UNIT IV – PHASE RULE & ALLOYS

Statement and explanation of terms involved – one component system – water system – condensed phase rule – construction of phase diagram by thermal analysis – simple eutectic systems (Pb – Ag system only) – alloys – importance, ferrous alloys – nichrome and stainless steel – heat treatment of steel, non-ferrous alloys – brass and bronze.

Introduction:

Phase rule is stated by William Gibbs in 1874. It is very important and versatile tool for the study of heterogeneous equilibria. It is necessary to know about the terms like phase, component and degree of freedom. to understand the phase rule.

Explanation of terms:

Phase:

A phase is defined as "an homogeneous, physically distinct and mechanically separable portion of the system, which is separated from other such parts by definite boundary". A phase may be gas, liquid or solid.

Examples:

1. Two miscible liquids (alcohol & water) will form one liquid phase only.
2. Two immiscible liquids (benzene & water) will form two separate liquid phases.
3. A gaseous mixture, being thoroughly miscible in all proportions will form one phase only.
4. A solution of a substance in a solvent consists of one phase only. For eg., Solution of glucose in water.
5. Water consists of three phases at the freezing point.

$$\textbf{Ice}_{(s)} \rightleftharpoons \textbf{Water}_{(l)} \rightleftharpoons \textbf{Water vapour}_{(g)}$$

6. For a heterogeneous system

(i) $$Fe_{(s)} + H_2O_{(g)} \rightleftharpoons FeO_{(s)} + H_{2(g)}$$

It consists of two solid phases, $Fe_{(s)}$ & $FeO_{(s)}$ and one gaseous phase consists of $H_2O_{(g)}$ & $H_{2(g)}$. Thus, three phases exist in equilibrium.

(ii $$CaCO_{3\,(s)} \rightleftharpoons CaO_{(s)} + CO_{2\,(g)}$$

It consists of two solid phases, $CaCO_{3\,(s)}$ & $CaO_{(s)}$ and one gaseous phase, $CO_{2\,(g)}$. Thus, three phases exist in equlibirium.

Component:

The number of components is defined as, "The smallest number of independently variable constituents taking part in equilibrium by means of which the composition of each phase can be expressed wither directly or in terms of chemical equations".

Example for one component system:

At freezing point of water, three phases are in equilibrium.

$$\textbf{Ice}_{(s)} \rightleftharpoons \textbf{Water}_{(l)} \rightleftharpoons \textbf{Water vapour}_{(g)}$$

The chemical composition of all the phases is H_2O, hence it is one component system.

Example for two component system:

Consider the decomposition of $CaCO_3$ into CaO & CO_2.

$$CaCO_{3\,(s)} \rightleftharpoons CaO_{(s)} + CO_{2\,(g)}$$

The composition of any phase can be expressed in terms of at least any two of the independently variable constituents, $CaCO_3$, CaO & CO_2. Thus it is a two component system.

For example, $CaCO_3$ solid phase: $CaCO_3 = CaCO_3 + 0\ CaO$

CaO solid phase: $CaO = 0\ CaCO_3 + CaO$

CO_2 solid phase: $CO_2 = CaCO_3 - CaO$

Consider the dissociation of Copper sulphate,

$$CuSO_4 . 5H_2O_{(s)} \rightleftharpoons CuSO_4 . 3H_2O_{(s)} + 2H_2O_{(g)}$$

The composition of each phase can be represented by the simplest components $CuSO_4$ & H_2O. Hence it is two component systems.

Degree of freedom / variance:

It is defined as, "the minimum number of independent variables (such as temperature, pressure and composition of the phases) which much be specified in order to define the system completely".

If **F = 1**, system is univariant or mono variant.
If **F = 2**, system is bivariant.
If **F = 3**, system is trivariant, etc.

For example,

(i) Ice, liquid water and water vapour co – exist at the freezing point of water.

$$\textbf{Ice}_{(s)} \rightleftharpoons \textbf{Water}_{(l)} \rightleftharpoons \textbf{Water vapour}_{(g)}$$

All the three phases are in equilibrium only at a particular temperature and pressure; hence no condition need be specified. The system is, therefore, Zero variant or non-variant or invariant or has no degrees of freedom. As soon as the temperature or pressure is altered, three phases will not remain in equilibrium and one of the phases disappears.

