Applied Chemistry – II (MU)

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Semester II – Common to All Branches

(Book Code – etME173)

Corrosion

Syllabus Topic : Introduction

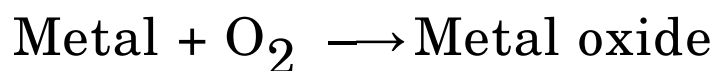**Q.**   Define corrosion. *(May 2016)*

Ans. :

Corrosion

    "Any process causing deterioration or destruction of any material is known as *corrosion*". *Metals* being *highly reactive,* are greatly affected by action of the factors responsible for corrosion.

Q.   Explain how rate of corrosion of the following metals is influenced by atmospheric oxygen. (i) Molybdenum (ii) Tin. *(May 2016)*
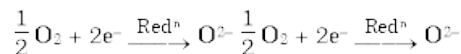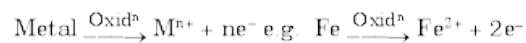
Ans.:

- This type of corrosion occurs due to attack of atmospheric oxygen on metal surface either at low or high temperatures, forming metal oxide as

$$\text{Metal} + O_2 \longrightarrow \text{Metal oxide}$$

- Normally, more active metals get corroded faster than less active metals. For example, alkali metals and alkaline earth metals get oxidized even at low temperatures as compared to other metals which are less active.

Mechanism of chemical corrosion due to oxidation

$$Metal \xrightarrow{Oxid^n} M^{n+} + ne^- \quad e.g. \quad Fe \xrightarrow{Oxid^n} Fe^{2+} + 2e^-$$

$$\frac{1}{2}O_2 + 2e^- \xrightarrow{Red^n} O^{2-} \quad \frac{1}{2}O_2 + 2e^- \xrightarrow{Red^n} O^{2-}$$

$$M^{n+} + O^{2-} \longrightarrow M_2O_n \qquad Fe^{2+} + O^{2-} \longrightarrow FeO$$

- The extent of the corrosion, depends upon the type of the oxide film formed by metals. The oxide films formed are classified into three categories.

a) Stable oxide film
  i) Porous – e.g. Iron Oxide
  ii) Non-porous – e.g. Oxides of A1, Ni, Cr etc.
b) Unstable oxide film – e.g. Oxides of noble metals
c) Volatile oxide film – e.g. Oxides of molybdenum

Table 1.2.1 : Role of oxide film

Sr. No.	Type of oxide film	Example	Role/ Effect
(a)	Stable oxide film (i) porous oxide film.	Iron oxide FeO / Fe_2O_3 / Fe_3O_4	Being porous film, the corrosion of under lying metal continues. The rate of corrosion slows down.
	(ii) Non-porous	Al_2O_3 Al-oxide	Being non-porous film, the corrosion of underlying metal stops till the film is intact.
(b)	Unstable oxide film	Oxides of noble metals.	Being unstable film, the oxide decomposes and metal surface continues to be exposed. Hence, corrosion of underlying metal continues.
(c)	Volatile oxide film	Oxides of some metals like molybdenum.	Being Volatile oxide, it is lost to environment, leaving fresh metal exposed. Rate of corrosion very high, till entire metal lost.

Syllabus Topic : Types of Corrosion

Q. Why silver, gold and platinum do not undergo oxidation corrosion ? *(May 2013)*

Ans. :

b) **Unstable oxide films** are those which get decomposed on the metal surfaces forming back the metal and oxygen.

Metal + Oxygen → Metal oxide → Metal + Oxygen
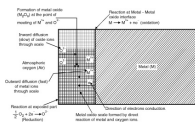
Fig. 1.2.3 : Schematic representation of oxidation mechanism of metals

Example : Oxides of metals like gold, platinum, silver, etc.

Hence, *such metals* forming unstable oxide film *do not get corroded,* but loss of metal continues, slowly.
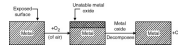

Fig. 1.2.4 : Unstable oxide layer

Q. Explain wet corrosion in acidic medium with schematic diagram and mechanism.

(May 2013, May 2014, May 2014)

Ans. :

Wet corrosion in acidic medium

- An electrochemical reaction is one which results in the transfer of electrons.

- When metal surface is in immediate contact of *aqueous acidic/alkaline/ neutral/electrolytic solutions,* the short circuited galvanic cells get set all along the surface of metal. This gives rise to corrosion which proceeds by electrochemical principles. In fact,

- Wet corrosion is more common than dry corrosion.

- The co-ordinating metal(s) behave like *galvanic cells* thereby the *part of metal acting as an anode* is consumed while *the other part* which is *acting as a cathode* remains unchanged.

- **Theory :** This type of corrosion occurs, under following conditions,
  - (i) Where a conducting liquid is in contact with metal, or
  - (ii) Where two dissimilar metals or alloys are either immersed or dipped partially in a solution.
- These type of conditions are always suitable for formation of *separate anodic and cathodic areas* between which the electric current can flow through the conducting solution.
- *At anode,* the liberation of electrons takes place, i.e. *oxidation reaction.* Consequently at anode, *the destruction of metal occurs,* either by dissolving it as metal ions or by converting it into a compound such as its oxide.
- *At cathode,* the absorption of electrons takes place, i.e. *reduction reaction.* These reactions do not affect the part of the metal acting as a cathode, since most of the metals cannot be further reduced.
- Thus, corrosion occurs always at anode.

  Reactions : At anode

  $$\underset{\text{(Metal)}}{M} \longrightarrow \underset{\text{(Metal ion)}}{M^{n+}} + \underset{\text{(Electrons)}}{ne^-}$$

- Formation of metal ions (M^{n+}) at anode causes dissolution of metal and free electrons are liberated. These free electrons are consumed in cathodic

reactions with either.

(a) Evolution of H_2 gas. Or,

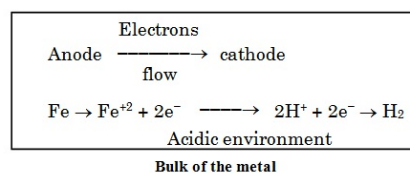(b) Formation of a product [oxide of metal] due to absorption of O_2 gas.

depending upon the nature of the corrosive environment.

Mechanism of Electrochemical Corrosion/ Wet Corrosion
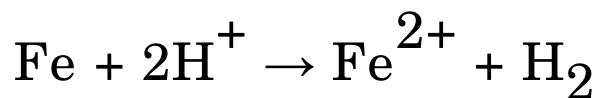
a) Evolution of Hydrogen type

- Corrosion, by this mechanism occurs usually if environment, surrounding to the metal is acidic.

- **Example :** Pipe lines made from iron metal get corroded if industrial waste material, or solutions of non-oxidising acids, is transported through them.
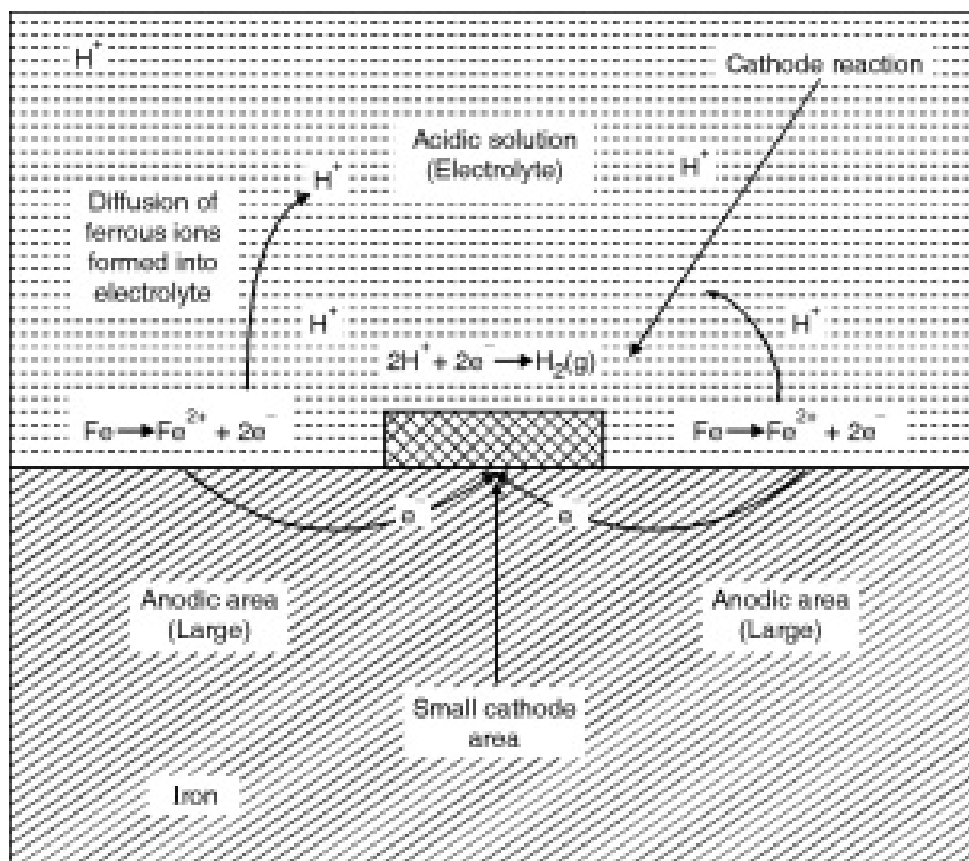
  The following reaction occurs

- From above reactions, we can say that the *flow of electrons takes place from the anode to the cathode.* These electrons are gained by cathodic reaction, and at cathode H^+ ions are eliminated as H_2 gas. The overall mechanism can be represented as

$$Fe + 2H^+ \rightarrow Fe^{2+} + H_2$$

- Thus displacement of H_2 ions from acidic solution by metal ions takes place.

Fig. 1.2.6 : Schematic representation of Mechanism of wet corrosion by hydrogen evolution

Thus, all metals have tendency to get dissolved in the acidic solution with simultaneous evolution of H_2 gas.

Q. What is 'oxidation corrosion' ? Discuss the role of nature of oxide formed in oxidation corrosion. *(Dec. 2013)*

OR

Q. Explain why pure aluminium metal exhibits good corrosion resistance in atmospheric oxygen. *(May 2014, Dec. 2014, Dec. 2015, May 2015)*
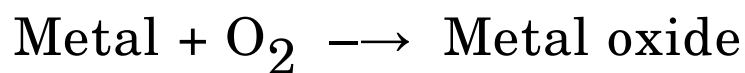
Q. What is dry corrosion ? *(May 2015)*

Ans. :

- Chemical/Atmospheric or dry corrosion occurs mainly by, *direct attack* of atmospheric gases such as O_2, CO_2, H_2S, *halogens*, SO_2 etc. on the surface of metals. The metal forms corresponding compounds such as *oxides, carbonates, sulphides, halides or sulphates*. The action of some *organic* or *anhydrous inorganic liquids, or melt of metals* also cause this type of corrosion.
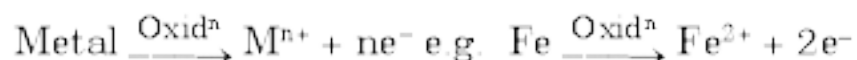
Corrosion due to oxygen

- This type of corrosion occurs due to attack of atmospheric oxygen on metal surface either at low or high temperatures, forming metal oxide as

$$\text{Metal} + O_2 \longrightarrow \text{Metal oxide}$$

- Normally, more active metals get corroded faster than less active metals. For example, alkali metals and alkaline earth metals get oxidized even at low temperatures as compared to other metals which are less active.

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$$M^{n+} + O^{2-} \longrightarrow M_2O_n \qquad Fe^{2+} + O^{2-} \longrightarrow FeO$$

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(c)	Volatile oxide film	Oxides of some metals like molybdenum.	Being Volatile oxide, it is lost to environment, leaving fresh metal exposed. Rate of corrosion very high, till entire metal lost.

Q. What is electrochemical corrosion ? With suitable diagram and electrode reactions explain electrochemical mechanism of rusting of iron in neutral, aqueous medium.
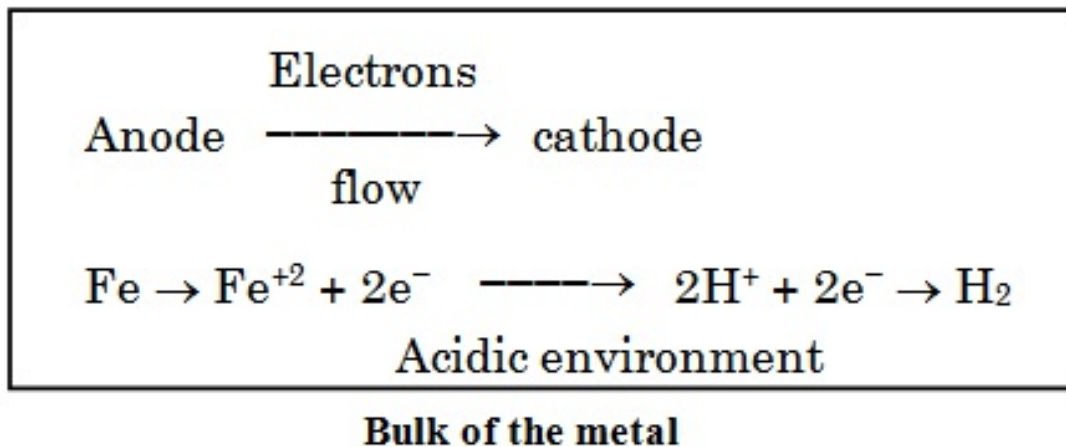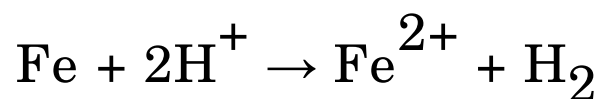
Ans. :

Evolution of Hydrogen type

- Corrosion, by this mechanism occurs usually if environment, surrounding to the metal is acidic.

- **Example :** Pipe lines made from iron metal get corroded if industrial waste material, or solutions of non-oxidising acids, is transported through them.

  The following reaction occurs

  Electrons

  Anode $\dashrightarrow$ cathode
  flow

  $Fe \rightarrow Fe^{+2} + 2e^- \dashrightarrow 2H^+ + 2e^- \rightarrow H_2$

  Acidic environment

  Bulk of the metal

- From above reactions, we can say that the *flow of electrons takes place from the anode to the cathode.* These electrons are gained by cathodic reaction, and at cathode H^+ ions are eliminated as H_2 gas. The overall mechanism can be represented as

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- Thus displacement of H_2 ions from acidic solution by metal ions takes place.

Fig. 1.2.6 : Schematic representation of Mechanism of wet corrosion by hydrogen evolution

Thus, all metals have tendency to get dissolved in the acidic solution with simultaneous evolution of H_2 gas.

Absorption of oxygen type

- **Rusting of iron** in neutral aqueous solution of electrolytes in the presence of atmospheric oxygen is the most common example of this type of corrosion (mechanism).

- Thus, iron metal in such cases is always with a coat of thin film of iron oxide (Fe_2O_3). Since, the film is porous in nature, the surface of iron exposed to atmosphere acts as an anode while rest of surface acts as a cathode.

Anodic reaction

$$Fe \rightarrow Fe^{2+} + 2e^- \text{ (Oxidation)}$$
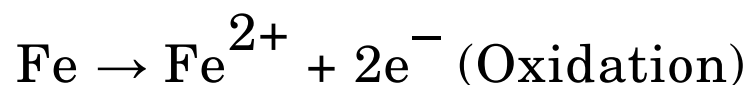
Thus, at anode iron dissolves as ferrous ions with liberation of electrons.
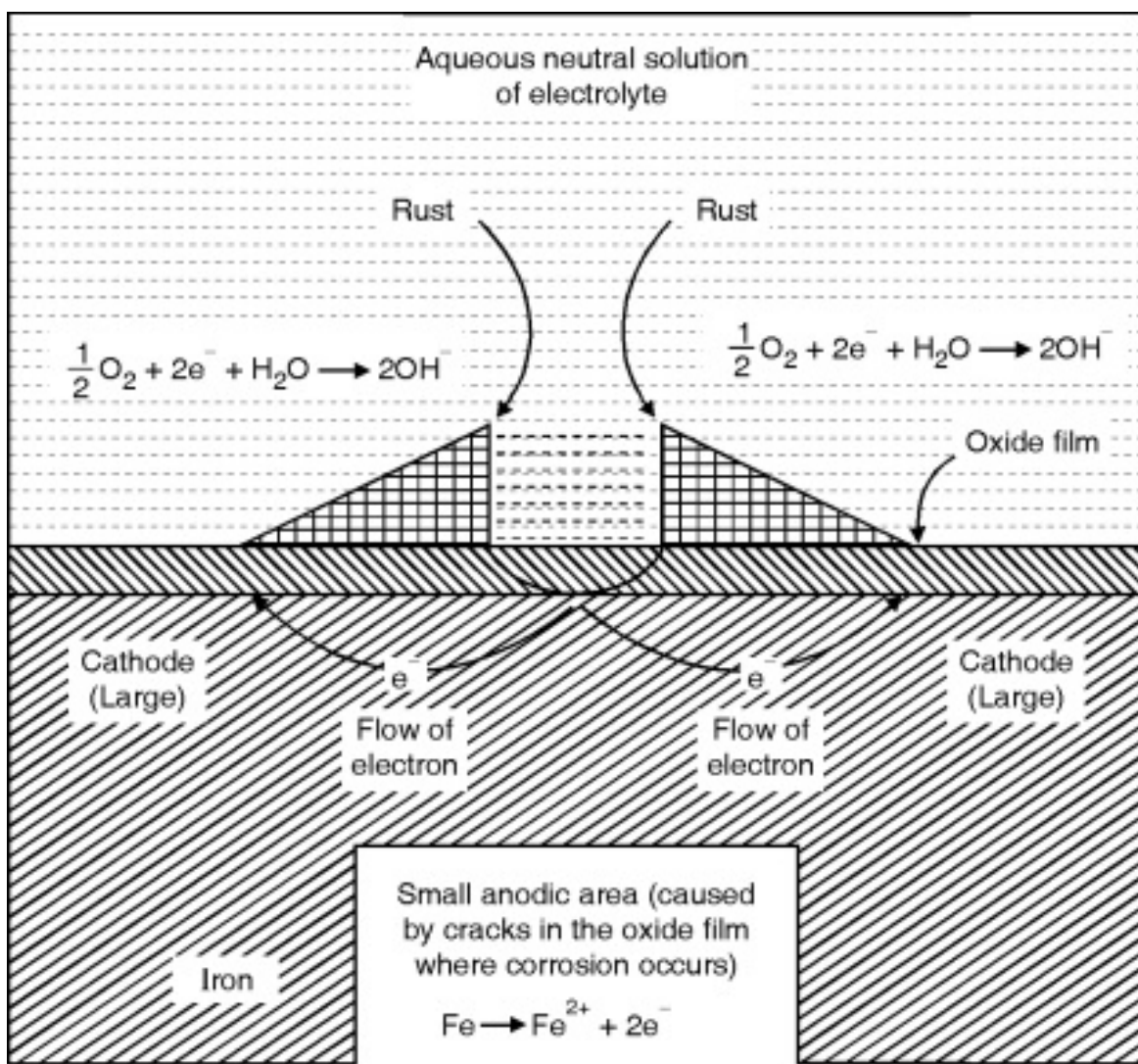
Fig. 1.2.7 : Schematic representation of Mechanism of wet corrosion by oxygen absorption

Cathodic reaction

- The liberated electrons flow through iron metal from anode to the cathode, where electrons are intercepted by the dissolved oxygen as

$$\frac{1}{2} O_2 + H_2O + 2e^- \longrightarrow 2OH^- \ (Reduction)$$
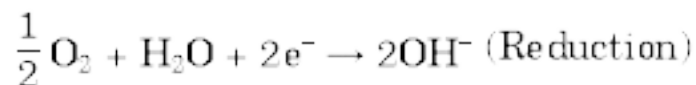
- The Fe^{+2} ions and OH$^-$ ions diffuse and when they meet, $Fe(OH)_2$ is precipitated, as

$$Fe^{2+} + 2OH^- \longrightarrow Fe(OH)_2 \downarrow$$
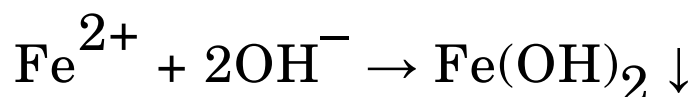
- Effect of O_2 supply on corrosion product :

- If enough supply of O_2 is available, then $Fe(OH)_2$ readily get oxidized to $Fe(OH)_3$ as

  $$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3\downarrow \text{ (yellow Rust)}$$

- This substance is commonly known as *yellow rust* and it actually corresponds to

  $$Fe_2O_3H_2O \text{ or } FeO(OH) \text{ and not } Fe(OH)_3$$

- If the supply of oxygen is limited, the product formed may be Ferroso-ferric hydroxide.

- If oxygen supply is increased, cathodic reaction is influenced forming more number of OH^- ions, and subsequently anodic reaction is also influenced, eliminating more number of electrons, thereby increasing the rate of corrosion.

Syllabus Topic : Types of Electrochemical Corrosion-Galvanic cell corrosion, Concentration cell corrosion (differential aeration), Pitting corrosion, Intergranular corrosion, Stress corrosion.

Q. Give the anode and cathode reactions involved in the corrosion of steel pipe connected to copper plumbing. *(May 2012)*

OR

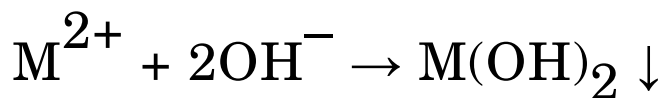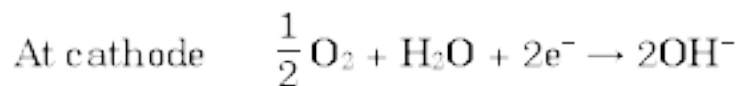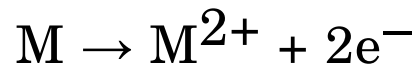**Q.** Explain Galvanic corrosion. *(Dec. 2012)*

Ans. :

- The *name* of this type of corrosion is *indicative* that there must be formation of a *galvanic cell* on metal surface causing corrosion. Such cells get set up all along the surface of metal when it faces the electrolytic environment and two dissimilar metals in contact.

- For example, in ships floating on the sea water, the portion of it in contact with marine water gets corroded, if there is a difference in the materials used in assembling the ship.

- If metal iron or brass alloy is used together to join various parts, due to difference in potential, a galvanic cell gets set, leading to corrosion.

- In such cases all along the surface of metal small galvanic cells are set up, where area of high potential acts as an anode and the one with lower potential acts as a cathode.

- The portion of metal acting as anode, deteriorates and at cathode the cathodic product gets evolved/deposited, depending upon the environment, and mechanism of the corrosion, i.e. by absorption of oxygen or evolution of hydrogen, as the case may be.

- The case where the former type of mechanism takes place is seen in *electrolytic/alkaline environment*

while the latter type is seen in *acidic* environment.

