.

4.Write down preparation and explosive properties of RDX.

PART-C(6 MARKS)

1. Explain preparation and explosive properties of lead azide.

2. Explain preparation and explosive properties of cyclonite.

3. Explain preparation and explosive properties of PETN.

4. What are rocket propellants. Write a note on rocket propellants.



(Deemed to be University Under Section 3 of UGC Act 1956)

COIMBATORE-641 021

(For the Canditates admitted from 2016 & onwards)

III B.Sc Chemistry

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE (16CHU503A)

Unit V (CHEMICAL EXPLOSIVES)

S.No	Question	Option 1	Option 2	Option 3	Option 4	Answer
1	A material when subjected to sudden shock releases energy in an extremely brief period which is observed in the form					
2	It is possible to make gaseous mixtures like hydrogen peroxide and vapour-air to explode under suitable conditions	petrol	benzene	diesel	kerosene	petrol
3	Explosive reactions are	endothermic	exothermic	reversible	endother mic and reversible	exothermic
4	When an explosion occurs in a confined space, the conditions developed within the system can be instrumental to					
	shatter the confining	high P	low P	high T	low T	high P

	walls					
5	The quanitity of					
	power realisable					
	from a given weight				volume	
	of an explosive is	weight to	power to	power to	to power	power to weight
	called	power ratio	weight ratio	volume ratio	ratio	ratio
6	Explosives are mainly	defence	medical	agricultural	industrial	defence
	used for	purposes	purposes	purposes	purposes	purposes
7	The were	•••		· ·	· · ·	
	the first to use					
	explosives in the war					
	in 1346	americans	british	indians	russians	british
8	GTN were known by	1856	1836	1846	1826	1846
9	It was Alfred Bobel. a					
-	swedish chemist.					
	who demonstrated					
	that GTN, when					
	absorbed in					
	could be handled					
	and transported					
	safely	gypsum	kieselguhr	mica	alum	kieselguhr
10	Gun powder is a	0/1-00				
	mixture of potassium					
	nitrate, sand and	charcoal	peat	lignite	dolomite	charcoal
11	GTN was first			ů.		
	prepared by an	Indian	Italian	American	British	Italian
12					Glyceryl	
		Glyceryl	Glycerol	Glyceryl	tetranitrat	Glyceryl
	GTN is nothing but	trinitrate	trinitrate	trinitrite	e	trinitrate
13					solid and	
		solid			liquid	
	TNT is a	explosive	liquid explosive	gas explosive	explosive	solid explosive
14					solid and	
		solid			liquid	
	GTN is a	explosive	liquid explosive	gas explosive	explosive	liquid explosive
15	Primary and					
	secondary high					
	explosives are					
	generally referred to	low		mixed	mild	
	as	explosives	high explosives	explosives	explosives	high explosives
16	Low explosives are					
	otherwise known as	propellants	mild	mixed	shockers	propellants
17	For any compound					
	to serve as an					
	explosive, how many					
	chemical bond it					
	should have?	1	2	3	4	1

18	For an explosive, the	negative free	positive free		high free	negative free
	molecule should	energy of	energy of	low free energy	energy of	energy of
	have	formation	formation	of formation	formation	formation
19				photo and		
		photo	thermal	thermal	electrical	thermal
	A good explosives	conditions of	conditions of	conditions of	conditions	conditions of
	must be stable in	storage	storage	storage	of storage	storage
20					industrial	
					and	
					agricultur	
	Lead azide is a	military	industrial	agricultural	ai	military
21	populai	explosive	explosive	explosive	explosive	explosive
21	of reacting with	bronzo	brass	connor	tin	brass
22	The caps of load	DIONZE	DIASS	coppei		DI dSS
22	azide are loaded					
	with it must be of	copper	tin	aluminium	boron	aluminium
23	reacts	copper		didinitian	501011	didifinitiani
	with sodium forming					
	sodium amide	nitrogen	nitrate	nitrite	ammonia	ammonia
24	In preparation of					
	lead azide, sodium					
	azide cane be					
	obtained by				hydrogen	
	treatement with	nitrous oxide	nitric oxide	carbon dioxide	peroxide	nitrous oxide
25	Sodium azide when					
	treated with a					
	solution of			copper	ammoniu	
	-gives lead azide	lead nitrate	lead acetate	sulphate	m nitrate	lead acetate
26	Hale's method are					
07	used to prepare	RDX	lead azide	cordite	dynamite	RDX
27	Bachmann method is					
	a method used to		DDV	a a valita	du un o uno itro	DDV
20	Molfrom mothod is	lead azide	RUX	cordite	dynamite	KDX
20	used to prepare	cordite	PETN	cyclonite	dynamite	cyclonite
29	BDX can be prepared	corune		cyclonice	dynamite	cyclonite
2)	by of					
	hexamethylene					
	tetramine with con				hvdrofor	
	nitric acid	hvdrolvsis	nitrolysis	hvdrogenation	mylation	nitrolvsis
30	The addition of	, - ,	1	, 0	,	/
_	and					
	ammonium nitrate					
	to acetic anhydride			para	propanald	para
	gives cyclonite	formaldehyde	formic acid	formaldehyde	ehyde	formaldehyde
31	Combination of	Bachmann	wolfram	aldol method	henry	Bachmann

Ebele-Schiessler-Ross method is known as aluminium powder copper bronze powder copper powder aluminium powder 32 Torpex is a mixture of RDX, TNT and powder aluminium powder bron powder bronze powder aluminium powder aluminium powder 33 PFTN is prepared under the propanaldehyd and ethyl acetate acetaldehyde e hydravita cannizaro 34 PETN is prepared by the aldol reaction reaction favorski wurtz cannizaro 35 PETN can be desensitised by mixing it with TN and TNT in equal proportions is called propertions is called propertione addition of sodium chloride and ammonium nitrate		Hale's method and	method	method		method	method
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33 PETN is prepared from formaldehyde and propanaldehyd ethyl acetate propanaldehyd e butanalde hyde acetaldehyde 34 PETN is prepared by the cannizaro favorski wurzt cannizaro 35 PETN ran be desensitised by mixing it with TNT GTN DDT TNT TNT 36 A mixture of PETN and TNT in equal proportions is called by proportions is called the like missile pentolite DDT cordite RDX pentolite 37 The addition of sodium chloride and ammonium nitrate		of RDX, TNT and	powder	boron powder	bronze powder	powder	powder
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37 The addition of sodium chloride and ammonium nitrate		proportions is called	pentolite	DDT	cordite	RDX	pentolite
sodium chloride and ammonium nitrate	37	The addition of					
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		ammonium nitrate					
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temperatureGTNDDTcorditePETNGTN38A rocket engine is a tube like missile which carries both the fuel and the 		lower the flame					
38 A rocket engine is a tube like missile which carries both the fuel and the control oxidant reductant oxidase reductase oxidant 39 Homogeneous solid propellants are solid state intervent on the control oxidase reductase oxidant 40		temperature	GTN	DDT	cordite	PÈTN	GTN
tube like missile which carries both the fuel and the arre 	38	A rocket engine is a					
which carries both the fuel and the 		tube like missile					
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an example for di propellants tri propellants propellants propellant propellants	43	Hydrogen peroxide is			mono	tetra	mono
		an example for	di propellants	tri propellants	propellants	propellant	propellants

					S	
44	The fuels that are					
	commonly used in bi					
	propellants are liquid					
	ethanol, hydrazine,					
	aniline, petrol,					
	kerosene and				carbon	
	ammonia	hydrogen	nitrogen	oxygen	dioxide	oxygen
45	A good explosives					
	should have				low an	
	energy density	high	low	medium	high	high
46	Rockets exployed for	-			-	
	launching Indian					
	satellites use					
	propellants for					
	the first stage	solid	liquid	semi solid	cryogenic	solid
47	The fluids of oxygen-				semi solid	
	hydrogen are	cryogenic	solid	liquid	propellant	cryogenic
	referred to as	propellants	propellants	propellants	s	propellants
48	Cordite factory is					
	located aruvankadu					
	near	kothagiri	coonoor	vilupuram	dindigul	coonoor
49	High explosive				-	
	factory is located at	kothagiri	kirkee	coonoor	vilupuram	kirkee
50	Ordnance factory is				west	
	located in	maharashtra	karnataka	delhi	bengal	maharashtra
51	Bharath explosives				Andhra	
	are located in	Tamil nadu	Uttar pradesh	Karnataka	pradesh	Uttar pradesh
52	Remarkable					
	explosive					
	nitroglycerine					
	dynamite was	albert				
	invented by	einstein	alfred nobel	mendeleev	darwin	alfred nobel
53	inititates					
7 4	explosion	detonator	propellants	RDX	PETN	detonator
54	Plastic explosives					
	contain a high					
	explosive admixed					
	with or oil	wax	varnish	paint	grease	wax
55	Mono propellants					
50	contain a single	acia	base	bona	ester	pase
56	Double propellants		h	1		h
57	contain two	acia	base	DONG	ester	base
51	Dranallanta ara	IOW	high overlasives	meaium	mixed	
59	Propenants are	explosives	nigh explosives	explosives	explosives	iow explosives
58		sym	sym	sym	sym	sym
	KDX IS	trimethylene	tetramethylene	trimethylene	triethylen	trimethylene

		trinitramine	trinitramine	tetranitramine	е	trinitramine
					tetranitra	
					mine	
59	A					
	oxygen balance					
	signifies a good				irreversibl	
	explosive	negative	positive	reversible	е	negative
60	Explosives can be					
	categorised under					
	mechanical and					
	chemical explosives	molecular	atomic	bulk	nano	atomic

