Applied Chemistry Modules

3. Module-3: Engineering Materials, Nanochemistry & Fuels

Module-3

Engineering Materials, Nanochemistry & Fuels

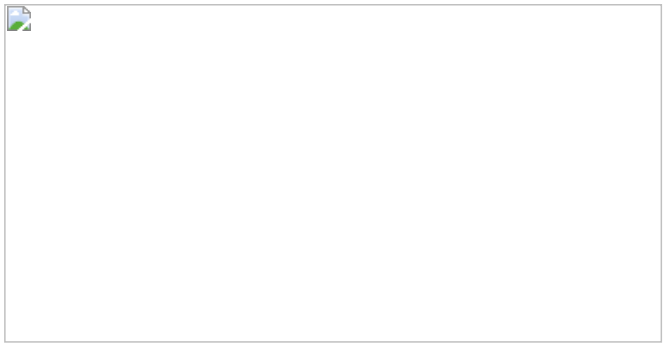
1. Alloys

An alloy is a homogenous solid mixture of two or more elements in which at least one is a metal.

Alloys containing mercury as one of the constituents are called amalgams.

Alloys with iron as one of the major components are called ferrous alloys

Alloys which do not contain iron are non-ferrous alloys.



Purpose of making alloys

- To increase the corrosion resistance of metals (Steel has more resistance to corrosion than iron)
- To increase the hardness of the metal (presence of carbon can make iron harder)
- To lower the melting point of metal (Solder melts at $180^{o}C$, which is lower than the melting point of Sn & Pb)
- To modify the chemical activity of the metal (Stainless steel can resist the attach of chemicals better than iron)
- To modify colour (Brass, an alloy of Cu(red) & Zn(white), has an attractive yellow colour
- To provide better castability (Type metal [Pb+Sn+Sb] is used for casting printing types)

2. Glasses

Glass is an amorphous, hard, brittle transparent material obtained by fusing a mixture of sodium carbonate, calcium carbonate and silica.

Types of glasses

Soda glass or soft glass

It is a mixture of sodium and calcium silicates. The raw materials required for the production are sand, lime stone and sodium carbonate. Soda glass is used in making window glass, bottles, bulbs, jars and dishes.

Borosilicate glass or Pyrex glass

It is a mixture of sodium aluminium borosilicate. It can withstand high temperature. It is used for making laboratory glass wares, kitchen wares etc

Safety glass

It is a type of glass which when breaks does not allow its broken pieces to fly apart. It is obtained by placing a thin layer of vinyl plastics with an adhesive between two sheets of glass. It is commonly used in automobiles.

Insulating glass

It is a transparent unit of glass, prepared by two or more plates of glass separated by 6 to 13mm gap filled with dehydrated air. This air gap provides high insulation against heat. If such a glass is used for separating rooms, the apartment will remain cool during summer and warm during winter.

3. Refractories

Refractories are heat resistant materials that are used for giving linings for high temperature furnaces, reactors etc.

Ex: Silicon carbide (Carborundum), Al_2O_3, Mullite ($3Al_2O_3$ $2SiO_2$)

The capacity of a material to withstand the heat without appreciable deformation or softening under

particular operating conditions is called refractoriness.

Properties of Refractories

- Infusible and should not peel, crack or bend at the operating temperature
- Must withstand thermal shock
- Resist size change
- Resistance to spalling
- Low porosity
- Resist the abrasive action of gases, molten metal's etc

4. Polymers

Polymers are formed by the joining of repeating structural units on a large scale.

The repeating structural units are known as monomers. Monomers are linked to each other by covalent bonds.

The process of formation of polymers from monomers is called polymerisation.

Homo polymers & Co-polymers

Polymers formed from only one type of monomer are called homopolymers.

Ex: Polythene, PVC, Natural rubber etc

Polymers formed from more than one type of monomers are called homopolymers.

Ex: Buna-S, Buna-N, Bakelite etc

Polymer	**Monomer**	**Uses**
Polyethylene (PE)	Ethylene (Ethene)	Sheets, carry bags, table cloths, bottles, cables etc
Polyvinylchloride (PVC)	Vinylchloride	Pipes, bottles, bank cards, gloves, jackets, wire insulation etc
Buna-S (SBR)	Styrene + Butadiene	Tyres, hoses, washers etc
Buna-N (NBR)	Acrylonitrile + Butadiene	Solvent pipes, conveyer belts, solvent tanks etc
Nylon-6,6	Hexamethylene diamine & Adipic acid	Carpets, fabric, fish nets, ropes etc
Bakelite	Phenol & Formaldehyde	Handles of kitchen wires, telephones, electric switches, fancy items, plug tops etc
Natural rubber	Isoprene	Tyres, rubber bands, gloves etc