- The rate of corrosion is obviously very high in latter type. In former one, for iron metal generally three types of iron oxides are formed in succession with the increasing valency of iron. **For example : FeO, Fe$_2$O$_3$ and Fe$_3$O$_4$.**

- In such type of environment, on metal surface small anodic and cathodic areas are formed. Here, cathodic area is slightly larger and hence rate of corrosion is comparatively higher. The mechanism of corrosion in slightly alkaline medium, proceeds as, At anode $\qquad$ $M \rightarrow M^{2+} + 2e^-$

$$\text{At cathode} \quad \frac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^-$$

$$M^{2+} + 2OH^- \rightarrow M(OH)_2 \downarrow$$

- If the metals are surrounded by *aqueous alkaline/acidic/neutral solution,* the mechanism of cathodic reaction proceeds to form OH$^-$ ions, and subsequently Fe(OH)$_2$ or Fe(OH)$_3$.

- If the metal is exposed to acidic medium the mechanism at cathode proceeds to form H$_2$ gas, while anodic reactions remain the same.

- To avoid the formation of galvanic cells,

    a) The metals should be pure.

    b) The materials used to assemble the different

parts should be of same potentials.

c) Moisture and other electrolytic/aqueous medium, if present, other corrosion controlling methods may be used.

Q. Explain concentration cell corrosion with the help of suitable example. *(May 2012, Dec. 2013, Dec. 2014, May 2015)*

Ans. :

Concentration cell corrosion

- This type of corrosion is due to the *electrochemical attack* on the metal surface, which is exposed to an electrolyte *of varying concentrations* or *of varying aeration*.

- The variation is caused due to local difference in metal ion concentration caused by,

    (i) Local difference in temperature

    (ii) Inadequate agitation

    (iii) Slow diffusion of metal ions, produced by oxidation at anode.

- It is the most common type of corrosion, and it occurs when one part of the metal is exposed to a different air concentration from the other part.

- This causes a difference in potential between differently aerated areas. It has been found that poor oxygenated parts are anodic and rest are cathodic.

Consequently, differential aeration of metal causes a flow of current, called differential current.

- **Example :** Metal (Iron) tank/drum storing water or a strip of zinc metal partially dipped in dilute solution of salt; like NaCl and if solution is not agitated properly then the parts of the strip above and closely adjacent to the water line are more strongly aerated; because they have more supply of oxygen while remaining parts of the same strip which are immersed to greater depth have less supply of oxygen and these are poorly aerated and show lower oxygen concentration or lesser access of oxygen, and thus they become anodic.

- Thus, difference of potential is created which causes a flow of current between the two differently aerated areas of the same metal. Zinc will dissolve at anodic areas as,

$$Zn \rightarrow Zn^{2+} + 2e^- \text{ (Oxidation)}$$
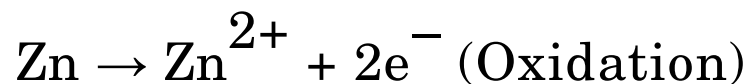
O^2 will take up electrons at the cathodic areas to form OH^- ions.

$$\frac{1}{2} O_2 + H_2O + 2e^- \rightarrow 2OH^- \text{ (Reduction)}$$
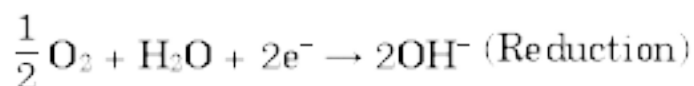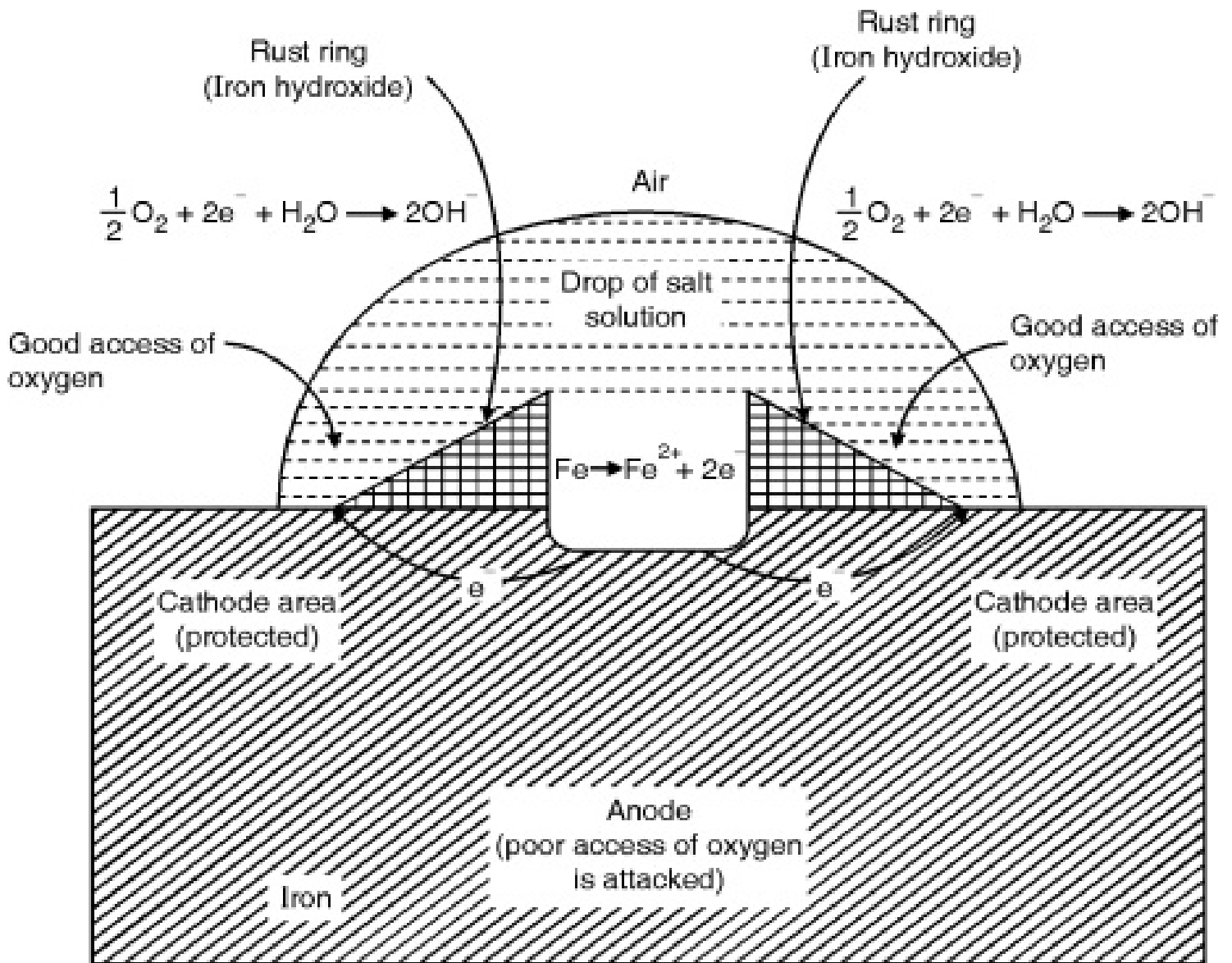
Fig. 1.3.1 : Concentration cell corrosion

Q. Explain stress corrosion with appropriate diagram and examples. *(Dec. 2012)*

Ans. :

Stress corrosion

- It is similar to intergranular corrosion.

- Stress corrosion (or stress cracking) "is the combined effect of static tensile stresses and the corrosive environment on a metal."

- It is characterized by a highly localized attack which

occurs even when overall corrosion is negligible.

- For stress corrosion to occur the essential conditions are : (i) presence of tensile stress, and (ii) a specific corrosive environment .

- The specific substances act as the corrosive agents and are selective for particular material in particular environment,

For example

(a) Caustic alkalis and strong nitrate solution for mild steel;

(b) Traces of ammonia for brass; (c) acid chloride solution for stainless steel.
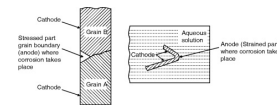
Fig. 1.3.3 : Stress corrosion

- This type of corrosion is seen in fabricated articles of certain alloys (like high-zinc brasses and nickel brasses) due to the presence of stresses caused by heavy working like rolling, drawing or insufficient annealing.

- The pure metals are relatively immune to stress corrosion.

- Stress corrosion involves in a localized electrochemical corrosion, forming anodic areas with respect to the more cathodic areas at the metal

surface.

- Presence of stress produces strains, which result in localized zones of higher electrode potential.

- These chemically-active sites are attacked, even by a mild corrosive environment.

- This results in the formation of a crack, which grows and propagates in a plant.

- The attack of corrosion continues till failure of structure occurs.

- Typical example of stress corrosion are given below :

  Seasonal cracking is a term applied to stress corrosion of copper alloys, mainly brasses. Pure copper is immune to stress corrosion, but presence of small amounts of alloying element (like P, As, Sb, Zn, Al, Si) result in marked sensitivity. For examples, alpha brass (which when highly stressed) undergo intergranular cracking in an atmosphere, containing traces of ammonia or amines.

Q. Explain intrrgranular corrosion with a suitable diagram and example. *(May 2016)*

Ans. :

Intrrgranular corrosion

- This type of corrosion occurs along grain boundaries under following conditions

  (i) The material, highly sensitive to corrosive

attack and

(ii) Corrosive liquid possesses *a selective character of attacking only at the grain boundaries*, but leaving the grain centres (interiors) untouched or only slightly attacked.

- This type of corrosion is due to the fact that the grain boundaries contain material, which shows electrode potential more anodic than that of the grain centre in the particular corroding medium. This may be due to precipitation of certain compounds at the grain boundaries,

- Due to such disproportionated precipitation, a solid solution is aggregated at centre, adjacent to boundary.

- The solid solution thus formed is *anodic* with respect to the grain centres as well as to the precipitated compound. Hence it gets attacked preferentially in the corrosive environment (see Fig. 1.3.2).
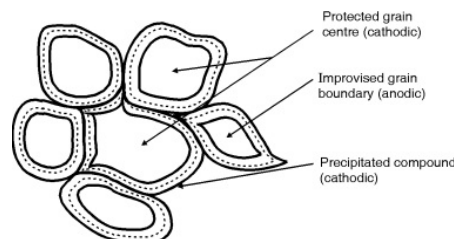
Fig. 1.3.2 : General intergranular attack

- This type of corrosion is, generally, observed in alloys. For example : During the welding of stainless steel (an alloy of Fe, C and Cr), chromium carbide is precipitated at the grain boundaries.

- Hence chromium composition adjacent to grain boundaries is increased and is more anodic with respect to the solid solution within the grain (which is richer in chromium) and it is also anodic to the particles of the chromium carbide so-precipitated.

- Intergranular corrosion is observed to occur near the grain boundaries and occurs on microscopic scale, without any apparent external signs of any intensive attack.

- On account of this, sudden failure of material occurs (without any pre-warning), due to loss of cohesion between grains.

- The remedy is *proper heat-treatment*, followed by rapid quenching to avoid the heterogeneous precipitation that, usually, occurs due to slow-cooling (annealing).

Syllabus Topic : Factors affecting the rate of corrosion-Nature of metal, position of metal in galvanic series, potential difference, overvoltage, relative area of anodic and cathodic parts, purity of metal, nature of the corrosion product, temperature, moisture, influence of pH, concentration of the electrolytes.

Q. Discuss the effect of the following factors on the rate of corrosion :

(a) Relative area of anode and cathode

(b) pH

(c) Over voltage

Ans. :

(a) Relative area of anode and cathode

- If two *dissimilar* metals are in contact, one forming anode while another forming cathode, then the corrosion of the anodic metal (part) is directly proportional to the ratio of the areas occupied by the cathode and anode.

$$\text{Thus, corrosion at anode } \alpha = \frac{\text{Area of cathodic part}}{\text{Area of anodic part}}$$

- Hence, if cathode is large and anode is small, then corrosion at anode is higher and vice-versa.

(b) pH

- *In acidic, pH, the rate of corrosion is higher,* because the mechanism of electrochemical corrosion proceeds by evolution of hydrogen gas at cathode. On the contrary, in alkaline or neutral electrolytic medium the electrochemical corrosion occurs by following the mechanism of absorption of oxygen; thereby forming an oxide film as a cathodic product.

- Such a film gets adhered to the surface of the

metal and further rate of corrosion is governed by *nature of the corrosion product* which is discussed earlier.

(c) Over voltage

- When a metal, which occupies a high position in galvanic series (say zinc), is placed in 1N-H_2SO_4, it undergoes corrosion forming a film and evolving hydrogen gas.

- The initial rate of reaction is quite slow, because of high overvoltage (= 0.70 V) of zinc metal, which reduces the effective electrode potential to a small value.

- If a few drops of copper sulphate ($CuSO_4$) are added, the corrosion rate of zinc is accelerated, because some copper gets deposited on the zinc metal, forming *minute cathodes*, where the hydrogen overvoltage is only 0.33 V. *Thus, reduction in overvoltage of the corroding metal/alloy accelerates the corrosion rate.*

- "The difference between the potential of the electrode when the gas evolution was actually observed and the theoretical reversible value of the same solution is called the overvoltage or overpotential".

Q. Explain the following factors affecting the rate of corrosion

:

    (i)   Position of metal in galvanic series.

    (ii)   Temperature *(Dec. 2012, Dec. 2014)*

Ans. :

(i) Position of metal in galvanic series

This is a major factor for corrosion of metals. If two dissimilar metals are in corroding environment, the metal having higher electrode potential and position in the galvanic series undergoes corrosion, i.e. it acts as an anode.

(ii) Temperature

The rate of corrosion is greater at higher temperature, because diffusion of gases increases with the rise in temperature. Another example of increase of corrosion with rising temperature is *caustic embrittlement* as observed in boiler.

Q.   How do the following factors affect the rate of corrosion ?

    (i)   Passive character of metal.   (Dec. 2013)

Ans. :

Nature of metal depends upon its position in galvanic series and potential difference.

Q.   How do the following factors affect the rate of corrosion ?

    (i)   Purity of metal

    (ii)   Nature of corrosion products   (Dec.2015, May 2016)

Ans. :

(i) Purity of metal

- If the metals are impure, then the impurities present in them cause heterogeneity, which *gives rise to small electro-chemical cells* at the sites where metal and impurities are exposed, to the corrosive environment and thus, the corrosion starts, which then affects the entire metal.

- **Example :** Zinc metal, if with the impurities of Fe or Pb, undergoes corrosion at the sites where the impurities are exposed because of the formation of local small electrochemical cell. *Thus more the percentage of impurity, higher is the corrosion of zinc metal.*

(ii) Nature of corrosion products

- Chemical/Atmospheric or dry corrosion occurs mainly by, *direct attack* of atmospheric gases such as O_2, CO_2, H_2S, *halogens*, SO_2 etc. on the surface of metals.

- The metal forms corresponding compounds such as *oxides, carbonates, sulphides, halides or sulphates*. The action of some *organic* or *anhydrous inorganic liquids, or melt of metals* also cause this type of corrosion.

This type of corrosion is divided into following classes

(i) Corrosion due to oxygen – leading to formation of oxides.

(ii) Corrosion due to other gases – leading to formation of other compounds.

(iii) Corrosion due to other corrosive liquids – such as other molten metals.

Q. What is cathodic protection ? Discuss the sacrificial anode method of corrosion control.

(May 2012, Dec. 2013, May 2014)

OR

Q. What is the principle of cathodic protection method of corrosion control ?

**Ans. :**

Cathodic protection

- Cathodic protection is nothing but a method used to reverse the flow of current between the two dissimilar metals, under corroding environment thereby reversing the action of the metals in contact. This is achieved by applying the external circuit and forcing the anodic metal to behave as a cathode.

Use of sacrificial anode

- To achieve protection by *sacrificial anode* method, the metal to be protected from corrosion is *connected by a wire* to another piece of metal which is *more reactive* than the *base metal* itself.

- This results in the corrosion of the piece of metal connected, thereby saving base metal.

- Since the more active metal sacrifices itself, by undergoing corrosion and saving the base metal, *the method is named as sacrificial anode or auxiliary anode method.*

- When the piece of more active metal gets corroded completely, it is simply replaced by new piece.

- The metals normally used are Mg, Zn or Al.

- This method is used normally to protect pipelines carrying water or industrial wastes, and which are normally embedded under the soil, thereby facing the conditions of soil corrosion as well as microbiological corrosion.
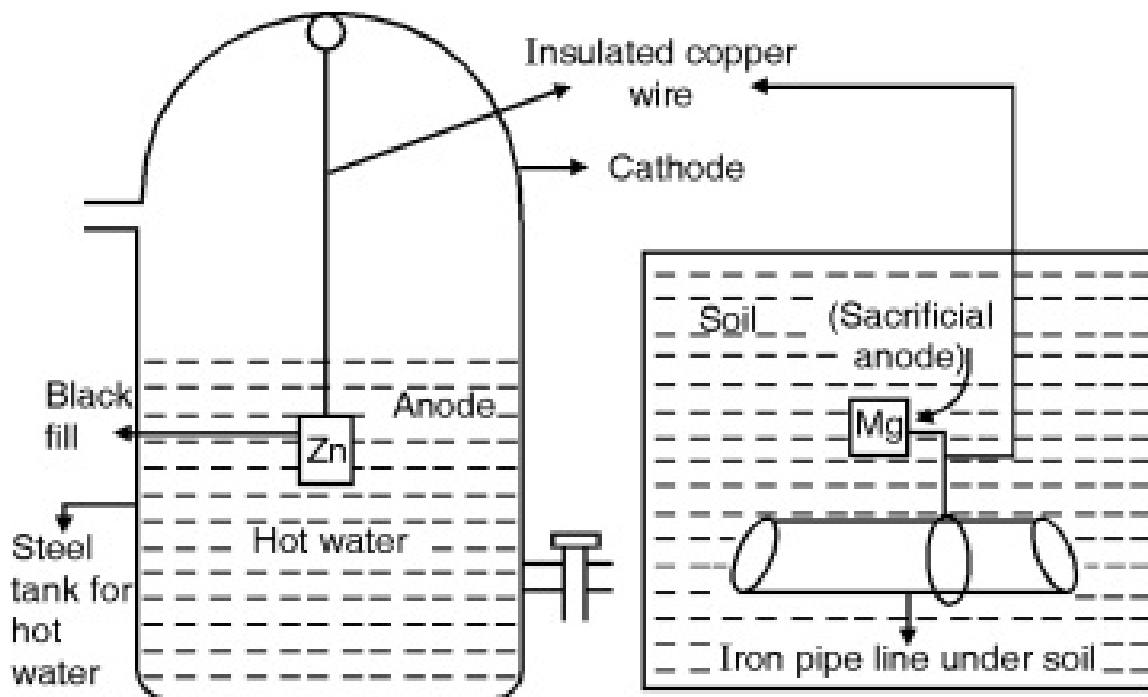
Fig. 1.5.2 : Corrosion control by sacrificial anode method

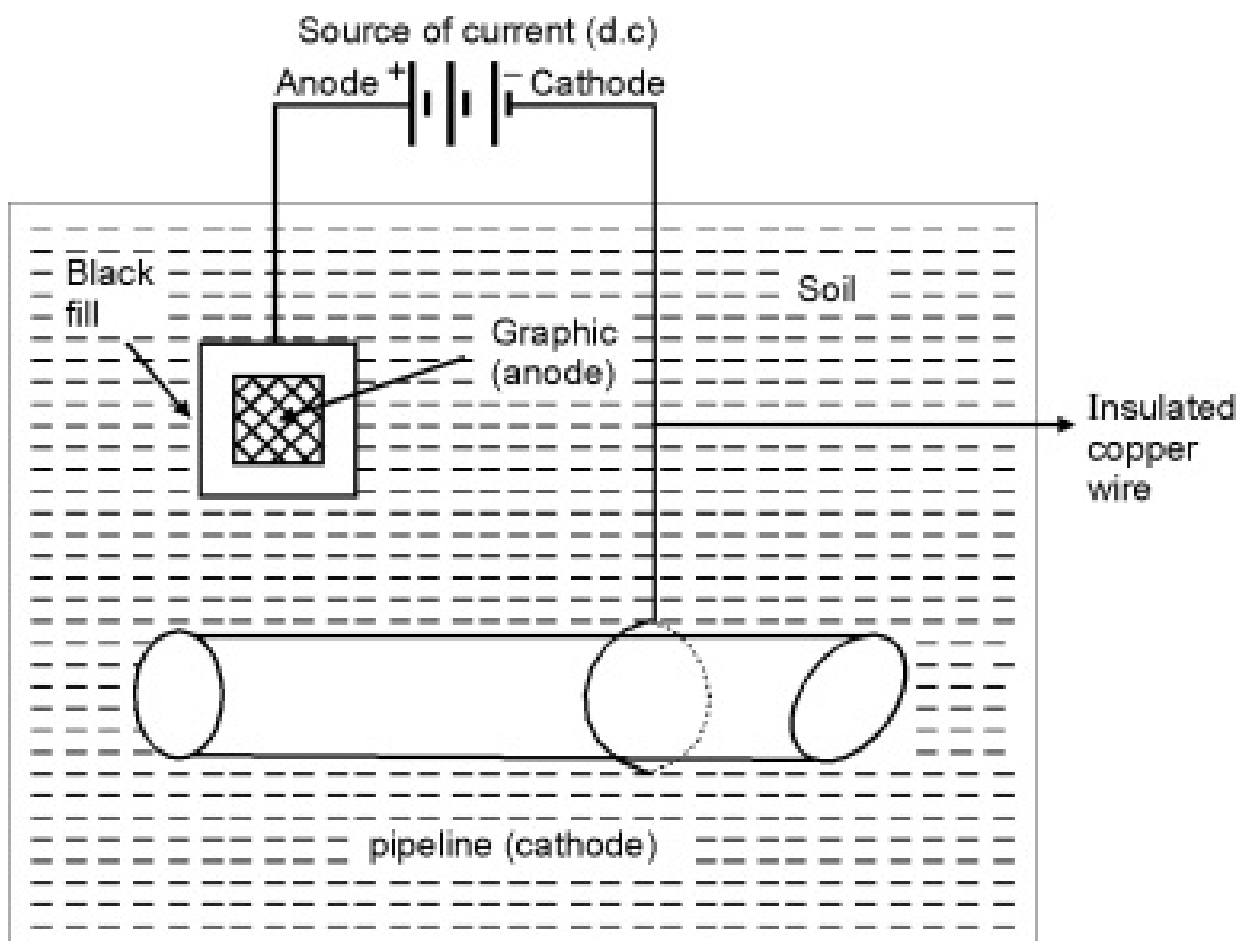**Q.** Describe impressed current method of corrosion control. *(May 2013, Dec. 2013, May 2014, May 2015)*

Ans. :

Impressed current method

- In impressed current method, a current is applied in the opposite direction to that of corrosion current, thereby nullifying the effect of the latter one on the base metal, i.e. converting the base metal, to cathode from an anode.

- Such an impressed current can be obtained by using *d.c. source such as battery or dry cell* along with an insoluble anode such as *platinum, stainless-steel, graphite etc.*

- In this method, as shown in Fig. 1.5.3, the insoluble anodic metal used (i.e. platinum, steel, scrap iron

etc.) is normally *embedded underground.* To this, with the help of d.c. current source, the impressed current is applied, and whole of this assembly is connected to the metallic structure to be protected.

- The connections are done by using wires.

- The insoluble anode is kept inside back-fill made up of *gypsum or any such material,* which can help in increasing the electrical contact with the soil.

