ENGINEERING CHEMISTRY-CY8151

Unit-III

Phase Rule and Alloys

Question Bank (Part-A & Part-B)

Part-A (2 Marks)

Phase Rule

1. State phase rule and explain the terms involved in it. **(2005, 2007)**

2. State phase (P) with suitable examples. **(2009)**

3. What is meant by degree of freedom (F)? **(2011, 2017, 2018)**

4. Define Component with examples. **(2018)**

5. How many phases and components are present in the following system? **(2010, 2012)**

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

(b) $CuSO_{4\,(s)} + 5H_2O_{(l)} \rightleftharpoons CuSO_4.5H_2O_{(s)}$

(c) $NH_4Cl_{(s)} \rightleftharpoons NH_{3\,(g)} + HCl_{(g)}$

6. Calculate the number of phases present in the following systems.

(a) $Ice_{(s)} \rightleftharpoons Water_{(l)} \rightleftharpoons Vapour_{(g)}$

(b) $MgCO_{3\,(s)} \rightleftharpoons MgO_{(s)} + CO_2$

(c) $NH_4Cl \rightleftharpoons NH_{3\,(g)} + HCl_{(g)}$

One Component System

7. What is Triple point? **(2014)**

8. What is eutectic point?

9. What is Metastable equilibrium?

Reduced Phase Rule

10. State reduced phase rule (or) Write down the condensed phase rule. Explain **(2009, 2014, 2015)**

11. State the number of degree of freedom for the following system **(a)** $CaCO_3$ **(s)** $\rightleftharpoons$ CaO **(s)** +CO_2 **(g)**

(b) PCl_5 **(s)** $\rightleftharpoons$ PCl_3 **(g)** + Cl_2 **(g)**

Two Component System

12. Differentiate melting point, eutectic point, and triple point.

13. What are the uses **(or)** significance of eutectic mixture? **(2008)**

14. What are the uses of phase diagram? **(2017, 2018)** **15.** Mention the applications of phase rule?

ALLOYS

Alloys

16. Define an Alloy **(2014)**

17. Mention the advantages of alloy making.

18. Mention any five purposes of making alloys. **(2009)**

Heat Treatment of Alloys

19. What is meant by Quenching in heat treatment of metals?

Ferrous Alloys

20. What is meant by 18/8 Stainless steel?

21. What is nichrome? Mention its composition and uses. **(2009, 2014)**

Non-Ferrous Alloys

22. Give any two uses each of brass and bronze.

23. What is Alnico?

24. What is Bronze? Why is it superior to steel?

25. What is hardening of metal of steel? Mention its purpose. **(2015)**

Part-B (8 Marks)

Phase Rule

1. State Phase rule and explain the terms involved in it with examples?

One Component System

2. Draw and explain the phase diagram of water system **(Or)** Apply phase rule to water system and explain the characteristics. **(Or)** Draw a neat one component water system and explain.

Thermal Analysis and Cooling Curves

3. With two cooling curves for pure substance and mixture, discuss briefly about thermal analysis. **(2018)**

Two Component System

4. Draw a neat two component lead silver system and explain. **(Or)** Discuss in detail the lead silver system (Simple eutectic). Give its applications **(2018)**

Alloys

5. What are the purpose of alloy making? Illustrate with suitable examples **(Or)** Explain the significance of alloying **(2015)**

6. Bring out the effect of alloying of metals with examples

Heat Treatment of Alloys

7. Explain the different methods of heat treatment of alloys. **(Or)** Write a short note on heat treatment of steel **(or)** metals **(or)** alloys **(2015, 2016)**

Ferrous Alloys

8. Mention two ferrous alloys. Give their composition and uses. **(Or)**

Write short notes on ferrous alloys. Give the composition and uses of Nichrome and stainless steel. **(2012, 2014)**

Part-A

1. **State phase rule and explain the terms involved in it. (2005, 2007)**

If the equilibrium between any number of phases is not influenced by gravity, or electrical, or magnetic forces but are influenced only by **pressure, temperature and concentration**, then the **number of degree of freedom (F)** of the system is related to **number of components (C)** and **number of phases (P)** by the following phase rule equation.

$$F = C - P + 2$$

2. **State phase (P) with suitable examples. (2009)**

Phase is defined as, **"any homogeneous physically distinct and mechanical separable portion** of a system which is separated from other parts of the system by **definite boundaries".**

Consider a water system consisting of three phases.

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

Each phase is physically distinct and homogeneous and there are definite boundaries between phases. So this forms three phases.

3. **What is meant by degree of freedom (F)? (2011, 2017, 2018)**

Degree of freedom is defined as, **"the minimum number of independent variable** factors such as temperature, pressure and concentration **which must** be fixed in order to **define the system completely".**

4. **Define Component with examples**. **(2018)**

Component is defined as, **"the smallest number of independently variable** constituents, by means of **which the composition** of each phase can be **expressed in the form of a chemical equation".**

Consider a water system consisting of three phases.