(ii) For a system consisting of water in contact with its vapour,

$$\textbf{Water}_{(l)} \rightleftharpoons \textbf{Water vapour}_{(g)}$$

In this case only temperature is sufficient to specify the state of the system since once temperature is fixed, vapour pressure of the system is automatically fixed. Hence, degree of freedom is one and the system is univariant.

(iii) For a system consisting of water vapour phase only, need both the temperature and pressure to define the system completely. Hence, degree of freedom is two and the system is bivariant.

Phase rule:

It was stated by Williams Gibbs in 1874. It may be stated as, "When an equilibrium between any number of phases is influenced only by temperature, pressure and concentration, but not influenced by gravity, or electrical or magnetic forces or by surface tension then the number of degree of freedom (F) of the system is related to the number of components (C) and of phases (P) by the phase rule equation. F = C – P + 2

Advantages of phase rule:

- It is applicable to both chemical and physical equilibria.
- It is applicable to macroscopic systems and hence no information is required regarding molecular, micro structure.
- We can conveniently classify equilibrium states in terms of phases, components and degree of freedom.
- The behaviour of system can be predicted under different conditions.
- According to phase rule, different systems behave similarly if they have same degrees of freedom.
- Phase rule helps in deciding under a given set of conditions:
  (a) Existence of equilibrium among various substances.
  (b) Inter convergence of substances.
  (c) Disappearance of some of the substances.

Limitations of phase rule:

- It is applicable only for the systems which are in equilibrium.
- Only three degrees of freedom Viz., Temperature, pressure and composition are allowed to influence the equilibrium systems.

- Under the same conditions of temperature and pressure, all the phases of the system must be present.
- It considers only the number of phases, rather than their amounts.

Phase diagram:

The diagram which represents the conditions of equilibrium between different phases is called phase diagram.

One component system:

The water system consists of three phases, Viz., ice, water and water vapour.

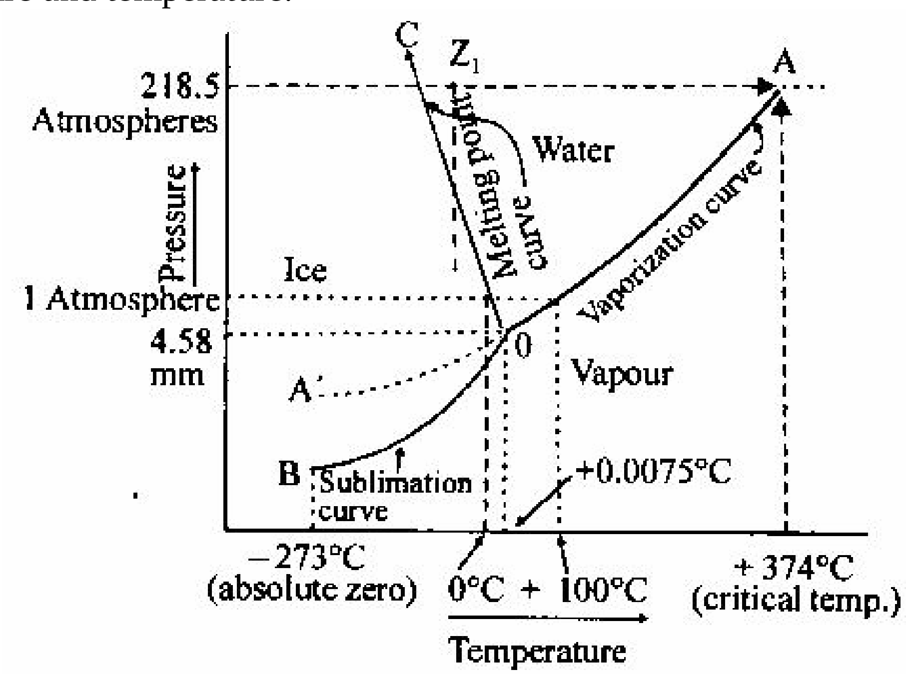
$$\textbf{Ice}_{(s)} \rightleftharpoons \textbf{Water}_{(l)} \rightleftharpoons \textbf{Water vapour}_{(g)}$$

H_2O is the only chemical compound involved, hence the number of component is one (C = 1). From phase rule, F = C – P + 2 = 1 – P + 2 = 3 – P
i.e. the degree of freedom depends on the number of phases present at equilibrium.