Addition polymers & Condensation polymers

The **addition polymers** are formed by the repeated addition of monomer molecules possessing double or triple bonds. No biproducts are eliminated during the formation of addition polymers Ex: Polyethylene, Polypropylene, PVC etc

The **condensation polymers** are formed by repeated condensation reaction between two different bi-functional or tri-functional monomeric units. In these polymerization reactions, the elimination of small molecules such as water, alcohol, hydrogen chloride, etc. take place. The examples are terylene (dacron), nylon 6, 6, etc.

Thermoplastics & Thermosetting plastics

Thermoplastics	**Thermosetting plastics**
Can be recycled	Cannot be recycled

Formed by addition polymerization	Formed by condensation polymerization
Linear polymers	Cross linked polymers
Soften on heating	Becomes hard on heating
Ex:PE,PP,PVC,PS etc	Ex:Bakelite, Melmac etc

Natural Rubber

The monomer of natural rubber is isoprene.

Vulcanization

Heating of natural rubber with sulphur is called vulcanization. Rubber obtained thus is called vulcanized rubber. Vulcanization introduces sulphur cross links between molecular chains of rubber.

Advantages of vulcanization

1. Vulcanization improves tensile strength, abrasion resistance etc. of rubber
2. It improves the thermal resistance of rubber
3. It increases the resistance of rube to oxidation and swelling
4. It enhances the elasticity of rubber

5. Nanochemistry

Nano= one billionth

One nanometer(1 nm) = one billionth of a meter OR 10^{-9} m

Nanomaterials:- Nanomaterials are materials which have particle size in the range 1nm-100nm.

Ex: Carbon nano tubes (CNTs), Fullerenes, Carbon black, Nano gold etc

Nanochemistry is a branch of science which deals with the synthesis and characterization of nanomaterials.

Nanotechnology:- The branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules.

Classification of nanomaterials

Nanomaterials can be classified based on the number of dimensions as – zero dimensional (0D), one-dimensional (1D) and two-dimensional (2D).

(i) Zero-dimensional nanomaterials: Here, all dimensions (x, y, z) are at nanoscale, i.e., no dimensions are greater than 100 nm. It includes nanospheres and nanoclusters.

(ii) One-dimensional nanomaterials: Here, two dimensions (x, y) are at nanoscale and the other is outside the nanoscale. This leads to needle shaped nanomaterials. It includes nanofibres, nanotubes, nanorods, and nanowires.

(iii) Two-dimensional nanomaterials: Here, one dimension (x) is at nanoscale and the other two are outside the nanoscale. The 2D nanomaterials exhibit plate like shapes. It includes nanofilms, nanolayers and nanocoatings with nanometre thickness.

Applications of nanomaterials

- They act as better catalysts
- Tumors can be detected and located with incredible accuracy
- To destroy tumor (using nano shells)
- For DNA mapping
- Nanotechnology will enable the delivery of right amount of medicines to the exact spot of the body (Controlled drug delivery)
- To create biocompatible joints and stents with long life.

Carbon nanotube(CNT)

CNTs are nanomaterials which have particles in the form of cylindrical tubes with diameter less than 100nm. CNTs are formed by the folding of graphene layers.

Types of CNT

- Single walled carbon nanotube (SWNT)
- Multi walled carbon nanotube (MWNT)


Graphene


Graphene is a single layer (monolayer) of carbon atoms, tightly bound in a hexagonal honeycomb lattice.

Layers of graphene stacked on top of each other form graphite, with an interplanar spacing of 0.335 nanometers.

Properties of graphene:-

- High thermal conductivity
- High electrical conductivity
- High elasticity and flexibility
- High hardness
- High resistance. Graphene is approximately 200 times stronger than steel, similar to diamond resistance, but much lighter.
- Able to generate electricity by exposure to sunlight
- Transparent material
- Antibacterial effect. Bacteria are not able to grow in it.

Uses of graphene:-

- Sensors
- Battery electrodes
- Structural composites
- Anti-corrosion coatings
- Efficient solar panels

Fullerenes

Fullerene is one of the allotropic forms of the carbon. In fullerenes, the carbon atoms are arranged in a series and form a cage like structure. C_{60} is the most common fullerene.

Uses of fullerenes:-

- Biological antioxidants.
- For controlled drug delivery
- Catalysts
- Polymer additives
- In portable power devices