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

The chemical composition of all the three phases is H_2O, but are in different physical form. Hence the number of **component** is **one.**

5. **How many phases and components are present in the following system? (2010, 2012)**

(a) $\mathbf{CaCO_3}_{(s)} \rightleftharpoons \mathbf{CaO}_{(s)} + \mathbf{CO_2}_{(g)}$

- It consists of two solid phases and one gaseous phase.

Number of phases **(P) = 3**

Number of component **(C) = 2, F = C-P+2, F = 2-3+2, F = 1**

(b) $\mathbf{CuSO_{4\,(s)} + 5H_2O_{\,(l)} \rightleftharpoons CuSO_4.5H_2O_{\,(s)}}$

- It consists of two solid phases and one liquid phase.

Number of phases **(P) = 3**

Number of component **(C) = 2**

(a) $\mathbf{NH_4Cl_{\,(s)} \rightleftharpoons NH_{3\,(g)} + HCl_{\,(g)}}$

Number of phases **(P) = 2**

Number of component **(C) = 1**

F = C-P+2;

1-2+2 = 1

6. Calculate the number of phases present in the following systems.

(a) $\mathbf{Ice_{\,(s)} \rightleftharpoons Water_{\,(l)} \rightleftharpoons Vapour_{\,(g)}}$

Number of phases (P) = 3

(b) $\mathbf{MgCO_{3\,(s)} \rightleftharpoons MgO_{\,(s)} + CO_2}$ Number of phases (P) = 3

(c) $\mathbf{NH_4Cl \rightleftharpoons NH_{3\,(g)} + HCl_{\,(g)}}$

Number of phases (P) = 2

7. What is Triple point? (2014)

It is the point at which three phases namely solid, liquid and vapour are **simultaneously at equilibrium**.

8. What is eutectic point?

It is the point at which two solid and one liquid phase are in equilibrium. **Solid A + Solid B $\rightleftharpoons$ Liquid**

9. What is Metastable equilibrium?

Sometimes water can be cooled below 0°C without the formation of ice, this water is known as super-cooled water. **The equilibrium between super-cool water and the vapour** is known as metastable equilibrium.

10. State reduced phase rule (or) Write down the condensed phase rule. Explain (2009, 2014, 2015)

A solid–liquid equilibrium of an alloy has practically no gaseous phase and the effect of pressure is negligible. Therefore, experiments are conducted under atmospheric pressure. Thus **the system in which only the solid and liquid phases are considered and the gaseous phase is ignored is called a condensed system.** Since the pressure is kept constant the phase rule becomes

$$F' = C-P+1$$

11. State the number of degree of freedom for the following system

(a) $CaCO_3$ **(s)** $\rightleftharpoons$ CaO **(s)** +CO_2 **(g)**

F = C-P+1

= 2-3+2

F = 1

(b) PCl_5 **(s)** $\rightleftharpoons$ PCl_3 **(g)** + Cl_2 **(g)**

F = C-P+1

= 2-3+2

F = 1

12. Differentiate melting point, eutectic point, and triple point.

Melting point:

It is the temperature at which the solid and liquid phases, **having the same composition, are in equilibrium.**

Solid A $\rightleftharpoons$ Liquid A

Eutectic point:

It is the temperature at which **two solids and a liquid phase are in equilibrium.**

Solid A+ Solid B $\rightleftharpoons$ Liquid

Triple point:

It is the temperature at **which three phases are in equilibrium**

Solid $\rightleftharpoons$ Liquid $\rightleftharpoons$ Vapour

13. What are the uses (or) significance of eutectic mixture? (2008)

i. Suitable alloy composition can be predicted with the help of eutectic systems **ii.** Eutectic systems are used in preparing solders, used for joining two metal pieces together

14. What are the uses of phase diagram? (2017, 2018)

- It is possible to predict the phase diagrams whether an eutectic alloy or a solid solution is formed on cooling a homogeneous liquid containing mixture of two metals.
- The phase diagrams are useful in understanding the properties of materials in the heterogeneous equilibrium system.

15. Mention the applications of phase rule?

- ➢ It is applicable to both physical and chemical equilibria.
- ➢ It is convenient method of classifying the equilibrium states interms of phases, components and degree of freedom.
- ➢ It indicates that the different systems having the same degrees of freedom behave similarly.

Alloys

16. Define an Alloy (2014)

An alloy is defined as **"homogenous solid solution of two or more different elements, one of which at least is essentially a metal".**

17. Mention the advantages of alloy making. ➢ To increase the hardness of the metal.

- ➢ To resist the corrosion of the metal.
- ➢ To modify the colour of the metal.
- ➢ To modify chemical activity of the metal.

18. Mention any five purposes of making alloys. **(2009) (i)** To increase the hardness of the metal.

(ii) To lower the melting points of the metal.

(iii) To resist the corrosion activity of the metal.

(iv) To modify chemical activity of the metal.

