



VIVEKANANDA COLLEGE, THAKURPUKUR

**NAAC Accredited Grade—A
STUDY MATERIAL**

Subject : Physical Chemistry

Course Title : Applications of Thermodynamics II

Topic : Mathematical Problems & Questions-answers discussion on
The Phase Equilibrium Chapter.

Paper : Physical Chemistry – **3** (CODE: CEMA-CC-4-9-TH)

Semester : 4th Semester

Teacher : Dr. Sanjib Kumar Bhar*

Department : Chemistry

**Associate Professor, Department of Chemistry, Vivekananda College,
Thakurpukur*

Mathematical Problems:

1. Calculate the molal solubility of CO₂ in water at 298 K and a CO₂ pressure of 3.3 x 10⁻⁴ atm, which corresponds to the partial pressure of CO₂ in air. (K = 1.24 x 10⁶ torr)

Henry's law suggests P = K x₂ where K = Henry's constant and x₂ = mole fraction of CO₂.

$$\begin{aligned}x_2 &= P / K = 3.3 \times 10^{-4} \times 760 \text{ torr} / 1.24 \times 10^6 \text{ torr} \\ &= 2.0225 \times 10^{-7}\end{aligned}$$

n₂/n₂+n₁ where n₂ = no of moles of CO₂ present and n₁ = no of moles of water

$$n_1 = 1000/18 = 55.555 \text{ mole}$$

$$\therefore n_2/n_2+n_1 = 2.0225 \times 10^{-7}$$

$$\text{Or, } n_2 (1 - 2.0225 \times 10^{-7}) = 55.555 \times 2.0225 \times 10^{-7}$$

$$\text{Or, } n_2 = 1.1236 \times 10^{-5} \text{ molal}$$

$$\therefore \text{Molality of CO}_2 \text{ present} = \mathbf{1.1236 \times 10^{-5} \text{ molal}}$$

2. Liquids A and B form an ideal solution, the vapour pressures of pure A and B are 66 torr and 88 torr respectively. Calculate the composition of the vapour in equilibrium with a solution containing 36 mole percent of A.

$$\begin{aligned}\text{From Raoult's law, } p_A &= x_A \cdot P^\circ_A = 0.36 \times 66 \text{ torr} = 23.8 \text{ torr} \\ &\text{and}\end{aligned}$$

$$p_B = x_B \cdot P^\circ_B = 0.64 \times 88 \text{ torr} = 56.3 \text{ torr}$$

$$\therefore \text{total pressure } p_A + p_B = (23.8 + 56.3) = 80.1 \text{ torr}$$

$$\text{Composition of A} = x_{A(\text{vap})} = \mathbf{23.8 / 80.1 = 0.297} \text{ and composition of B} = x_{B(\text{vap})} = \mathbf{56.3 / 80.1 = 0.7028}$$

3. Calculate the Gibbs free energy and entropy of mixing of 1.6 moles of Argon at 1 atm and 25 °C with 2.6 moles of nitrogen at 1 atm and 25 °C. Assume ideal behavior.

$$\begin{aligned}\Delta G_{\text{mix}}(\text{ideal}) &= nRT \sum x_i \ln x_i = 4.2 \text{ mole} \times 8.314 \text{ J mole}^{-1}\text{K} \times 298 \text{ K} [(1.6/4.2 \ln(1.6/4.2) \\ &+ 2.6/4.2 \ln(1.6/4.2)]\end{aligned}$$

$$\begin{aligned}
&= 10405.8024\text{J} (-0.3676 - 0.2969) \\
&= \mathbf{6914.43\text{J}} \\
&= \mathbf{6.914\text{J}}
\end{aligned}$$

$$\begin{aligned}
\Delta S_{\text{mix}}(\text{ideal}) &= -nR \sum x_i \ln x_i = -4.2 \text{ mole} \times 8.314 \text{ J mole}^{-1} \text{ K}^{-1} [1.6/4.2 \cdot \ln(1.6/4.2) + \\
&2.6/4.2 \cdot \ln(2.6/4.2)] \\
&= -34.9188 \times (-0.3676 - 0.2969) \text{ J K}^{-1} \\
&= \mathbf{23.2 \text{ J K}^{-1}}
\end{aligned}$$

4. If 29 mg of N₂ dissolves in 1 L of water at 0 °C and 760 torr N₂ pressure, how much N₂ will dissolve in 1L of water at 0 °C and 5 atm N₂ pressure?