Three different cases are possible.

(a) P = 1, F = 2 (Bivariant system)
(b) P = 2, F = 1 (Univariant system)
(c) P = 3, F = 0 (Invariant system)

The water system can be represented by a two dimensional diagram with convenient variables, pressure and temperature.



Phase diagram of water system.

It consists of (1) Curves OA, OB and OC.
(2) Areas: AOB, AOC and BOC.
(3) Triple point.
(4) Meta stable equilibrium.

Curves OA, OB and OC:

CURVE	REPRESENTATION	EQUILIBRIUM	No OF PHASES
OA Vapour pressure curve.	Vapour-pressure of a liquid water.	$Water_{(l)} \rightleftharpoons Water\ vapour_{(g)}$	2
OB Sublimation curve	Vapour-pressure of Solid – ice .	$Ice_{(s)} \rightleftharpoons Water\ vapour_{(g)}$	2
OC Fusion Curve	Melting of ice.	$Ice_{(s)} \rightleftharpoons Water_{(l)}$	2

Along the curves, the equilibrium has **two phases** and **one component**.
Therefore P = 2, C = 1 and F = C – P + 2
= 1 – 2 + 2
= 1
Hence the system along OA, OB and OC is **univariant**.

Areas AOB, AOC and BOC:

CURVE	REPRESENTATION	No OF PHASES
AOC	Conditions of water existence.	1
AOB	Conditions of water vapour existence.	1
BOC	Conditions of ice existence.	1

In all the areas system has one phase and one component. Therefore p = 1, C = 1 and F = C – P + 2 = 1 – 1 + 2 = 2. Hence the system is bivariant.

Triple point "O":

The curves OA, OB and OC meets at the triple point "O" where all the three phases are co – exist. This occurs at the temperature, $0.0075^{o}C$ and pressure, 4.58 mm Hg.
Therefore P = 3, C = 1 and F = C – P + 2 = 1 – 3 + 2 = 0
Hence the system is invariant. If the temperature or pressure is changed the three phase system would not exist.

Meta stable equilibrium:

The vapour pressure curve of water OA can be continued after the triple point upto A'. It is represented by dashed line OA'. The super cooled water/vapour system is meta stable. On slight disturbance it reverts to stable system (ice).

Condensed phase rule / reduced phase rule:

The phase rule equation is F = C – P + 2

For a two component system, C = 2 then F = 2 – P + 2 = 4 – P

The minimum number of phase at equilibrium is one. Then F = 4 – 1 = 3.

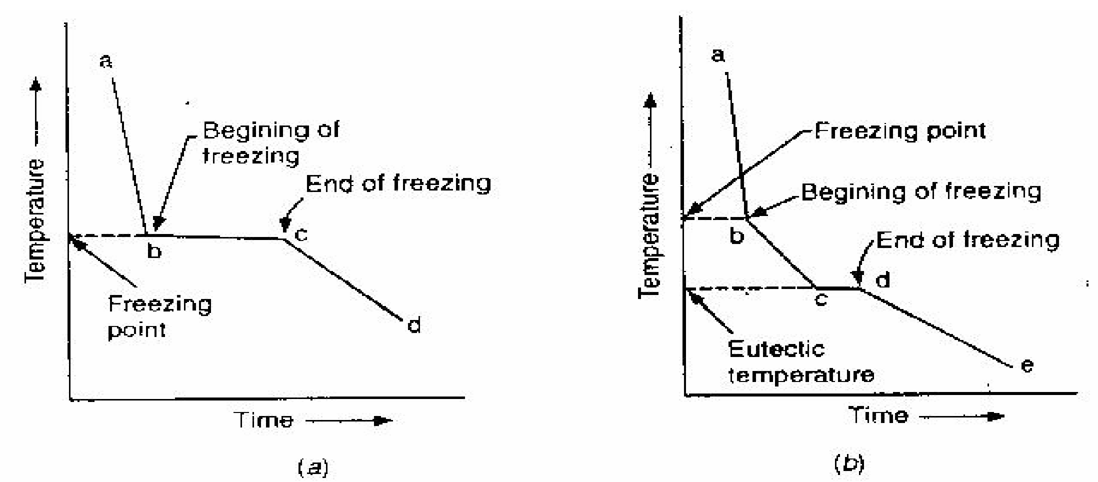
Hence the maximum number of degree of freedom is three and temperature, pressure and composition are required to define the system. This leads to 3 dimensional figures which cannot be explained on a paper. Hence one of the three variable to be kept constant.