19. What is meant by Quenching in heat treatment of metals?

It is the process of heating steel beyond the critical temperature and then suddenly cooling it either in oil or brine-water or some other fluid.

20. What is meant by 18/8 Stainless steel?

If it contains **18% Cr** and **8% Ni,** it is referred to as **18/8** stainless steel. It is the most widely used stainless steel.

21. What is nichrome? Mention its composition and uses. (2009, 2014)

Nichrome is an alloy of Nickel and Chromium. Its composition is

Metal	Percentage
Nickel	60
Chromium	12
Iron	26
Manganese	2

Uses:

i. Widely used for making resistance coils, heating elements in stoves.

ii. Used in making parts of boilers, steam-lines stills, gas-turbines.

22. Give any two uses each of brass and bronze.

(i) Uses of brass

(a) Guilding metal: It is used in forgings, rivets, hard wares, and jewellery.

(b) Dutch metal: It is also used in the manufacture of cheap jewellery, battery caps, and flexible hoses. **(ii) Uses of bronze**

(a) Coinage bronze: It is used in the manufacture of pumps, valves, coins, and statues.

(b) Gun metal: It is also used in foundry works, steam plants and water fittings.

23. What is Alnico?

It is an alloy of **Al, Ni,** and **Co.** Its composition is

Metal	Percentage
Aluminium	12
Nickel	20
Cobalt	6
Iron	62

24. What is Bronze? Why is it superior to steel?

Bronze is a copper alloy containing copper and tin. They possess,

(i) Lower melting point than steel and are more readily produced from their constituent metals.

(ii) Better heat and electrical conducting property than most of the steels, **(iii)** Non-oxidizing, corrosion resistance and water resistance property.

25. What is hardening of metal of steel? Mention its purpose. (2015)

The process of heating steel beyond the critical temperature and then suddenly cooling it either in oil or brine-water or some other fluid.

Purpose:

(i) Increases its resistance to wear, ability to cut other metals and strength, but steel becomes extra brittle.

(ii) Increases abrasion-resistance, so that can be used for making cutting tools.

Part-B

Phase Rule

1. State Phase rule and explain the terms involved in it with examples?

Phase rule

If the equilibrium between any number of phases is not influenced by gravity, or electrical, or magnetic forces but are influenced only by **pressure, temperature** and **concentration,** then the **number of degree of freedom (F)** of the system is related to **number of components (C)** and **number of phases (P)** by the following phase rule equation.

$$F = C - P + 2$$

1. Phase (P)

Phase is defined as any homogenous physically distinct and mechanically separable portion of a system which is separated from other parts of the system by definite boundaries'.

(a) Gaseous phase:

- ❖ All gases are completely miscible and there is no boundary between one gas and the other.

EXAMPLES

Air which is a mixture of O_2, H_2, N_2, CO_2 and water vapors, constitute a single phase.

(b) Liquid phase:

- ❖ The number of liquid phase depends on the number of liquids presents and their miscibility.

(i) If two liquids are immiscible they will from three separate phases two liquid phase and one vapour phase.

EXAMPLES **Benzene-water**

(ii) If two liquids are completely miscible they will form one liquid phase and open vapour phases.

EXAMPLES **Alcohol -water**

(c) Solid phase:

Every solid constitutes a separate phase.

EXAMPLES Decomposition of $CaCO_3$

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

It involves three phase, solid of $CaCO_3$ solid CaO and gaseous CO_2

EXAMPLES Consider a water system consisting of three phases.

$$\text{Ice (s)} \rightleftharpoons \text{water (l)} \rightleftharpoons \text{vapour (g)}$$

Each phase is physically distinct and homogenous and there are definite boundaries between phases. So this forms three phases.

EXAMPLES

A solution of a substance in a solvent consists of one phase only. Sugar solution in water.

2. <u>Component (C)</u>

Component is defined as, **"the smallest number of independently variable** constituents, by means of **which the composition** of each phase can be **expressed in the form of a chemical equation".**

EXAMPLES Consider a water system consisting of three phases.

Ice(s) $\rightleftharpoons$ Water (l) $\rightleftharpoons$ Vapour (g)

The chemical composition of all the three phases is H_2O, but is in different physical form. Hence the number of **component** is **one.**

EXAMPLES An aqueous solution of NaCl is a two component system. The constituents are NaCl and H_2O.

3. <u>Degree of freedom (F)</u>

Degree of freedom is defined as, **"the minimum number of independent variable** factors such as temperature, pressure and concentration **which must** be fixed in order to **define the system completely".**

A system having 1, 2, 3, and 0, degrees of freedom is called univariant, bivariant, trivariant, and nonvariant respectively.

EXAMPLES Consider the following equilibrium

Ice (s) $\rightleftharpoons$ Water (l) $\rightleftharpoons$ Vapour (g)

These three phases will be in equilibrium only at a particular temperature and pressure. Hence, this system does not have any degree of freedom, so it is nonvariant or zerovariant.

2. Draw and explain the phase diagram of water system (Or)

Apply phase rule to water system and explain the characteristics. (Or)

Draw a neat one component water system and explain.