Prepared by H.Revathi, Asst Prof, Department of Chemistry, KAHE

Reg. No. : -----

[16CHU503A]

KARPAGAM ACADEMY OF HIGHER EDUCATION (Deemed to be University) (Established Under Section 3 of UGC Act 1956) COIMBATORE-21 B.Sc. Degree Internal Examination,July 2018 (For the candidates admitted from 2017& onwards) III B.Sc CHEMISTRY INTERNAL EXAM I

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE Time: 2 hours Maximum: 50 marks

PART- A (20 x 1= 20 Marks)

Answer ALL the Questions

1.A super cooled liquid possessing no sharp melting point is known as

a)Glassb)ceramics c)cement d)refractory

2. The material having high compressive strength is

a)cement b)refractory c)ceramics d)Glass

3.Porcelain is a type of ceramics which comes under the

a)whitewares b)structural clay products

c)chemical stonewares d)whitewares and chemical stonewares

4.Certain earths, which are highly plastic, when wet and which, when heated to redness, loses their plasticity and are converted into a hard mass are known as

a)cement b)clay c)ceramics d)Glass

5. Clays are formed by the weathering of igneous, and felspathic rocks by various agencies

through time and are composed essentially of hydrated

a)aluminium nitrate b) aluminium silicates

c)magnesium nitrate d)magnesium sulphate

6.Kaolin is otherwise known as

a)cement b)china clay c)ceramics d)Glass

7.A compound that contains limestone powder, hydrated oxides, mud and organic impurities are known as

a)primary clay b)secondary clay c)china clay d)Glass

8. The main constituent in soft glass is

a)potassium b)sodium c)calcium d)magnesium

9. The main constituent in hard glass is

a)potassium b)sodium c)calcium d)magnesium

10.Flint glass are nothing but

a)soft glass b)hard glass c)lead and red lead d)shock proof glass

11.Soft glasses are widely used in

a)window glasses b)combustion tubes c)cathode ray tubes d)electrical insulators 12.Hard glass are used for

a)cooling operations b)heating operations c)thermal operations d)electrical operations 13. The glass borosilicate glass are otherwise known as

a)silica glass b)optical glass c)toughened glass d)jena glass 14.Borosilicate glass contain virtually only silica and

a)carbon b)boron c)aluminium d)sulphur

15. The glass which is used for pipelines for corrosive liquids are

a)glass wool b)hard glass c)jena glass d)insulating glass

16. Which among these is not the natural inorganic fertilizers

a)chile saltpeter b)Ammonium nitrate c)Rock phosphate d)potassium salt 17.Ammonium nitrate is

a)hydrophobic b)hydroscopic c)hydrogenous d)hydrated

18.21% of nitrogen present in

a)ammonium nitrate b)ammonium sulphate c)CAN d)urea

19. Which one of the following is called double salt.

a)ammonium nitrate b)CAN c)urea d)triple super phosphate

20.Urea have -----% of nitrogen in it.

a)50% b)48% c)45-47 % d)46-50%

PART- $B(3 \times 2 = 6 \text{ Marks})$

Answer ALL the Questions

21.How will you classify Glass?22.Write down the properties of hard glass23.Write a note on carbon fibre.

PART- C(3 x 8= 24 Marks)

Answer ALL the Questions

24.a.Discuss the important properties of Glass. Explain the manufacture of soft glass.

(OR)

b.Write composition and properties for the following glasses

(i)lead glass (ii)safety glass (iii)photosensitive glass

25.a.How will you classify ceramics.Write a note on fullerences and carbon nanotubes

(OR)

b. What is known as setting of cement.Describe the manufacture of cement.

26.a.Write down the manufacture steps for urea and ammonium nitrate

(OR)

b.What are fertilizers? Explain the manufacture of ammonium phosphate and superphosphate of lime.

[16CHU503A]

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University) (Established Under Section 3 of UGC Act 1956) COIMBATORE-21 B.Sc. Degree Internal Examination,July 2018 (For the candidates admitted from 2017& onwards) III B.Sc CHEMISTRY INTERNAL EXAM I

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE ANSWER KEY

PART-A

1.a)Glass

2.d)Glass

3.a)whiteares

4.b)clay

5.b)aluminium silicates

6.b)china clay

7.b)secondary clay

8.b)sodium

9.a)potassium

10.c)lead and red lead

- 11.a)window glasses
- 12.b)heating operations
- 13.d)jena glass
- 14.b)boron

15.a)jena glass

16.d)potassium salt

17.b)hydroscopic

18.b)ammonium sulphate

19.a)ammonium nitrate

20.c)45-47%

PART B

21.Glass can be classified as silicate and non-silicate glasses

22. A potash-lime glass with a high silica content, used for making brilliant glassware.

23. Carbon fibers or carbon fibres (alternatively CF, graphite fiber or graphite fibre) are fibers about 5–10 micrometres in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion.

PART C

24.a) Optical properties

Glass is in widespread use largely due to the production of glass compositions that are transparent to visible light. In contrast, polycrystalline materials do not generally transmit visible light. The individual crystallites may be transparent, but their facets (grain boundaries) reflect or scatter light resulting in diffuse reflection. Glass does not contain the internal subdivisions associated with grain boundaries in polycrystals and hence does not scatter light in the same manner as a polycrystalline material. The surface of a glass is often smooth since during glass formation the molecules of the supercooled liquid are not forced to dispose in rigid crystal geometries and can follow surface tension, which imposes a microscopically smooth surface. These properties, which give glass its clearness, can be retained even if glass is partially light-absorbing—i.e., colored.

Glass has the ability to refract, reflect, and transmit light following geometrical optics, without scattering it (due to the absence of grain boundaries). It is used in the manufacture of lenses and windows. Common glass has a refraction index around 1.5. This may be modified by adding low-density materials such as boron, which lowers the index of refraction (see crown glass), or increased (to as much as 1.8) with high-density materials such as (classically) lead oxide (see flint glass and lead glass), or in modern uses, less toxic oxides of zirconium, titanium, or barium. These high-index glasses (inaccurately known as "crystal" when used in glass vessels) cause more chromatic dispersion of light, and are prized for their diamond-like optical properties.

According to Fresnel equations, the reflectivity of a sheet of glass is about 4% per surface (at normal incidence in air), and the transmissivity of one element (two surfaces) is about 90%. Glass with high germaniumoxide content also finds application in optoelectronics—e.g., for light-transmitting optical fibers.



Simple optical device: the magnifying glass

• Strand of optical glass fiber

Other properties

In the process of manufacture, silicate glass can be poured, formed, extruded and molded into forms ranging from flat sheets to highly intricate shapes. The finished product is brittle and will fracture, unless laminated or specially treated, but is extremely durable under most conditions. It erodes very slowly and can mostly withstand the action of water. It is mostly resistant to chemical attack, does not react with foods, and is an ideal material for the manufacture of containers for foodstuffs and most chemicals. Glass is also a fairly inert substance.

Corrosion

Main article: Corrosion § Corrosion of glasses

Although glass is generally corrosion-resistant and more corrosion resistant than other materials, it still can be corroded. The materials that make up a particular glass composition has an effect on how quickly the glass corrodes. A glass containing a high proportion of alkalis or alkali earths is less corrosion-resistant than other kinds of glasses.

Glass flakes have applications as anti-corrosive coating.

Strength

Glass typically has a tensile strength of 7 megapascals (1,000 psi), however theoretically it can have a strength of 17 gigapascals (2,500,000 psi) due to glass's strong chemical bonds. Several factors such as imperfections like scratches and bubblesand the glass's chemical composition impact the tensile strength of glass. Several processes such as toughening can increase the strength of glass.