Fig. 1.5.3 : Corrosion control by impressed current method

- Such an anode can be single, if the area of the metallic structure to be protected is small.
- There can be many such anodes, *connected in series* if the area of the metallic structure to be

protected is wider, i.e. long pipeline etc.

Q. Explain sacrificial anodic protection method. (Dec. 2014, May 2015)

Ans. :

Sacrificial **anodic** protection method

- This method to protect base metal is used under certain conditions, such as, where metal to be protected possesses active passivity. e.g. stainless steel.

- The principle involved is to increase the passivity of the base metal by applying current in the direction in which the metal would become more anodic.

- The important factors which *influence* this method can be summarized as below :

  i) The metal to be protected should possess high passivity, over wider range of potential.

  ii) The passivity should be increased at low current density, thereby reducing the cost.

  iii) The cathodic metal used should possess adequate resistance to corrosion under working conditions. Generally, platinum clad metals or other corrosion resistant alloys are used.

  By using *anodic protection* technique, the complicated metal structures can be protected, because *the method is highly effective,* if proper selection is done in choosing cathodic metal for a given set of working conditions.

Advantages of Anodic Protection Method

i) Operating cost is low.

ii) Wide range of corroding environments can be tackled.

iii) Complicated metallic structures can be protected.

iv) The applicability of method can be checked in laboratory on small scale and use of cathodic metal can be fixed by trial and error techniques, before going on large scale.

v) During operation, from protection current density, rate of corrosion can be known.

Disadvantages Anodic Protection Method

i) Method is useful only for metals showing *passivity*.

ii) Initial cost of installation is high, due to use of high-starting current, reference electrode, auxiliary electrode and a potentiostat.

iii) If system goes out of control, the rate of corrosion increases suddenly.

Syllabus Topic : Metallic coatings-hot dipping-galvanizing and tinning, metal cladding, metal spraying, Electroplating, Cementation. Organic coatings-Paints (only constituents and their functions)

Q. Define paints. Explain the different constituents of paints with their functions.

(Dec. 2014, May 2014, Dec. 2015, May 2016)

Q. Mention any three constituents of paint and give their functions. (May 2016)

Ans. :

Paints Definition

Paints are formed by using various ingredients which are listed below. Each ingredient is mixed for a particular function.

Different constituents of paints with their functions

Organic coating	Constituent	Examples	Functions
1) Paint	Drying oils or vehicle	Linseed oil, soyabean oil, dehydrated castor oil, neem oil, fish oil, etc.	They help pigments to be held on surface. They provide dried film by oxidation or polymerisation. They provide durable water resistant film of paint.
	ii) Pigments	White pigments : White lead, ZnO, Titanium oxide, *Coloured pigments* Red lead, Fe_2O_3, chrome red, etc.	Provide opacity, colour strength, and protection. Provide resistance against abrasion. Minimise shrinkage and cracking caused on drying.
	iii) Thinners	Turpentine, spirits, benzene, naphtha, xylol, kerosene, methylated naphthalene etc.	Adjust viscosity of formulation. Help in drying of the paint. Suspend the pigments and dissolve film forming material.
	iv) Driers	Oxygen carrying catalysts, Linoleates of Co, Mn, Zn, etc.	Improve drying process. Act as catalyst in drying process.

Q.   State the characteristics of a good paints. (May 2013, Dec. 2013)

Ans. :

Ideally a paint should possess the following characteristics

1)   Its power to cover the surface should be as high as

possible.

2) Its consistency should be adequate so that it can be spread easily.

3) On drying it should be able to give strong, uniform, highly adherent and impervious film.

4) The layer should not be cracked, peeled or blistered on drying.

5) The layer should be washable and durable.

6) Its colour should not be changed on prolonged exposure to air.

7) Its corrosion resistance should be high.

8) The texture of the dried coat should be smooth, uniform and glossy.

Q. What are metallic coatings ? *(May 2013)*

Ans. :

Methods of cleaning and preparation of metal surfaces :

(1) Solvent cleaning   (2) Acid cleaning

(3) Chemical cleaning   (4) Alkali cleaning

(5) Mechanical cleaning   (6) Flame cleaning

(7) Sand blasting   (8) Acid pickling and etching

This type of coatings are either anodic or cathodic depending upon the electrode potential of base metal and coating metal.

Q. Distinguish between anodic and cathodic coating. *(May 2014)*

Ans. :

Sr. No.	Anodic coating	Cathodic coating
1.	This type of coatings protect base metal "sacrificially".	This type of coatings protect the base metal because of high corrosion resistance and noble behaviour.
2.	The coating metal is at lower electrode potential than base metal.	The coating metal is at higher electrode potential than base metal.
3.	Corrosion of base metal does not enhance even on breaking "anodic coating", as it heals its film.	Corrosion of base metal enhances, if there is small cut / break in coating.

Syllabus Topic : Methods of Application of Metallic Coatings

Q. Discuss the electroplating method of applying metallic coating in detail. (May 2012)

Ans. :

- In this method, freshly cleaned base metal is *made cathodic.*

- A galvanic cell is set up in suitable bath (electrolytic solution) containing solution of the compound of the metal to be coated on base metal. Anode is the coating metal.

- The method is highly useful to produce coatings of metals such as *Cu, Zn, Sn, Ni, Cr, Cd, Pb, Ag, Au, Pt* and various alloys.
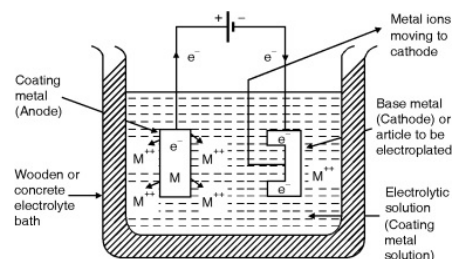
Theory of Electroplating

- A metal salt in aqueous solution undergoes ionisation

to form ions.

- When a potential difference is applied to this salt solution by dipping two electrodes in the solution, the metal ions migrate to the cathode and get deposited there.

- If anode is of the same metal of which the salt is in the solution, the salt is reformed by the anode metal passing into the solution in the form of ions.

Process of Electroplating

- Electroplating is carried out in an electrolytic cell. As shown in Fig. 1.7.5.

- The article to be electroplated is first cleaned with organic solvents to remove oils, greases etc and then treated with dilute HCl (e.g. for copper and nickel plating) and dilute H_2SO_4 (e.g. for chrome plating) to remove oxide scales etc. The cleaned article is then made cathode of the electrolytic cell and is hung on racks placed on the cathode bar.

- The anode is either the coating material or an electrode of inert material like graphite.

Fig. 1.7.5 : Electroplating

- The electrolyte, which is a soluble salt solution of coating metal is taken in the cell.

- The anode and cathode are dipped in the electrolytic solution and a direct current of electricity is passed.

- Under the influence of electric current, coating metal ions migrate to the cathode and get deposited there. Thus a thin coating of metal is produced on the article made as cathode.

- In order to have brighter and smooth deposits, low temperature, high current density and low metal ion concentration etc are the favourable conditions. Small articles like bolts, nuts, screws, washers etc are packed in barrel and the latter is slowly rotated during electroplating.

Q. What are the methods of metallic coatings ? Describe metal cladding with appropriate diagram. (Dec. 2012, Dec. 2015, May 2016)

Ans.:

- The following methods are generally used for applying the metallic coatings on the base metals :

    (1) Hot dipping.

        (a) Coating zinc on iron, i.e. galvanizing. (Anodic coating)

        (b) Coating tin on iron, i.e. tinning. (Cathodic coating)

    (2) Metal spraying.

(3) Diffusion or cementation.

    (a) Coating of zinc by diffusion, i.e. sherardising.

    (b) Coating of Al by diffusion, i.e. calorising.

    (c) Coating of Cr by diffusion, i.e. chromising.

    (d) Coating of Si by diffusion, i.e. siliconising.
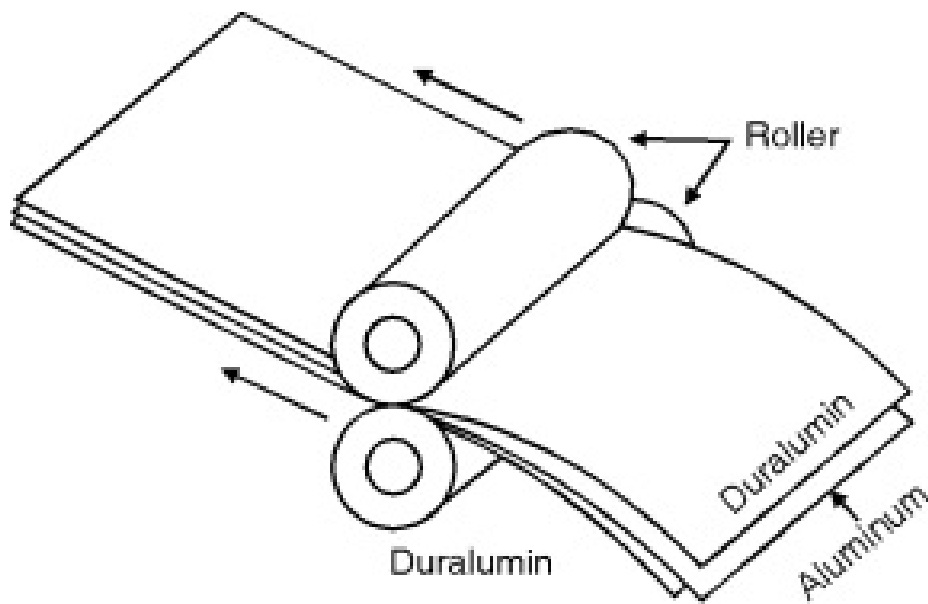
(4) Metal cladding.

(5) Electroplating.

Each of these methods are further discussed, to know the details of process, equipment, application, advantages and disadvantages

Metal cladding

- It is a process by which a dense, homogeneous layer of coating metal and base metal sheet in the form of a sandwich is passed through the roller under pressure and at elevated temperature, which results in close adherence known as metal cladding.

  Choice of cladding material depends upon the extent of corrosion resistance desired and the given conditions of a corroding environment in which the base metal is placed / to be used.

Fig. 1.7.3 : Metal cladding[Alclad]

- Generally, passive metals like Ni, Cu, Pb, or alloys such as stainless steel, alloys of Ni, Cu, Pb are used as cladding material.

- The method is highly useful especially to produce long sheets, cladded with thin metals like aluminium. The cladded sheets known as alcad are widely used in aircraft industry in which a plate of duralumin is sandwiched between two layers of 99.5% pure aluminium.

Q. Distinguish between Galvanizing and Tinning. (May 2013, Dec. 2014, May 2015)

Ans. :

Sr. No.	Galvanizing	Tinning
1.	It is a process of coating iron/steel with a thin coat of zinc to protect them from rusting. Not used for coating copper or brass sheets.	It is process of coating iron/steel with a thin coat of tin to protect them from corrosion. Also used to coat brass or copper sheets.
2.	The iron / steel sheets are cleaned with dilute H_2SO_4 i.e. "pickling" to remove scales / oxides / impurities.	The steel articles are cleaned with dilute H_2SO_4, "pickling". Which removes oxides / scales / impurities.
3.	In this process, NH_4cl flux is used.	In this process, $Zncl_2$ flux is used.
4.	Molten zinc is maintained at 425-430°C.	Molten Tin is maintained at about 230-235°C.
5.	Galvanized sheets are used in making roof tops, nails, wires, buckets, tubes, pipes etc.	Tinned sheets are used in making containers.
6.	Galvanized sheets can not be used to store food stuffs as Zinc gets dissolved in dilute acids and produces poisonous compounds.	Tinned containers are used to store food stuffs, oils, ghee etc. as it is safe and does not react with dilute acids and does not produce any poisonous compounds.

Q. Why is galvanization of iron articles preferred to tinning ? (Dec. 2013)

Ans. :

Applications

Galvanised iron is used for making water pipelines, roofing sheets, wires, nails, screws, bolts, nuts, tubes, etc. Being anodic coating, if coating is broken, even then corrosion rate does not increase, as iron (base metal) acts as cathode and Zn as anode. Hence, galvanizing gives better protection for iron than tin.

Q. What are metallic coatings ? Explain the following methods of coating.

    (i) Cementation coating (Sherardizing). (May 2016)

Ans. :

Sherardising

- This is a process in which by diffusion method zinc is coated on iron. The method is normally employed for small structures like screws, nails, nuts and bolts etc. where the process of galvan zing by hot dipping cannot be useful.

- The surfaces of base metal articles are cleaned by acid pickling or any other suitable method and after washing and drying, these articles are packed with Zn dust in a drum, which is sealed so as to avoid the contact of oxygen from atmosphere.

- The drum is then slowly rotated at the temperature of about 350°C – 400°C. (Temperature raised by gas heating or by electricity) for about 3 to 12 hours in an inert atmosphere.

- Due to high temperature, zinc gets diffused and due to uniform rotation gets coated on to the surfaces of small articles in contact there by forming an iron – alloy on the surface of base metal.

- As the heating and rotation is continued, finally, on outer part of base metal surface, an uniform layer of zinc gets adhered providing a very high level protection to the base metal.

- Method is highly advantageous, because the operation is simple, cost is low and it can provide a very thin layer of zinc on small articles with intrinsic

designs without changing the shapes or dimensions. Such zinc coated steel is used in making furnitures, hinges, window casements etc.

Alloys

Syllabus topic : Introduction

Q. What is an alloy ? *(Dec. 2013, May 2014, May 2015)*

Ans. :

Alloy :

- *An alloy is a solid mixture of two or more metals or non-metals.* Alloy must have necessarily,

    (i) at least one metal (base metal)

    (ii) at least one additional metal or non-metal.

- Alloy can also be defined *as a solid solution where the solutes are the alloying elements whereas the solvent is the element in excess proportion (base or main metal).*

Syllabus topic : Purpose of Making Alloys

Q. Explain any four purposes of alloying with suitable examples.

(Dec. 2013, May 2014, May 2015, May 2016)

Ans. :

Purposes of alloying

- The purpose of alloying the metal is to improve,

    (i)   Hardness

    (ii) Tensile strength

    (iii) Corrosion resistance

    (iv) Castability

    (v)   Colours While to decrease,

    (vi) Melting point

Syllabus topic : Plain Carbon Steels

Q.   What are the drawbacks of plain carbon steels ? (*May 2014, Dec. 2014, May 2016*)
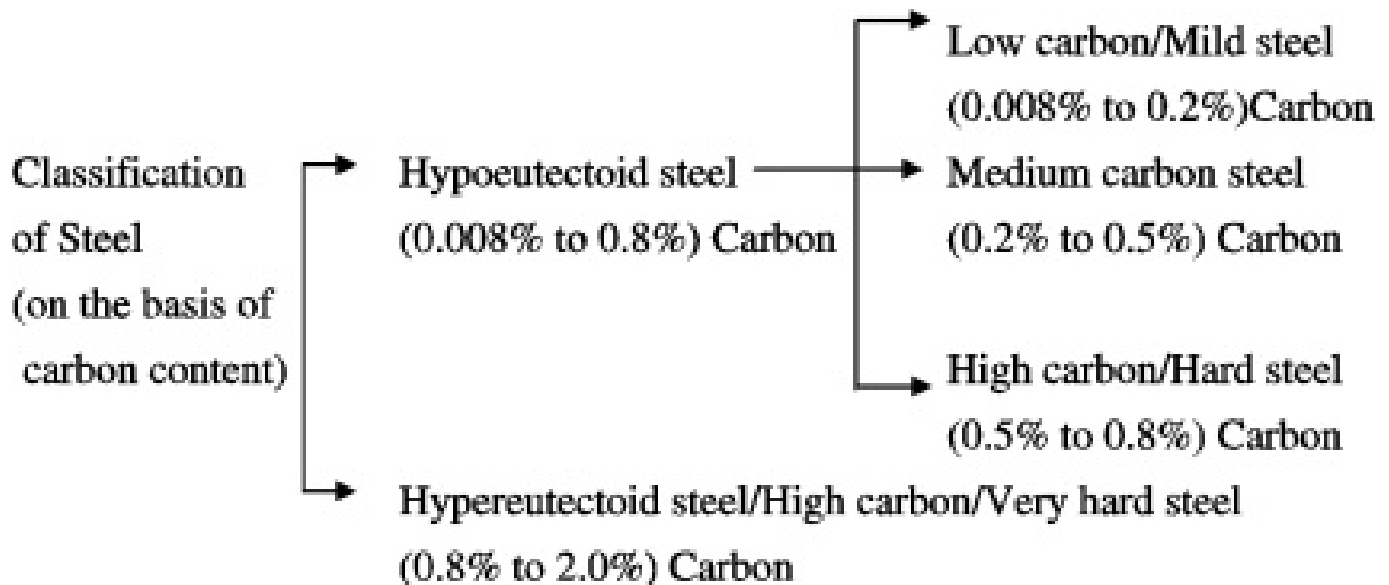
Ans. :

Drawbacks of plain carbon steels

(i)   With increasing percentage of carbon, the *ductility decreases* and *brittleness increases.*

(ii) Plain carbon steels cannot be deep hardened on heat treatment, because due to effect of heat, only *surface of steel gets hardened* while the *inner layers* of steel *remains soft.*

(iii) During the use, the *mechanical properties* of plain carbon steels get deteriorated at higher temperature. Thus the *uses of plain carbon steels* to make/manufacture various machine parts has limitation of temperature.

(iv) The *corrosion resistance* of plain carbon *steels is very*

low. As a result, this steel has *limited use* in manufacturing various machine parts, though strength and welding characteristics may be suitable.

Q. How are plain carbon steels classified based on carbon content ? *(Dec. 2014)*

Ans. :

- The **plain carbon steels** are further classified/named on the basis of its carbon content as,

Classification of Steel (on the basis of carbon content) →
- Hypoeutectoid steel (0.008% to 0.8%) Carbon →
  - Low carbon/Mild steel (0.008% to 0.2%)Carbon
  - Medium carbon steel (0.2% to 0.5%) Carbon
  - High carbon/Hard steel (0.5% to 0.8%) Carbon
- Hypereutectoid steel/High carbon/Very hard steel (0.8% to 2.0%) Carbon

Q. What are plain carbon steels ? *(May 2016)*

Ans. :

Plain carbon steels

- The alloys of iron with other metal (s) or/and non-metal are known as *ferrous alloys*. The metal iron generally forms alloys by mixing with carbon, known as "Plain Carbon Steels".

- Since these steels essentially contain iron and carbon, are known as plain carbon steels. The percentage of carbon in steels ranges from 0.008% to 2%.

Q. Explain the effect of the following alloying elements on steel :

(i) W   (ii) MO

(iii) Ni   (iv) Cr *(Dec. 2012)*

OR

Q. Explain the effect of following elements on alloying :

(i) Nickel   (ii) Chromium

(iii) Cobalt   (iv) Molybdenum

(v) Tungsten. *(May 2013, May 2014, Dec. 2014, May 2015)*

Ans. :

Sr. No.	Element	Special Effects
i)	Nickel	Enhances ductility, toughness, resistance to heat and corrosion elasticity, tensile strength etc.
ii)	Chromium	Added upto 18 % Enhances hardenability, corrosion and oxidation resistance, increases high-temperature strength. In high carbon steels, it increases abrasion resistance and toughness.
iii)	Cobalt	Contributes to hardness of steel.
iv)	Manganese	Improves certain properties with respective range of proportions : e.g. 1.0 to 1.5 % = Steel gains toughness plus brittleness, also improves strength. If high % i.e. 11 to 14 % = Steel gains high degree of hardness.
v)	Molybdenum	Enhances, (i) Resistance to softening in tempering. (ii) Tensile and creep strengths at high temperatures. (iii) Hardenability (iv) Corrosion resistance of stainless steels especially in chloride environment. (v) In austenite the grain coarsening temperature. (vi) Resistance to susceptibility to embrittlement during tempering
vi)	Tungsten	It helps to form hard and abrasion resisting carbide film in tool steels. Increases shock resistance ; Imparts high temperature hardness in tempered steels. It enhances creep strength in some high temperature steels.
vii)	Vanadium	Increases hardenability, tensile strength, shock resistance, ductility.

Syllabus topic : Non-Ferrous Alloys

Q. Give the composition and uses of Duralumin. *(May 2012, Dec.2014, May 2016)*

Ans. :

Element Composition	Properties	Uses
(a) Duralumin Al = 95% Cu = 4% Mn = 0.5% Mg = 0.5%	It is light weighted, tough, highly ductile, easily castable, good conductor of heat and electricity and corrosion resistant. It can easily be worked as it possesses high machinability. Its tensile strength can be raised by heat treatment, upto about 2000 kg-cm² without affecting its ductility. It approaches steel in strength and yet its density is one third that of steel.	Due to high strength with low density, it finds extensive use in aircraft industry in the form of a 'clad'. It is also used in making surgical instruments, cables, fluorescent tube caps etc. It is also used in making automobile and locomotive parts because of its high ductility and good electrical conductivity.

Q. Give the composition, properties and uses of Gun metal. *(Dec. 2012, May 2016)*

Ans. :

Sr. No.	Name of alloy	Composition	Properties	Uses
i)	Gun metal	Cu = 85% Zn = 4% Sn = 8% Pb = 3%	Highly strong, can resist explosion, hard, tough.	For hydraulic fittings, high pressure steam plants marine pumps, water fillings etc.

Q. Give the composition, properties and uses of German

silver. *(May 2013, Dec. 2015)*

Ans. :

Sr. No.	Name of alloy	Composition	Properties	Uses
1)	German silver	Cu = 25-50 % Zn = 10-35 % Sn = 5-35 %	Posseses good strength, high corrosion resistance to electrolyte ; High ductility, malleability. Appears like silver.	Decorative articles, utensils, table wares, ornaments, cutlery, etc.

Q. Distinguish between Brass and Bronze. *(May 2013, Dec. 2015)*

Ans. :

Brasses	Bronzes
1. These are non-ferrous alloys of copper, with zinc, known as "Common Brasses"	These are non-ferrous alloys of copper with tin common bronzes.
2. They may contain trace amount of tin, apart from Cu and Zn, known as "Special Brasses".	They may contain trace amount of Phosphorus / Aluminium / Iron – special bronzes.
(3) **Main brasses are :** (a) Commercial brass (b) Dutch metal (c) Cartridge brass	**Main Bronzes are :** (a) Coinage/common bronze (b) Gun metal (c) High phosphorus bronze
(4) **Special brasses are :** (a) German silver (b) Admirality brass	**Special bronzes are :** (a) Nickel bronze (b) Aluminium bronze
(5) Copper % ranges between 25 to 90 % in different brasses.	Copper % ranges between 80 to 95% in different bronzes.

Q. Give the composition, properties and uses of Wood's metal. (*Dec. 2013, May 2014*)

Ans. :

Sr. No.	Name of alloy	Composition	Properties	Uses
i)	Woods metal	Bi = 50 % Pb = 25 % Sn = 12.5 % Cd = 12.5 %	Melting point 65.5°C Density 9.7 gms/cu.cm Stable. Incompatible with acids, oxidizing agents, halogens, interhalogen compounds. Harmful by inhalation or if swallowed. May be harmful in contact with the skin. Skin and eye irritant. Non-hazardous for air, sea and road freight.	Wood's metal is useful as a low-melting solder, low-temperature casting metal, as a filler when bending thin-walled metal tubes. Wood's metal is also useful for repairing antiques.