<u>The Water system:</u>

Water exists in three possible phases namely solid, liquid, and vapour. Hence, there can be three forms of equilibria.

$\rightleftharpoons$ **Solid Liquid**

$\rightleftharpoons$ **Liquid Vapour**

$\rightleftharpoons$ **Soild Vapour**

This phase diagram contains curves, areas, and triple point. The phase diagram for the water system is shown in the below **figure 1**.

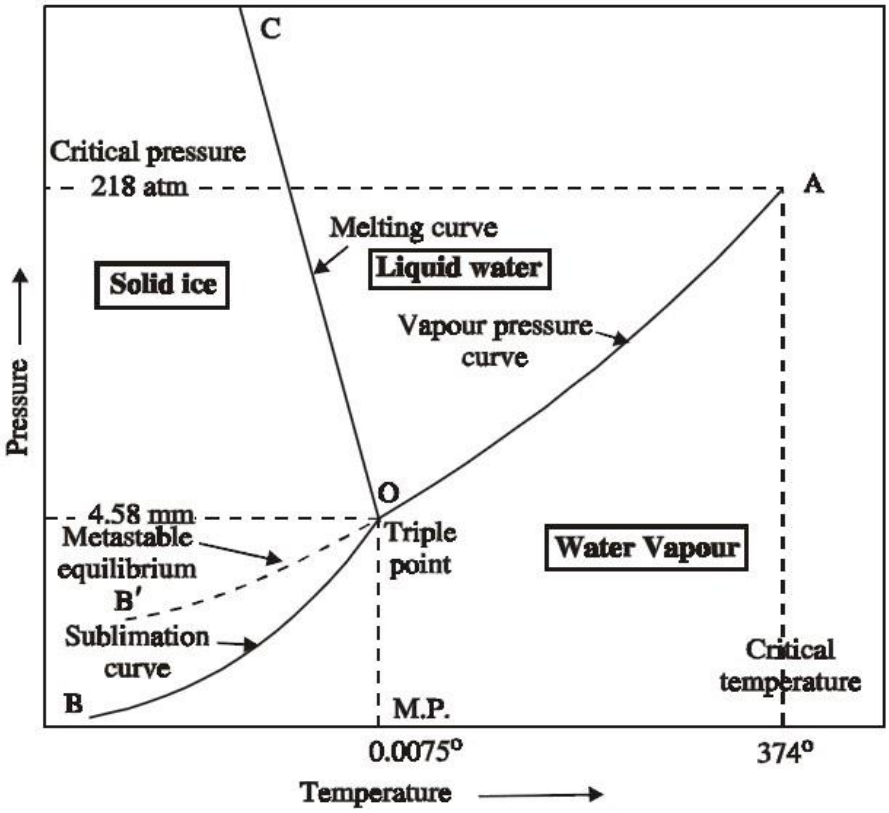


Figure 1

1. <u>Curve OA:</u>

- ❖ The curve OA is called **Vapourisation curve.**
- ❖ It represents the equilibrium between water and vapour.

Water ⇌ Water vapour

F = C-P+2

F = 1-2+2

F = 1 **Univariant** ❖ Beyond critical temperature (**C**) equilibrium disappear only the vapour will exist.

2. <u>Curve OB:</u>

- ❖ The curve OB is called **Sublimation curve** of ice ❖ It represents the equilibrium between ice and vapour.

Ice ⇌ vapour

F = C-P+2

F = 1-2+2

F = 1 **Univariant**

- ❖ The curve extent upto absolute zero beyond only ice will exists.

3. <u>Curve OC:</u>

- The curve OC is called melting point curve of ice.
- It represents the equilibrium between ice and water.

Ice ⇌ water

F = C-P+2

F = 1-2+2

F = 1 **Univariant**

- Melting point of ice decrease with increase in pressure.

4. Point "O" (triple point)

- The three curves **OA, OB, OC** meet at a point **'O'** is called triple point.
- It represents the equilibrium between solid, liquid, and vapour
- Temperature and pressure at the point **'O'** are **0.0075°C** and **4.58 mm** respectively.

Ice ⇌ liquid ⇌ Vapour.

F = C-P+2

F = 1-3+2

F = 0 **Non-variant**

5. Curve OB' (Metastable equilibrium)

- The curve OB' is called vapour pressure curve of the super cool water.
- It represents the metastable equilibrium between super cooled water and vapour

Super cooled water ⇌ vapour

- Water cooled below 0°C without the ice formation is called super cooled water.

  Super-cooled water is unstable and it converted into solid by 'seeding'.

6. Areas

- AOC, BOC, AOB represent ice, water and vapour respectively.
- The degree of freedom of the system is two.

F = C-P+2

F = 1-1+2

F = 2 **Bi-variant**

Thermal Analysis and Cooling Curves

3. With two cooling curves for pure substance and mixture, discuss briefly about thermal analysis

Thermal analysis

Thermal analysis is a method involving a study of the cooling curves of various compositions of a system during solidification. The shapes of the freezing point curves for any system **(involving metals)** can be determined by thermal analysis. The form of the cooling curve indicates the composition of the solid.

