Department of Humanities and Applied Sciences

Applied Chemistry (Semester-I) (2024-25)

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Module 3

Alloys

ATHARVA COLLEGE OF ENGINEERING

Detailed Content

A) Purpose of making alloys.

B) i) Gibbs Phase rule – Statement, Terms involved with examples.

ii) Reduced phase rule, Two-component system (Pb-Ag) & Numerical.

iii) Merits and Limitations of Phase rule.

Alloys

- Pure metals are soft, chemically reactive, high melting and less corrosion resistant.
- The properties of any metal can be modified by alloying it with one or more elements to develop desired properties in it.
- An Alloy is an intimate mixture of two or more elements out of which one must be a metal.
- Alloys are formed from metals and non-metals.
- Alloying maintains the chemical properties of elements while enhancing their physical properties.

Purpose of making alloys

1. Improving Strength and Durability

Example: Steel (iron + carbon)

Applications: Construction, bridges, machinery

2. Enhancing Corrosion Resistance

Example: Stainless Steel (iron + chromium + nickel)

Applications: Kitchen utensils, medical instruments, outdoor structures

3. Increasing Hardness

Example: Bronze (copper + tin)

Applications: Tools, weapons, sculptures

Purpose of making alloys

4. Improving Workability

Example: Aluminium Alloys (aluminium + copper/magnesium)

Applications: Aerospace parts, lightweight structures

5. Enhancing Electrical and Thermal Conductivity

Example: Brass (copper + zinc)

Applications: Electrical contacts, plumbing fittings

6. Achieving Specific Aesthetic Qualities

Example: Gold Alloys (gold + silver/copper)

Applications: Jewellery, decorative items

Purpose of making alloys

7. Reducing Material Costs

Example: Aluminium Alloys (alternative to titanium/steel)

Applications: Consumer goods, automotive parts

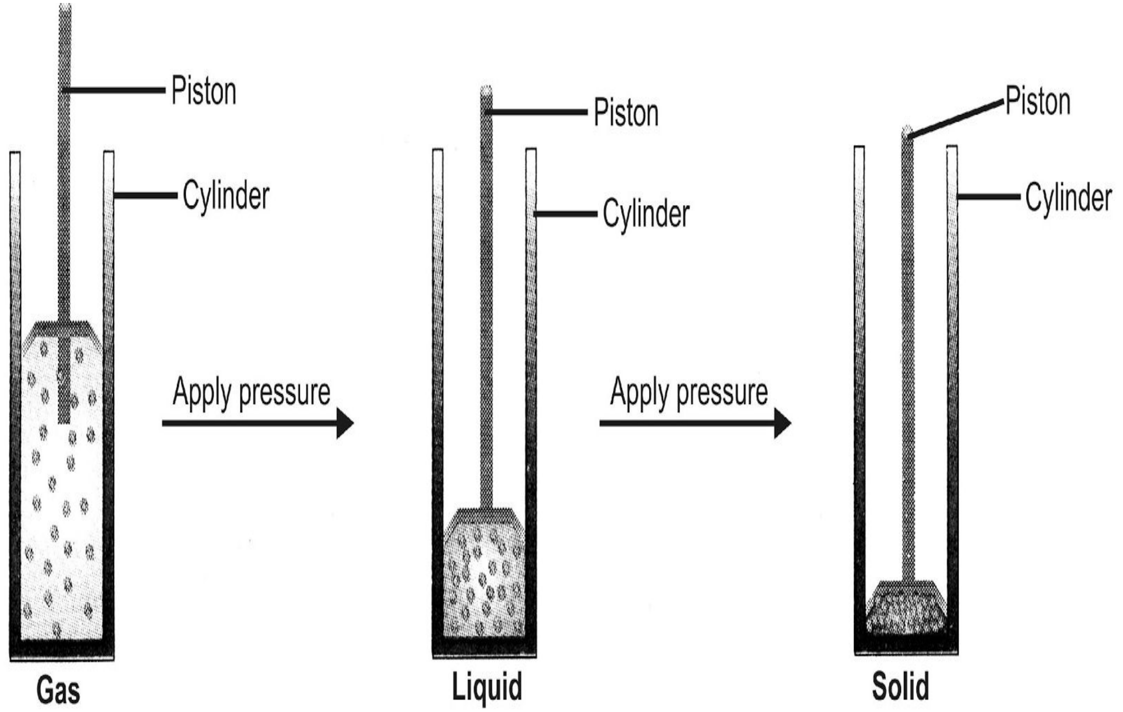
8. Optimizing Specific Functional Properties

Example: Nitinol (nickel + titanium)

Applications: Medical devices, precision instruments

Phase rule

- Phase rule is a given by Willard Gibbs, which deals with the behavior of heterogeneous system in a state of equilibria.
- The effect of changing temperature, pressure and concentration/component on a heterogeneous system in equilibrium, such a diagram is known as *phase diagram* .