As per first condition $x_{\text{N}_2} = K \cdot P = K \cdot 760 \text{ torr}$

∴ According to second condition, $x'_{\text{N}_2} = K \cdot 5 \times 760 \text{ torr}$

∴ $x'_{\text{N}_2} = 5 \times x_{\text{N}_2} = \mathbf{5 \times 29 \text{ mg per L} = 145 \text{ mg/L}}$

5. A litre of CO₂. At 15 °C and 1.00 atm dissolves in 1.00 litre of water at the same temperature when the pressure of CO₂. is 1.00 atm. Compute over which the partial pressure of CO₂. is 150 torr at this temperature.

No of moles of CO₂. present = $PV/RT = 1 \times 1 \text{ lit. atm} / .082 \text{ lit. atm. K}^{-1} \text{ mol}^{-1} \times 288 \text{ K} = 0.04234 \text{ mole}$

Mole fraction CO₂. = $.04234 / (.04234 + 1000/18) = 7.615 \times 10^{-4} = x_2$

We know that $x_2 = K \cdot P$

Or, $K = x_2 / P = 7.615 \times 10^{-4} / 1 \text{ atm} = 7.615 \times 10^{-4} \text{ atm}^{-1}$

But when partial pressure is 150 torr = 150 / 760 atm, then

$x'_2 = K \cdot p_{\text{new}} = 7.615 \times 10^{-4} \text{ atm}^{-1} \times (150/760) \text{ atm} = 1.503 \times 10^{-4}$

Therefore, new concentration of CO₂ in water(1lit) = $1.503 \times 10^{-4} = / (n'_2 + n_1)$

So, $(n'_2 + 1000/18) \times 1.503 \times 10^{-4} = n'_2$

By solving we get new concentration of CO₂ (n'₂) = 8.351 x 10⁻³ (m)

6. A phenol + water system separates system into two-liquid phases at a temperature of 60 °C. The first phase contains 16.8 mass% of phenol, the second phase contains 44.9 % of water by

mass. If the system contains 90 g of water and 60 g of phenol, what is the mass of each phase?

Let the weight of the water rich layer = a

∴ Weight of phenol rich layer = 150-a

For the first phase: Phenol = 16.8 % by weight and water = 83.2% by weight

For the second phase: Water = 44.9 % by weight and Phenol = 55.1% by weight

By problem, $0.551 \times (150 - a) + 0.168 \times a = 60$

$$\text{Or, } 82.65 - 0.551a + 0.168a = 60$$

$$\text{Or, } (0.551 - 0.168) \times a = (82.65 - 60) = 22.65$$

$$\text{Or, } 0.383 \times a = 22.65$$

$$a = 22.65 / 0.383$$

$$= 59.138 \text{ g.}$$

So, weight of the water rich layer = 59.138 g.

And weight of the phenol rich layer = (150-59.138) g.

7. A certain solution of benzoic acid in benzene has freezing point 3.1°C and boiling point of 82.6°C at 1 atm pressure. Explain these observations and suggest the structure of the solute particles at two temperatures. [Given: $T_f = 278.5 \text{ K}$ (normal), $T_b = 353 \text{ K}$ (normal), $K_f = 5.12 \text{ kg mol}^{-1}$, $K_b = 2.53 \text{ kg mol}^{-1}$ for benzene)

$$\Delta T_f = K_f \cdot C_m \text{ and } \Delta T_b = K_b \cdot C_m \text{ also } i_f = (\Delta T_f)_{\text{expt}} / (\Delta T_f)_{\text{theo}} ; i_b = (\Delta T_b)_{\text{expt}} / (\Delta T_b)_{\text{theo}}$$

$$(\Delta T_f)_{\text{expt}} = (278.5 - 276.1) \text{ K} = 2.4 \text{ K} = 2.4^\circ\text{C}$$

$$(\Delta T_f)_{\text{theo}} = K_f \cdot C_m = 5.12 \text{ kg. mol}^{-1} C_m$$

$$\therefore i_f = (\Delta T_f)_{\text{expt}} / (\Delta T_f)_{\text{theo}} = 2.4^\circ\text{C} / 5.12 \text{ kg. mol}^{-1} C_m = 0.46875^\circ\text{C} / \text{kg. mol}^{-1} C_m$$