Example 1: Cooling curve for a pure solid

A pure substance in the fused state is allowed to cool slowly and the temperature is noted at different time interval. Then graph is plotted between temperature and time.

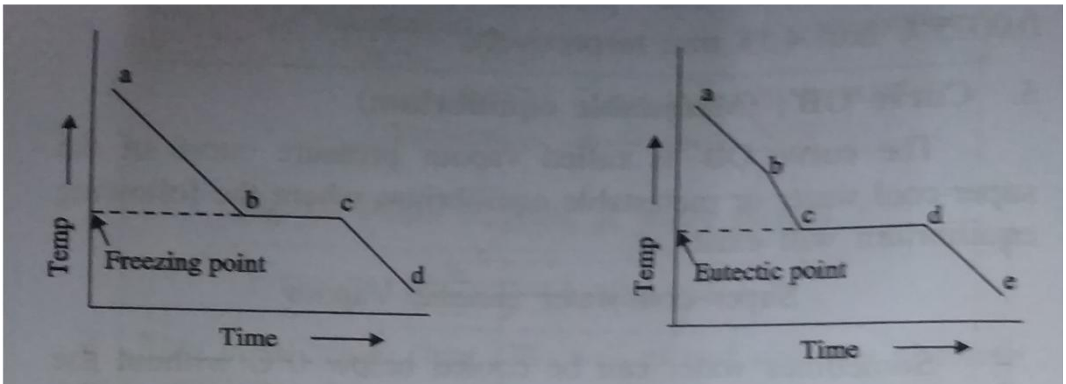


Fig. 5.2 Cooling curve of pure solid **Fig 5.3 Cooling curve of a mixture A+B**

Initially the rate of cooling is continuous. When it reaches the point **'b'** solid begins to appear, now the temperature remains constant until the liquid melt is completely solidified. Solidification completes at the point **'c'**. The horizontal line '**bc'** represents the equilibrium between the solid and liquid metal. After the point **'c'** temperature of the begins to decrease along the curve **'cd'.**

Example: 2 Cooling curve for a mixture

If a mixture of two substances **(say A and B)** in the fused state is allowed to cool slowly, the cooling curve is obtained in similar manner.

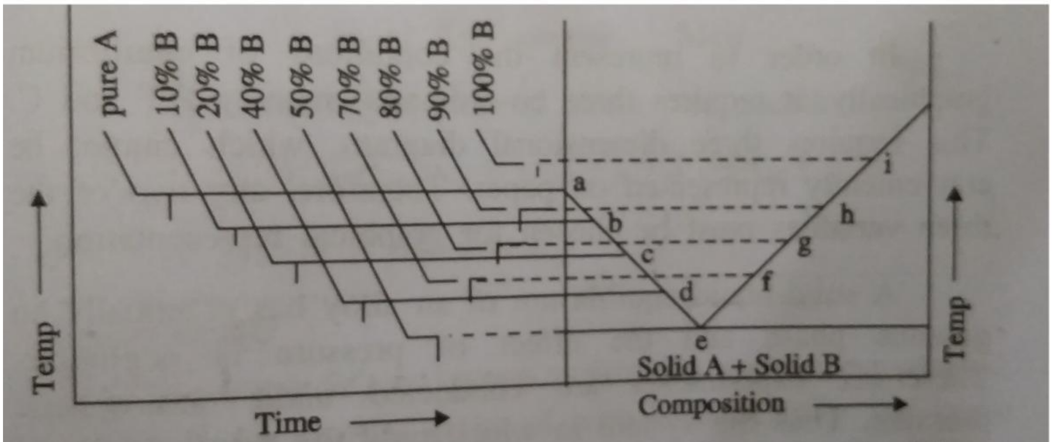


Fig. 5.4 Cooling curve of various compositions of two solids

Initially the rate of cooling is continuous. When it reaches the point **'b'** one substance either (**A** or **B**) begins to solidify out of the melt, which is indicated by a break and the rate of cooling in different. On further cooling at the break point **'c'** the second compound also begins to solidify. Now the temperature remains constant until the liquid melt is completely solidified, which forms the eutectic mixture **(line cd).** After the break point **'d'** cooling of solid mass begins. The temperature of horizontal line **'cd'** gives the eutectic temperature.

The experiment is repeated for different compositions of **A** and **B** and the various cooling curves are recorded. From the cooling curves of various compositions, the main phase diagram can be drawn by taking composition in X-axis and the temperature Y-axis

Uses of cooling curves

i. Melting point and eutectic temperature can be noted from the cooling curves. ii. Percentage purity of the compounds can be noted from the cooling curve.
iii. The procedure of thermal analysis can be used to derive the phase diagram of any two component system.