F = C – P + 1 (Two component system)

F = 2 – P + 1 = 3 – P. This is the reduced / condensed form of the phase rule.

Thermal analysis:

Thermal analysis is the study of the cooling curves of various compositions of a system during solidification. It is used for finding the shape of the freezing – point curves of any system especially those involving metals. For any mixture of a definite composition, it is possible to find out freezing point and eutectic point from the cooling curves.



Cooling curves

Figure: (a). When a pure substance in the fused state is allowed to cool slowly and the temperature noted at definite intervals. The graph of rate of cooling will be continuous curve. When the freezing point is reached and the solid makes its appearances by the break in the continuity of the cooling curve and the temperature remains constant, until the liquid is fully solidified. There after, the fall in temperature will again become continuous.

Figure: (b). When a mixture of two solids in the fused state is allowed to cool slowly and the temperature noted at definite intervals. The graph of rate of cooling will be continuous curve. When a solid phase begins to form, the rate of cooling curve exhibits a break. However, the temperature does not remain constant as in the previous case of cooling of a pure substance. The temperature decreases continuously until the eutectic point reached. Now the temperature remains constant, till the completion of solidification. There after, the fall of temperature becomes uniform, but the rate of fall is quite different from the previous one.

Applications:

1. The melting point and eutectic temperature of various solids can be obtained.
2. The percentage of the compounds can be found out.
3. The behaviour of the compound can be understood from the cooling curve.
4. The procedure of thermal analysis can be used to derive the phase diagram of any two component system.

Eutectic system:

Eutectic – **Easy to melt**. Consider a binary system in which two components are miscible in all proportions in the liquid (molten) state. They do not react chemically and each component has the property of lowering each other's freezing point. Such a binary system is called Eutectic system.

Eutectic mixture:

A solid solution of two component system which has the lowest freezing point of all the possible mixtures of the components is called eutectic mixture.

Eutectic point:

Minimum freezing point attainable corresponding to the eutectic mixture is called **eutectic point** (means lowest melting point). The eutectic mixture has a definite composition and a sharp melting point. In this respect it resembles a compound. However, it is not a compound for the components are not present in **stoichiometric proportions**.

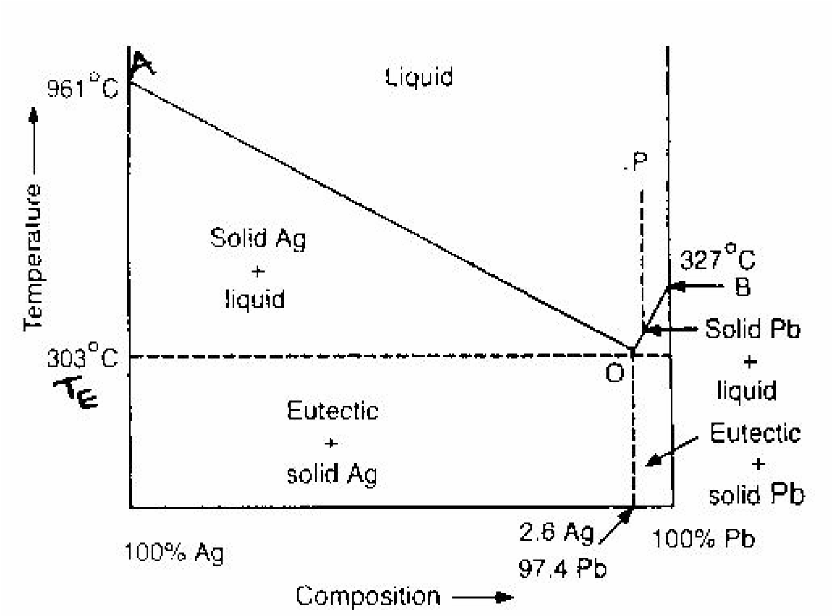
When the solid was examined under a powerful microscope, both the constituents were seen to lie as separate crystals. Moreover, physical properties such as density and heat of solution of eutectic solid were almost equal to the mean values of the constituents. Hence it is a mixture and not a chemical compound.