Manufacture and processing of glass

Batch processing system (batch house)

Batch processing is one of the initial steps of the glass-making process. The batch house simply houses the raw materials in large silos (fed by truck or railcar) and holds anywhere from 1-5

days of material. Some batch systems include material processing such as raw material screening/sieve, drying, or pre-heating (i.e. cullet). Whether automated or manual, the batch house measures, assembles, mixes, and delivers the glass raw material recipe (batch) via an array of chutes, conveyors, and scales to the furnace. The batch enters the furnace at the 'dog house' or 'batch charger'. Different glass types, colors, desired quality, raw material purity / availability, and furnace design will affect the batch recipe.

Furnace



Batch feed (doghouse) of a glass furnace

The *hot end* of a glassworks is where the molten glass is formed into glass products, beginning when the batch is fed into the furnace at a slow, controlled rate by the batch processing system (batch house). The furnaces are natural gas- or fuel oil-fired, and operate at temperatures up to 1,575 °C (2,867 °F).^[3] The temperature is limited only by the quality of the furnace's superstructure material and by the glass composition. Types of furnaces used in container glass making include 'end-port' (end-fired), 'side-port', and 'oxy-fuel'. Typically, furnace "size" is classified by metric tons per day (MTPD) production capability.

Forming process



Glass container forming

There are currently two primary methods of making glass containers: the *blow & blow* method for narrow-neck containers only, and the *press & blow* method used for jars and tapered narrow-neck containers .



Figure 1: Steps during Blow&Blow container forming process

In both methods, a stream of molten glass, at its plastic temperature (1,050-1,200 °C [1,920-2,190 °F]), is cut with a shearing blade to form a solid cylinder of glass, called a *gob*. The gob is of predetermined weight just sufficient to make a bottle. Both processes start with the gob falling, by gravity, and guided, through troughs and chutes, into the blank moulds, two halves of which are clamped shut and then sealed by the "baffle" from above.

In the **blow and blow** process, the glass is first blown through a valve in the baffle, forcing it down into the three-piece "ring mould" which is held in the "neckring arm" below the blanks, to form the "finish", [The term "finish" describes the details (such as cap sealing surface, screw threads, retaining rib for a tamper-proof cap, etc.) at the open end of the container.] The compressed air is blown through the glass, which results in hollow and partly formed container. Compressed air is then blown again at the second stage to give final shape.

Containers are made in two major stages. The first stage moulds all the details ("finish") around the opening, but the body of the container is initially made much smaller than its final size. These partly manufactured containers are called **parisons**, and quite quickly, they are blow-molded into final shape.

Referring to the mechanism, the "rings" are sealed from below by a short plunger. After the "settleblow" finishes, the plunger retracts slightly, to allow the skin that's formed to soften. "Counterblow" air then comes up through the plunger, to create the parison. The baffle rises and the blanks open. The parison is inverted in an arc to the "mould side" by the "neckring arm", which holds the parison by the "finish".

As the neckring arm reaches the end of its arc, two mould halves close around the parison. The neckring arm opens slightly to release its grip on the "finish", then reverts to the blank side. *Final blow*, applied through the "blowhead", blows the glass out, expanding into the mould, to make the final container shape.

In the **press and blow** process, the parison is formed by a long metal plunger which rises up and presses the glass out, in order to fill the ring and blank moulds. The process then continues as before, with the parison being transferred to the final-shape mould, and the glass being blown out into the mould.

The container is then picked up from the mould by the "take-out" mechanism, and held over the "deadplate", where air cooling helps cool down the still-soft glass. Finally, the bottles are swept

onto a conveyor by the "push out paddles" that have air pockets to keep the bottles standing after landing on the "deadplate"; they're now ready for annealing.

Forming machines



IS machine during bottle production

The forming machines hold and move the parts that form the container. The machine consist of basic 19 mechanisms in operation to form a bottle and generally powered by compressed air (high pressure - 3.2 bar and low pressure - 2.8 bar), the mechanisms are electronically timed to coordinate all movements of the mechanisms. The most widely used forming machine arrangement is the *individual section* machine (or IS machine). This machine has a bank of 5–20 identical sections, each of which contains one complete set of mechanisms to make containers. The sections are in a row, and the gobs feed into each section via a moving chute, called the *gob distributor*. Sections make either one, two, three or four containers simultaneously. (Referred to as *single, double, triple* and *quad* gob). In the case of multiple gobs, the *shears* cut the *gobs* simultaneously, and they fall into the blank moulds in parallel.

b.Lead glass

(i)Lead glass, commonly called **crystal**, is a variety of glass in which lead replaces the calcium content of a typical potash glass. Lead glass contains typically 18–40% (by weight) lead(II) oxide (PbO), while modern **lead crystal**, historically also known as flint glass due to the original silica source, contains a minimum of 24% PbO. Lead glass is desirable owing to its decorative properties.

(ii)safety glass

Safety glass is glass with additional safety features that make it less likely to break, or less likely to pose a threat when broken. Common designs include toughened glass (also known as tempered glass), laminated glass, wire mesh glass (also known as wired glass) and engraved glass. Wire mesh glass was invented by Frank Shuman. Laminated glass was invented in 1903 by the French chemist.

(iii)photosensitive glass

Photosensitive glass, also known as photostructurable glass (PSG), or photomachinable glass, is a crystal-clear glass that belongs to the lithium-silicate family of glasses, in which an image of a mask can be captured by microscopic metallic particles in the glass when it is exposed to short wave radiations such as ultraviolet light.^[1] Photosensitive glass was first discovered by S. Donald Stookey in 1937.

25.a) A **fullerene** is an allotrope of carbon in the form of a hollow sphere, ellipsoid, tube, and many other shapes. Spherical fullerenes, also referred to as Buckminsterfullerenes or buckyballs, resemble the balls used in association football. Cylindrical fullerenes are also called carbon nanotubes (buckytubes). Fullerenes are similar in structure to graphite, which is composed of stacked graphene sheets of linked hexagonal rings. Unless they are cylindrical, they must also contain pentagonal (or sometimes heptagonal) rings.

The first fullerene molecule to be discovered, and the family's

namesake, buckminsterfullerene (C_{60}), was manufactured in 1985 by Richard Smalley, Robert Curl, James Heath, Sean O'Brien, and Harold Kroto at Rice University. The name was an homage to Buckminster Fuller, whose geodesic domes it resembles. The structure was also identified some five years earlier by Sumio Iijima, from an electron microscope image, where it formed the core of a "bucky onion". Fullerenes have since been found to occur in nature. More recently, fullerenes have been detected in outer space. According to astronomer Letizia Stanghellini, "It's possible that buckyballs from outer space provided seeds for life on Earth

Carbon nanotubes (**CNTs**) are allotropes of carbon with a cylindrical nanostructure. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, electronics, optics and other fields of materials science and technology. Owing to the material's exceptional strength and stiffness, nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1,significantly larger than for any other material.

In addition, owing to their extraordinary thermal conductivity, mechanical, and electrical properties, carbon nanotubes find applications as additives to various structural materials. For instance, nanotubes form a tiny portion of the material(s) in some (primarily carbon fiber) baseball bats, golf clubs, car parts or damascus steel.

Nanotubes are members of the fullerene structural family. Their name is derived from their long, hollow structure with the walls formed by one-atom-thick sheets of carbon, called graphene. These sheets are rolled at specific and discrete ("chiral") angles, and the combination of the rolling angle and radius decides the nanotube properties; for example, whether the individual nanotube shell is a metal or semiconductor. Nanotubes are categorized as single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs). Individual nanotubes naturally align themselves into "ropes" held together by van der Waals forces, more specifically, pi-stacking.

- 1. b.Manufacture of cement
- 2. Mixing of raw material

- 3. Burning
- 4. Grinding
- 5. Storage and packaging

1. Mixing of raw material

The major raw materials used in the manufacture of cement are Calcium, Silicon, Iron and Aluminum. These minerals are used in different form as per the availability of the minerals.

Table shows the raw materials for Portland cement manufacture

Calcareous Materials	Argillaceous Materials					
Calcium	Silicon	Aluminum	Iron			
Limestone	Clay	Clay	Clay			
Marl	Marl	Shale	Iron ore			
Calcite	Sand	Fly ash	Mill scale			
Aragonite	Shale	Aluminum ore refuse	Shale			
Shale	Fly ash		Blast furnace dust			
Sea Shells	Rice hull ash					
Cement kiln dust	Slag					

The mixing procedure of the manufacture of cement is done in 2 methods,

- Dry process
- Wet process

a) Dry Process

The both calcareous and argillaceous raw materials are firstly crushed in the gyratory crushers to get 2-5cm size pieces separately. The crushed materials are again grinded to get fine particles into ball or tube mill.