4. Draw a neat two component lead silver system and explain (Or)

Discuss in detail the lead silver system (Simple eutectic). Give its applications

<u>The Lead-Silver system</u>.

Since the system is studied at constant pressure, the vapour phase ignored and the condensed phase rule is used,

F' = C-P+1 It

contains lines, areas, and the eutectic point.

1. <u>Curve AO</u>:

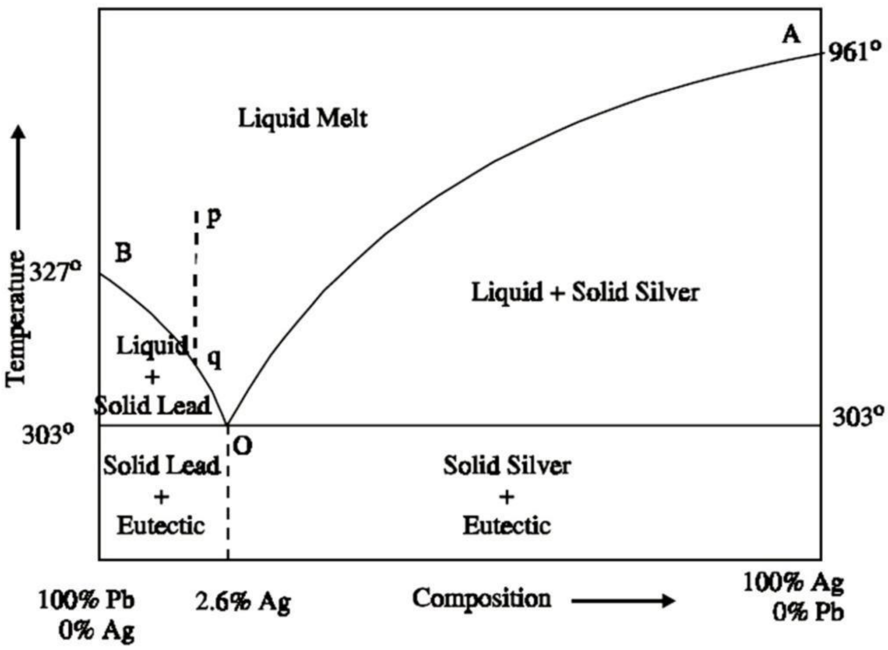
- The curve AO is called freezing point of Ag.
- Point 'A' is melting point of pure Ag. **(961°C)**
- The curve AO is the melting point depression of Ag by the addition of Pb.
- Along the curve AO

Solid Ag $\rightleftharpoons$ Melt

F' = C-P+1

F' = 2-2+1

F' = 1 Univariant



Phase diagram of Lead - Silver system

2. <u>Curve BO:</u>

- ❖ The curve BO is known as freezing point of Pb.
- ❖ Point B is melting point of pure Pb **(327 °C)**
- ❖ The curve BO is the melting point depression of Pb by the addition of Ag. ❖ Along the curve BO,

Solid Pb $\rightleftharpoons$ melt

F' = C-P+1

F' = 2-2+1

F' = 1 **Univariant**

3. <u>Point 'O' (Eutectic point)</u>

❖ The curve AO & BO meet at point ' O' at **303°C** three phase (solid Ag, solid Pb, liquid melt)

Solid Pb + Solid Ag $\rightleftharpoons$ Melt

F' = C-P+1

F' = 2-3+1

F' = 0 **Non-variant**

❖ The point 'O' is eutectic point (**97.4% Pb + 2.6% Ag**) ❖ Below this point metal solidify.

<u>4. Areas:-</u>

❖ The area above the line AOB has a single phase **(molten Pb + Ag)**

F' = C-P+1
F' = 2-1+1
F' = 2 Bi-variant

- The area below the line AO, BO, 'O' have two phases

F' = C-P+1
F' = 2-2+1
F' = 1 Univariant

Application of pattinson's process for the desilverisation of argentiferous lead

- "The process of raising the relative proportion of **Ag** in the alloy is known as **Pattinson's process**."
- Argentiferous lead consists **0.1%** of **Ag** is heated above its melting point, so system consists only liquid phase by point **p**.
- It is allowed to cool temperature fall along the line **pq**. As soon it reaches **q, Pb** is crystallized out and the solution contain relatively increasing amount of **Ag**.
- On further cooling, more and more **Pb** is separated out along the line 'BO' until the point 'O' is reached, where the percentage of Ag rises to **2.6 %.**

Limitations of phase rule:

1. Applicable for the system in equilibrium
2. Variables like P, T & C only considered but not electrical, magnetic and gravitational forces.
3. All phases must present under same condition of pressure and temperature.
4. Solid and liquid phase must not be in finely divided state.

ALLOYS

5. **What are the purpose of alloy making? Illustrate with suitable examples (Or)**

Explain the significance of alloying

Generally pure metals possess some useful properties such as high melting point, high densities, malleability, ductility, good thermal and electrical conductivity.

1. **To increase the hardness of the metal**

   Generally pure metals are soft, but their alloys are hard.