Gibbs phase rule

Provided equilibrium between any number of phases is not influenced by gravitational, electric or magnetic forces or by surface action, but only by temperature, pressure and concentration, then the number of degrees of freedom of system is related to number of components and phases by the phase rule equation, $F=C-P+2$,for any system at equilibrium at definite temperature and pressure.

1. Phase (P)
2. Components (C)
3. Degrees Of Freedom (F)

Phase

It is defined as **" Physically distinct, homogenous and mechanically separable part of a system".**

(i) A gaseous mixture constitutes a single phase since gases are completely miscible.

example : **Air**

(ii) Two or more liquids which are miscible with one another constitute a single phase as there is no bounding surfaces separating the different liquids.

example : **water and alcohol**, **chloroform and benzene** constitute one phase system.

(iii) A system consisting of a liquid in equilibrium with its vapour constitute a two phase system

example : $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$

How many phases are there in each of the following systems?

Questions

1. Liquid water, pieces of ice and water vapor are present together.
2. Calcium Carbonate undergoes thermal decomposition.
   $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
3. A solution of NaCl in water
4. Liquid water + water vapor
5. Liquid water + water vapor + air

Answers

1. Number of phases = 3
2. Number of phases = 3
3. Number of phases = 1
4. Number of phases = 2
5. Number of phases = 2

Component

It is defined as "Minimum number of independent variable constituents which are required to express the composition of each phase in the system".

In a chemically reactive system, the number of components is given by

$$C = N - E$$

Where, C - components.

N - Number of chemical species

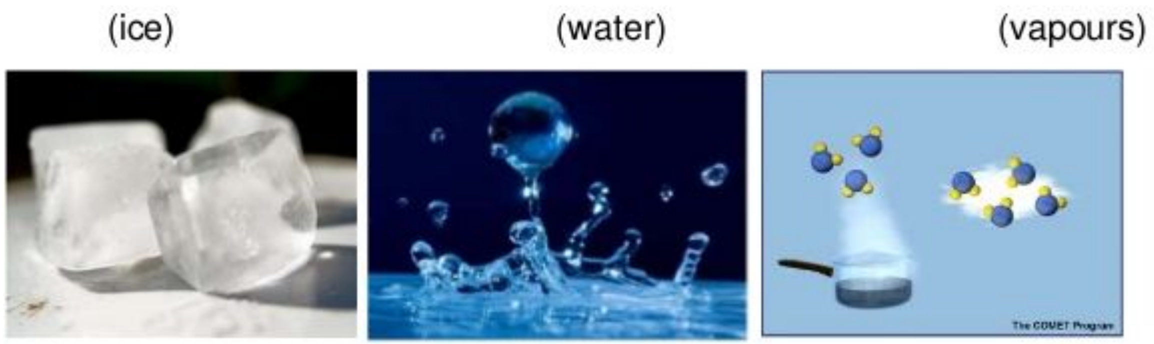
E - Number of independent equations relating to the concentrations of the species.

- Each independent chemical equilibrium involving the constituents count as one equation.
- The condition that a solution be electrically neutral also counts as one equation if ions are considered as constituents

Examples

Water system

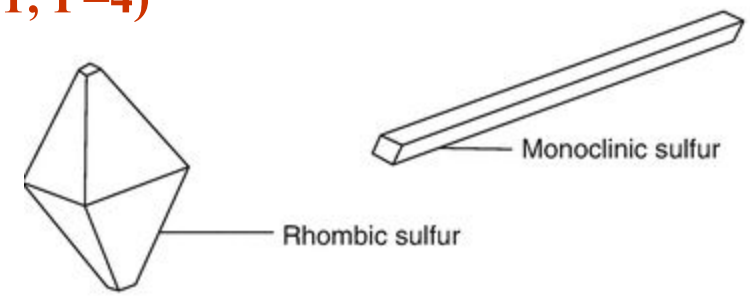
Solid, liquid water and water vapours **(C=1 ; P = 3)**



Sulphur system

(a) monoclinic sulphur, (b) rhombic sulphur (c) liquid sulphur (d) sulphur vapour.