Each finely grinded material is stored in hopper after screening. Now these powdered minerals are mixed in required proportion to get dry raw mix which is then stored in silos and kept ready

to be sent into rotary kiln. Now the raw materials are mixed in specific proportions so that the average composition of the final product is maintained properly.

b) Wet Process

The raw materials are firstly crushed and made into powdered form and stored in silos. The clay is then washed in washing mills to remove adhering organic matters found in clay.

The powdered limestone and water washed clay are sent to flow in the channels and transfer to grinding mills where they are completely mixed and the paste is formed, i.e., known as slurry.

The grinding process can be done in ball or tube mill or even both. Then the slurry is led into collecting basin where composition can be adjusted. The slurry contains around 38-40% water that is stored in storage tanks and kept ready for the rotary kiln.



2. Burning of Raw Materials

The burning process is carried out in the rotary kiln while the raw materials are rotated at 1-2rpm at its longitudinal axis. The rotary kiln is made up of steel tubes having the diameter of 2.5-3.0

meter and the length differs from 90-120meter. The inner side of the kiln is lined with refractory bricks.

The kiln is supported on the columns of masonry or concrete and rested on roller bearing in slightly inclined position at the gradient of 1 in 25 to 1 in 30. The raw mix of dry process of corrected slurry of wet process is injected into the kiln from the upper end. The kiln is heated with the help of powdered coal or oil or hot gases from the lower end of the kiln so that the long hot flames is produced.

As the kiln position is inclined and it rotates slowly, the material charged from upper end moves towards lower end at the speed of 15m/hr. In the upper part, water or moisture in the material is evaporated at 400oC temp, so this process is known as Drying Zone.

The central part i.e. calcination zone, the temperature is around 10000C, where decomposition of lime stone takes place. The remaining material is in the form of small lumps known as nodules after the CO_2 is released.

$$CaCO_3 = CaO + CO_2$$

3.Grinding of Clinkers

The cooled clinkers are received from the cooling pans and sent into mills. The clinkers are grinded finely into powder in ball mill or tube mill. Powdered gypsum is added around 2-3% as retarding agent during final grinding. The final obtained product is cement that does not settle quickly when comes in contact with water.

After the initial setting time of the cement, the cement becomes stiff and the gypsum retards the dissolution of tri-calcium aluminates by forming tricalcium sulfoaluminate which is insoluble and prevents too early further reactions of setting and hardening.

$$3CaO.Al_2O_3 + xCaSO_4.7H_2O = 3CaO.Al_2O_3.xCaSO_4.7H_2O$$

4. Storage and packaging

The grinded cement is stored in silos, from which it is marketed either in container load or 50kg bags.

26.a)Manufacture of urea

Urea is in many ways the most convenient form for fixed nitrogen. It has the highest nitrogen content available in a solid fertilizer (46 %). It is easy to produce as prills or granules and easily transported in bulk or bags with no explosive hazard. It leaves no salt residue after use on crops. Its specific gravity is 1.335, decomposes on boiling and is fairly soluble in water. The principal raw materials required for this purpose are NH3 & CO2.Two reactions are involved in the manufacture of urea. First, ammonium carbamate is formed under pressure by reaction between $CO_2 \& NH_3$.

CO₂ + 2NH₃ NH₂COONH₄ H= -37.4 Kcal

This highly exothermic reaction is followed by an endothermic decomposition of the ammonium carbamate.

 $NH_2COONH_4 NH_2CONH_2 + H_2O H = + 6.3 Kcal$

Manufacture of ammonium nitrate

Much of the nitric acid made in industry is used to make the fertilizer, ammonium nitrate (NH₄NO₃).

Ammonia is an

alkali, so it will undergo a neutralization reaction with nitric acid. The salt made is ammonium nitrate:

ammonia + nitric acid \rightarrow ammonium nitrate NH₃(aq) + HNO₃(aq) \rightarrow NH₄NO₃(aq)

b. Triammonium phosphate can be prepared in the laboratory by treating 85% phosphoric acid with 30% ammonia solution:

 $H_3PO_4 + 3 NH_3 \rightarrow (NH_4)_3PO_4$

 $(NH_4)_3PO_4$ is a colorless, crystalline solid. The solid, which has the odor of ammonia, is readily soluble in water. The salt converts to diammonium hydrogen $(NH_4)_2HPO_4$.

Preparation of diammonium hydrogen phosphate (DAP)[edit]

DAP is a simple salt and a complex fertilizer. It is also the source of nitrogen and phosphorus nutrients.

 $H_3PO_4 + 2 NH_3 \rightarrow (NH_4)_2HPO_4$

On heating, $(NH_4)_2$ HPO₄ evolves ammonia, giving colorless crystals of the monoammonium salt.

(NH₄)₂ HPO₄ is a colorless, odorless, crystalline solid, which insoluble in water.

CIA I ANSWER KEY	2016-
	2019
	Batch

Reg. No. : -----

[16CHU503A]

KARPAGAM ACADEMY OF HIGHER EDUCATION (Deemed to be University) (Established Under Section 3 of UGC Act 1956) COIMBATORE-21 B.Sc. Degree Internal Examination, August 2018 (For the candidates admitted from 2016& onwards) III B.Sc CHEMISTRY INTERNAL EXAM II

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE Time: 2 hours Maximum: 50 marks

PART- A (20 x 1= 20 Marks)

Answer ALL the Questions

1. Surface coating is otherwise known as

a)metallic coating b)protecting coating c)glass coating d)ceramic coating

2. Which step is considered as first step in coating of a base metal

a)cleaning b)washing c)drying d)washing and drying

3. The process of cleaning is accelerated by vigorous evolution of which of the following

elements?

a)nitrogen b)oxygen c)hydrogen d)carbon

4. Which one of the elements act as anode in lithium battery

a)lithium b)titanium c)cadmium d)sulphur

5.An example for inorganic surface coating is

a)paints b)varnishes c)enamels d)wax polishes

6.An example for organic surface coating is

a)enamels b)metal coatings c)lacquers d)surface conversions

7.0il paint is a type of

a)varnishes b)lacquers c)paints d)spirit varnish

8. Coating of zinc on iron is known as

a)tinning b)plating c)galvanising d)hot dipping

9.In ----- molten metal coat droplets are atomised and blown on the surface of the base

metal with compressed air using a spray gun

a)cementation b)metal spraying c)metal cladding d)electroplating

10. In coal-fired fuel cells the gassification of coal is achieved at temperature of about b)650°C c)700°C d)660°C a)560°C 11. Which one of the energies are converted to electrical energy in a battery? a)mechanical b)chemical c)thermal d)geothermal 12. Which type of reaction is occurred during anode half-cell reaction in coal-fired fuel cells a)oxidation b)reduction c)combustion d)hydration 13. The difference between the two voltages of the donor acceptor pair is the a)cell voltage b)voltage c)emf d)potential 14.Hydrocarbon-oxygen fuel cells are based on the combustion of which of the below elements? b)carbon and hydrogen d)hydrocarbon a)hydrogen c)oxygen 15. All secondary batteries are c)reversible and irreversible a)irreversible b)reversible d)non rechargeable 16. The number of electrons released in oxidation reaction of hydrogen-oxygen fuel cell are a)2 b)3 c)4 d)1 17. The silicon-graphene additive helps reduce corrosion of the positive terminal when charged up to voltages of -----V or more. a)1.35 b)2.35 c)3.35 d)4.35 18.At 200°C, the phosphoric acid polymerises to a)polyphosphoric acid b0polyphosphorus acid c)acrolein d)dacron 19. ----- cells could be considered to be between a traditional lithium-ion battery (with liquid electrolyte) and a completely plastic, solid-state lithium-ion battery a)prototype b)dry c)alkaline d)daniel 20. An example for p type semiconductor is a)Si doped with Ca b)Si doped with Al c)Si doped with Cu d)Si doped with B

PART- B(3 x 2= 6 Marks)

Answer ALL the Questions

21.What is known as electrolessplating?22.Give few examples for anodizing.23.What are reversible cell.Give an example.

PART- C(3 x 8= 24 Marks)

Answer ALL the Questions

24.(a)List out the constituents of paint. Explain the function of each constitute with examples.

(OR)

(b)Explain electroplating by taking an example. Write down the cell reactions involved in electroplating.

25.(a)Write a note on i) heat retardant paints ii) fire retardants paints.

(OR)

(b) Explain the working of fuel cell

26.(a)Explain the working of solar cell.