   Ex: Gold and silver are soft metals, they are alloyed with copper to make them hard
2. **To lower the melting points of the metal** Alloying makes the metal easily fusible.

   Ex: Wood's metal (an alloy of lead, bismuth, tin and cadmium) melts at **60 °C**, which is far below the melting points of any of these constituent metals.

3. **To resist the corrosion of the metal**

   Metals, in pure form, are quite reactive and easily corroded by surrounding, thereby their life is reduced. But if a metal is alloyed, it resists corrosion.

   Ex: pure iron gets rusted, but when it is alloyed with carbon or chromium (stainless steel), resists corrosion.

4. **To modify chemical activity of the metal**

   Chemical activity of the metal can be increased or decreased by alloying.

   Ex: Sodium amalgam is less active than sodium but aluminium amalgam is more active than aluminium.

5. **To modify the colour of the metal**

   The dull coloured metals are improved by alloying with metals.

   Ex: Brass, an alloy of copper (red) and zinc (silver-white), is white in colour.

6. **To get good casting of metal**

   Some metals expand on solidification but are soft and brittle. The addition of other metals produce alloys which are hard, fusible and expand on solidification and thus give good casting.

   Ex: An alloy of lead with **5%** tin and **2%** antimony is used for casting printing type, due to its good casting property.

6. Bring out the effect of alloying of metals with examples

Addition of small amounts of certain metals, such as **Ni, Cr, Mo, Mn, V** and **Al** imparts some special properties like hardness, tensile strength, resistance to corrosion and coefficient of expansion, on steel. Such products known as special steels or alloy steels.

Element	Effect on Properties	Uses of alloys
1. Nickel	i. Fine grains are produced. ii. Co-efficient of expansion decreases and corrosion resistance increases.	For making balance wheels
2. Chromium	Tensile strength, depth hardening and resistance to corrosion are increased.	For making surgical instruments, cutlery, connecting rods, etc.
3. Manganese	i. Hot shortness is removed ii. Resistance to abrasion is increased	For making grinding wheels, steering spindles and rails.

4. Vanadium	i. Reversible stresses are produced ii. Tensile strength and resistance to abrasion are increased	For making axless, crank pins, heavy locomotive forgings, piston rods, etc.
5. Molybdenum	Cutting hardness at high temperature is increased. Because phases are stabilized.	For making high speed tools.
6. Tungsten	i. Grain structure is refined. ii. Magnetic retentivity as well as cutting hardness are increased.	For making cutting tools, permanent magnets, etc.
7. Nickel & Chromium	Corrosion resistance tensile strength are increased.	For making stainless steel.

7. Explain the different methods of heat treatment of alloys. (Or) Write a short note on heat treatment of steel (or) metals (or) alloys

Heat treatment is defined as **"the process of heating and cooling of solid steel article under carefully controlled conditions'.**

Objectives:

i. Improvement of magnetic and electrical properties ii. Refinement of grain structure iii. Removal of imprisoned gases and internal stresses iv. Improve fatique and corrosion resistance

Types of heat treatment of alloys

The main characteristics and the relevant heat- treatment processes are

1. **Annealing**
2. **Hardening**
3. **Tempering**
4. **Normalizing**
5. **Carburizing**
6. **Nitriding**

1. Annealing

Annealing means softening. This is done by heating the metal to high temperature, followed by slow cooling in a furnace.

Purpose of annealing

(i) It increases the machinability.
(ii) It also removes the imprisoned gases.

Types of annealing

Annealing can be done in two ways
(i) Low temperature annealing **(or)** process annealing.
(ii) High temperature annealing **(or)** full annealing.

(i) Low temperature annealing (or) process annealing

It involves in heating steel to a temperature below the lower critical temperature followed by slow cooling.

Purpose

1. It improves machinability by relieving the internal stresses or internal strains.
2. It increases ductility and shock resistance.
3. It reduces hardness.

(ii) High temperature annealing (or) full annealing.

It involves in heating steel to a temperature about **30** to **50** **^{o}C** above the higher critical temperature and holding it at that temperature for sufficient time to allow the internal changes to take place and then cooled to room temperature.

The approximate annealing temperature of various grade of carbon steel are.

1. **Mild steel = 840-870 ^{o}C**
2. **Medium carbon steel = 780-840 ^{o}C**
3. **Steel =760-780^{o}C**

Purpose

1. It increases ductility and machinability.
2. It makes the steel softer, together with increase toughness.

2. Hardening

It is the process of heating steel beyond the critical temperature and suddenly cooling either oil or brine-water or some other fluid. Hardening increases the hardness of steel. The faster rate of cooling, harder will be the steel produced. Medium and high-carbon steels cannot be hardened.

Purpose

i. Increases resistance to wear, ability to cut other metals and strength, but steel becomes extra brittle.
ii. Increases abrasion resistance, so used making cutting tools.