Applications:

1. Alloys which are known to form eutectic mixture's are used as 'fail – safe' device in boilers, as plugs in automobiles, fire – splinklers and other such safety devices.
2. Eutectic systems, because of their low melting points are also used for joining two metal pieces together. Example: Pb – Sn solders.

Lead – Silver system:

It is a two – component system with four possible phases – solid Ag, solid Pb, solution of Ag + Pb and its vapour. The two metals are completely miscible with each other in liquid state and do not form any chemical compound. There is almost no effect of pressure on equilibrium, the temperature and composition are considered to construct the phase diagram at constant atmospheric pressure.



Phase diagram of Pb – Ag system.

It consists of (1) Curves AO and BO.
(2) Eutectic point – "O" .
(3) Areas: Above AOB / Below AO / Below BO.

Curves AO & BO:

CURVE AO	CURVE BO
It is the freezing point curve of Ag (961°C)	It is the freezing point curve of Pb (327°C)
It shows decrease in freezing point / melting point of Ag due to the addition of Pb to Ag	It shows decrease in freezing point / melting point of Pb due to the addition of Ag to Pb.
Solid Ag is equilibrium with solution of Pb in Ag.	Solid Pb is equilibrium with solution of Ag in Pb.

Here C = 2 and P = 2, then the reduced phase rule is F = C – P + 1 = 2 – 2 +1 = 1. Hence the system is **univariant**. The point O (303°C) represents a fixed composition of 97.4 % Pb and 2.6 % Ag, and is called **eutectic composition**. On cooling, the whole mass crystallizes out as such.

Eutectic point 'O':

The curves AO & BO meet at the point O is called eutectic point. Here, solid Ag, Solid Pb and solution of Ag & Pb are in equilibrium. Thus, C = 2 and P = 3.
Hence the reduced phase rule is F = C – P + 1 = 2 – 3 + 1 = 0 and the system is **invariant**.
The point O (303^{o}C) represents a fixed composition of 97.4 % Pb and 2.6 % Ag, and is called **eutectic composition**.

Area above AOB:

The components Ag and Pb are exist as solution. Thus, C = 2 and P = 1.
Hence f = C – P + 1 = 2 – 1 + 1 = 2, the system is bivariant. The system will exist when the temperature T > 303^{o}C , Pb < 97.4 % and Ag > 2.6 %.

AREA	EXISTENCE	P	C	F
Below AO	Ag + Solution of Pb / Ag	2	2	1
Below BO	Pb + solution of Ag / Pb	2	2	1
Below T_E line	Solid Ag + Solid Pb	2	2	1

All these areas have P = 2 and F = 1. The system is **univariant.**

Pattinson's process:

The recovery of Ag from argentiferrous lead is explained in the process with the help of phase diagram. Argentiferrous lead contain 0.1 % Ag and 99.9 % Pb. This alloy on heating above 327^{o}C, then it is allowed to cool. The melted alloy reaches Y on the curve BO, solid Pb separates out and solution having more Ag. On further cooling, more of Pb separated till the eutectic point reached. At "O" an alloy containing 2.6 % Ag and 97.5 % Pb is obtained.

Alloys:

High malleability, ductility, luster and good electrical conductivity are the few useful properties possessed by metal. But for most of the applications, their tensile strength, corrosion resistance and hardness are not sufficient. These properties can be improved by mixing (alloying) metal with some other metal / non-metal.