(OR)

(b)Explain the construction and working of lead acid accumulator

[16CHU503A]

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University) (Established Under Section 3 of UGC Act 1956) COIMBATORE-21 B.Sc. Degree Internal Examination,July 2018 (For the candidates admitted from 2017& onwards) III B.Sc CHEMISTRY INTERNAL EXAM II

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE ANSWER KEY

PART A

1.b)protective coating	ıg
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2.a)cleaning

3.c)hydrogen

4.a)lithium

5.a)paints

6.c)lacquers

7.c)paints

8.c)galvanizing

9.b)metal spraying

10.b)650⁰ C

11.b)chemical

12.a)oxidation

13.a)cell voltage

14.d)hydrocarbon

15.b)reversible

16.a)2

17.d)4.35

18.b)polyphosphorus acid

19.a)prototype

20.d)Si doped with B
PART B

21.Electroless plating is technique in which electrical energy is converted to chemical energy not by passing electrical energy but by using reducing agent.

22. Anodizing is nothing but oxidation.

Examples. Anodizing of aluminium

23. Reversible cell is one which cells and cell reactions can be reversed. Eg., lead acid battery.

PART C

24.a) **Paint** is any liquid, liquefiable, or mastic composition that, after application to a substrate in a thin layer, converts to a solid film. It is most commonly used to protect, color, or provide texture to objects. Paint can be made or purchased in many colors—and in many different types, such as watercolor, synthetic, etc. Paint is typically stored, sold, and applied as a liquid, but most types dry into a solid.

Components

Vehicle

The vehicle is composed of the binder; or, if it is necessary to thin the binder with a diluent like solvent or water, it is the combination of binder and diluent. In this case, once the paint has dried or cured very nearly all of the diluent has evaporated and only the binder is left on the coated surface. Thus, an important quantity in coatings formulation is the "vehicle solids", sometimes called the "resin solids" of the formula. This is the proportion of the wet coating weight that is binder, i.e. the polymer backbone of the film that will remain after drying or curing is complete.

Binder or film former

The binder is the film-forming component of paint. It is the only component that is always present among all the various types of formulations. Many binders are too thick to be applied and must be thinned. The type of thinner, if present, varies with the binder.

The binder imparts properties such as gloss, durability, flexibility, and toughness.

Binders include synthetic or natural resins such as alkyds, acrylics, vinyl-acrylics, vinyl acetate/ethylene (VAE), polyurethanes, polyesters, melamine resins, epoxy, silanes or siloxanes or oils.

Diluent or solvent or thinner

The main purposes of the diluent are to dissolve the polymer and adjust the viscosity of the paint. It is volatile and does not become part of the paint film. It also controls flow and application properties, and in some cases can affect the stability of the paint while in liquid state. Its main function is as the carrier for the non volatile components. To spread heavier oils (for example, linseed) as in oil-based interior house paint, a thinner oil is required. These volatile substances impart their properties temporarily—once the solvent has evaporated, the remaining paint is fixed to the surface.

This component is optional: some paints have no diluent.

Water is the main diluent for water-borne paints, even the co-solvent types.

Solvent-borne, also called oil-based, paints can have various combinations of organic solvents as the diluent, including aliphatics, aromatics, alcohols, ketones and white spirit. Specific examples are organic solvents such as petroleum distillate, esters, glycol ethers, and the like. Sometimes volatile low-molecular weight synthetic resins also serve as diluents.

Pigment and filler

Pigments are granular solids incorporated in the paint to contribute color. Fillers are granular solids incorporate to impart toughness, texture, give the paint special properties, or to reduce the cost of the paint. Alternatively, some paints contain dyes instead of or in combination with pigments.

Pigments can be classified as either natural or synthetic. Natural pigments include various clays, calcium carbonate, mica, silicas, and talcs. Synthetics would include engineered molecules, calcined clays, blanc fixe, precipitated calcium carbonate, and synthetic pyrogenic silicas.

Hiding pigments, in making paint opaque, also protect the substrate from the harmful effects of ultraviolet light. Hiding pigments include titanium dioxide, phthalo blue, red iron oxide, and many others.

Fillers are a special type of pigment that serve to thicken the film, support its structure and increase the volume of the paint. Fillers are usually cheap and inert materials, such as diatomaceous earth, talc, lime, barytes, clay, etc. Floor paints that must resist abrasion may contain fine quartz sand as a filler. Not all paints include fillers. On the other hand, some paints contain large proportions of pigment/filler and binder.

b. **Electroplating** is a process that uses electric current to reduce dissolved metal cations so that they form a thin coherent metal coating on an electrode. The term is also used for electrical oxidation of anions on to a solid substrate, as in the formation of silver chloride on silver wire to make silver/silver-chloride electrodes. Electroplating is primarily used to change the surface properties of an object (such as abrasion and wear resistance, corrosion protection, lubricity, aesthetic qualities), but may also be used to build up

thickness on undersized parts or to form objects by electroforming.

The process used in electroplating is called **electrodeposition**. It is analogous to a concentration cell acting in reverse. The part to be plated is the cathode of the circuit. In one technique, the anode is made of the metal to be plated on the part. Both components are immersed in a solution called an electrolyte containing one or more dissolved metal saltsas well as other ions that permit the flow of electricity. A power supply supplies a direct current to the anode, oxidizing the metal atoms that it comprises and allowing them to dissolve in the solution. At the cathode, the dissolved metal ions in the electrolyte solution are reduced at the interface between the solution and the cathode, such that they "plate out" onto the cathode. The rate at which the anode is dissolved is equal to the rate at which the cathode is plated, vis-à-vis the

current through the circuit. In this manner, the ions in the electrolyte bath are continuously replenished by the anode.

Other electroplating processes may use a nonconsumable anode such as lead or carbon. In these techniques, ions of the metal to be plated must be periodically replenished in the bath as they are drawn out of the solution. The most common form of electroplating is used for creating coins, such as US pennies, which are made of zinc covered in a layer of copper.

he cations associate with the anions in the solution. This cations are reduced at the cathode to deposit in the metallic, zero valence state. For example, for copper plating, in an acid solution, copper is oxidized at the anode to Cu^{2+} by losing two electrons. The Cu^{2+} associates with the anion SO^{2-}

 $_4$ in the solution to form copper(II) sulphate. At the cathode, the Cu²⁺ is reduced to metallic copper by gaining two electrons. The result is the effective transfer of copper from the anode source to a plate covering the cathode.

The plating is most commonly a single metallic element, not an alloy. However, some alloys can be electrodeposited, notably brass and solder.

Many plating baths include cyanides of other metals (such as potassium cyanide) in addition to cyanides of the metal to be deposited. These free cyanides facilitate anode corrosion, help to maintain a constant metal ion level and contribute to conductivity. Additionally, non-metal chemicals such as carbonates and phosphates may be added to increase conductivity.

When plating is not desired on certain areas of the substrate, stop-offs are applied to prevent the bath from coming in contact with the substrate. Typical stop-offs include tape, foil, lacquers, and waxes.

The ability of a plating to cover uniformly is called *throwing power*; the better the throwing power the more uniform the coating.

25.a)(i) heat retardant paints

The coating can be applied to tiles, metal asphalt, walls, concrete & is easy to apply. The coating comes in white colour & can be applied by applying primer coat on the substrate. At times people also call these coatings as Heat Resistant Paints.

Heat resistant coatings are specially prepared to withstand high heat temperatures for prolonged period of time. The presence of silicone resins increase heat resistance of paints as result of which the paint will not degrade or tarnish quickly as compared to the conventional paints or coatings. The heat resistant coatings are not the same as fire retardant paints. The latter is prepared to tolerate fire damage. Heat resistant coatings cannot avert combustible materials like wood from blazing.

Heat resistant coatings are not designed to extinguish fire. The coatings only reduce chances of fire, and are functional and effective to control fire & reduce flammability of fuels by decelerating the combustion power for a limited time frame only. The fact remains, no element is completely incombustible. Heat resistant coatings are in-tumescent and swell up and increase in volume when subjected to high temperatures. The swelled up paint produces a shielding substance named 'char' which discourages heat conduction. This lends sufficient time for fire-

fighters to take complete control or the area under fire. Heat resistant coatings come with fire retardant ratings showing the critical fire resistance sustainability.

(ii)Fire retardant paints

The fire-retardant paint helps that fire does not spread in case of fire in a building. Therefore, it is **one of the most efficient measures to prevent fire spreading rapidly**, as it contributes flame and smoke not to spread. Fire-retardant paint is essential especially when it comes to residential buildings, since containing fire allows people inside the building to have more time to leave it.

It is important to differentiate fire retardant paint from intumescent paint. The first one avoids the spread of the flame, while the second one reacts when there is an increase in temperature in the building by swelling and creating **a thick layer of foam that insulates the elements that cover it**, containing the fire and preventing it from damaging the structure of the building.