(C = 1; P=4)



Salt + water system

Sat. Solution of NaCl (a) Solid salt (b) Salt Solution (c) water vapour
(C = 2; P=3)

The chemical composition of all three phases can be expressed in terms of NaCl and H_2O.

Degrees of Freedom

"It is defined as the minimum number of independent variables such as temperature, pressure and concentration which should be specified in order to define the system completely".

Examples

(i) State of a pure gas can be specified by two variables P and T or P and V, third variable can be calculated.

Hence pure gas has degree of freedom two (F = 2) **Bivariant**

(ii) $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$ (F = 1) **Monovariant**

(iii) A gaseous mixture say N_2 and O_2 gases is completely defined when three variables (T, P and C).

(F = 3) **Trivariant**

Reduced phase rule

In a two component system, C = 2. According to phase rule –

$$F = C - P + 2$$
$$= 2 - P + 2$$
$$= 4 - P$$

The minimum number of phases in a two component system is one. So the maximum number of degree of freedom is –

$$F = 4 - P$$
$$= 4 - 1$$
$$= 3$$

Reduced phase rule

- Three variables (pressure, temperature and concentration) must be specified in order to describe a two component system completely.

- For the graphic representation of these variables, a 3D diagram is required in which the three co-ordinate axes representing pressure, temperature and concentration are at right angles to each other.

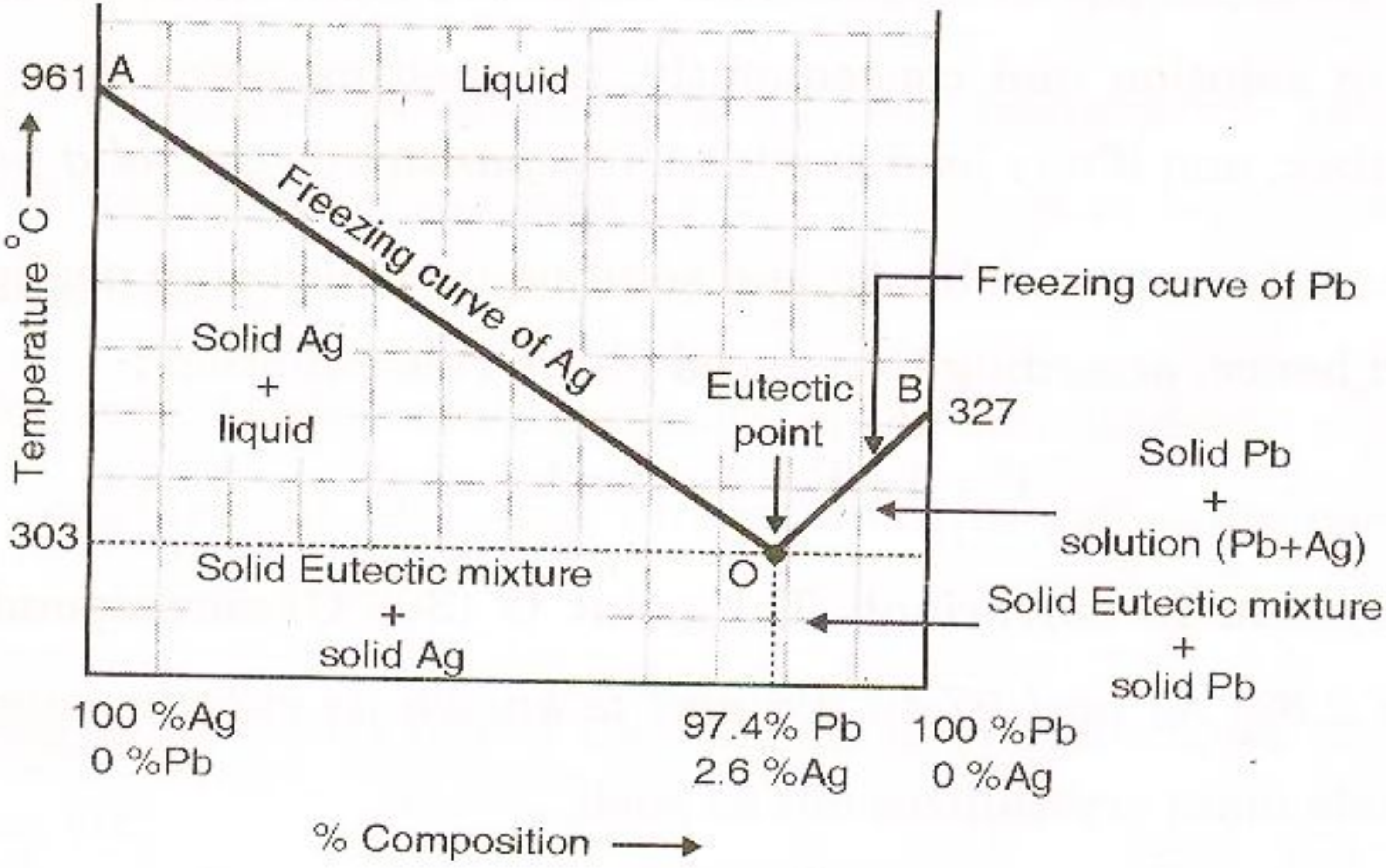
- Phase equilibria is mainly deal with 2D diagram. So, one of the variables is kept constant.