$$(\Delta T_b)_{\text{expt}} = (82.6^\circ\text{C} - 80^\circ\text{C}) = 2.6^\circ\text{C}$$

$$(\Delta T_b)_{\text{theo}} = 2.53 \text{ kg. mol}^{-1} \cdot C_m$$

$$i_b = (\Delta T_b)_{\text{expt}} / (\Delta T_b)_{\text{theo}} = 2.6^\circ\text{C} / 2.53 \text{ kg. mol}^{-1} \cdot C_m = 1.02766^\circ\text{C} / \text{kg. mol}^{-1} C_m$$

$$\therefore i_b / i_f = (1.02766 \text{ }^\circ\text{C} / \text{kg. mol}^{-1} C_m) / (0.46875 \text{ }^\circ\text{C} / \text{kg. mol}^{-1} C_m) = 2.19$$

Higher i means number of particles are higher. Hence, a greater number of particles are present near the boiling point in comparison to that near the freezing point.

i_f / i_b is just nearly half of the i_b . At low temperature benzoic acid remains as associated form and probably as dimer and dissociates as monomer at higher temperature.

8. The melting point of phenol is $40 \text{ }^\circ\text{C}$. A solution containing 0.172 g . acetanilide in 12.54 g . phenol freezes at $39.25 \text{ }^\circ\text{C}$. Calculate the cryoscopy constant and the latent heat of fusion of phenol.

Molecular formula of acetanilide = $\text{C}_8\text{H}_9\text{NO} = 8 \times 12 + 9 \times 1 + 14 + 16 = 135$;

$$\Delta T_f = K_f \cdot C_m$$

$$\text{Or, } (40 - 39.25) \text{ }^\circ\text{C} = 0.75 \text{ }^\circ\text{C}$$

$$\text{Or, } K_f \cdot C_m = 0.75 \text{ }^\circ\text{C}$$

$$\text{Or, } K_f = 0.75 \text{ }^\circ\text{C} / C_m$$

$$C_m = 1000 \times 0.172 / (135 \times 12.54) = 0.1016 \text{ (m)}$$

$$K_f = 0.75 / 0.1016 = 7.3818 \text{ K mol g}^{-1}$$

$$K_f = R T_f^2 / 1000 \cdot L_f$$

$$L_f = R T_f^2 / 1000 \times K_f = 8.314 \text{ J mol}^{-1} \text{K}^{-1} \times 313^2 \text{ K}^2 / (1000 \times 7.3818 \text{ K mol}^{-1} \text{g}) = 110.24 \text{ J / g} \\ = 110.34 \text{ J.g}^{-1}$$

9. Water boils at 373 K at one atmospheric pressure. At what temperature will it boil when atmospheric pressure becomes 528 mm of Hg at some space station? Latent heat of water 2.28 kJ g^{-1} ($R = 8.314 \text{ JK}^{-1} \text{ mol}^{-1}$)

$$\ln(P_2/P_1) = \Delta H_v / R [1/T_1 - 1/T_2] \text{ where } \Delta H_v = 2.28 \text{ kJ g}^{-1} = 2280 \times 18 \text{ J mole}^{-1} = 41040 \text{ J mole}^{-1}$$

$$\text{or, } \ln(528/760) = (41040/8.314) \text{ K}^{-1} [1/373 - 1/T_2]$$

$$\text{or, } -0.3642 = 4936.25 \text{ K}^{-1} [1/373 - 1/T_2]$$

$$\text{or, } 1/373 - 1/T_2 = -7.378 \times 10^{-5} \text{ K}^{-1}$$

$$\text{or, } 1/T_2 = [1/373 + 7.378 \times 10^{-5}] \text{ K}^{-1}$$

$$\text{or, } 1/T_2 = 2.7547 \times 10^{-3} \text{ K}^{-1}$$

or, $T_2 = 363 \text{ K}$

10. The vapour pressure of n-butyl alcohol is given by the equation:

$$\log_{10} P(\text{mm}) = -2443 / T + 9.136$$

Calculate the heat of vaporization per mole of the liquid at the normal boiling point, 117°C .