The main characteristics of fire-retardant paint are as follows:

- It reduces flammability and combustion of building materials it coats.
- Fire-retardant paint does not prevent fires from occurring, but **delays the expansion of fires.**
- There are different types and, depending on each type, it can be applied on metal, wood, lacquered surfaces, etc.
- It is suitable for **both indoor and outdoor surfaces**.
- It can be **applied with spray gun, brush or roller**.

b) A **fuel cell** is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or another oxidizing agent. Fuel cells are different from batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy comes from chemicals already present in the battery. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

The first fuel cells were invented in 1838. The first commercial use of fuel cells came more than a century later in NASA space programmes to generate power for satellite sand space capsules. Since then, fuel cells have been used in many other applications. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are also used to power fuel cell vehicles, including forklifts, automobiles, buses, boats, motorcycles and submarines.

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (protons) to move between the two sides of the fuel cell. At the anode a catalyst causes the fuel to undergo oxidation reactions that generate protons (positively charged hydrogen ions) and electrons. The protons flow from the anode to the cathode through the electrolyte after the reaction. At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, another catalyst causes hydrogen ions, electrons, and oxygen to react, forming water. Fuel cells are classified by the type of electrolyte they use and by the difference in startup time ranging from 1 second for proton exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC). A related technology is flow batteries, in which the fuel can be regenerated by recharging. Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are "stacked", or placed in series, to create sufficient voltage to meet an application's requirements.^[2] In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40–60%; however, if waste heat is captured in a cogeneration scheme, efficiencies up to 85% can be obtained.

The fuel cell market is growing, and in 2013 Pike Research estimated that the stationary fuel cell market will reach 50 GW by 2020.

Types of fuel cells; design

Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three adjacent segments: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electric current is created, which can be used to power electrical devices, normally referred to as the load.

At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide.



Design features in a fuel cell include:

- The electrolyte substance, which usually defines the *type* of fuel cell, and can be made from a number of substances like potassium hydroxide, salt carbonates, and phosphoric acid.
- The anode catalyst, usually fine platinum powder, breaks down the fuel into electrons and ions.
- The cathode catalyst, often nickel, converts ions into waste chemicals, with water being the most common type of waste.
- Gas diffusion layers that are designed to resist oxidization.

A typical fuel cell produces a voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors:

- Activation loss
- Ohmic loss (voltage drop due to resistance of the cell components and interconnections)
- Mass transport loss (depletion of reactants at catalyst sites under high loads, causing rapid loss of voltage).

To deliver the desired amount of energy, the fuel cells can be combined in series to yield higher voltage, and in parallel to allow a higher current to be supplied. Such a design is called a *fuel cell stack*. The cell surface area can also be increased, to allow higher current from each cell. Within the stack, reactant gases must be distributed uniformly over each of the cells to maximize the power output.

26.a) A **solar cell**, or **photovoltaic cell**, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is

a physical and chemicalphenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices can be combined to form modules, otherwise known as solar panels. In basic terms a single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts.

Solar cells are described as being photovoltaic, irrespective of whether the source is sunlight or an artificial light. They are used as a photodetector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating either electron-hole pairs or excitons.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

In contrast, a solar thermal collector supplies heat by absorbing sunlight, for the purpose of either direct heating or indirect electrical power generation from heat. A "photoelectrolytic cell" (photoelectrochemical cell), on the other hand, refers either to a type of photovoltaic cell (like that developed by Edmond Becquerel and modern dye-sensitized solar cells), or to a device that splits water directly into hydrogen and oxygen using only solar illumination.

The solar cell works in several steps:

- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
- Electrons are excited from their current molecular/atomic orbital. Once excited an electron can either dissipate the energy as heat and return to its orbital or travel through the cell until it reaches an electrode. Current flows through the material to cancel the potential and this electricity is captured. The chemical bonds of the material are vital for this process to work, and usually silicon is used in two layers, one layer being doped with boron, the other phosphorus. These layers have different chemical electric charges and subsequently both drive and direct the current of electrons.
- An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.
- An inverter can convert the power to alternating current (AC).

The most commonly known solar cell is configured as a large-area p–n junction made from silicon. Other possible solar cell types are organic solar cells, dye sensitized solar cells, perovskite solar cells, quantum dot solar cells etc. The illuminated side of a solar cell generally have a transparent conducting film for allowing light to enter into active material and to collect the generated charge carriers. Typically, films with high transmittance and high electrical conductance such as indium tin oxide, conducting polymers or conducting nanowire networks are used for the purpose.

b. Lead acid battery

The **lead–acid battery** was invented in 1859 by French physicist Gaston Planté and is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by automobile starter motors.

As they are inexpensive compared to newer technologies, lead-acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Large-format lead-acid designs are widely used for storage in backup power supplies in cell phone towers, high-availability settings like hospitals, and stand-alone power systems. For these roles, modified versions of the standard cell may be used to improve storage times and reduce maintenance requirements. *Gel-cells* and *absorbed glass-mat* batteries are common in these roles, collectively known as VRLA (valve-regulated lead-acid) batteries.

In 1999 lead–acid battery sales accounted for 40–45% of the value from batteries sold worldwide excluding China and Russia, and a manufacturing market value of about \$15 billion.

Discharge



Fully discharged: two identical lead sulfate plates

In the discharged state both the positive and negative plates become lead(II) sulfate (PbSO 4), and the electrolyte loses much of its dissolved sulfuric acid and becomes primarily water. The discharge process is driven by the conduction of electrons from the negative plate back into the cell at the positive plate in the external circuit.

Negative plate reaction

 $Pb(s) + HSO_{4}^{-}(aq) \rightarrow PbSO_{4}(s) + H^{+}(aq) + 2e^{-}$ Release of two conducting electrons gives lead electrode a net negative charge

As electrons accumulate they create an electric field which attracts hydrogen ions and repels sulfate ions, leading to a double-layer near the surface. The hydrogen ions screen the charged electrode from the solution which limits further reactions unless charge is allowed to flow out of electrode.

Positive plate reaction

$$PbO_{2}(s) + HSO_{4}(aq) + 3H^{+}(aq) + 2e^{-} \rightarrow PbSO_{4}(s) + 2H_{2}O(l)$$

The total reaction can be written as

 $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

The sum of the molecular masses of the reactants is 642.6 g/mol, so theoretically a cell can produce two faradays of charge (192,971 coulombs) from 642.6 g of reactants, or 83.4 ampere-hours per kilogram (or 13.9 ampere-hours per kilogram for a 12-volt battery). For a 2 volts cell, this comes to 167 watt-hours per kilogram of reactants, but a lead–acid cell in practice gives only 30–40 watt-hours per kilogram of battery, due to the mass of the water and other constituent parts. .

Charging



Fully recharged: Lead negative plate, Lead dioxide positive plate and sulfuric acid electrolyte

In the fully charged state, the negative plate consists of lead, and the positive plate lead dioxide, with the electrolyte of concentrated sulfuric acid.

Overcharging with high charging voltages generates oxygen and hydrogen gas by electrolysis of water, which is lost to the cell. The design of some types of lead-acid battery allow the electrolyte level to be inspected and topped up with any water that has been lost.

Due to the freezing-point depression of the electrolyte, as the battery discharges and the concentration of sulfuric acid decreases, the electrolyte is more likely to freeze during winter weather when discharged.

Ion motion

During discharge, H⁺

produced at the negative plates moves into the electrolyte solution and then is consumed into the positive plates, while HSO⁻

⁴ is consumed at both plates. The reverse occurs during charge. This motion can be by electrically driven proton flow or Grotthuss mechanism, or by diffusion through the medium, or by flow of a liquid electrolyte medium. Since the density is greater when the sulfuric acid concentration is higher, the liquid will tend to circulate by convection. Therefore, a liquidmedium cell tends to rapidly discharge and rapidly charge more efficiently than an otherwise similar gel cell.