Q. What are alloy steels ? Explain special effects of the following metals on properties of alloy steels :
(i) Chromium (ii) Nickel (iii) Cobalt (iv) Tungsten *(Dec. 2013)*

Ans. :

Aloy steels

- These are steels which are exposed to high temperatures during preparation of equipments.

- Heat resistance / sustainance is improved by adding specific metals in appropriate proportion.

Sr. No.	Element	Special Effects
i)	Nickel	Enhances ductility, toughness, resistance to heat and corrosion elasticity, tensile strength etc.
ii)	Chromium	Added upto 18 % Enhances hardenability, corrosion and oxidation resistance, increases high-temperature strength. In high carbon steels, it increases abrasion resistance and toughness.
iii)	Cobalt	Contributes to hardness of steel.
iv)	Manganese	Improves certain properties with respective range of proportions : e.g. 1.0 to 1.5 % = Steel gains toughness plus brittleness, also improves strength. If high % i.e. 11 to 14 % = Steel gains high degree of hardness.
v)	Molybdenum	Enhances, (i) Resistance to softening in tempering. (ii) Tensile and creep strengths at high temperatures. (iii) Hardenability (iv) Corrosion resistance of stainless steels especially in chloride environment. (v) In austenite the grain coarsening temperature. (vi) Resistance to susceptibility to embrittlement during tempering
vi)	Tungsten	It helps to form hard and abrasion resisting carbide film in tool steels. Increases shock resistance ; Imparts high temperature hardness in tempered steels. It enhances creep strength in some high temperature steels.

Syllabus topic : Powder Metallurgy

Q. What is powder metallurgy ? Explain cold powder extrusion moulding.

(May 2012, Dec. 2013, Dec. 2014, May 2015)

Ans. :

Powder metallurgy

Powder metallurgy is a process which deals with the product of useful components from fine metal powders, from individual, mixed or alloyed with or without the

inclusion of non-metallic constituents.

The ceramic powder alone or with a binder are fed to die made out of rigid material.

There are two modes for cold pressing :

(a) Axial   (b) Isostatic

Axial Process

In this powders are compacted between two punches as shown in Fig. 2.9.1 The steps are as shown,
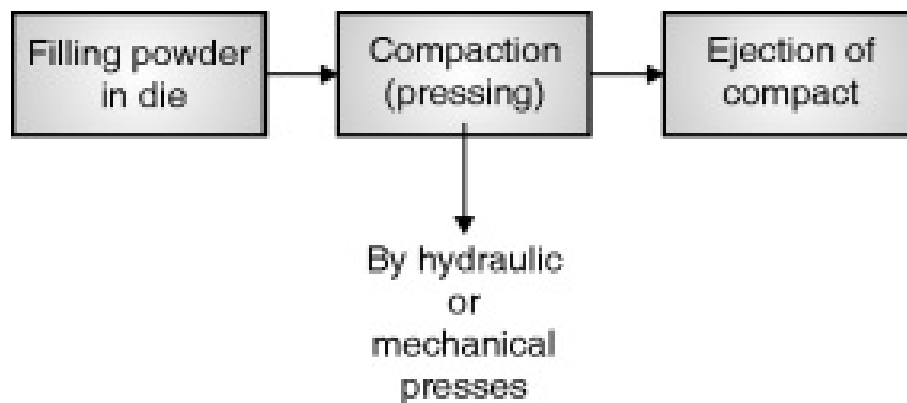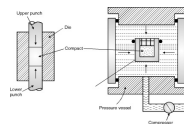

Fig. 2.9.1

Advantages

(1) The process is simple, economical
(2) It is used for mass production.

(a) Axial pressing   (b) Isostatic pressing

Fig. 2.9.2 : Schematic representation of cold pressing principles

Isostatic Pressing

In this the powder is compacted by taking in die, applying high pressure.

Q. What are ceramic powders ? Discuss the manufacture and use of alumina. *(May 2012)*

OR

Q. What are ceramic powders ? Explain manufacture of silicon carbide ceramic powder.

(Dec. 2012)

OR

Q. Explain manufacture of high purity alumina ceramic powder. *(May 2016)*

Ans. :

Alumina is most widely used ceramic.

There are two types of alumina on the basis of purity :

(a) High purity

(b) Low purity

(1) Manufacture

(a) High purity alumina : Purity > 99.99 % it is prepared by using highly pure precursor salts of aluminium such as sulphates / nitrides / chlorides, which are decomposed to give alumina ceramic powder.

(b) Low purity alumina : This is produced from aluminium ore-bauxite by Bayer process – yielding two oxides, i.e. Al_2O_3 and Fe_2O_3 with trace quantity of other oxides. Alumina is

separated from other oxides by converting into sodium aluminate which is inturn converted into $Al(OH)_3$ by hydrolysis and then calcined to get Al_2O_3.
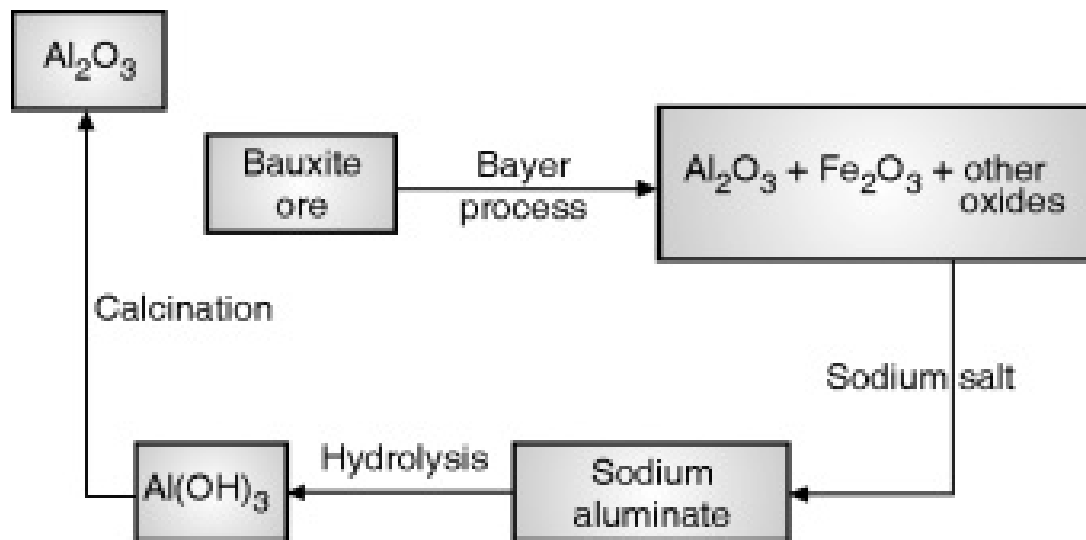
Fig. 2.11.1

(2) Uses of alumina

- High purity alumina is used

    (1) To make high transluscent tubes used in sodium vapour lamps

    (2) In various high tech electronic applications,

Q.   Explain the powder injection moulding method for compacting in powder metallurgy.

(Dec. 2012, Dec. 2014, May 2016)

Ans. :

The metal / ceramic powder is converted into suitable feed stock. Then it is mixed with a chemical compound which acts as "binder". The role of binder is to impact flow properly to feed stock, which enable it to be mouldable

under conditions of temperature.
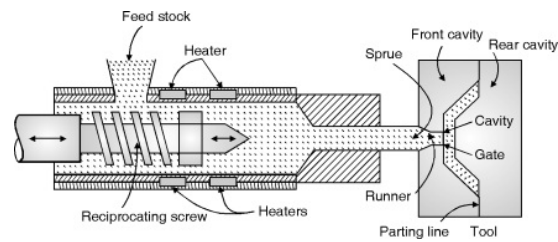
Fig. 2.9.3 : Schematic representation of powder injection moulding equipment

The feed stock is heated, to melt and then is forced through sprue and runner channel as shown in Fig. 2.9.3.

Uses : PIM is used to mould complicated shapes.

Q. Write a note on Compacting and Sintering. *(May 2013)*

OR

Q. What is 'compaction' in powder metallurgy ? *(May 2016)*

Ans. :

The sintering operation consists of following steps :

(i) Heating the compacted components in furnaces provided with controlled atmosphere.

(ii) Soaking

(iii) Cooling

The heating is done keeping temperature below the melting point of all principal constituents of compact, or in certain cases at least any one constituent of compact.

The different types of furnaces used for sintering operation are

(a) Belt type

(b) Walking beam type

(c)   Sealed high temperature batch type

(d)   Pusher type

(e)   Roller hearth type

(f)   Vaccume type.

In most commonly employed commercial sintering operations, controlled atmosphere applied/maintained, is with respect to *endothermic gas, nitrogen-hydrogen mixture, exothermic gas, cracked ammonia etc.*

Compacting

- The blended and mixed metal powders are then fed into suitable dies to give them desired shape. This process requires specific pressure. This is an important step in powder metallurgy, because proper shape of finished product (alloy/mixture) governs many properties.

- Compacting is important because,

  (i)   It reduces void space between metal particles

  (ii) It increases density of compact.

  (iii) It produces adhesion and cold welding of powders.

  (iv) It facilitates the sintering operation,

      (a) By deforming the powder plastically so as to allow re-crystallisation during sintering, and

      (b) By increasing the contact areas between the powder particles i.e. increasing green strength and facilitating subsequent

sintering.

The compacting is carried out in either hydraulically or mechanically operated press.

(i) Cold Pressing   (ii) Powder Injection Moulding (PIM)

(iii) Hot Compaction.

Q.   How are metal powders prepared ? *(Dec. 2013)*

Ans. :

Metal powders are generally pure products. Their degree of purity, particle size and shape depends on the method by which the metal powder is manufactured.

The following methods have been used in powder production.

1.   Mechanical communition

2.   Atomisation

3.   Reduction of metal oxides.

4.   Electrodeposition

5.   Decomposition.

Q.   List various steps involved in powder metallurgy. Mention the aim of each step.

Give any two advantages of powder metallurgy. *(May 2014)*

Ans. :

Thus powder metallurgy can be summarised in following steps/stages.

(a)   Converting metal/s into powders.

(b) Blending and mixing of powders.

(c) Pressing or compressing or compacting in appropriate shapes.

(d) Sintering the pressed powder compacts.

(e) Sizing or coining the product.

Solder ; An alloy of tin and lead.

*Tungsten carbide cutting tool tip*s

Powder metallurgy is used in manufacturing alloys such as *Wood's metal*, where hot intimate mixture of powders of respective constituents is compressed under high pressure in a mould.

Advantages of powder metallurgy

Powder metallurgy has been proved to be advantageous over other usual techniques in multiple ways, such as,

- By PM, materials can be made using, *metal-metal* or *metal-non-metal* in any desirable compositions.

- *Dimensional accuracy* and *finish of the materials are excellent.*

Q. How are metal powders prepared using.

  (i) Atomization

  (ii) Chemical reduction *(May 2015)*

Ans.:

(i) Atomization

In this method, liquid metal is forced through a small

orifice and jet of liquid is broken down by blast of compressed gas. Now a days in advanced/modified atomisation process, the metal is atomised by striking a rapidly rotating disc.

(ii) Reduction of Metal Oxides / Chemical Reduction

- In this process oxides of metals are reduced by using appropriate reduction technique.

- **For example :** Iron powders, are obtained by reducing iron oxides. Such oxides are obtained in the form of iron ore concentrates, mill scales or steel scraps.

- Reduction of metal oxide to metal powder is achieved using solid or gaseous reducing medium.

- **For example :** Ferrochrome, which is an alloy of chromium and iron is prepared in powder form by reducing chromium iron ore, with carbon.

❏ ❏ ❏

Syllabus Topic : Characteristic Properties of Good Fuels

Q. Give the characteristics of good fuel. *(Dec. 2012)*

Ans. :

Characteristics of good fuel

- Fuels are characterized by testing certain physical and chemical properties.

- The physical properties for which fuels are tested and their ideal requirements are listed below. This help in selection of a fuel for given purpose :

  (i) Calorific value should be as high as possible.

  (ii) Ignition temperature - Moderate

  (iii) Flame temperature should be as high as possible.

  (iv) Flash and Fire point should be as high as possible.

  (v) Aniline point should be low.

(vi) Cloud and Pour point should be as low as possible.

(vii) Viscosity should be adequate.

(viii) Coke number should be as high as possible.

(ix) Moisture content – As low as possible.

(x) Volatile matter – As low as possible

(xi) Ash matter should be absent

(xii) Easy risk free transportation should be possible.

(xiii) Storage space – Ideally fuel should occupy small space.

(xiv) Air requirements – Adequate

(xv) Harmless products should be produced on combustion

Syllabus Topic : Cracking- Definition, Types of cracking I) Thermal cracking – (i) Liquid phase thermal cracking (ii) Vapour phase thermal cracking. II) Catalytic cracking- (i) Fixed-bed catalytic cracking (ii) Moving-bed catalytic cracking. Advantages of Catalytic cracking.

Q. What is cracking ? Discuss the fixed bed catalytic cracking method in detail. *(May 2012, Dec. 2012, Dec. 2013, Dec. 2014, May 2015, Dec. 2015, May 2016)*

Ans. :

Cracking

- Cracking is a process of converging heavy oil with

higher molecular weight hydrocarbons to the oil with lower molecular weight hydrocarbon which is known as gasoline.

(a) Fixed bed catalytic cracking
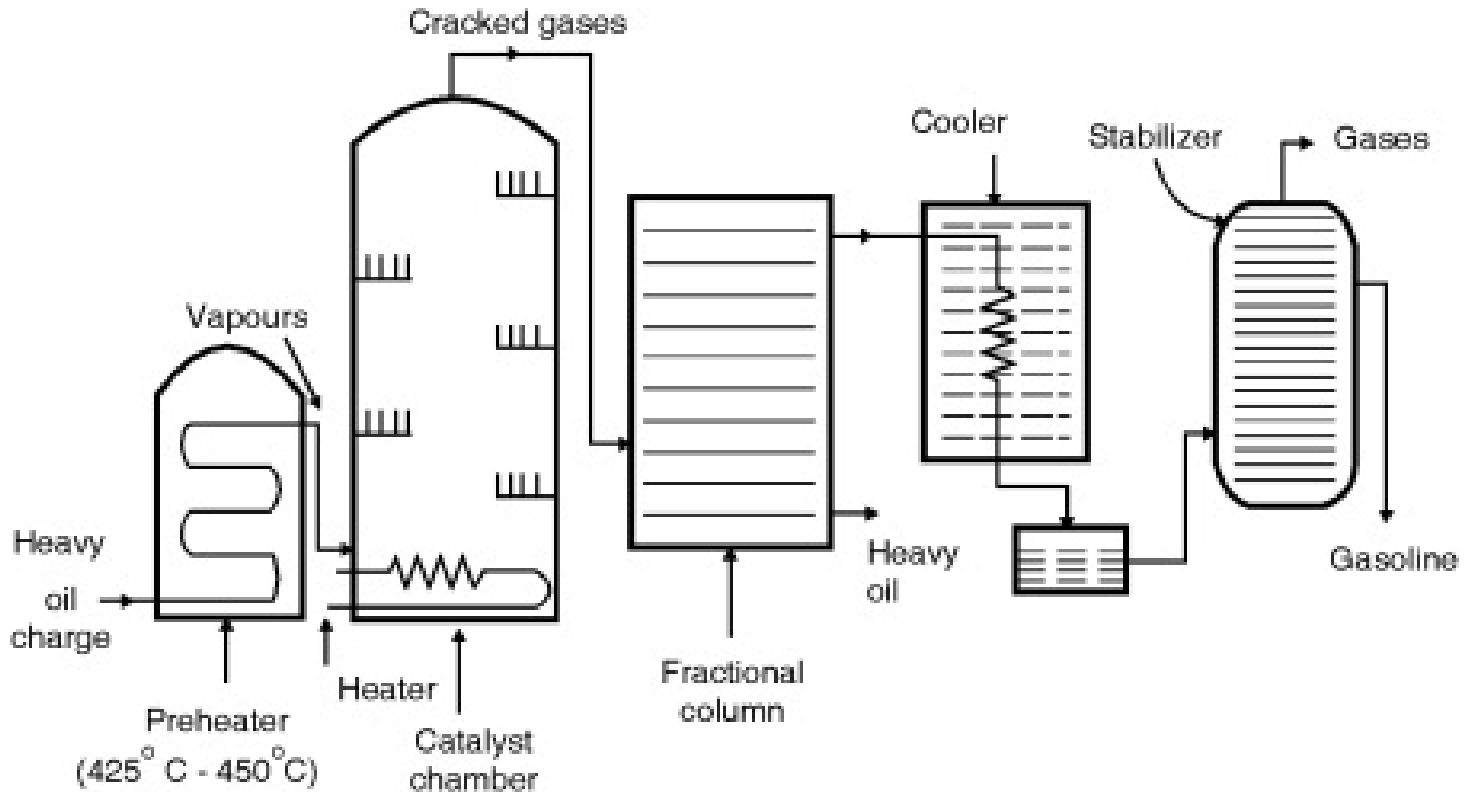
Fig. 3.7.1 : Fixed bed catalytic cracking

* In this method, vapours of the heavy oil are heated in the presence of catalyst due to which a better yield of petrol is obtained. The flow sheet of this method is shown in Fig. 3.7.1.

* In this method, heavy oil is vaporised by heating in an electrical heater. Then the vapours are passed over a series of trays containing catalyst. Generally, the catalyst used are *crystalline alumino-silicate, bentonite, bauxite and zeolites*.

- The reaction chamber is maintained at 425°C to 540°C and under a pressure of 1.5 kg/cm^2.

- The cracked gases are taken out from the top of the reaction chamber (cracker) and allowed to pass into fractionating tower, where gasoline fraction is collected. The octane value of this gasoline is about 80 – 85.

- During the cracking, free carbon is also formed which deposits on catalyst, then the flow of vapours of heavy oil is passed over the second set of reaction chamber and the catalyst in earlier chamber is regenerated by burning the carbon deposits with the help of air and reused.

Q. Mention any two advantages of catalytic cracking over thermal cracking.

(May 2014, Dec. 2014, Dec. 2015, May 2016)

Ans. :

Advantages of catalytic

i) The cracking reaction can be carried out at lower temperature and pressure.

ii) The cracking is specific in nature and can give proper quality of gasoline.

iii) The octane value of gasoline is higher by catalytic process, hence better for petrol engine.

Syllabus Topic : Petrol- Refining of petrol,

Q. What is knocking ? Define octane number. What is unleaded petrol ? *(May 2012, Dec.2015)*

Ans. :

Knocking

- Knocking is a term related to the internal combustion engine working on petrol.

- Knocking can be defined as, "a sharp metallic sound similar to rattling of hammer, which is produced in the internal combustion engine due to immature ignition of the air-gasoline mixture".

Octane number

- A petrol engine produces cracking noise and vibration together called as 'knocking' if petrol vapours entered in engine alongwith air, burns instantly (small explosion) with the firing of spark.

Unleaded petrol

This is practically zero lead quantity gasoline supplied for motor fuels.

- In car exhaust, if catalytic converter is connected, leaded petrol can not be used; because, lead destroys

the active sites of catalyst.

Q. Define Cetane number. Give their significance.

(May 2013, Dec. 2013, May 2014, Dec. 2014, Dec. 2015)

Ans. :

- Combustion of diesel takes place under compression and heat conditions :

  i) First only air is forced in cylinder and compressed to produce 500 - 700° C.

  ii) Then the oil droplets are injected into the cylinder. The oil droplets absorb heat, oil molecules get decomposed and *atomisation* takes place.

  iii) The atomised oil chemically combines with O_2 to produce more heat, expansion of combustion gases, push on the piston.

  For example,

  $$8 C + 18 H + 25 O \rightarrow 8 CO_2 + 9 H_2O$$
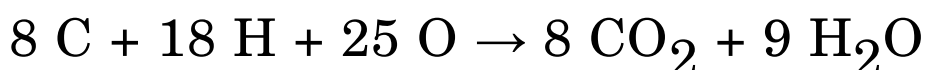
  Step (ii) should be as fast as possible (1/500 sec. for fast speed) otherwise if there is time lag then the diesel knock is produced.

- The ignition lag depends upon the engine design, type of injector and mainly on chemical nature of fuel.

- A diesel having mostly straight chain alkane molecules and minimum branched chain alkanes, negligible aromatic hydrocarbons, has least diesel

knock.

- The suitability of a diesel is determined in terms of cetane number. 2-methyl naphthalene liquid has maximum ignition lag and its cetane number is taken as zero. n-hexadecane burns in diesel engine smoothly without ignition lag and its cetane number is taken as 100.

- A standard diesel engine is taken for the study of cetane number of a diesel.

- *Cetane number of a diesel is defined as the % of n-hexadecane in the mixture of n-hexadecane and 2-methyl naphthalene which has same ignition character like the ignition character of the diesel under test.*

2-methyl naphthalene (C.N. = Zero)   n - hexadecane or cetane (C.N. = 100)
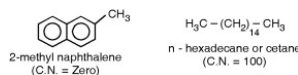
- The cetane number and structure of the hydrocarbon are related as follow :

  n-alkanes > cycloalkanes > alkenes > branched alkanes > aromatics.

- **Requirements :** The cetane number requirements are 25 for low speed engine, 35 for medium speed engine and above 45 for high speed engines.

- **Increasing cetane number :** The cetane number of a diesel can be increased by mixing diesel with oxygen atoms containing additives e.g. ethyl nitrite,

ethyl nitrate, isoamyl-nitrate, acetone peroxide etc. These additives reduce surface tension of diesel, help finer spray and atomisation easier.

- **The cetane number of some of the diesels are as follows :**

  High speed diesel $\rightarrow$ 45

  Medium speed diesel $\rightarrow$ 35

  Low speed diesel $\rightarrow$ 25.

Q. Explain refining of petroleum with suitable diagram. *(May 2013, Dec. 2015)*

Ans. :

Refining of petroleum

The gasoline obtained after fractionation of crude oil / cracking / synthesis may contain the following impurities :

(i) Some sulphur compounds

(ii) Some polyolefins [easily oxidisable hydrocarbons]

Therefore, such gasoline is treated chemically to purify it further, by removing impurities.

- Gasoline is made free from sulphur compounds by treating it with either of agents as sodium plumbite, sodium hypochlorite or by converting it to simpler compound like H_2S which can be oxidised to give free sulphur etc.

- Other agents are $CuCl_2$, Fuller's earth, sodium iso-butyrate, sodium naphthenate, activated bauxites etc.

- Gasoline is made free from other polyolefins by "Fractionating" in a tower. This step is known as "stabilization of gasoline".

Q. Define Octane number of gasoline, Name any two anti-knock agents.*(Dec. 2013, May 2014, Dec. 2014, Dec. 2015)*

Ans. :

Octane number

- For example, if a sample of petrol gives as much knocking as the mixture of 65% iso-octane and 35% n-heptane, then the octane number of petrol is 65.

- Tetra Ethyl Lead $[(C_2 H_5)_4 Pb]$.

Q. How is knocking tendency of gasoline related to chemical structure of hydrocarbons present ? *(May 2014)*

Ans. :

- Knocking is a term related to the internal combustion engine working on petrol.

- In internal combustion engine, a mixture of gasoline vapours and air is used as a fuel. The combustion or burning of a fuel is initiated by a spark in the cylinder as shown in Fig. 3.8.1.