3. Tempering

It is the process of heating the already hardened steel to temperature lower than its own hardening temperature and then cooling it slowly. In tempering, the temperature to which hardened steel is re-heated is of great significance and controls the development of the final properties. Thus

(i) For retaining strength and hardness, reheating temperature should not exceed **400^{o}C**.
(ii) For development better ductility and toughness, reheating temperature should be within **400 -600^{o}C**.

Purpose

1. It removes any stress and strains that might have developed during quenching.
2. It reduces the brittleness and also some hardness but toughness and ductility are simultaneously increased.
3. Cutting-tools like blades, cutters, tools-bites always requires tempering.

4. Normalisling

It is the process of heating steel to a definite temperature (**above its higher critical temperatures**) and allowing it to cool gradually in air.

Purpose

1. It recovers the homogeneity of the steel structure.
2. It refines grains.
3. It removes the internal stress.
4. It increase the toughness.
5. Normalized steel is suitable for the use in engineering works.
6. A normalized steel will not be as soft as an annealed job of the same materials. Also normalizing take much lesser time than annealing process.

5. Carburizing

The mild steel article is taken in a cast iron box containing small pieces of charcoal (**carbon materials**). It is then heated to about **900** to **950 ^{o}C** and allowed to keep it as such for sufficient time. So that the carbon is absorbed to required depth. The article is then allowed to cool slowly within the iron box itself. The outer skin of the article is within the iron box itself. The outer skin of the article is covered into high- carbon steel containing about **0.8 to 1.2 %** carbon.

Purpose

To produce hard-wearing surface on steel article.

6. Nitriding

Nitrating is the process of heating the metal alloy in presence of ammonia at a temperature to about **550 $_{\circ}$C**. The nitrogen (**obtained by the dissociation of ammonia**) combines with the surface of the alloy to form hard nitride.

Purpose: To get super–hard surface.

8. Mention two Ferrous alloys. Give their composition and uses. (Or) Write short notes on Ferrous alloys. Give the composition and uses of Nichrome and stainless steel.

Ferrous alloys are the type of steels in which the elements like **Al, B, Cr, Co, Mn** are present in sufficient quantities, in addition to carbon and iron, to improve the properties of steels.

Properties:

i. High yield point and high strength ii. Sufficient formability, ductility and weldability iii. Sufficiently corrosion and abrasion resistant

Important Ferrous Alloys

1. Nichrome

Nichrome is an alloy of nickel and chromium.

Metal	**Percentage**
Nickel	60%
Chromium	12%
Iron	26%
manganese	2%

Properties:

i. It shows good resistance to oxidation and heat.
ii. Steels containing **16** to **20 %** chromium with low carbon content **(0.06 to 0.15%)** possess oxidation resistance upto **900$_{\circ}$ C.**
iii. Steel containing **18%** nickel, with small amounts of chromium can withstand temperature above **900$_{\circ}$ C**.

iv. It can withstand heat upto **1000** to **1100 ^{o}C.**

Uses:

i. It is widely used for making resistance coils, heating elements in stoves ii. Used making parts of boilers, steam-lines stills, gas-turbines, aero-engine valves, retorts, annealing boxes.

2. **Stainless Steels**

These are alloy steels containing chromium together with other elements such as **Ni, Mo, Cr** is effective content **16%** or more. The carbon content in stainless steel ranges **0.3** to **1.5%.**

Stainless steel resists corrosion by atmospheric gases and also by other chemicals. Protection against corrosion is mainly due to the formation of dense, non-porous, tough film of chromium oxide at the surface of metal. If this film cracks, it gets automatically healed-up by atmospheric oxygen. **Types**

1. **Heat treatable stainless steels**
2. **Non heat treatable stainless steels**

1. Heat treatable stainless steels Composition:

These steels mainly contain upto **1-2%** of carbon and less than **12-16%** of chromium.

Properties

Heat-treatable stainless steels are magnetic, tough and can be worked in cold condition.

Uses

i. They can be used upto **800 ^{o} C.**

ii. They are used in making surgical instruments, scissors, blades

2. Non-heat treatable stainless steels

These steels possess less strength at high temperature. They are more resistatnt to corrosion.

Types

According to their composition, they are of two types.

(i) Magnetic type

Composition

It contains **12-22 %** of chromium and **0.35%** of carbon

Properties

i. It can be forged, rolled and machined by the use of specially designed tools ii. It resists corrosion better than heat-treatable stainless steel.

Uses

It is used in making chemical equipments and automobile parts.

(ii) Non-Magnetic type

Composition

It contains **18-26%** of chromium, **8-21%** of nickel and **0.15%** of carbon. Total percentage of Cr and Ni in such steel is more than **23%**.

18/8 Stainless steel

If the steel contains **18% Cr** and **8% Ni**, it is referred to as **18/8** stainless steel. It is the most widely used stainless steel.

Properties

i. It exhibits maximum resistance to corrosion
ii. Corrosion resistance of which can be further increased by adding a little quantity of molybdenum.

Uses

It is used in making household utensils, sinks, dental and surgical instruments.