- When P is kept constant , vapour phase of the system is not considered.

- In this case system is said to be condensed and phase rule is said to reduced to:

  $$F = C - P + 1$$

Two-component system (Pb-Ag)



The phase diagram of Pb- Ag system

In the phase diagram of Pb-Ag, the following features are observed:-

1) CURVE AO

- Indicates freezing point of Ag on addition of Pb 961^{0} C
- Along the curve , solid Ag and solution coexist and hence,

$$
\begin{aligned}
F &= C - P + 1 \\
&= 2-2+1 \\
&= 3-2 \\
&= 1
\end{aligned}
$$

2) CURVE BO

- Is the freezing curve of Pb
- Represents the effect on freezing point of Pb on addition of Ag
- Point B – melting point of pure lead(327 ^{O}C).

3) POINT O (Eutectic point)

- System is invariant
- we get F=0
- Point O – fixed composition of Ag = 2.6% and Pb = 97.4% and temperature is 303° C is called eutectic composition mixture

4) AREA AOB

- Represents solution of Pb-Ag.
- This area, silver and lead are present as a homogeneous liquid solution. Thus, there is only one phase in this region. Applying the condensed rule to any point in this area,
- We obtain F=C-P+1 = 2-1+1=2 Therefore, system is bivariant.

The Lead – Silver system is utilized in Pattison's Process of desilverization of lead.

Merits

i. It provides a simple method of classifying **equilibrium states of systems.**

i. The phase rule confirms that the different systems having the same **number of degrees of freedom** behave in same manner.

i. It is applicable only to **macroscopic systems** and not concerned with molecular structure.

i. It predicts the **behavior of the systems** with changes in the variables that govern the system in equilibrium.

i. It predicts that, under a given conditions whether a number of substances taken together would **remain in equilibrium** or it involves in some **interconversion or elimination.**

i. It does not give the information about the nature of the reactants or products in the reactions.

i. It finds extensive use in the study of many heterogeneous systems.

i. It is extremely useful in the extraction of metals.

Limitations

i. The phase rule is **applicable to heterogeneous systems in equilibrium**, hence it is not applicable for the **systems which are slow** to attain the equilibrium state.

i. It is applicable to a **single equilibrium state**. It never gives information about the other possible equilibrium in the system.

i. Variables such as **temperature, pressure and composition** are only taken into account in Gibbs phase rule,.

i. It does not take in account the **electric and magnetic influences**. For consideration of such variables, the factor 2 of the Phase rule has to be adjusted accordingly.

i. All the phases in the system must be present under the **same Temperature, Pressure and Gravitational force .**

i. Solid or liquid phases are not finely divided, If it happens deviation must occurs.

“Strength comes from combining different elements, and success comes from blending hard work with perseverance”.

Thank you