- Due to combustion, gases are formed which move the piston down the cylinder. The rate of combustion and movement of piston depend upon the composition of fuel, temperature and design of the engine.

- The movement of the piston must be even/uniform without any vibration.

- But sometimes, the rate of combustion becomes so great that the fuel on ignition, instantaneously produces sudden increase in the gaseous volume which causes uneven movement of the piston with rattling noise in the engine. It is called as knocking of the engine. The knocking results in the loss of efficiency of I.C. engine.

- Thus knocking can be defined as, "a sharp metallic sound similar to rattling of hammer, which is produced in the internal combustion engine due to immature ignition of the air-gasoline mixture".

- Knocking causes (i) loss of large amount of energy (ii) damage to the piston and cylinder.

- The knocking tendency of a fuel increases with the composition i.e. more the carbon length in paraffins, the knocking is high.

- The petrol is a mixture of various lower hydrocarbons and the knocking of the engine depends upon the structure of hydrocarbons, present in the petrol.
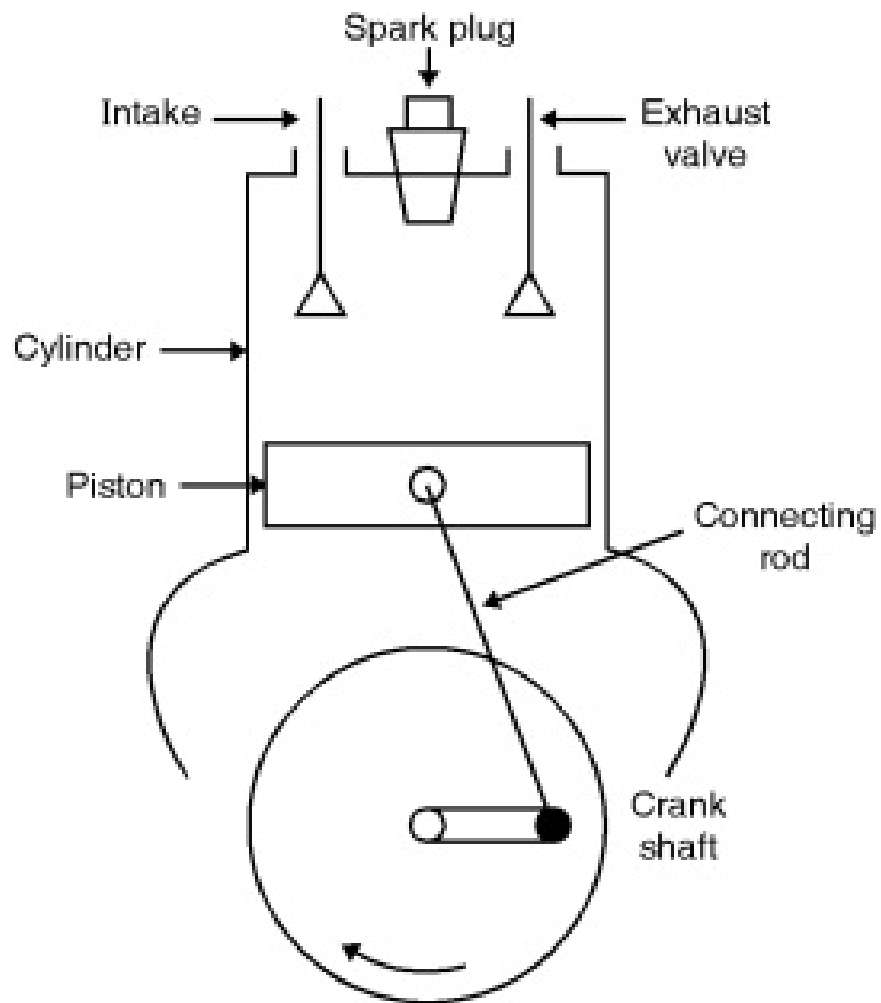
Fig. 3.8.1 : Spark in engine initiating combustion

- It is observed that the sudden burning of hydrocarbons, which produces a large volume in short time, causes knocking.

- Thus, the straight chain saturated hydrocarbons have more knocking tendency than the straight chain unsaturated hydrocarbons, as it burns with a little difficulty.

- Further, the cyclic compounds have less tendency to knock than the straight chain compounds.

- The presence of double bond and aromaticity is also important. The aromatic hydrocarbons burn uniformly, thus it has a little tendency towards

knocking. The position of double bond also matters, hydrocarbons having double bond near the centre of chain have less knocking property.

Q. With a suitable diagram, explain process of refining of petroleum. (*May 2014*)

Ans. :

Process of refining of petroleum

The gasoline obtained after fractionation of crude oil / cracking / synthesis may contain the following impurities :

(i) Some sulphur compounds

(ii) Some polyolefins [easily oxidisable hydrocarbons]

Therefore, such gasoline is treated chemically to purify it further, by removing impurities.

- Gasoline is made free from sulphur compounds by treating it with either of agents as sodium plumbite, sodium hypochlorite or by converting it to simpler compound like H_2S which can be oxidised to give free sulphur etc.

- Other agents are $CuCl_2$, Fuller's earth, sodium iso-butyrate, sodium naphthenate, activated bauxites etc.

- Gasoline is made free from other polyolefins by "Fractionating" in a tower. This step is known as "stabilization of gasoline".

Syllabus Topic : Biodiesel- Method to obtain Biodiesel from vegetable oils (Trans-

Q. What is Bio-diesel ? Explain the trans-esterification method for production of Bio-diesel from vegetable oil. What are its advantages ?

(May 2012, Dec. 2013, Dec.2014, May 2015)

Ans. :

Bio-diesel

Chemically biodiesel is *the methyl esters of long chain carboxylic acids*. Biodiesel is obtained by transesterification of vegetable oil or animal fats with methyl alcohol using sodium metal or sodium methoxide, as catalyst.

Method / Steps to obtain Biodiesel – A Green Fuel :

i) Filter the cheap or waste vegetable oil / fat.

ii) Heat it at 110° C with stirring to remove any water from it.

iii) Prepare sodium methoxide from sodium metal and methanol. Add the sodium methoxide about 2% by weight to the vegetable oil or fat.

iv) Add methanol about 20% by volume to the mixture.

v) Heat the mixture with stirring for 30 minutes.

vi) Cool and mix sufficient water, stir well. The glycerol and soap dissolve in water phase.

vii) Separate the water insoluble phase (biodiesel) from water phase.

viii) Add antioxidant to the biodiesel to avoid it to become gummy due to oxidation and polymerisation.

- Biodiesel can be obtained from various vegetable oils like soyabeen oil, palm oil, groundnut oil, cottonseed oil, musturd oil, sunflower oil etc. and also from animal fats.

- The product is given name 'biodiesel' on account of that it is obtained from biological product and it is *biodegradable material* or Green Fuel.

Advantages of Biodiesel

Biodiesel can be used as a good fuel for diesel engines but generally it is used as its 20% mixture with diesel.

i) Biodiesel is cheaper.

ii) It has high cetane numbers *46 to 54* and high C.V. of about 40 kJ/gm.

iii) It is regenerative and environment friendly.

iv) It does not give out particulate and CO pollutants.

v) It has certain extent of *lubricity*.

vi) Its use provides good market to vegetable oils and reduces our dependence for diesel on foreign countries, saving currency.

vii) It is clean to use biodiesel in diesel engines.

Syllabus Topic : Calorific Value – GCV and NCV

Example 3.3.2 (May 2016, 3 Marks)

A sample of coal has the following composition by mass : C = 70%, H = 9%, and O = 4%, S = 2%, N = 1%, and Ash = 14%. Calculate gross calorific value of the fuel using Dulong's formula.

Solution :

Given data

$$C = 70\%$$
$$S = 2\%$$
$$H = 9\%$$
$$N = 1\%$$
$$O = 4\%$$
$$Ash = 14\%$$

To calculate GCV and NCV of coal sample

$$GCV = \frac{1}{100}\left[8080\,C + 34500\left(H - \frac{O}{8}\right) + 22405\right]$$

$$= \frac{1}{100}[8080 * 70 + 34500\,(9 - 4/8) + 2240 * 2]$$

$$= \frac{1}{100}[565600 + 293250 + 4480] = \frac{1}{100}[863330]$$

$$= 8633.30 \text{ kcal/kg}$$

∴ **GCV = 8633.30 kcal / kg**   **...Ans.**

Now NCV = GCV − (0.09 × % H × 587)

$$= 8633.30 - (0.09 \times 9 \times 587)$$

$$= 8633.30 - 475.47$$

$$= \textbf{8157.83 kcal / kg}$$ **...Ans.**

Syllabus Topic : Solid Fuels

Example 3.5.4 (May 2015, 5 Marks)

A coal sample was subjected to ultimate analysis :

1.6 gm of coal on combustion in a Bomb calorimeter gave 0.47 gm of $BaSO_4$ Calculate % of sulphur in the coal sample.

Solution :

Given data :

Weight of $BaSO_4$ ppt : 0.47 gms

Weight of coal sample : 1.6 gms

$$\% \, S = \frac{\text{Weight of } BaSO_4}{\text{Weight of Coal}} \times \frac{32}{233} \times 100$$

$$= [0.47 / 1.6] \times [32 / 233] \times 100$$

$$= 4.04 \ \%$$

Syllabus Topic : Solved Numericals (GCV, NCV Calculations by Dulong Formula)

Example 3.12.13 (May 2012, 4 Marks)

A sample of coal has the following composition – C = 90%, H = 8%, N = 2%, S =1.5%, O = 5% and remaining ash. Calculate the GCV and LCV (Latent heat of condensation of steam = 587 cal/g)

Solution :

$$G.C.V. = \frac{1}{100} \left[8080 \times C + 34500 \left(H - \frac{O}{8} \right) + 2240S \right] \text{Kcal/kg}$$

$$= \frac{1}{100} \left[8080 \times 90 + 34500 \left(8 - \frac{5}{8} \right) + 2240 \times 1.5 \right] \text{Kcal/kg}$$

$$= \frac{1}{100} \left[727200 + 254437.5 + 3360 \right] \text{Kcal/kg}$$

$$= \frac{1}{100} \left[984997.5 \right] \text{Kcal/kg}$$

$$\therefore \quad \text{G.C.V.} \quad = \quad 9849.975 \text{ K.cal/kg}$$

$$\text{LCV} \quad = \quad \text{G.C.V.} - [\ 0.09 \times H \times 587\ ] \text{ kcal/kg}$$

$$= \quad 9849.975 - [0.09 \times 8 \times 587\ ] \text{ kcal/kg}$$

$$= \quad [9849.975 - 422.84] \text{ kcal/kg}$$

$$\therefore \quad \text{L.C.V.} \quad = \quad 9427.335 \text{ kcal/kg}$$

> **Ans. :** *G.C.V. = 9849.975 kcal.kg*
> *L.C.V. = 9427.335 kcal/kg*

Example 3.12.14 (Dec. 2013, 5 Marks)

A sample of coal has the following composition by weight : C = 82%, H = 6%, O = 8%, S = 0.5%, N = 3% and Ash = 0.5%. Calculate the Gross and Net Calorific value using Dulong's formula.

Solution :

To Calculate Gross and Net calorific value,

Dulong formula,

$$\text{G.C.V} = \frac{1}{100} \left[8080\ C + 34500 \left(H - \frac{O}{8} \right) \right] + 2240\ S) \text{ kcal\textbackslash kg}.$$

$$= \frac{1}{100} \left[8080 \times 82 + 34500 \left(6 - \frac{8}{8} \right) + 2240 \times 0.5 \right] \text{kcal\textbackslash kg}$$

$$= \frac{1}{100} [662560 + 172500 + 1120] \text{ kcal/kg}$$

$$= \frac{1}{100} [836180] = \boxed{8361.80 \text{ kcal/kg}}$$

$$\text{G.C.V} \quad = \quad 8361.80 \text{ kcal/kg} \qquad \textbf{...Ans.}$$

$$\text{Net Calorife Value} = \text{G.C.V.} - \left[\frac{9 \times H}{100} \times 587 \right] \text{kcal\textbackslash kg}.$$

$$= 8361.80 - \left[\frac{9 \times 6}{100} \times 587 \right] \text{ kcal\textbackslash kg}$$

$$= \quad 8361.80 - 316.98$$

$$\text{N.C.V} = \boxed{8044.82 \, \text{kcal}\backslash\text{kg.}}$$

Example 3.12.15 (May 2014, 5 Marks)

A sample of coal has the following composition by mass : C = 80%, H = 4%, O = 6%, S = 3%, N = 2% and Ash = 5%. Calculate gross and net calorific value using Dulong's formula.

Solution :

$$GCV = \frac{1}{100}\left[8080\,C + 34500\left(H - \frac{O}{8}\right) + 2240\,S\right]$$

$$= \frac{1}{100}\left[8080 \times 80 + 34500\left(4 - \frac{6}{8}\right) + 2240 \times 3\right]$$

$$= \frac{1}{100}\left[646400 + 112125 + 6720\right] = \frac{1}{100}\left[765245\right]$$

$$\therefore \quad GCV = \boxed{7625.45 \, \text{Kcal} / \text{Kg}}$$

$$\therefore \quad NCV = GCV - (0.09\,H \times 587)$$

$$= 7625.45 - (0.09 \times 4 \times 587) = 7625.45 - (211.32)$$

$$\therefore \quad NCV = \boxed{7414.13 \, \text{Kcal} / \text{Kg}}$$

> **Ans. :**   G.C.V. = **7625.45 kcal/kg.**
> N.C.V. = **7414.13 kcal/kg.**

Example 3.12.16 (Dec. 2014, 3 Marks)

A sample of coal has the following coraposition by mass : C = 75%, H = 7%, O = 8%, S = 4%, N = 2% and Ash = 4 %. Calculate Gross Calorific value of the fuel using Dulong's formula.

Solution :

$$H.C.V = \frac{1}{100}\left[8080\,C + 34500\left(H - \frac{O}{8}\right) + 2240\,S\right]$$

$$= \frac{1}{100}\left[8080 \times 75 + 34500\{7 - 8/8\} + 2240 \times 4\right]$$

$$= \frac{1}{100}\left[606000 + 34500\{7 - 1\} + 8960\right]$$

$$= \frac{1}{100}\left[606000 + 207000 + 8960\right]$$

$$= \frac{1}{100} \, [821960] = \boxed{8219.60 \text{ kcal/kg.}}$$

$$\text{L.C.V.} = \left[\text{H.C.V} - \frac{9}{100} \text{H} \times 587\right] \text{kcal/kg.}$$

$$\text{L.C.V.} = \left[\text{H.C.V} - \frac{9}{100} \text{H} \times 587\right] \text{kcal/kg.}$$

$$= [8219.60 - 0.09 \times 7 \times 587]$$

$$= [8219.60 - 369.81] = \boxed{7849.79 \text{ kcal/kg.}}$$

Ans. :   H.C.V. = 8219.60 kcal/kg.

L.C.V. = 7849.79 kcal/kg.

Syllabus Topic : Solved Numericals : Combustion of Solid Fuels - Requirement of weight and Volume of O₂ and Air

Example 3.13.12 (Dec. 2012, 6 Marks)

Calculate the weight and volume of air required for complete combustion of 1 kg of coal containing ; C = 65%, H = 4%, O = 7%, N = 3%, moisture = 15% and remaining is ash. (molecular weight of air = 28.94g)

Solution :

$$\therefore \text{ Volume of air required } =$$

$$\because \quad 28.94 \text{ Kg air } \equiv 22400 \text{ ml Volume at NTP}$$

$$\therefore 8.6087 \text{ Kg air } = \left[\frac{22400 \times 8.6087}{28.94}\right] = 6663.27 \text{ ml}$$

$$= \boxed{6.663 \text{ litres.}}$$

Ans. : Wt. of air needed = 8.6087 Kg.
Volume of air needed = 6.663 litres.

Example 3.13.13 (May 2013, 6 Marks)

A Coal sample has the following composition by weights :
C = 82%, H = 3%, O = 8%, S = 2%, N = 2% and Ash = 3%.
Calculate the minimum amount of air required both by
weight and volume for complete combustion of 2 kg of
coal. (Molecular weight of air = 28.949 gm)

Solution :

Calculation of Weight of O_2 needed for 1 Kg of coal

% Constituent	Weight in kg.	Combustion Reaction	Weight of O_2 in kg.
C = 82	0.82	$C + O_2 \rightarrow CO_2$ 12 32	$0.82 \times \dfrac{32}{12} = 2.187$
H = 3	0.03	$H_2 + \dfrac{1}{2}O_2 \rightarrow H_2O$ 2 16	$0.03 \times \dfrac{16}{2} = 0.240$
S = 2	0.02	$S + O_2 \rightarrow SO_2$ 32 32	$0.02 \times \dfrac{32}{32} = 0.020$
O = 8	0.08	–	0.08
		Total O_2 Required	= 2.447
		Oxygen available	– 0.080
		∴ Oxygen needed	2.367 kg.

$$\therefore \text{Weight of air needed} = 2.367 \times \frac{100}{23} \text{ Kg}$$

$$= \quad 10.29 \text{ kg.}$$

$\therefore$ Weight of air for 2 kg coal $= (10.29 \times 2)$

$= \boxed{20.58 \, \text{kg}}$

To calculate volume of air for 2 kg coal,

$\because 28.949 \, \text{kg air} \equiv 22.4 \, \text{Litres}$

$\therefore 20.58 \, \text{kg air} \equiv \left(\dfrac{22.4 \times 20.58}{28.949} \right) \text{Litres}$

$\equiv \boxed{15.92 \, \text{Litres}}$

Ans. : *Weight of air = 20.58 kg*

Volume of air = 15.92 L

Syllabus Topic : Solved Numericals : Combustion of Gaseous Fuels – Requirement of Oxygen and Air [Volume and Weight]

Example 3.14.9 (May 2015, 5 Marks)

A gaseous fuel has the following composition by volume.

CH_4 = 35%, C_2H_4 = 5%, CO = 15%, H_2 = 40% N_2 = 1

water vapour = 4%

Calculate volume and weight of air required for complete combustion of $1m^3$ of fuel. [molecular weight of air = 28.94]

Solution :

Given data : CH_4 = 35 %, C_2H_4 = 5 %, CO = 15%,

O_2 = Nil

H_2 = 40 %, CO_2 = 2 %, N_2 = 1 %,

Water Vapours = 4 %

Calculate of quantity of O_2

Component	Reaction	Volume of O_2
$CH_4 = 0.35\ m^3$	$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$	$0.35 \times 2 = 0.7\ m^3$
$C_2H_4 = 0.05\ m^3$	$C_2H_4 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$	$0.05 \times 3 = 0.15\ m^3$
$CO = 0.15\ m^3$	$CO + \frac{1}{2}\ O_2 \rightarrow CO_2$	$0.15 \times \frac{1}{2} = 0.075\ m^3$
$H_2 = 0.4\ m^3$	$H_2 + \frac{1}{2}\ O_2 \rightarrow H_2O$	$0.4 \times \frac{1}{2} = 0.2\ m^3$

Volume of (Total) O_2 required = 1.125 m³

O_2 available in fuel = 0.00

∴ Net O_2 required = 1.125 m³

∴ Volume of air required = 1.125 × 100 / 21 m³

= 5.357 m³ = 5357 Ltrs

∴ Weight of air

∴ 22.4 litres = 28.94 kg air

∴ 5357 litres = 5357 × 28.94 / 22.4] kg of air

= 6921 kg of air

Ans. : Volume of air = 5.357 m^3 or 5357 litres

Weight of air = 6921 kg

Example 3.14.14 (May 2012, 4 Marks)

A gaseous fuel has the following composition by volume :
H_2 = 35%, CH_4 = 45% C_2H_6 = 6%, CO=12% and remaining N_2. Calculate the minimum amount of air required a 27°C and 760 mm Hg pressure for the complete combustion of 1 cu.m of the fuel.

Solution :

$$H_2 = 0.35\ m^3, \quad C_2H_6 = 0.06\ m^3$$

$$CH_4 = 0.45\ m^3, \quad CO = 0.12\ m^3$$

Calculate of O_2 required

Sr. No.	Reaction	Volume of O_2 required
1.	$H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$ 1 vol. 0.5 vol.	$0.35 \times 0.5 = 0.175 \, m^3$
2.	$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O$ 1 vol. 2 vol.	$0.45 \times 2 = 0.90 \, m^3$
3.	$C_2H_6 + 3.5\,O_2 \longrightarrow 2CO_2 + 3\,H_2O$ 1 vol. 3.5 vol.	$0.06 \times 3.5 = 0.210 \, m^3$
4.	$CO + \frac{1}{2}\,O_2 \longrightarrow CO_2$ 1 vol. 0.5 vol.	$0.12 \times 0.5 = 0.06 \, m^3$
5.	N_2 No reaction.	—
	$\therefore$ Total O_2 required	$= 1.345 \, m^3$
	O_2 present in fuel.	Nil

$\therefore$ Volume of air required $=$ Volume of $O_2 \times \dfrac{100}{21}$

$$= \left(1.345 \times \frac{100}{21} \right) m^3$$

$$= 6.4048 \, m^3$$

$$= 6.4048 \text{ litres of air}$$

$\therefore$ Weight of air $=$ $\because$ 22.4 litres air $\equiv$ 28.94 kg

$$\therefore \quad 6.4048 \text{ litres air} \equiv$$

$$= \boxed{8.274 \text{ kg}}$$

$$\text{Now,} \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\therefore \quad \frac{760 \times 6.4048}{273} = \frac{760 \times V_2}{273}$$

$$\therefore \quad V_2 = \frac{6.4048 \times 300}{273} = \boxed{7.038 \text{ litres air}}$$

$\therefore$ Weight of air at 760 mm and 27°C :

$\because$ 22.4 litres air $\equiv$ 28.94 kg

$\therefore$ 7.038 litres air $\equiv$ 9.092 kg

Ans. : Volume of air = 7.038 Litres

Weight of air = 9.092 kg

Example 3.14.15 (May 2013, 5 Marks)

A gaseous fuel has the following composition by volume : H_2 = 10%, CH_4 = 30%, C_3H_8 = 20%, CO = 20%, CO_2 = 15%, N_2 = 5%. Calculate the volume of air required for complete combustion of $1m^3$ of this gas.

Solution :

Calculation of volume of O_2 required for complete combustion of $1m^3$ of geseous fuel.