As per Clausius – Clapeyron equation, $dP / dT = \Delta H_v / T (V_g - V_L)$ (1)

We have $\log_{10} P(\text{mm}) = -2443 / T + 9.136$

Differentiating w. r. t. temperature T , we get,

$$1/P \cdot dP / dT = 2443 / T^2$$

$$\text{Or, } dP / P = 2443 dT / T^2$$

$$\text{Or, } \ln P = -2443/T + \text{Constant}$$

$$\text{Or, } \log_{10} P = -2443/2.303T + \text{Constant}$$

From equation (1), $dP / dT = \Delta H_v / T (V_g - V_L) = \sim \Delta H_v / T$. $V_g = \Delta H_v \cdot P / RT^2$

$$\text{Or, } dP / P = \Delta H_v / RT^2$$

$$\text{Or, } \log_{10} P = -\Delta H_v / 2.303 RT + \text{Constant} \dots\dots\dots(3)$$

Comparing equation (3) with the given equation, we get,

$$-\Delta H_v / 2.303R = -2443$$

$$\text{Or, } \Delta H_v = 2443 \times 2.303 \times 8.314 = 46776 \text{ J K}^{-1} \text{ mol}^{-1} = 46.776 \text{ kJ K}^{-1} \text{ mol}^{-1}$$

11. Calculate the rate of change of transition temperature with pressure of Sulphur if transition temperature is 95.5°C at 1atm pressure, enthalpy of transition per gram of Sulphur is 13.41 J and monoclinic Sulphur (stable above transition points) has a greater specific volume than that of rhombic sulphur by $0.0126 \text{ cm}^3 \cdot \text{g}^{-1}$.

$$dP / dT = \Delta H_v / T \Delta V$$

$$dT / dP = T \Delta V / \Delta H_v = 368.5 \text{ K} \times 0.0126 \text{ cm}^3 \cdot \text{g}^{-1} / 13.41 \text{ J g}^{-1} = 0.34624 \text{ K} \cdot \text{cm}^3 / \text{J}$$

$$= 0.34624 \text{ K} \cdot \text{cm}^3 / 9.8628 \text{ atm cm}^3 = 0.0351 \text{ K atm}^{-1}$$

∴ Rate of change of transition temperature with pressure of Sulphur temperature = $0.0351 \text{ K atm}^{-1}$.

12. The Henry's law constant for a solution of acetone in chloroform is 150 torr when the solution is at 308K. Calculate the value of vapour pressure of acetone when it's mole fraction is 0.14.

According to Henry's law: $P = x_B \cdot K_H$; where K_H = Henry's constant

$$\therefore P = 0.14 \times 150 \text{ torr} = 21 \text{ torr}$$

13. The solubility of O₂ in water at NTP is 0.0632 g per litre. At what pressure one litre of water at 0 °C dissolves 4.0 g of oxygen?

$$x_{O_2} = (0.0632 / 32) / (0.0632 / 32 + 1000/18) = 1.975 \times 10^{-3} / 55.5575 = 3.55 \times 10^{-5}$$

$$K_H = P / x_{O_2} = 1 \text{ atm} / 3.55 \times 10^{-5} = 2.813 \times 10^4 \text{ atm.}$$

$$P_{\text{new}} = (4/32) / (4/32 + 1000/18) \times 2.813 \times 10^4 \text{ atm.} = 0.125 / 55.6805 = 63.15 \text{ atm.}$$

14. The total vapour pressure of 4 % (mole/molecule) solution of NH₃ in water is 50 torr, the vapour pressure of pure water is 17.0 torr at this temperature. Applying Henry's law and Raoult's law, calculate the two partial pressures and total pressure for 5 % solution.

$$P_{\text{total}} = p_{NH_3} + p_{H_2O}$$

$$x_{NH_3} = 0.04; x_{H_2O} = 0.96$$

$$p_{H_2O} = x_{H_2O} \cdot P^{\circ} = 0.96 \times 17.0 \text{ torr} = 16.32 \text{ torr}$$

$$p_{NH_3} = P_{\text{total}} - p_{H_2O} = 50 \text{ torr} - 16.32 \text{ torr} = 33.68 \text{ torr}$$

$$\text{From Henry's law, } p_{NH_3} = K_H \cdot x_{NH_3}$$

$$\text{Or, } 33.68 \text{ torr} = K_H \times 0.04;$$

$$K_H = 33.68 \text{ torr} / 0.04 = 842 \text{ torr}$$

$$\text{By problem, } p_{NH_3} = K_H \cdot x_{NH_3} = 842 \text{ torr} \times 0.05 = 42.1 \text{ torr}$$

$$p_{H_2O} = 0.95 \times 17.0 \text{ torr} = 16.15 \text{ torr}$$

$$\text{Therefore, total new pressure} = (16.15 + 42.1) \text{ torr} = 58.25 \text{ torr}$$

Short Question and Answers

Q1. What is the maximum no. of phases that co-exist for a component system?

$$F = C - P + 2 = 2 - P + 2 = 4 - P. \text{ For } P = 4, F = 0$$

When P is maximum, then F is minimum i.e. F = 0

Q2. For a substance having three phases (solid, liquid, vapour) are in equilibrium at the triple point is invariant whereas the freezing pt. is variable. How would you account for this?