"Alloy is homogeneous solid solution of two or more different elements, one of which is atleast a metal".

Properties of alloys:

1. High tensile strength.
2. High ductility.

3. High toughness.
4. High elasticity.
5. High heat-resistance.
6. High corrosion resistance.
7. High hardness.
8. High resistance to abrasion.
9. High resistance to oxidation.
10. High magnetic permeability and so on.

Ferrous alloys:

Alloys containing iron as one of their main component are called ferrous alloys.

Example: Nichrome and stainless steel, etc

Nichrome:

It contains 60% Ni, 1.2% Cr and rest Fe. It can be used at 1000 to 1100^{o}C. The presence Ni improves tensile-strength, ducility, toughness, elasticity, heat and corrosion – resistances and the presence of Cr imparts high corrosion – resistance, hardness and toughness simultaneously.

Uses:

In making parts of boilers, steam-lines, gas-turbines, aero-engine valves, retorts, annealing boxes and other machineries / equipments exposed to high temperatures.

Stainless steel:

It is also called corrosion – resistant steels. It contains Cr, Ni, Mo, etc. Cr is especially effective, if its content is 16% or more. The presence of Mo imparts high corrosion-resistance, abrasion-resistance at elevated temperatures.

It resists corrosion due to the formation of dense, tough film of chromium oxide at the surface of metal. If this film is broken in service, it gets healed-up automatically by oxygen of air.

There are **two** main types of stainless steel.

1. Heat treatable stainless steel.
2. Non – heat treatable stainless steel.

Heat treatable stainless steel:

It contains up to 1.2% carbon and 12 – 16 % Chromium. It is tough, magnetic and can be worked in cold state. It is satisfactory for resisting weather and water. It can be used at temperatures up to 800^{o}C. It is used in making surgical instruments, scissors, blades and cutlery, etc.

Non-heat treatable stainless steel:

It has less strength but more corrosion resistance at higher temperatures. There are two types of non-heat treatable stainless steel:

(a) **Magnetic type:**

It has less than 0.35% carbon and up to 12 – 22% Cr. The corrosion resistance of magnetic type steels is better than heat-treatable stainless steels. It can be forged, rolled or cold drawn. It can be machined with the help of specially designed tools. It is used in making automobile parts and chemical equipments.

(b) **Non-magnetic type:**

It contains 18 – 26% Cr, 8 – 21 % Ni and carbon (up to 0.15%). Most widely used common stainless steels contain 18% Cr and 8% Ni. It is also called "18/8 stainless steel'. The addition of small amount of Mo increases the corrosion resistance. It is used in making dental and surgical instruments, household utensils, decorative pieces and sinks etc.

Heat treatment of steel:

It is defined as, "the process of heating and cooling of solid steel article under carefully controlled conditions, thereby developing in it certain physical properties, without altering its chemical composition". It causes the refinement of grain structure, removal of the imprisoned gases and the removal of internal stresses.

The various heat-treatment processes are as follows:

1. **Annealing:**

It means **softening.** The process of heating the metal to a certain high temperature, followed by very slow cooling in a planned manner in a furnace is called **annealing**. It increases machinability and removes the imprisoned gases and internal stresses.

Annealing process is classified into two categories as follows:

(a) **Low – temperature annealing:**

It involves in heating steel to a temperature below the lower critical point, followed by slow cooling. It improves machinability by relieving the internal stress or strain and it increases ductility and shock – resistance, but reduces hardness.

(b) **High – temperature annealing:**

It involves in heating steel to a temperature about 30 to 50^{o}C above the higher critical temperature, followed by slow cooling. It increases ductility, toughness and machinability.

2. **Hardening or Quenching:**

It is a process of heating steel beyond critical temperature and then suddenly cooling it either in oil or brine – water. The rapid cooling produces hardened steel. Medium and high-carbon steels can be hardened, but low-carbon steels cannot be hardened. It results greater hardness and high resistance to wear & ability to cut other metals, but it has excess brittleness.

3. Tempering:

It is a process of heating the already hardened steel to a temperature lower than its own hardening temperature and then, allowing it to cool slowly. The hardened steel is re-heated to the temperature below 400^oC, causes the retaining of strength & hardness, it is re-heated to the temperature range 400 to 600^oC, causes better ductility and toughness. Tempering removes stress and strain developed during quenching process, reduces the brittleness and hardness, etc.