KARPAGAM ACADEMY OF HIGHER EDUCATION

COIMBATORE-21 (For the candidates admitted from 2016& onwards) B.Sc. Degree Internal Examination, October 2018 CHEMISTRY INTERNAL TEST-III

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE Time: 2 hours Maximum: 50 marks

PART- A (20 x 1= 20 Marks)

Answer ALL the Questions

1. A substance that increases the reaction rate without itself getting used up is known as a

a)Buffer b)Catalyst c)Inhibitor d)Activated Complex

2.In a reaction, a positive catalyst will decrease the value of

a) ΔH b)Activation energy c) ΔS d)rate constant

3.In the hydrogenation of vegetable oils, the catalyst commonly used is

a)Fe₂O₃ b)Activated charcoal c)ZnO d)Ni

4. The catalyst and the reactant are in the same phase which is called

a)Heterogenous b)Activation energy c)Homogeneous d)rate constant

5. Which of the following is an example of autocatalysis

a)Decomposition of KCIO₃ + MnO₂ mixture b)The decomposition of nitroglycerine

c)Breakdown of 6C1₄ d)Hydrogenation of vegetable oil using Ni catalyst

6.An auto catalyst is

a)Catalyst for catalyst b)one which starts a reaction c)one of the products of the reaction which

acts as a catalyst d)Which retards a chemical reaction

7.Catalytic poison acts by

a)Chemically combining with catalyst b)Coagulating the catalyst

c)Getting adsorbed on the active centres on the surfaces d)Chemical combination with anyone of the reactants

8.In temporary poisoning, catalytic poison acts by

a)Coagulating the catalyst b)Chemical combination with anyone of the reactants c)Chemically combining with catalyst d)Getting adsorbed on the active centres on the catalyst 9.A substance like CO,As₂O₃,HCN etc, which paralyses the catalytic activity of a catalyst is called a)A negative catalyst b))Auto catalyst c) Promotor d)Poison 10. The efficiency of an enzyme in catalysing a reaction is due to its capacity a)to form a strong enzyme substrate moleculeb)to change the shape of the substrate molecule c)to lower the activation energy of the rection d)to decrease the bond energy of all substrate molecules 11.Explosives are mainly used for c)agricultural purposes a)defence purposes b)medical purposes d)industrial purposes 12. First to use explosives in the war in 1346 were a)Americans b)British c)Indians d)Russians 13.GTN were known by a)1856 b)1836 c)1846 d)1826 14.It was Alfred Nobel, a swedish chemist, who demonstrated that GTN, when absorbed in ----------- could be handled and transported safely d)alum a)gypsum b)kieselguhr c)mica 15.Gun powder is a mixture of potassium nitrate, sand and a)charcoal b)peat c)lignite d)dolomite 16.GTN was first prepared by an b)Italian a)Indian c)American d)British 17.GTN is nothing but a)Glyceryl trinitrate b)Glycerol trinitrate c)Glyceryl trinitrite d)Glyceryl tetranitrate 18.TNT is a a)solid explosive b)liquid explosive c)gas explosive d)solid and liquid explosive 19. Primary and secondary high explosives are generally referred to as a)low explosives b)high explosives c)mixed explosives d)mild explosives 20. For any compound to serve as an explosive, how many chemical bond it should have? a)1 b)2 c)3 d)4

PART- B(3 x 2= 6 Marks)

Answer ALL the Questions

21.Mention few applications of zeolites.

22. What is homogenous catalysis?

23.What are explosives?

PART- C(3 x 8= 24 Marks)

Answer ALL the Questions

24.a.Explain the catalytic steps of heterogenous catalysis and mention few industrial applications.

(**OR**)

b. Compare deactivation and regeneration of catalysts.

25.a.Write down the general principles and properties of catalysts.

(**OR**)

b. Explain the manufacture and explosive properties of cyclonite

26.a. What are propellants? How the rocket propellants are introduced? Mention few examples.

(OR)

b.Write down the preparation of following explosives (i) PETN (ii) lead azide

[16CHU503A]

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University) (Established Under Section 3 of UGC Act 1956) COIMBATORE-21 B.Sc. Degree Internal Examination,July 2018 (For the candidates admitted from 2017& onwards) III B.Sc CHEMISTRY INTERNAL EXAM III

INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE ANSWER KEY

PART A

1.b)catalyst

2.b)activation energy

3.d)Ni

4.c)homogeneous

5.b)decomposition of nitroglycerine

6.c)one of the products of the reaction which acts as a catalyst

7.c)getting adsorbed on the active centres on the surfaces

8.d)getting adsorbed on the active centres on the catalyst

9.d)poison

10.c)to lower the activation energy of the reaction

11.a)defence purposes

12.b)British

13.c)1846

14.b)kieselguhr

15.a)charcoal

16.b)Italian

17.b)Glycerol trinitrate

18.a)Solid explosive

19.b)high explosives

20.a)1

Department of Chemistry, KAHE

PART B

21.Zeolites can be used to purify water. Zeolites are used in cracking of petroleum

22. Homogeneous catalysis are which reactants and catalyst are in same phase.

23. An **explosive material**, also called an **explosive**, is a reactive substance that contains a great amount of potential energy that can produce an explosion if released suddenly, usually accompanied by the production of light, heat, sound, and pressure.

PART C

24.a) In chemistry, **heterogeneous catalysis** refers to the form of catalysis where the phase of the catalyst differs from that of the reactants. Phase here refers not only to solid, liquid, vs gas, but also immiscible liquids, e.g. oil and water. The great majority of practical heterogeneous catalysts are solids and the great majority of reactants are gases or liquids.^[1]Heterogeneous catalysis is of paramount importance in many areas of the chemical and energy industries. Heterogeneous catalysis has attracted Nobel prizes for Fritz Haber in 1918, Carl Bosch in 1931, Irving Langmuir in 1932, and Gerhard Ertl in 2007.

Examples

• Reduction of nitriles for instance in a synthesis of phenethylamine with Raney nickel and ammonia:



The cracking, isomerisation and re-forming of hydrocarbons to form appropriate and useful blends of petrol.

Catalytic converters are often used in automobiles. Three main reactions are catalysed by catalytic converters.

The oxidation of carbon monoxide to carbon dioxide: $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ The reduction of nitrogen monoxide back to nitrogen: $2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$ The oxidation of hydrocarbons to water and carbon dioxide: $2 C_6H_6 + 15 O_2 \rightarrow 12 CO_2 + 6 H_2O$ This process can occur with any of the hydrocarbons, but most commonly is performed with petrol or diesel.

Asymmetric heterogeneous catalysis affords enantiomerically enriched compounds using chiral heterogeneous catalysts.

The vast majority of heterogeneous catalysts are based on metals or metal oxides, however, some chemical reactions can be catalyzed by carbon-based materials, e.g., oxidative dehydrogenations^[13] or selective oxidations.^[14] Ethylbenzene + 1/2 O₂ \rightarrow Styrene + H₂O Acrolein + 1/2 O₂ \rightarrow Acrylic acid

Gas streams with strongly nonequilibrium gas phase concentrations can be achieved via epicatalysis

b.Deactivation of catalyst

Poisoning contaminants in the reactor feed

• Fouling thermal degradation (sintering, evaporation, volatilization), leaching by the reaction mixture

• Coking (formation of deposits) coverage of the surface by coke or carbon from undesired reactions of hydrocarbon reactants, intermediates, and products

Mechanical damage

Regeneration of catalysts

The catalyst regeneration step involves both chemical reactions and transport of reactants and products. Some studies (e.g. Müller et al. (2010)) show that the diffusion resistance of oxygen into the pores strongly influences the actual speed of coke combustion. In addition, the concentration profile of the coke in a catalyst particle during the combustion may be non-uniform (Tang et al. (2004)). This leads to the use of a two-phase model, where the mass balance is considered in the catalyst and in the surrounding gas phase. The process model developed is also based on the following additional assumptions: (i) the ideal gas law can be used, (ii) the internal temperature gradients in the catalyst particles are neglected owing to high thermal conductivity of the catalyst material, (iii) the heat and mass transfer resistances between solid and gas are neglected.

Based on the above assumptions, and taking into account the possible presence of intraparticle diffusion resistance, and as the radial temperature gradient in the reactor is not negligible (according to the Mears criterion (Mears, 1971)), a two-dimensional heterogeneous model was thus considered. The model equations include mass balances on both solid and gas phases for

each component, heat balance on a pseudo-homogeneous phase and momentum balance on gas

phase. As the pore diameters are small, the effective mass diffusion coefficient in the catalyst is given as:

(3)De=eptp11Dk+1Dm

where $\varepsilon_p = 0.571$ and $\tau_p = 2.5$ are respectively the catalyst porosity and tortuosity, $D_m = 1.114 \times 10^{-9} T^{1.726}$ is the molecular diffusion and Knudsen diffusivity D_k is given by the relation: (4)Dk=13dpore8RT π M

The mass balance of component *i* in the solid phase (noted with subscript *s*) is derived as: (5)Ns,Tep $\partial xs,i\partial rp+cT,sep\partial xs,i\partial t=ep1rp2\partial \partial rp(DecT,srp2\partial xs,i\partial rp)+ps\sum j=1NR[Rj(vij-xs,i\sum i=1NCvij)]$

where r_p is the radial coordinate in pellet, ρ_s the catalyst density, c_T the overall gas

concentration, N_T is the total mole flux, R_j the rate of reaction j, v_{ij} the stoichiometric coefficient

of component *i* in reaction *j*, and x_i the component *i* mole fraction.