% Constitute	Volume of constituent (m^3)	Combustion Reaction	Volume of O_2 required m^3
$H_2 = 10$	$0.10 \, m^3$	$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ 1 0.5	$0.10 \times 0.5 = 0.05$
$CH_4 = 30$	$0.30 \, m^3$	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ 1 2	$0.30 \times 2 = 0.60$
$C_3H_8 = 20$	$0.20 \, m^3$	$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ 1 5	$0.20 \times 5 = 1.00$
$CO = 20$	$0.20 \, m^3$	$CO + \frac{1}{2} O_2 \rightarrow CO_2$ 1 0.5	$0.20 \times 0.5 = 0.10$
CO_2 and N_2		No Combustion Reaction	
		∴ Total O_2 required	$1.75 \, m^3$

$$\therefore \text{Volume of air} = \text{Volume of } O_2 \times \frac{100}{21} = \left(1.75 \times \frac{100}{21}\right) m^3$$

$$= \boxed{8.333 \, m^3}$$

$$= \boxed{8333 \, \text{litres}}$$

Ans.: **Volume of air required = 8333 L**

Example 3.14.16 (Dec. 2013, 6 Marks)

A gaseous fuel has the following composition by volume :
$H_2 = 50\%$, $CO = 10\%$, $CH_4 = 30\%$, $C_2H_4 = 5\%$, $N_2 = 1\%$, $O_2 = 2\%$ and $CO_2 = 2\%$. Calculate volume and weight of air required for complete combustion of $1m^3$ of fuel. (Molecular weight of air = 28.949)

Solution :

Calculation of volume of O_2 in m^3 for 1 m^3 of gaseous fuel

Sr. No.	Constituent %	Constituent Volume – m^3	Combustion Reaction	Volume of O_2
1.	$H_2 = 50$	0.5	$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ 1 1/2	$0.5 \times 0.5 = 0.25$
2.	$CO = 10$	0.1	$CO + \frac{1}{2} O_2 \rightarrow CO_2$ 1 $\frac{1}{2}$	$0.1 \times 0.5 = 0.05$
3.	$CH_4 = 30$	0.30	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ 1 2	$0.3 \times 2.0 = 0.60$
4.	$C_2H_4 = 5$	0.05	$C_2H_4 + 3O_2 \rightarrow 2\,CO_2 + 2\,H_2O$ 1 3	$0.05 \times 3 = 0.15$
5.	N_2 and CO_2	No reaction	**Total O_2 required**	1.05
6.	$O_2 = 2$	0.02	**O_2 available in fuel**	0.02
			$\therefore O_2$ needed	$1.03\ m^3$

$\therefore$ Volume of air needed $= \left(\text{Volume of } O_2 \text{ needed} \times \frac{100}{21}\right) m^3$

$= 1.03 \times \frac{100}{21}$

$= 4.904\ m^3 = \boxed{4904\ litres}$

$\therefore$ Weight of air :

$\because$ 22.4 litres air $= 28.94$ kg

$\therefore$ 4904 litres air $= \boxed{\frac{4904 \times 28.94}{22.4}}$ kg air.

$= \boxed{6338\ kg\ air}$

Ans. : Volume of air needed = 4905 L
Weight of air needed = 6338 kg

Example 3.14.17 (May 2014, 6 Marks)

A gaseous fuel has the following composition by volume. H_2 = 55%, CH_4 = 30%, C_2H_4 = 5%, CO = 5%, N_2 = 1%, CO_2 = 2% and O_2 = 2%. Calculate volume and weight of air required for complete combustion of $1m^3$ of fuel. (Molecular weight of air = 28.949)

Solution :

Calculation of volume of O_2 in m^3 for 1 m^3 of gaseous fuel

Sr. No.	Constituent %	Constituent Volume – m^3	Combustion Reaction	Volume of O_2
1.	H_2 = 55	0.55	$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ 1 1/2	$0.55 \times 0.5 = 0.275$
2.	CO = 5	0.05	$CO + \frac{1}{2} O_2 \rightarrow CO_2$ 1 $\frac{1}{2}$	$0.05 \times 0.5 = 0.025$
3.	CH_4 = 30	0.30	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ 1 2	$0.3 \times 2.0 = 0.60$
4.	C_2H_4 = 5	0.05	$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$ 1 3	$0.05 \times 3 = 0.15$
5.	N_2 and CO_2	No reaction	Total O_2 required	1.05
6.	O_2 = 2	0.02	O_2 available in fuel	0.02
			$\therefore O_2$ needed	1.03 m^3

$$\therefore \text{Volume of air needed} = \left(\text{Volume of O}_2 \text{ needed} \times \frac{100}{21}\right) m^3$$

$$= 1.03 \times \frac{100}{21}$$

$$= 4.904 \, m^3 = \boxed{4904 \text{ litres}}$$

$\therefore$ Weight of air :

$$\because \quad 22.4 \text{ litres air} \equiv 28.94 \text{ kg}$$

$$\therefore \quad 4904 \text{ litres air} \equiv \left[\frac{4904 \times 28.94}{22.4}\right] \text{ kg air.}$$

$$\equiv \boxed{6338 \text{ kg air}}$$

Ans. : Volume of air needed = 4905 L

Weight of air needed = 6338 kg

Example 3.14.18 (Dec. 2014, 6 Marks)

A gaseous fuel has the following composition by volume :
H_2 = 40%, CH_4 = 30%, CO = 10%, C_3H_8 = 12%, N_2 = 3%,

O_2 = 2% and CO_2 = 3%. Calculate volume and weight of air required for complete combustion of $1m^3$ of fuel. (Molecular Weight of air = 28.949)

Solution :

Calculation of volume of O_2 required for complete combustion of $1m^3$ of gaseous fuel.

% Constitute	Volume of constituent (m^3)	Combustion Reaction	Volume of O_2 required m^3
H_2 = 40	0.40 m³	$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ 1 0.5	0.40 × 0.5 = 0.20
CH_4 = 30	0.30 m³	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ 1 2	0.30 × 2 = 0.60
C_3H_8 = 12	0.12 m³	$C_3H_8 + 5 O_2 \rightarrow 3 CO_2 + 4 H_2O$ 1 5	0.12 × 5 = 0.60
CO = 10	0.10 m³	$CO + \frac{1}{2} O_2 \rightarrow CO_2$ 1 0.5	0.10 × 0.5 = 0.05
CO_2 and N_2		No combustion reaction	
O_2 = 2		minus	0.02
		∴ Total O_2 required	1.42 m³

∴ Volume of air = Volume of $O_2 \times \frac{100}{21}$

= [1.42 × 100/21] m³

= 6.762 m³

= 6762 litres

∴ Weight of air :

∵ 22.4 litres air ≡ 28.94 kg

∴ 6762 litres air ≡ 6762 × 28.94 / 22.4 kg air.

≡ 8736.26 kg air

Ans. :   Volume of air needed = 6762 L

Weight of air needed = 8736.26 kg

Example 3.14.19 (May 2016, 6 Marks)

A gaseous fuel has the following composition by volume. $CO = 40\%$, $H_2 = 2\%$, $C_3H_8 = 4\%$, $CH_4 = 4\%$, $N_2 = 4\%$ and $O_2 = 6\%$. Calculate volume and weight of air required for complete combustion of $1 m^3$ of fuel (Molecular weight of air = 28.949)

Solution :

Calculation of volume of O_2 in m^3 for $1 m^3$ of gaseous fuel

Sr. No.	Constituent %	Constituent Volume – m^3	Combustion Reaction	Volume of O_2
1.	$H_2 = 42$	0.42	$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ 1 1/2	$0.42 \times 0.5 = 0.21$
2.	$CO = 40$	0.40	$CO + \frac{1}{2} O_2 \rightarrow CO_2$ 1 $\frac{1}{2}$	$0.40 \times 0.5 = 0.20$
3.	$CH_4 = 4$	0.04	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ 1 2	$0.04 \times 2.0 = 0.08$
4.	$C_3H_8 = 4$	$0.04 m^3$	$C_3H_8 + 5 O_2 \rightarrow 3 CO_2 + 4 H_2O$ 1 5	$0.04 \times 5 = 0.20$
5.	N_2 and CO_2	No reaction	Total O_2 required	0.69
6.	$O_2 = 6$	0.06	O_2 available in fuel	0.06
			$\therefore O_2$ needed	$0.63 m^3$

$$\therefore \text{ Volume of air needed } = \left(\text{Volume of O}_2 \text{ needed} \times \frac{100}{21}\right) \text{ m}^3$$

$$= 0.63 \times \frac{100}{21}$$

$$= 3.00 \text{ m}^3$$

$$= 3000 \text{ litres}$$

∴ Weight of air :

∵   22.4 litres air ≡ 28.94 kg

∴ 3000 litres air ≡ 3000 * 28.94 / 22.4 kg air.

≡ $\boxed{3875 \text{ kg air}}$

Ans. : **Volume of air needed = 3000 L**

Weight of air needed = 3875 kg

Example 3.14.20 (Dec. 2015, 6 Marks)

A gaseous fuel has the following composition by volume.

CO = 46% H_2 = 30% CH_4 = 10% C_2H_4 = 4% N_2 = 1%
CO_2 = 2% and O_2 = 7%

Calculate volume and weight of air required for complete combustion of 1m^3 of fuel. (Mol.wt of air=28.949).

Solution :

Calculation of volume of O_2 in m^3 for 1 m^3 of gaseous fuel

Sr. No.	Constituent %	Constituent Volume – m³	Combustion Reaction	Volume of O_2
1.	$H_2 = 30$	0.3	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$ $1 \qquad 1/2$	$0.3 \times 0.5 = 0.15$
2.	$CO = 46$	0.46	$CO + \frac{1}{2}O_2 \rightarrow CO_2$ $1 \qquad \frac{1}{2}$	$0.46 \times 0.5 = 0.23$
3.	$CH_4 = 10$	0.10	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $1 \qquad 2$	$0.1 \times 2.0 = 0.20$
4.	$C_2H_4 = 4$	0.04	$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$ $1 \qquad 3$	$0.04 \times 3 = 0.12$
5.	N_2 and CO_2	No reaction	**Total O_2 required**	0.70
6.	$O_2 = 7$	0.07	**O_2 available in fuel**	0.07
			∴ O_2 needed	**0.63 m³**

$$\therefore \text{Volume of air needed} = \left(\text{Volume of } O_2 \text{ needed} \times \frac{100}{21}\right) m^3$$

$$= 0.63 \times \frac{100}{21}$$

$$= 3.00 \; m^3 = \boxed{3000 \text{ litres}}$$

∴ Weight of air :

$$\because \; 22.4 \text{ litres air} \equiv 28.94 \text{ kg}$$

$$\therefore \; 3000 \text{ litres air} \equiv 3000 * 28.94 / 22.4 \text{ kg air.}$$

$$\equiv \boxed{3875 \text{ kg air}}$$

Ans.: Volume of air needed = 3000 L
Weight of air needed = 3875 kg

Example 3.15.12 (May 2012, 3 Marks)

1kg of coal sample was used for determination of Nitrogen by Kjeldhal's method. The ammonia evolved was passed into 50 ml of 0.1N sulphuric acid. The excess acid required 42ml of 0.1N NaOH for neutralization. Calculate the

percentage of N_2.

Solution :

Given data :

Weight of coal = 1 kg,   Volume of H_2SO_4 = 50 ml.

Normality of H_2SO_4 = 0.1 N,   Volume of NaOH = 4.2 ml.

Normality of NaOH = 0.1 N

To calculate % N in coal sample

$$\% \ N = \frac{\text{Volume of acid cosumed} \times \text{Normality of acid} \times 1.4}{\text{Weight of coal sample}}$$

Here, Volume of acid consumed = (50 − 42) ml.

= 8 ml.

∴ Equivalents of H_2SO_4 = 8 × 0.1

= 0.8 milli equivalents.

∴ Weight of N_2 = (0.8 × 14) gms

= 11.2 gm

$$\therefore \ \% \ N_2 = \frac{\text{Weight of } N_2}{\text{Weight of coal sample}} \times 100$$

$$\therefore \ \% \ N_2 = \frac{11.2}{1000} \times 100 = \boxed{1.12}$$

Ans. : *Volatile matter in coal = 1.12*

Example 3.15.13 (May 2012, 4 Marks)

An air dried sample of coal weighing 2.9 g was taken for volatile matter determination. After losing volatile matter the coal sample weighed 1.96 g. If it contains 4.5%

moisture, Find the percentage volatile matter in it.

Solution :

Given data :

$$\text{Weight of coal} \quad = \quad 2.9 \text{ gm}$$

$$\text{After losing volatile matter} \quad = \quad 1.96 \text{ gm}$$

$$\% \text{ moisture} \quad = \quad 4.5 \%$$

To calculate % volatile matter.

Let us calculate weight of coal after losing moisture,

Let the weight be X gms.

$$\% \text{ moisture} = \frac{\text{Loss in weight after heating in oven}}{\text{weight of coal}} \times 100$$

$$4.5 = \frac{2.9 - X}{2.9} \times 100$$

$$\frac{4.5 \cdot 2.9}{100} = 2.9 - X$$

$$\therefore \quad X \quad = \quad 2.9 - 0.1305$$

$$= \quad 2.7695 \text{ gm}$$

Now,

$$\% \text{ Volatile matter} = \frac{\text{Loss in weight due to V.M.}}{\text{Weight of coal}} \times 100$$

$$= \frac{2.7695 - 1.9600}{2.9} \times 100$$

$$= \frac{0.8095}{2.9} \times 100$$

$$= \boxed{27.91\%}$$

Ans. : *Volatile matter in coal = 27.91 %*

Example 3.15.14 (Dec. 2012, 3 Marks)

In a Kjeldahl's apparatus, 3.5g of the coal sample was analysed. The NH_3 gas evolved was absorbed in 50 ml of 0.1N H_2SO_4. The residual H_2SO_4 required 15 ml of 0.1N NaOH for neutralisation. Calculate percentage of nitrogen in the sample.

Solution :

$$\text{Weight of coal sample for } N_2 \text{ analysis} \quad = \quad 3.5 \text{ gms.}$$

$$\text{Volume of } H_2SO_4 \quad = \quad 50\text{ml}$$

$$N_{H2\,SO4} = 0.1\,N.$$

Volume of NaOH = 15 ml.

$$N_{NaOH} = 0.1\,N$$

To calculate N %

Here volume of acid consumed ($0.1\,NH_2SO_4$) = (50 – 15) ml.

$$= 35\,ml$$

$$\% N = \frac{\text{Volume of acid consumed} \times N_{acid} \times 1.4}{\text{Weight of coal}}$$

$$= \frac{35 \times 0.1 \times 1.4}{3.5} = \boxed{1.4\,\%}$$

Ans.: % N in coal Sample = 1.4 %

Example 3.15.15 (Dec. 2012, 5 Marks)

2.499 gms of coal sample was taken in silica crucible and heated in oven maintained at 110°C for one hour. The weight after heating was 2.368 gms. The same sample was analysed for volatile matter and weight obtained was 1.75g, the sample as further treated to get fixed wieght of 0.95 gms. Calculate the percentage of moisture, volatile matter, ash and fixed carbon for this sample.

Solution :

Given data

Weight of coal Sample : 2.499 gms. = w_1

Weight of coal after heating at 110°C : 2.388 gms. = w_2

Weight of coal after heating for V.M. : 1.75 gms. =

w_3

Fixed weight obtained = 0.95 gms. = w_4

$$\text{To calculate \% moisture} = \frac{\text{Loss in Weight}}{\text{Weight of coal}} \times 100$$

$$= \frac{w_1 - w_2}{w_1} \times 100$$

$$= \frac{0.111}{2.499} \times 100 = \boxed{4.44\%}$$

$$\text{To calculate \% V.M.} = \frac{\text{Loss in weight due to V.M.}}{\text{Weight of coal}} \times 100$$

$$= \frac{w_2 - w_3}{w_1} \times 100$$

$$= \frac{2.388 - 1.75}{2.499} \times 100 = \boxed{25.53\%}$$

$$\text{\% Ash} = \frac{\text{Constant weight}}{\text{Weight of coal}} \times 100$$

$$= \frac{0.95}{2.499} \times 100 = \boxed{38\%}$$

$$\text{\% Fixed carbon} = 100 - [\text{\% moisture} + \text{\% V.M.} + \text{\% Ash}]$$

$$= 100 - [4.44 + 25.53 + 38]$$

$$= 100 - [68.97]$$

$$\therefore \text{\% Fixed carbon} = \boxed{31.03\%}$$

$$\therefore \text{\% Moisture} = 4.44\%$$
$$\therefore \text{\% Volatile matter} = 25.53\%$$
Ans. :
$$\text{\% Ash} = 38.00\%$$
$$\text{\% Fixed Carbon} = 31.03\%$$

Example 3.15.16 (May 2013, 3 Marks)

A coal sample was subjected to ultimate analysis, 0.6 gm of coal on combustion in a Bomb colorimeter, produces 0.05 gm $BaSO_4$. Calculate the percentage of 'S' in coal sample

Solution :

$$\text{Weight of coal sample} = 0.6 \text{ gms.}$$
$$\text{Weight of } BaSO_4 = 0.05 \text{ gms.}$$

To calculate % S

$$\% S = \frac{\text{Weight of } BaSo_4 \text{ ppt}}{\text{Weight of Coal Sample}} \times \frac{32}{233} \times 100$$

$$= \frac{0.05}{0.6} \times \frac{32}{233} \times 100$$

$$= \frac{1.6}{139.8} \times 100$$

$$\therefore \quad \textbf{% S = 1.14 \%}$$

Ans. : $\boxed{\therefore \% S = 1.14\%}$

Example 3.15.17 (Dec. 2013, 3 Marks)

A coal sample was subjected to ultimate analysis. 1.5g of coal on combustion in a Bomb calorimeter gave 0.42g of $BaSO_4$. Calculate percentage sulphur in the coal sample.

Solution :

$$\text{Weight of Coal Sample} = 1.5 \text{ gms.}$$
$$\text{Weight of } BaSO_4 \text{ ppt} = 0.42 \text{ gms.}$$

To calculate % S in coal sample,

$$\% \, S = \frac{\text{Weight of BaSO}_4 \, \text{ppt}}{\text{Weight of coal sample}} \times \frac{32}{233} \times 100$$

$$= \frac{0.42}{1.5} \times \frac{32}{233} \times 100$$

$$= \frac{13.44}{349.5} \times 100$$

$$\therefore \% \, S = \boxed{3.85 \, \%}$$

$$\boxed{\textbf{Ans. :} \therefore \% \, S = 3.85 \, \%}$$

Example 3.15.18 (May 2014, 3 Marks)

A coal sample was subjected to ultimate analysis 1.5g of coal on combustion in a Bomb calorimeter gave 0.24g of $BaSO_4$. Calculate percentage sulphur in the coal sample.

Solution :

$$\% \, S = \frac{\text{Weight of BaSO}_4}{\text{Weight of coal sample}} \times \frac{32}{233} \times 100$$

$$= [0.24 \div 1.5] \times \frac{32}{233} \times 100$$

$$= [7.68 \div 349.5] \times 100$$

$$\therefore \% \, S = 2.197 \, \% \sim 2.2 \, \%$$

$$\boxed{\textbf{Ans. :} \therefore \% \, S = 2.197 \, \% \sim 2.2 \, \%}$$

Example 3.15.19 (Dec. 2014, 5 Marks)

2.5 g. of a coal sample was analysed for nitrogen content by Kjeldahl's method. The liberated ammonia required 12.7 ml of 0.5N H_2SO_4 solution for neutralization. In a

separate experiment, using Bomb calorimeter, 1.5 g of coal sample gave 0.28g of $BaSO_4$. Calculate percentage Nitrogen and Sulphur in the sample.

Solution :

Given Data :

Weight of coal sample for Nitrogen analysis = 2.5 gm

Volume of H_2SO_4 = 12.7 ml

Normality of H_2SO_4 = 0.5 N

Weight of coal sample = 1.5 gms in Bomb calorimeter

Weight of $BaSO_4$ = 0.28 gms

To calculate : percentage N

$$N\% = \frac{\text{Volume of acid consumed} \times N \text{ acid} \times 1.4}{\text{Weight of coal sample}}$$

$$= [12.7 \times 0.5 \times 1.4 \div 2.5]$$

$$= \boxed{3.56\%}$$

$$S\% = \frac{\text{Weight of } BaSO_4 \text{ ppt.} \times 32 \times 100}{\text{weight of coal sample} \times 233}$$

$$= \frac{0.35 \times 32 \times 100}{1.5 \times 233} \quad [0.28 \times 32 \times 100] \div [1.5 \times 233]$$

$$= \frac{1120}{349.5} \quad [896 \div 349.5]$$

$$\therefore \quad S\% = \boxed{2.56\%}$$

$$\boxed{\begin{aligned} \textbf{Ans.:} \quad N\% &= \textbf{3.56\%} \\ S\% &= \textbf{2.56\%} \end{aligned}}$$

Example 3.15.20 (May 2015, 5 Marks)

2.5 gm of air dried coal sample was taken in a silica crucible, after heating it in an electric oven at 110° C for 1 hr the residue was weighed 2.41 gm. The residue was heated in Silica crucible covered with vented lid at a temperature 925 ± 25° C for exactly 7 minutes. After cooling the weight of residue was found to contain 1.98 gm. The residue was then ignited to a constant weight of 0.246 gm. Report the results of above analysis.

Solution :

(1) Weight of coal taken = 2.5 g

   Mass of moisture in coal = 2.5 − 2.41

   = 0.09 g.

$$\therefore \% \text{ of moisture} = \frac{\text{Loss in weight of coal}}{\text{weight of coal taken}} \times 100$$

= [0.09 × 100 ÷ 2.5] % = **3.6 %**

(2) Mass of Volatile Matter = 2.41 − 1.78 = 0.63 g

   % of volume Matter = [0.635 × 100 ÷ 2.5] = **25.4 %**

(3) Mass of residue after ignition = 0.246 g

$$\% \text{ of Ash} = \frac{\text{Weight of ash left}}{\text{Weight of coal taken}} \times 100 = \frac{0.246 \times 100}{2.5}$$

= **9.8 %**

(4) % of Fixed Carbon = 100 − (% Moisture + V. M + Ash)

= 100 − (3.6 + 25.4 + 9.8) = 100 − 38.8 = **61.2 %**

Example 3.15.21 (May 2016, 5 Marks)

1.5 g of a coal sample was analysed for nitrogen content by Kjeldahl's method. The liberated ammonia required 14ml OF 0.1N H_2SO_4 solution for neutralization. In a separate experiment using Bomb Calorimeter, 1,5g of the same sample gave 0.3 g of $BaSO_4$. Calculate percentage nitrogen and sulphur in the sample.

Solution :

Given Data

Weight of coal sample for Nitrogen analysis = 1.5 gm

Volume of H_2SO_4 =   14 ml

Normality of H_2SO_4 =   0.1 N

Weight of coal sample   =   1.5 gms in Bomb calorimeter

Weight of $BaSO_4$ =   0.3 gms

To calculate :   Percentage N

$$N\% = \frac{\text{Volume of acid consumed} \times \text{N acid} \times 1.4}{\text{Weight of coal sample}}$$

$$= [14 \times 0.1 \times 1.4 \div 1.5]$$

$$= \boxed{1.30\%}$$

$$S\% = \frac{\text{Weight of } BaSO_4 \text{ ppt.} \times 32 \times 100}{\text{weight of coal sample} \times 233}$$

$$= [0.3 \times 32 \times 100] \div [1.5 \times 233]$$

$$= [960 \div 349.5]$$

$$\therefore \quad S\% = \boxed{2.74\%}$$

Ans. : $\boxed{\begin{array}{l} N\% = 1.30\% \\ S\% = 2.74\% \end{array}}$

Composite Materials

Syllabus Topic : Introduction

Q. What are composite materials ? Describe fiber reinforced composites. *(May 2012, Dec. 2012, Dec. 2014, May 2015)*

Ans. :

Composite materials :

Thus composite may be defined as, "A multiphase product made by using two or more existing materials which exhibits properties of its constituents as well as shows certain unique properties of its own."