4. Normalising:

It involves in heating steel to the temperature above its higher critical temperature and allowing it to cool gradually in air. It takes much lesser time than annealing process. It provides homogeneity of the steel structure, removal of internal stresses, refining of grains and increase of toughness.

5. Case – hardening:

It is a process through which a hard-wearing surface is produced on steel having a soft core inside. This process is mainly adopted for low-carbon steels, which cannot be hardened by quenching process. It involves in heating steel to red-heat and then, forcing the carbon content into its surface structure so that at a certain depth, all along its surface becomes rich in carbon.

The process of case-hardening is carried out in two stages:

(a) Carburizing:

The mild steel article is heated to 900 – 950^oC along with charcoal in a cast iron box and then allow remaining at that temperature for sufficient time. Then it is allowed to cool slowly, within the box. This process is called **carburizing**.

(b) Hardening:

The carburized article is re-heated to about 900^oC and then, quenched in oil so that brittleness is removed and becomes tough and soft. The article is then re-heated to about 700^oC and quenched in water so that the outer-casing, which prevents the softening during operation.

6. Flame hardening:

It is the process of heating an area to be surface-hardened by means of oxy-acetylene flame, followed by sudden cooling by spraying water on it. It consumes very less time for the hardening of steel.

7. Gas carburizing:

It is the process getting hard-wearing surface in which the metal is subjected to coal gas at high temperature, which causes the infusing of carbon into the outer layer. This method requires a lot of skill on the part of the operator.

8. Nitriding:

It is a process of getting super-hard surface in which the metal alloy is heated in presence of ammonia at a temperature of about 550^{o}C. It is quite time-consuming.

9. Cyaniding:

It is a type of case-hardening process in which the metal is immersed into a molten KCN or NaCN solution at a temperature of about 870^{o}C and then, quenching in oil or water. The hard surface is produced, due to the absorption of carbon and nitrogen by the metal surface.

Non-Ferrous alloys:

Alloy do not containing iron as one of their main components is called non-ferrous alloys. **Example:** Brass, bronze and alnico, etc

Brass:

It contains 60 – 70 % Cu and 10 – 40 % Zn. It has greater strength, durability and machinability than pure copper. It has low melting point than cu and Zn. It has greater corrosion-resistant against water.

Brass is mainly available in three forms as follows:

(a) Commercial brass:

It contains 90% Cu and 10 % Zn. It is stronger and harder than pure copper. It is golden in colour. It is used to make hardware screws, jewellery, rivets, etc.

(b) **Dutch-metal or low brass:**

It contains 80% Cu and 20 % Zn. It has golden colour. It is suitable for all drawing and forming operations. It is used in cheap jewellery, music instruments, battery capacitors, flexible hoses, tubes, etc.

(c) **Catridge brass or spinning brass:**

It contains 70% Cu and 30 % Zn. It is soft, ductile in the annealed state, harder and stronger than copper. It can be severely cold deformed by drawing, pressing and extrusion. It hardens quickly. It is used in catridge cases, condenser tubes, house-hold articles, etc.

Special brasses: It contains metals other than Cu and Zn.

(a) German silver:

It contains 25 – 50 % Cu, 10 – 35 % Zn and 5 – 35 % Sn. It has good strength and corrosion-resistance. It has extreme ductility and malleability. It is used in utensils, table wares, bolts, screws, ornaments, cutlery, corrosion-resistant implements, coinage, decorative articles, etc.

(b) Admiraly brass or Tobin branze:

It contains 59 – 62 % Cu, 0.5 – 1.5 % Sn and rest Zn. It has high corrosion-resistance and abrasion-resistance. It is used in propellers and marine works.

Bronze:

It contain 80 – 95 % Cu, 5 – 20 % Sn and the rest is the other metals like Pb, Zn, Al, Ni, etc. Bronze is mainly available in five forms as follows:

(a) Common bronze or coinage bronze:

It contains 89 – 92 % Cu and 8 – 11 % Sn. It is soft, ductile and durable. It is used in pumps, valves, wires, utensils, coins, statues, etc.