In the reactor, the mass balance per component is:

 $(6)ucT\partial xi\partial z + vcT\partial xi\partial r + cT\varepsilon\partial xi\partial t = \nabla (DecT\nabla xi) + \varepsilon p(1-\varepsilon)av (Ni|rp=Rp-xiNT|rp=Rp)$

where r and z are the radial and axial coordinates, u the gas superficial velocity, ε the porous bed

void fraction, a_v the specific area of catalyst pellet and N_i the mole flux of component *i*. 25.a) General principles and properties of catalysts

Catalysis is the increase in the rate of a chemical reaction due to the participation of an additional substance called a **catalyst**, which is not consumed in the catalyzed reaction and can continue to act repeatedly. Often only tiny amounts of catalyst are required in principle.

In general, the reactions occur faster with a catalyst because they require less activation energy. In catalyzed mechanisms, the catalyst usually reacts to form a temporary intermediate which then regenerates the original catalyst in a cyclic process.

Catalysts may be classified as either homogeneous or heterogeneous. A homogeneous catalyst is one whose molecules are dispersed in the same phase (usually gaseous or liquid) as the reactant molecules. A heterogeneous catalyst is one whose molecules are not in the same phase as the reactants, which are typically gases or liquids that are adsorbed onto the surface of the solid catalyst. Enzymes and other biocatalysts are often considered as a third category.

Technical perspective

In the presence of a catalyst, less free energy is required to reach the transition state, but the total free energy from reactants to products does not change. A catalyst may participate in multiple chemical transformations. The effect of a catalyst may vary due to the presence of other substances known as inhibitors or poisons (which reduce the catalytic activity) or promoters (which increase the activity and also affect the temperature of the reaction).

Catalyzed reactions have a lower activation energy (rate-limiting free energy of activation) than the corresponding uncatalyzed reaction, resulting in a higher reaction rate at the same temperature and for the same reactant concentrations. However, the detailed mechanics of catalysis is complex. Catalysts may affect the reaction environment favorably(like heat), or bind to the reagents to polarize bonds, e.g. acid catalysts for reactions of carbonyl compounds, or form specific intermediates that are not produced naturally, such as osmate esters in osmium tetroxide-catalyzed dihydroxylation of alkenes, or cause dissociation of reagents to reactive forms, such as chemisorbed hydrogen in catalytic hydrogenation.

Kinetically, catalytic reactions are typical chemical reactions; i.e. the reaction rate depends on the frequency of contact of the reactants in the rate-determining step. Usually, the catalyst participates in this slowest step, and rates are limited by amount of catalyst and its "activity". In heterogeneous catalysis, the diffusion of reagents to the surface and diffusion of products from the surface can be rate determining. A nanomaterial-based catalyst is an example of a heterogeneous catalyst. Analogous events associated with substrate binding and product dissociation apply to homogeneous catalysts.

Although catalysts are not consumed by the reaction itself, they may be inhibited, deactivated, or destroyed by secondary processes. In heterogeneous catalysis, typical secondary processes include coking where the catalyst becomes covered by polymeric side products. Additionally, heterogeneous catalysts can dissolve into the solution in a solid–liquid system or sublimate in a solid–gas system.

b. Cyclonite

RDX is the organic compound with the formula $(O_2NNCH_2)_3$. It is a white solid without smell or taste, widely used as an explosive. Chemically, it is classified as a nitramide, chemically similar to HMX. A more energetic explosive than TNT, it was used widely in World War II.

It is often used in mixtures with other explosives

and plasticizers or phlegmatizers (desensitizers). RDX is stable in storage and is considered one of the most energetic and brisant of the military high explosives

26.a. **Rocket propellant** is a material used either directly by a rocket as the reaction mass (propulsive mass) that is ejected, typically with very high speed, from a rocket engine to produce thrust, and thus provide spacecraft propulsion, or indirectly to produce the reaction mass in a chemical reaction. Each rocket type requires a different kind of propellant: chemical rockets require propellants capable of undergoing exothermic chemical reactions, which provide the energy to accelerate the resulting gases through the nozzle. Thermal rockets instead use inert propellants of low molecular weight that are chemically compatible with the heating mechanism at high temperatures, while cold gas thrusters use pressurized, easily stored inert gases. Electric propulsion requires propellants that are easily ionized or made into plasma, and in the extreme case of nuclear pulse propulsion the propellant consists of many small, non-weapon nuclear explosives of which the resulting shock wave propels the spacecraft away from the explosive, thereby creating propulsion. One such spacecraft was designed (but never built), being dubbed "Project Orion" (not to be confused with the NASA Orion spacecraft).

Solid rocket propellant was first developed during the 13th century under the Chinese Song dynasty, at a time when bows, arrows, and catapult-based projectile launchers were state-of-theart military technology in medieval Europe.^[1] The Song Chinese first used solid propellant (gunpowder fuel) in 1232 during the military siege of Kaifeng.

Chemical propellants

There are four main types of chemical rocket propellants: solid, storable liquid, cryogenic liquid, and a liquid monopropellant. Hybrid solid/liquid bi-propellant rocket engines are starting to see limited use as well.

Solid propellants

Description

Solid propellants are either "composites" composed mostly of large, distinct macroscopic particles or single-, double-, or triple-bases (depending on the number of primary ingredients), which are homogeneous mixtures of one or more primary ingredients. Composites typically consist of a mixture of granules of solid oxidizer (examples: ammonium nitrate, ammonium dinitramide, ammonium perchlorate, potassium nitrate) in a polymer binder (binding agent) with flakes or powders of energetic compounds (examples: RDX, HMX), metallic additives (examples: aluminium, beryllium), plasticizers, stabilizers, and/or burn rate modifiers (iron oxide, copper oxide). Single-, double-, or triple-bases are mixtures of the fuel, oxidizer, binders, and plasticizers that are macroscopically indistinguishable and often blended as liquids and cured in a single batch. Often, the ingredients of a double-base propellant have multiple roles. For example, RDX is both a fuel and oxidizer while nitrocellulose is a fuel, oxidizer, and plasticizer. Further complicating categorization, there are many propellants that contain elements of doublebase and composite propellants, which often contain some amount of energetic additives homogeneously mixed into the binder. In the case of gunpowder (a pressed composite without a polymeric binder) the fuel is charcoal, the oxidizer is potassium nitrate, and sulphur serves as a catalyst. (Note: sulphur is not a true catalyst in gunpowder as it is consumed to a great extent into a variety of reaction products such as K₂S.) During the 1950s and 60s researchers in the United States developed ammonium perchlorate composite propellant (APCP). This mixture is typically 69-70% finely ground ammonium perchlorate(an oxidizer), combined with 16-20% fine aluminium powder (a fuel), held together in a base of 11-14% polybutadiene acrylonitrile (PBAN) or Hydroxyl-terminated polybutadiene (polybutadiene rubber fuel). The mixture is formed as a thickened liquid and then cast into the correct shape and cured into a firm but flexible load-bearing solid. Historically the tally of APCP solid propellants is relatively small. The military, however, uses a wide variety of different types of solid propellants some of which exceed the performance of APCP. A comparison of the highest specific impulses achieved with the various solid and liquid propellant combinations used in current launch vehicles is given in the article on solid-fuel rockets

b.(i) Production is by the reaction of pentaerythritol with concentrated nitric acid to form a precipitate which can be recrystallized from acetone to give processable crystals.



Variations of a method first published in a US Patent 2,370,437 by Acken and Vyverberg (1945 to Du Pont) forms the basis of all current commercial production.

PETN is manufactured by numerous manufacturers as a powder, or together with nitrocellulose and plasticizer as thin plasticized sheets (e.g. Primasheet 1000 or Detasheet). PETN residues are easily detectable in hair of people handling it. The highest residue retention is on black hair; some residues remain even after washing.

(ii) Lead azide $(Pb(N_3)_2)$ is an inorganic compound. More so than other azides, $Pb(N_3)_2$ is explosive. It is used in detonators to initiate secondary explosives. In a commercially usable form, it is a white to buff powder.

Preparation and handling

Lead azide is prepared by metathesis between sodium azide and lead nitrate. Dextrin can be added to the solution to stabilize the precipitated product. The solid is not very hygroscopic, and water does not reduce its impact sensitivity. It is normally shipped in a dextrinated solution that lowers its sensitivity. When protected from humidity, it is completely stable in storage. An alternative method invo