Fibre Reinforced Composites

- Constitution :

    These are composite materials made up of

    (a) A polymer matrix

    (b) A filament

    (c) A bonding agent (which ties fibre filaments to polymers)

Commonly used fibres are *glass or metallic*. These fibres are employed either in continuously or discontinuously as staples or whiskers.

Properties of fibre reinforced composites

- The fibre reinforced composites possess,

    (1) High tensile strength

    (2) High specific gravity

    (3) High elastic modulus

    (4) They are stiff.

    (5) They possess lower overall density.

Factors governing properties of fibre-reinforced composites are

(1) Nature of fibres and matrix

(2) Properties of fibres and matrix

(3) Relative volume fraction of fibre and matrix

(4) Orientation and distribution of fibres in matrix phase.

(5) Length to diameter ratio of fibres

(6) Strength of interfacial bond between fibre phase and matrix.

Q. Give classification of composite material.*(May 2012, May 2013, May 2014, May 2016)*

Ans. : **Classification of composite material :**

The composites are classified on the basis of reinforcing material or structure as follows :

```
                          Composites
                              |
          ┌───────────────────┴───────────────────┐
          ▼                                         ▼
 On the basis of reinforcing              On the basis of
        material                              structure
          |                                       |
   ┌──────┴──────┐                                ▼
   ▼             ▼                      Structural composites
 Particle      Fibre reinforced                  |
 reinforced    Composites              ┌──────────┴──────────┐
 composites        |                   ▼                     ▼
   |        ┌──────┴──────┐         Laminates            Sandwich
 ┌─┴─┐      ▼             ▼                               panels
 ▼   ▼  Continuous    Discontinuous
                (long)       (short)
             aligned          |
                       ┌───────┴───────┐
                       ▼               ▼
                    Aligned         Random
```

Large-particle composites   Dispersion-strengthened Composites

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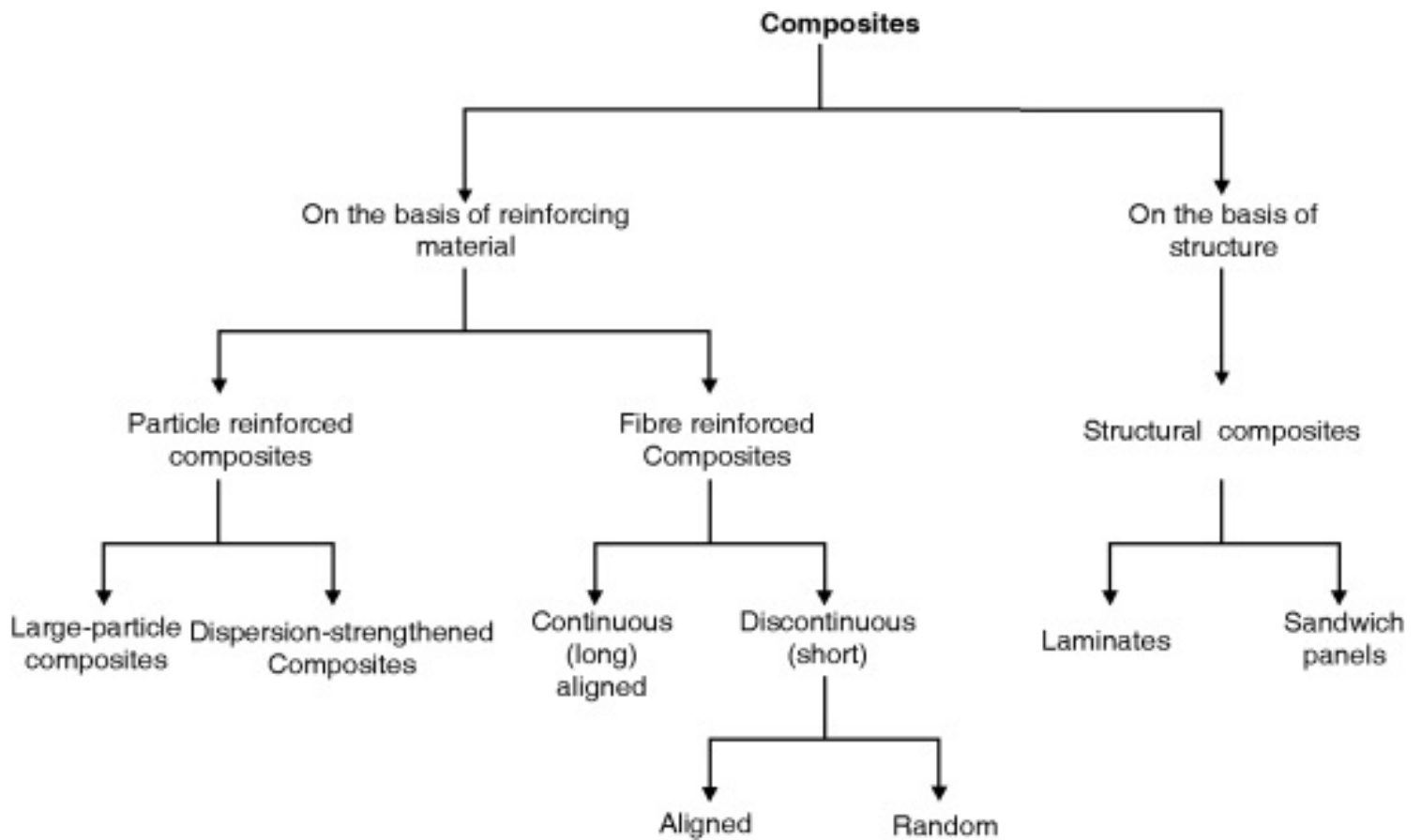
Syllabus Topic : Constitution of composites

Q. Define 'matrix phase' of composite material. State functions of matrix phase. *(Dec. 2013, Dec. 2014, May 2015, May 2016)*

Ans. :

- *Matrix material* should have the properties such as :

    1. It should have adequate ductility.

    2. Its should possess lower *elastic modulus* as compared to that of the fibre used.

    3. It should *get bonded to fibre* very strongly, but with minimum pull out of fibre.

- The matrix material is selected on the basis of the properties mentioned in combination of the fibre. The proper choice of matrix and fibre gives *strong bonding*

and ultimately a *good composite material.*

Examples

Metals such as Al, Cu which show high ductility bonded to the polymers such as thermoplastics and thermosets are most widely used as matrix material.

Functions of Martix

Functions of matrix constituent in polymer composite are,

(i)   *To bind* the reinforcing particles/fibres *strongly.*

(ii) It acts as medium for distribution of applied load to the dispersed phase.

(iii) It keeps the reinforcing *fibres in proper orientation* for the high strength development.

(iv) It *prevents* propagation of *cracks* due to its plasticity.

Q.   Define term : Dispersed phase *(May 2015)*

Ans. :

Dispersed phase :

The dispersed phase comprises of fibres, normally with small diameter preferred to bulk ones. A special type of fibres, widely known as *Whiskers* are used.

Syllabus Topic : Characteristic Properties of Composite Materials

Q.   Mention any four characteristic properties of composite

materials. *(Dec. 2014)*

Ans. :

Characteristic properties of composite materials

Composits are made from combination of metals, polymers and ceramics or only metals, and ceramics. They possess following unique characteristics over individually metal / polymers / ceramics.

(1) They possess

    (i)   Low specific gravity

    (ii)   High specific strength

    (iii) High specific stiffness

    (iv) Low Thermal expansion

    (v)   High corrosion resistance

    (vi) High oxidation resistance

(2) They can retain their strength at high temperature

(3) They show better toughness, impact and thermal shock resistace.

(4) They show better fatigue strength, and low thermal expansion and electrical conductivity.

Syllabus Topic : Classification of Composites :
Classification- (A) Particle - reinforced composites- i) Large – particle reinforced composites ii) Dispersion – strengthened composites. (B) Fiber – reinforced composites- i) Continuous – aligned ii) Discontinuous – aligned (short)- (a) aligned (b) randomly oriented (C) Structural Composites- i) Laminates (ii) Sandwich

Q. What are the applications of composites. *(Dec. 2012)*

Ans. :

Applications of composites

The composite materials find variety of applications in all those areas where, high mechanical strength, dimension stability, thermal stability, corrosion resistance, abrasion resistance etc. is desirable. They find application in following industries,

(a) Construction

(b) Electrical and electronics and telecommunication

(c) Transportation

(d) Agriculture

(e) Sport goods

(f) Automobile

(g) Aviation industry

(h) Mobiles

Q. Explain structural composites. *(Dec. 2012)*

Ans. :

Structural composites

A structural composite consists of both homogeneous and composite materials. Their properties depend upon, the characteristic properties of the constituent materials as well as the geometric design.

Structural composites are of two types such as,

(a)   Laminar composite : e.g. *plywood*

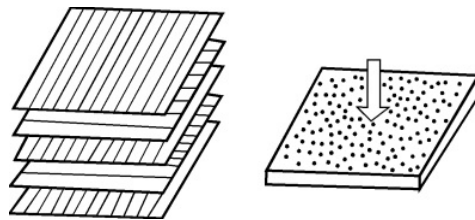(b)   Sandwich panel : e.g. *honeycomb core*

Q.   Explain Laminar composite with suitable example. *(May 2013, Dec. 2014)*

Ans. :

Laminar composite

*   It consists of *panels or sheets* which are two dimensional. These panels possess *preferred directions to achieve high strength.*

    e.g. plywood in which wood and continuous aligned fibre reinforced plastics are in preferred directions.

Fig. 4.4.1 : Oriented fibre-reinforced layers stacked successively for producing a laminar composite

*   Such successively oriented layers are stacked one above other with preferred directions (Fig. 4.4.1) and then are cemented. Such an arrangement or orientation ensures varying high strength with each successive layer.

*   Plywood is a laminated composite containing thin layers of wood where layers are alternatively glued together. This type of layering brings grain of each layer at right angles of its neighboring layer.

*   Use of fabric material such as cotton, paper or woven

glass fibres dispersed in suitable plastic matrix is also in practice to make laminar composites.

Q. Explain 'sandwpich panel' type layered composites with a suitable diagram. Mention their applications. *(Dec. 2013, May 2014, May 2015, Dec. 2015)*

Ans. :

This is another type of *layered composite*. It consists of

(1) *"Faces"* are formed by two strong outer sheets.

e.g Titanium, steel, aluminium alloys, plywood, fibre reinforced plastic material.

(2) *"Core"* which is layer of less dense material.

e.g. Synthetic rubbers, foamed polymers, inorganic cementing material etc.

All above three layers are joined together with an adhesive.

In these *"faces"* are capable of bearing *transverse bending stresses*. The *'core'* performs functions related to structural properties.

(i) Separation of faces from each other.

(ii) Resisting deformations perpendicular to the face plane.

(iii) Providing certain degree of shear rigidity along above planes which are perpendicular to the 'faces'.

With increase in thickness of core, its stiffness increases. The Fig. 4.4.2 shows 'honeycomb' structure which contain thin foils forming interlocked

hexagonal cells with their axes oriented at right angles in the direction of face sheet.

(a) Honeycomb core sandwich panel : Construction

(b) Sandwich panel : Fabricated
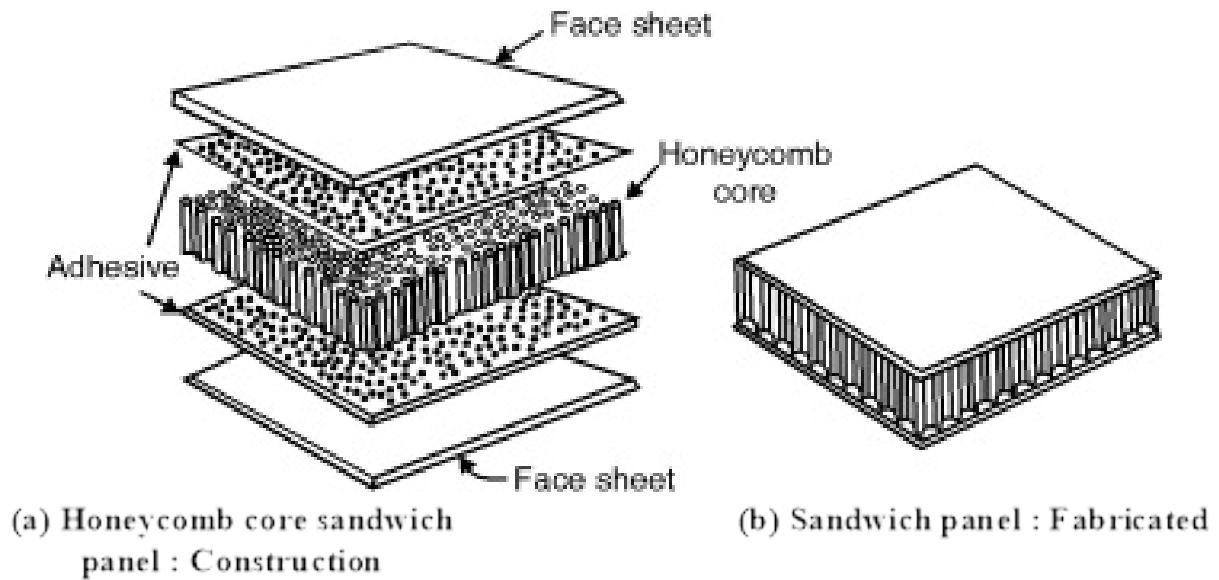
Fig. 4.4.2 : Schematic diagram

Q. What are glass fibre reinforced composites ? Outline their properties, application and limitations. *(May 2012, Dec. 2012, May 2016)*

Ans. :

Constitution

These are composite materials made up of

(a) A polymer matrix

(b) A filament

(c) A bonding agent (which ties fibre filaments to polymers)

Commonly used fibres are *glass or metallic.* These fibres are employed either in continuously or discontinuously as staples or whiskers.

Properties of fibre reinforced composites

The fibre reinforced composites possess,

(1) High tensile strength

(2) High specific gravity

(3) High elastic modulus

(4) They are stiff.

(5) They possess lower overall density.

Factors governing properties of fibre-reinforced composites are :

(1) Nature of fibres and matrix

(2) Properties of fibres and matrix

(3) Relative volume fraction of fibre and matrix

(4) Orientation and distribution of fibres in matrix phase.

(5) Length to diameter ratio of fibres

(6) Strength of interfacial bond between fibre phase and matrix.

Few important types of fibre reinforced composites, are given in Table 4.4.2, with properties and application.

Table 4.4.2 : Important fiber reinforced composites

Composite	Fibre phase	Matrix phase	Properties	Application	Limitation
1. Glass fibre reinforced polymer composite	Glass fibres (long as well as short)	Ploymers such as nylons, polyester etc.	1. Lower density 2. Higher tensile strength 3. Higher impact resistance 4. High resistance to corrosion and chemicals	1. Automobile parts 2. Pipes 3. Transportation industries 4. Industrial flooring 5. Storage tanks.	1. They can be used in low temperature service conditions; because polymers matrixes get deteriorated at higher temperatures. 2. The stiffness is comparatively low, hence cannot be employed as structural components.
2. Carbon fibre reinforced polymer composite	Glass fibres (long as well as small)	Polymers such as nylons, polyester etc.	1. Higher density 2. Excellent resistance to corrosion 3. Dimensional stability even at high temperature	1. Used to make structural components e.g. body or wings of aircraft helicopter. 2. Sports materials or fishing rods	High cost, hence used generally for specific purposes only.
3. Aramid fibre-reinforced polymer composite.	(a) Short aramid fibres or discontinuous	Polymeric material	1. High surface area. 2. High aspect ratio 3. Toughness to strength 4. Heat stability 5. High resistance to wear.	In automobile brakes and clutches.	Price is high, due to high cost of raw materials Note : These are about 4 times more in performance than that containing asbestos. Hence are best substitutes in place of asbestos containing material which is banned

					due to its ill effect on health
	(b) Long aramid fibres continuous	Polymeric material	1. Ductile like metals 2. It can sustain stresses.	1. In commercial aircrafts 2. Helicopter parts like rotor blades, motor housing 3. Business aircrafts as structural material 4. Protective apparel (thermal or ballistics)	Practically on limitations except cost. Note : In latest commercial aircrafts (like Boing –747 and Airbus 320), about 3-5% composites containing aramid or its hybrid fibres with carbon are employed.
4. Alumina and /or carbon fibre-reinforced metal composite	(a) Al_2O_3 or Carbon fibres	Aluminium Alloy	1. Low density 2. Resistant to thermal distortion 3. Resistant to wear 4. Creep resistant	To make engine components in automobile industry	
	(b) Al_2O_3 or W (tungsten)	Ni and cobalt based alloy	1. Excellent strength 2. Resistant to creep and rupture at high temperature.	To make components of turbine engine	

Syllabus Topic : Green Chemistry Introduction

Q. What is Green Chemistry ? *(Dec. 2012, May 2013)*

Ans. :

Green Chemistry

- Design of harmless processes to produce various products has emerged as a new branch commonly known as "clean chemistry" or *"Green Chemistry" or "Environmentally benign chemistry"*.

- *Green Chemistry* came into existence more than a decade back is now *becoming very popular*.

Syllabus Topic : Twelve Principles of Green chemistry

Q. Give the significance of green chemistry. *(Dec. 2012, May 2013)*

OR

Q. List the 12 principles of Green chemistry. *(May 2013)*

Ans. :

1. Prevention of waste
2. Maximise Atom economy
3. Non-hazardous chemical
4. Safer chemical
5. Auxiliary Substances
6. Energy efficiency
7. Renewable feedstocks
8. Derivatisation
9. Catalysts
10. Degradable products
11. New Analytical methods
12. Accident prevention

Q. Explain prevention of waste' principle in Green Chemistry. *(Dec. 2013, May 2014)*

Ans. :

Prevention is better than the cure"

- It is better to prevent waste than to treat and clean up waste after it is formed.

- It has been a common practice to *dump* waste on land or in water or released in air. This resulted in soil, water and air pollution.

- This made the legislation to be stringent on industries and hence there was compulsion to have

waste treatment and disposal units attached to the manufacturing plants. Thus the cost of process increased considerably.

- Thus green chemistry involves to design chemical syntheses in such a way that the process involves pathway to give products, leaving no waste to treat or clean up.

Q. Explain 'design for energy efficiency' principle in green chemistry. *(Dec. 2014)*

Ans. :

Design for energy efficiency

- The energy requirements of chemical processes should be minimized considering their environmental and economic impacts. The synthetic methods should be carried out at ambient temperature and pressure wherever possible.

- The aim of green chemistry is to increase energy efficiency.

- This can be achieved by use of catalysts, and by stopping the use of fossil / gaseous fuels which release solid or gaseous pollutants.

- The recently found substitutes are microwave radiations and ultra sound, which are used in the processes requiring very less energy.

- The energy efficiency of process can be increased by :
  a)   *proper heat transfer and*
  b)   *minimal wastage of energy during the process.*
- Many chemical are produced by *fermentation* process where energy requirement is low and also the products are less harmful.

Syllabus Topic : Conventional and Greener Synthesis of Indigo

Q.   Explain traditional and greener route of production of Indigo dye. By this reaction which principle of green chemistry is shown ? (*May 2013*)
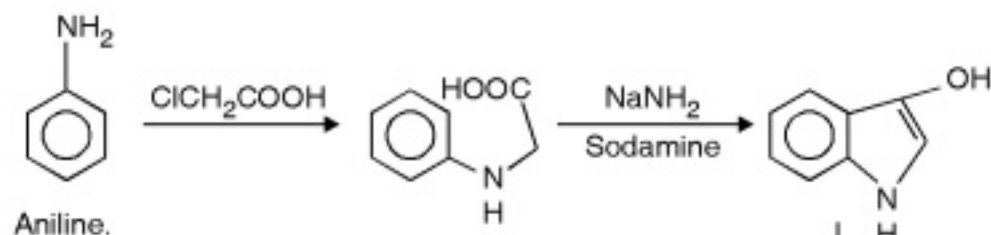
OR

Q.   Explain conventional and green chemistry route of production of Indigo dye. Highlight the green chemistry principle involved. (*Dec.2014, Dec.2015*)
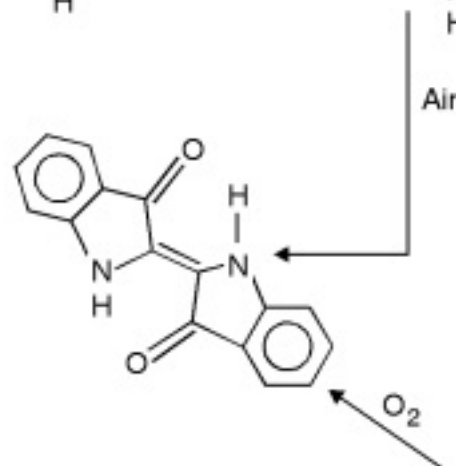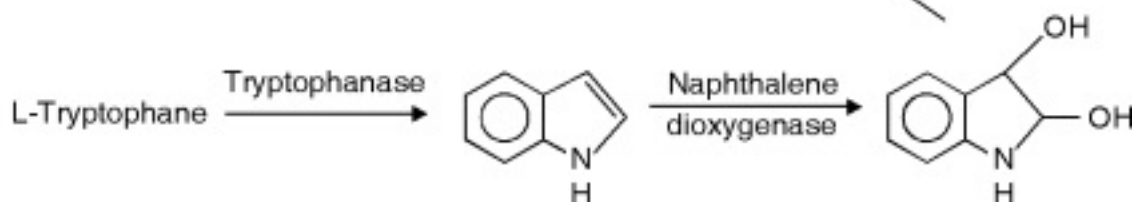
Ans. :

Synthesis of Indigo

(A) Conventional Route using hazardous Aniline

Aniline. $\xrightarrow{ClCH_2COOH}$ (intermediate) $\xrightarrow[Sodamine]{NaNH_2}$ (indole-OH)

Indigo molecule (dye)

Air

O_2

(B) Greener Route : Using enzyme

L-Tryptophane $\xrightarrow{Tryptophanase}$ (indole) $\xrightarrow[dioxygenase]{Naphthalene}$ (product)

Syllabus Topic : Conventional and Green Synthesis of Adipic Acid

Q. Explain conventional and green route of manufacturing Adipic acid. Also justify why the route is green. *(May 2012, Dec. 2013, May 2014, May 2015)*

OR

Q. Explain the traditional and green route for production of adipic acid. *(Dec. 2012)*

Ans. :

Traditional pathway : Using Benzene (Carcinogenic solvent)
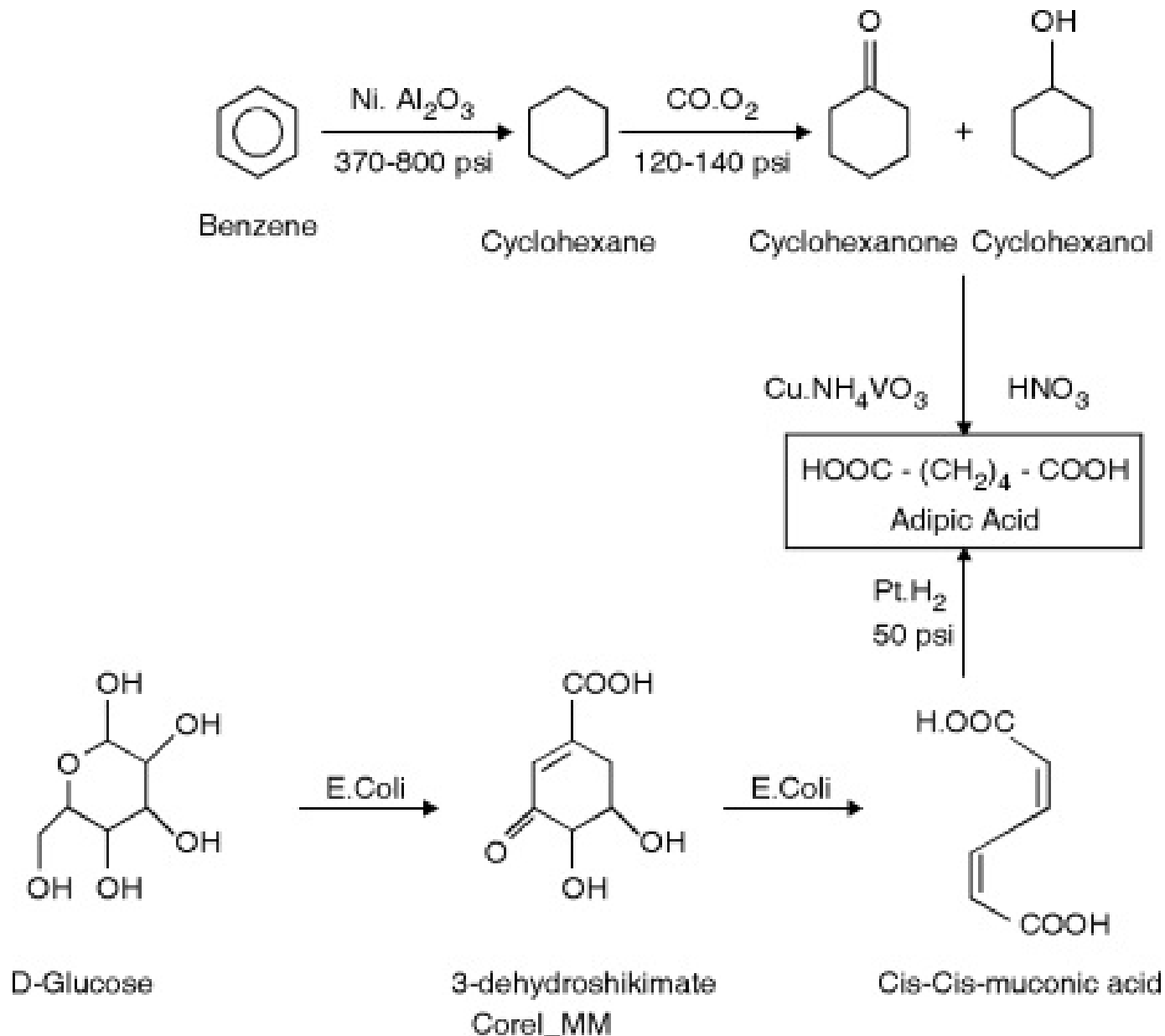
Greener pathway : Using glucose (absolutely safe)

(A) Traditional method : With larger number of steps (Atom economy = 40 %)

(B) Alternative Synthesis

With the atom economy = 77 % and recoverable catalyst.