(b) Gun metal:

It contains 85 % Cu, 4 % Zn, 8 % Sn and 3 % Pb. It is hard, tough and strong resistance to the force of explosion. It is used in foundry works, hydraulic fittings, heavy-load bearings, parts of high-pressure steam plants, water fittings, etc.

(c) High-phosphorous bronze:

It contains 10 – 13 % Sn, 0.4 – 1 % P and rest cu. It is hard, brittle and abrasion-resistant. It has low co-efficient of friction. It is used for making bearings, gears, taps, bushes, springs, turbine blades, fibres for moving coil galvanometers, fuses, etc.

(d) Aluminium bronze:

It contains 90 – 93 % cu and 7 – 10 % Al. It is quite strong, readily fusible, gives good castings, resistant to corrosion. It has good abrasion-resistance. It is golden yellow in colour. It is used in casting operations, bushes, bearings, jewellery, utensils, coins, photo frames, etc.

(e) Nickel bronze:

It contains 90 % cu, 9 % Ni and 1% Fe. It is hard, higher in tensile strength and better corrosion-resistant than copper. It is used in unhardened shafts, valves, and general purpose semi-hard bearings, etc.

References:

1. A text book of Engineering chemistry by Jain & Jain, 15^{th} edition, Dhanpat Rai Publication (P) Ltd, New Delhi.
2. A text book of Engineering chemistry by Shashi Chawla, Dhanpat Rai Publication (P) Ltd, New Delhi.
3. Engineering chemistry by R. Siva kumar & N. Siva kumar, Tata McGraw-Hill Publishing Company Ltd. New Delhi.

QUESTION BANK

PART – A

1. *State phase rule.*
2. *What is condensed phase rule?*
3. *Define phase.*
4. *A system consists of benzene and water. What is the number of phases?*
5. *What is meant by the term component?*
6. *How many components are present when NH_4Cl is heated in a closed vessel?*
7. *Define degree of freedom.*
8. *Give an example of invariant system.*
9. *What is triple point?*
10. *What is triple point of water system?*
11. *What is the difference between critical point and triple point?*
12. *What is meta stable state?*
13. *Apply the phase rule to calculate the degree of freedom at the triple point of a one component system.*
14. *Give the number of components of the following systems.*

    (a) $Fe_{(s)} + H_2O_{(g)} \rightleftharpoons FeO_{(s)} + H_{2(g)}$

    (b) $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$
15. *What is the significance of the triple point?*
16. *Mention any two merits of phase rule.*
17. *Mention any two limitations of phase rule.*
18. *What is meant by the term eutectic?*
19. *What are the eutectic temperature and eutectic composition of lead – silver system?*
20. *What is condensed phase rule? When is it applied?*
21. *What is the degree of freedom at eutectic point?*
22. *What is thermal analysis? Give its significance.*
23. *Differentiate between metal and alloy.*
24. *What are ferrous and non-ferrous alloys? Give examples.*
25. *What is meant by heat treatment of steel?*

PART – B

1. *Define the terms with suitable examples:*

(i) *Phase (ii) Component (iii) Degree of freedom.*

2. *Draw a neat labelled phase diagram of water system and explain areas, curves and triple point in it.*
3. *Explain condensed / reduced phase rule.*
4. *(a) "The eutectic is a mixture not a compound". Justify.*

   (b) State phase rule and explain the terms involved in it.
5. *With the help of a neat phase diagram, describe lead – silver system (OR)*

   Discuss phase rule and its applications to desilverization of lead.
6. *Write notes on:*

   (i) eutectic point (ii) reduced phase rule (iii) applications of phase diagrams.
7. *Describe thermal analysis with suitable cooling curves. Mention its significance.*
8. *Write short notes on: (i) annealing (ii) quenching (iii) tempering.*
9. *Write a note on: (i) cyaniding (ii) Nitriding (iii) Carurizing.*
10. *Give the composition, properties and uses of the following alloys:*

    (i) nichrome (ii) stainless steel (iii) brass (iv) bronze.

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