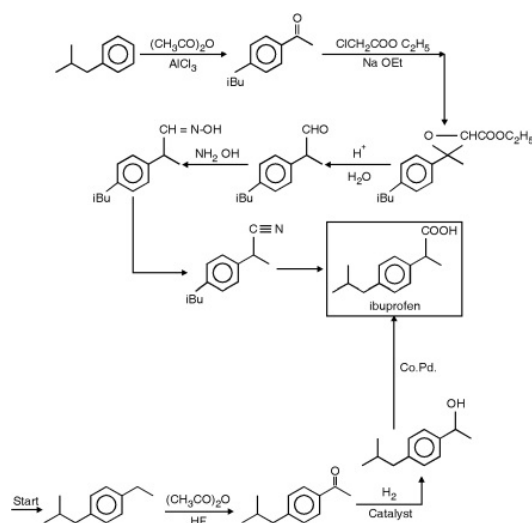**Q.** What are green solvents ? Give two industrial applications of green solvents. *(May 2012, Dec. 2012)*

Ans. :

Green solvents

The "Green solvents" – a newer concept involves the technology which has been popularly preferred over conventional solvent extraction process because of environmental concerns, such as the need to eliminate organic solvents and to find appropriate technologies for their disposal. e.g. Ionic liquid CO_2, propylene Glycol etc

Q. What is supercritical CO_2 ? Why is it considered a green solvent ? Give one application of supercritical CO_2. *(May 2016)*

Ans. :

Supercritical CO_2 :

- Supercritical fluids possess properties of gases and liquids in an intriguing manner, which could offer a range of applications / possibilities in both synthetic and analytical chemistry.

- Supercritical / Ionic liquid carbon dioxide has found to be an energy conserving, selective and waste

reducing alternatives to organic solvents and therefore is viewed as promising environmentally benign solvents. In addition, supercritical fluids can lead to reaction, which are difficult or even impossible to achieve in conventional solvents.

- Supercritical / Ionic liquid extraction is relatively new technology with a large potential for application in industry.

Principle

- The basic principle of Supercritical Fluid Extraction (SFE) technology is that when the *feed material is contacted* with a *supercritical fluid* then the *volatile substances* will *partition* into the *supercritical phase*.

- After the dissolution of soluble material the supercritical fluid containing the dissolved substances is removed from the feed material.

- The extracted component is then completely separated from the supercritical fluids (SCF) by means of a temperature and/or pressure change. The SCF may then be recompressed to the extraction conditions and recycled.

Choice of Solvents of Supercritical fluid Extraction

The choice of the SFE solvents is similar to a regular extraction. Principal considerations are as follow :
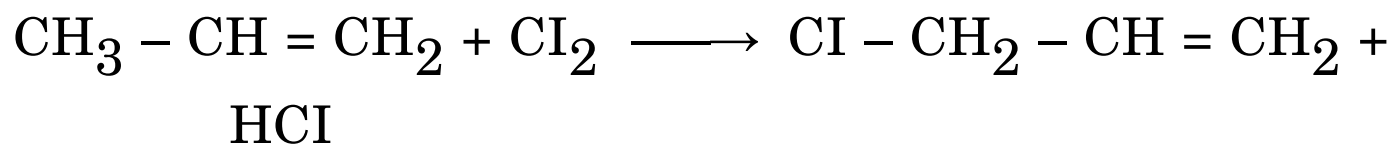
- Good solvent property

- Inert to the product

- Easy separation from the product

- Low cost

Carbon dioxide is the most commonly used *SCF*, primarily due to its low critical parameters (31.1°C, 73.8 bar), low cost and non-toxicity. However, several other SCF's have also been used in industrial processes.

Syllabus Topic : Numerical Problems on Atom Economy

Example 5.8.1 (Dec. 2014, 4 Marks)

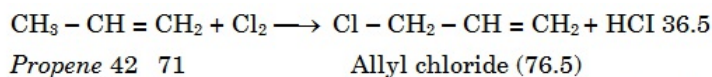Calculate the percentage atom economy for the following reaction with respect to Allyl chloride.

$$CH_3 - CH = CH_2 + Cl_2 \longrightarrow Cl - CH_2 - CH = CH_2 + HCl$$

Propene   Allyl chloride

Solution :

Reaction given

$$CH_3 - CH = CH_2 + Cl_2 \longrightarrow Cl - CH_2 - CH = CH_2 + HCl \ 36.5$$

Propene 42   71   Allyl chloride (76.5)

$$\% \text{ Atom economy} = \frac{\text{Molecular weight of product}}{\text{Total molecular wt. of reactants}} \times 100$$

$$= \frac{76.5}{42 + 71} \times 100 = \frac{76.5}{113} \times 100 = 67.7\%$$

Ans. :   % Atom economy = 67.7%

Example 5.8.5 (May 2012, May 2014, 4 Marks)

Calculate the percentage atom economy for the following

reaction *with respect to acetanilide :*

$$C_6 \ H_5 \ NH_2 \ + \ (CH_3CO)_2O \longrightarrow C_6H_5NHCOCH_3 \ + \ CH_3COOH.$$

<div align="center">Acetanilide</div>

Solution :

Reaction given :

$$C_6 \ H_5 \ NH_2 \ + \ (CH_3CO)_2O \longrightarrow C_6H_5NHCOCH_3 \ + \ CH_3COOH.$$

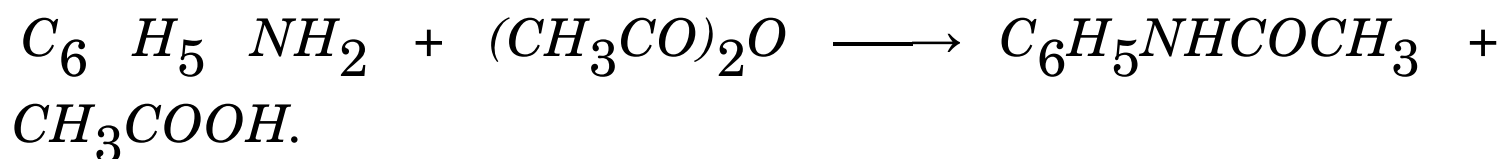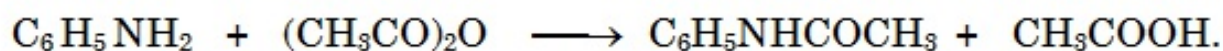| Aniline	Acetic Anhydride		Acetanilide	Acedic acid
Mol. wt. = 93	102		92	123

$$\% \text{ Atom economy} = \frac{\text{Molecular weight of product}}{\text{Total molecular weight of reactants}} \times 100$$

$$= \frac{123}{(93 + 102)} \times 100$$

$$= \frac{92}{128.5} \times 100 = 51.5\%$$

$$= \frac{123}{195} \times 100 = 63.07\ \%$$

Ans. : ┃ **% Atom economy = 63.07 %** ┃

Example 5.8.7 (May 2013, 4 Marks)

Calcualte % atom economy for following reactions :

Solution :

Benzene	Chlorine	Chlorobenzene	
Mol.wt = 78	71	112.5	

$$\% \text{ Alom Economy} = \frac{\text{Mol. Weight of product}}{\text{Total molecular weight of reactants}} \times 100$$

$$= \frac{112.5}{78 + 71} \times 100$$

$$= 75.5 \%$$

Example 5.8.8 (Dec. 2013, 4 Marks)

Calculate percentage atom economy for the following reaction with respect to acetophenone :

$$C_6H_6 + CH_3COCl \xrightarrow{AlCl_3} C_6H_5COCH_3 + HCl$$
benzene   acetophenone

Solution :

$$C_6H_6 + CH_3COCl \xrightarrow{AlCl_3} C_6H_5COCl + HCl$$
Benzene   Acetyl Chlorid   Acetophenone

Mol. wt. =   78   78.5   140.5

To Calculate % atom economy for reaction,

$$\% \text{ Atom Economy} = \frac{\text{Weight of product}}{\text{Total weight of Reactants}} \times 100$$

$$= \frac{140.5}{78 + 78.5} \times 100$$

$$= \boxed{89.78\%}$$

Example 5.8.9 (May 2015, 4 Marks)

Calculate percentage atom economy for the following reaction w.r. to methy is o-cyanate

$$CH_3NH_2 + COCl_2 \rightarrow CH_3-N=C=O + 2HCl$$
Methyl iso-cynate

Solution :

$$\text{Molecular weight} = \quad CH_3NH_2 + COCl_2 \longrightarrow CH_3-N=C=O + 2HCl$$
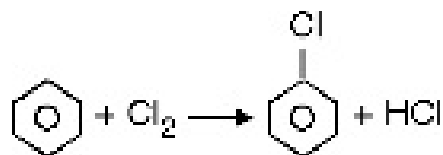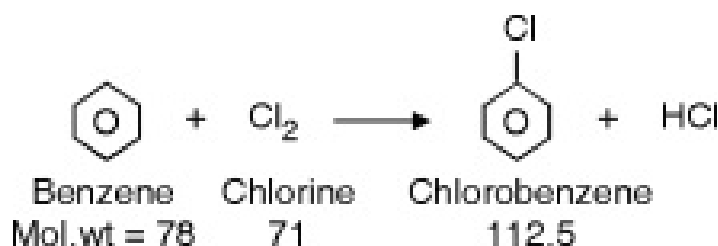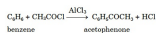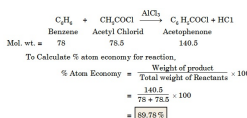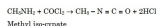   31   99   57

$$\% \text{ Atom economy} = \frac{\text{Molecular weight of product}}{\text{Total molecular weight of reactants}} \times 100$$
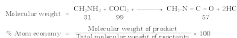
$$= 57 \div [31 + 99] \times 100$$

$$= 57 / 130 \times 100 = 44 \%$$

Ans. : % Atom economy = **44 %**

Example 5.8.10 (May 2016, 4 Marks)

Calculate percentage atom economy for the following reaction with respect to benzanilide ?

Solution :

$$C_6H_5NH_2 + C_6H_5COCl \rightarrow C_6H_5NHCOC_6H_5 + HCl$$

	Aniline	Benzoyl Chloride	Benzanilide
Mol. wt. =	93	140.5	196

To Calculate % atom economy for reaction,

$$\% \text{ Atom Economy} = \frac{\text{Weight of product}}{\text{Total weight of Reactants}} \times 100$$

$$= [196/93 + 140.5] \times 100 = \boxed{83.9\%}$$

Example 5.8.11 (Dec. 2015, 4 Marks)

Calculate percentage atom economy for the following reaction withrespect to cinnamaldehyde.

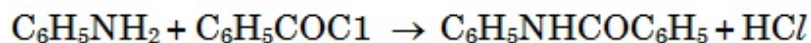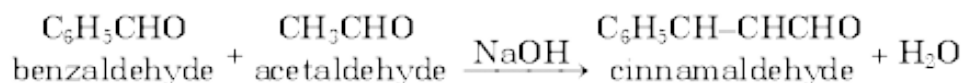$$\underset{\text{benzaldehyde}}{C_6H_5CHO} + \underset{\text{acetaldehyde}}{CH_3CHO} \xrightarrow{\text{NaOH}} \underset{\text{cinnamaldehyde}}{C_6H_5CH-CHCHO} + H_2O$$

Solution :

$$\underset{106}{C_6H_5CHO} + \underset{44}{CH_3CHO} \longrightarrow \underset{132}{C_6H_5CH = CH.CHO} + H_2O$$

Mol wt   106   44   132

$$\% \text{ Atom economy} = \frac{\text{Molecular weight of product}}{\text{Total molecular weight of reactants}} \times 100$$

$$= [132/106 + 44] \times 100$$

$$= 88\%$$

❑ ❑ ❑

Q. 1   Answer any five :   (5 × 3=15 Marks)

(a) State the characteristics of a good paints.

(b) Give composition, properties and uses of Duralumin.

(c) Define fuels. How are fuels classified ?

(d) Give various constituents and classification of composite material.

(e) Define Green Chemistry. What is aim of green chemistry?

(f) Distinguish between galvanizing and tinning.

(g) Determine the gross and net calorific value of the fuel which on ultimate analysis gave following results. C = 92%; H = 4%; O = 2%; N = 1%; S = 0.3%; Ash = 0.7%. Assume latent heat of condensation of steam as 580 kcal/kg.

Q. 2(a) Discuss differential aeration corrosion with the help of a suitable example. How can it be controlled ? (6 Marks)

(b) With a schematic diagram, explain fixed bed

catalytic cracking. Mention any two advantages of catalytic cracking over thermal cracking. (5 Marks)

(c) Give synthesis of Indigo dye by conventional and greener route. Which principlae of green chemistry is explained by this example ? (4 Marks)

Q. 3(a) The percentage analysis of coal contains 85% carbon, 5% hydrogen, 1% suphur,1% oxygen and remaining ash. Calculate weight and volume of air required for complete combustion of 4 kg of coal. (6 Marks)

(b) Explain Dispersed and matrix phase of composite material. State functions of matrix phase. (4 Marks)

(c) Calculate atom economy for following reaction

Acetaldehyde + Acetaldehyde ----------------------------→ crotonaldehyde (5 Marks)

Q. 4(a) What is the principle of cathodic protection method of corrosion control ? Discuss any one method of corrosion control by cathodic protection. (5 Marks)

(b) What are alloy steels ? Explain special effects of the following metals on properties of alloy steels. (6 Marks)
(i) Chromium   (ii) Nickel
(iii) Cobalt   (iv) Tungsten

(c) Write a note on 'glass fibre reinforced' composites. (4 Marks)

Q. 5 (a) What is powder metallurgy ? Explain power injection moulding method of compaction. (5 Marks)

(b) What is biodiesel ? Explain method to obtain biodiesel from vegetable oil. What are the advantages of biodiesel ? (6 Marks)

(c) What is 'oxidation corrosion'? Explain why pure aluminium metal exhibits good corrosion resistance in atmospheric oxygen. (4 Marks)

Q. 6 (a) How are metal powders prepared using.

(i) Atomization   (ii) Chemical reduction (6 Marks)

(b) A gaseous fuel has following composition by volume, CH_4 = 30%, H_2 = 40%, C_2H_6 = 6%, O2 = 7%, CO = 10 % N2 = 1%. Calculate the volume and wight of air required for complete combustion of $1m^3$ of fuel. (5 Marks)

(c) Give composition, properties and uses of (i) solders (ii) German silver (4 Marks)

Model Question Paper 2

Q. 1 Solve any five from following (5 × 3 = 15 Marks)

(a) Mention any three constituents of paint and

give their functions.

(b) Give composition, properties and uses of Magnelium

(c) Define GCV & HCV of fuel.

(d) Give applications of composite material.

(e) List 12 principles of green chemistry.

(f) Gold and platinum do not get corroded in atmospheric oxygen. Explain.

(g) Determine the gross and net calorific value of the fuel which on ultimate analysis gave following results. C = 88%; H = 5%; O = 4%; N = 1%; S = 2%; Ash = 0.7%. Assume latent heat of condensation of steam as 580 kcal/kg.

Q. 2 (a) How is the rate of corrosion influenced by : (6 Marks)

(i) pH of medium

(ii) Relative area of cathode and anode parts ?

(iii) Moisture

(b) With a schematic diagram, explain moving bed catalytic cracking. Mention any two advantages of catalytic cracking over thermal cracking. (5 Marks)

(c) Give synthesis of Adipic acid by conventional and greener route. Which principlae of green chemistry is explained by this example ? (4 Marks)

Q. 3 (a) The percentage analysis of coal contains 85%

carbon, 5% hydrogen, 1% suphur, 1% oxygen and remaining ash. Calculate weight and volume of air required for complete combustion of 4 kg of coal.

(b) Write note on "carbon fibre reinforced composites".   (5 Marks)

(c) Calculate atom economy for following reaction

2   Acetaldehyde   --------------------------------→ Crotonaldehyde
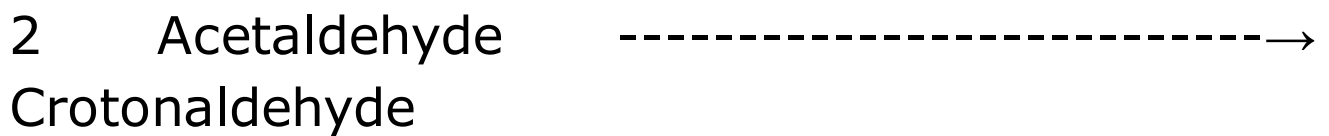
Q. 4 (a) What is 'oxidation corrosion' ? Discuss the role of nature of oxide formed in oxidation corrosion. (5 Marks)

(b) Explain :
(i) Alloy steels
(ii) Powder metallurgy
(iv) Atomisation method   (6 Marks)

(c) Write a note on 'laminar' composites. (4 Marks)

Q. 5 (a) What is an alloy ? Explain any four purposes of alloying with suitable examples. (5 Marks)

(b) What is "transesterification". Explain w.r.t bio-diesel. Give properties and advantages of bio diesel.   (6 Marks)

(c) Explain Galvanic corrosion.   (4 Marks)

Q. 6 (a) Write a note on Compacting and Sintering. (4 Marks)

(b) A gaseous fuel has following composition by volume, $CH_4 = 35\%$, $H_2 = 45\%$, $CO = 5\%$, $O_2 = 6\%$, $C_2H_6 = 8\%$, $N_2 = 1\%$. Calculate the volume and weight of air required for complete combustion of 1m3 of fuel.   (6 Marks)

(c) What are the advantages of alloying the metals ? Explain with two examples (5 Marks)

Model Question Paper 3

Q. 1   Answer any five : (5 × 3 = 15 Marks)

(a)   What are metallic coatings ? Distinguish between anodic and cathodic coating.

(b)   Give composition, properties and uses of wood's metal

(c)   Explain mining of crude petroleum with schematic diagram.

(d) What are unique properties of composites? Why are they called"advanced   materials"?

(e) "The aim of green chemistry if to increase energy efficiency" Explain with suitable example.

(f) Why is galvanization of iron articles preferred to tinning ?

(g) Determine the gross and net calorific value of the fuel which on ultimate analysis gave following results. $C = 92\%$; $H = 4\%$; $O = 2\%$; $N = 1\%$; $S = 0.3\%$; Ash $= 0.7\%$. Assume latent heat of condensation of steam as 580 kcal/kg.

Q. 2 (a) Explain Electroplating technique of metal coating? What are its advantages and disadvantages? (6 Marks)

(b) What is cracking ? Why is it significant ? Explain thermal and catalytic cracking. Mention any two advantages of catalytic cracking over thermal cracking. (5 Marks)

(c) Give synthesis of Indigo dye/carbaryl by conventional and greener route. Which principle of green chemistry is explained by this example ? (4 Marks)

Q. 3 (a) The percentage analysis of coal contains 85% carbon, 5% hydrogen, 1% suphur,1% oxygen and remaining ash. Calculate weight and volume of air required for complete combustion of 4 kg of coal.

(b) Write a note on "Aramid fibre reinforced polymer composites". (5 Marks)

(c) Calculate atom economy for following reaction

Benzaldehyde + acetaldehyde ------------------------ → Cinnamaldehyde

Q. 4 (a) Explain wet corrosion in acidic medium with schematic diagram and mechanism. (5 Marks)

(b) What is Powder Metallurgy. How are metal powders prepared using.
(i) Atomization   (ii) Chemical reduction (6 Marks)

(c) Write a note on 'sandwich panel' composites. (4 Marks)

Q. 5 (a) How are plain carbon steels classified based on carbon content ? What are the drawbacks of plain carbon steels ? (5 Marks)

(b) What are bio fuels ? Give examples of liquid and gaseous biofuels used commonly. List and explain methods to obtain the liquid biofuel. (6 Marks)

(c) What is the principle of cathodic protection method of corrosion control ? Explain the method of impressed current cathodic protection. (4 Marks)

Q. 6 (a) List composition, properties and uses of the following alloys :

German silver, High phosphor bronze (4 Marks)

(b) A gaseous fuel has following composition by volume, CH_4 = 42%, H_2 = 38%, C_2H_6 = 8%, N_2 = 1%. Calculate the volume and weight of air required for complete combustion of $2m^3$ of a gaseous fuel. (6 Marks)

(c) How properties of metals improve on alloying. Give 2 examples (5 Marks)

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