For the triple point, $F = C - P + 2 = 1 - 3 + 2 = 0$ i.e. the system is invariant. When we consider the freezing point, we will consider it under atmospheric pressure, and it has been observed that presence of air exists over the solid or liquid. Thus, the gaseous phase contains not only water

vapour but also contains air. Thus, the number of components becomes more than one and hence degree of freedom i.e. F will not be zero. Hence the freezing point is variable.

Q3. Density of monoclinic Sulphur is less than that of rhombic Sulphur – explain with the phase diagram.

In the phase diagram of Sulphur, slope of the curve is explained by the Clapeyron equation i.e. $dP/dT =$

$L_t / T (V_m - V_r)$; where L_t = latent heat of transition, V_m = volume of monoclinic Sulphur and V_r = volume of rhombic Sulphur. As $V_m > V_r$, so dP/dT becomes positive. Though monoclinic and rhombic variety of Sulphur have same molecular weight, hence density of monoclinic Sulphur is less than that of rhombic Sulphur.

Q4. “A mixture of salt and ice acts as a freezing mixture”. Or “Salt is spread over ice for its melting” – explain.

When salt is added into ice or when salt spreads over ice, then the ice mixture becomes three component system and applying phase rule, we get, $F = C - P + 2$. At constant P , it becomes $F = C - P + 1$. So, for the ice mixture, $F = 2 - 3 + 1 = 0$. So, the system is non variant and any variation of the variable will cause the disappearance of phase. Now a portion of the added salt dissolves in water and it causes the variation in composition. The easiest way is the disappearance of salt by getting dissolved in water. But for this type of dissolution of salt in water, it takes latent heat from the surroundings and hence surrounding temperature also falls. Due to this lowering of temperature, a mixture of salt and ice acts as a freezing mixture.

Q5. “A mixture of Na_2CO_3 and K_2CO_3 is used as fusion mixture” – explain.

Both Na_2CO_3 and K_2CO_3 are high melting solids and in the laboratory, Bunsen burner cannot provide such high temperature for melting the above compounds individually. But the mixture of both produces the solid solution having low melting point which is easily achievable in the laboratory with the help of Bunsen burner. Hence the mixture of Na_2CO_3 and K_2CO_3 is used as fusion mixture.

Q6. Why extraction of aluminum from Al_2O_3 needs fluorspar and cryolite?

Q7. “A mixture of Sn and Pb is used for soldering” – explain?

A mixture Sn and Pb produces a simple eutectic system having very low melting point solidifies with appreciable plasticity. This is why a mixture of Sn and Pb is suitable for soldering purpose in the electrical line.

Q8. Why ethyl alcohol and water cannot be separated into pure compounds by fractional distillation?

Ethyl alcohol and water cannot be separated into pure compounds by fractional distillation as they form azeotropic mixture having same composition at the vapour phase and in the liquid mixture.

Q9. Equimolar solutions may not be isotonic – justify your answer.

Equimolar solutions of non-electrolytes are isotonic but in the case of solutions of electrolytes, they are not isotonic as Van't Hoff factors (i) are different.

Q10. Is it possible to have quadruple point on a phase diagram for a one-component system?

$$F = C - P + 2 = 1 - P + 2 = 3 - P$$

For a quadruple point, $P = 4$, then $F = 3 - 4 = -1$ which is ridiculous. Hence it is not possible to have quadruple point on a phase diagram for a one-component system.

Q11. Calculate the number of components, number of phases and degrees of freedom of the following

system: (i) A liquid at its critical temperature (ii) A binary azeotrope.

Ans:

(i) $F = C - P + 2 = 1 - 2 + 2 - 1 = 0$

(ii) $C = S - R - Z$, where where C = Number of components,

S = Number of chemical species present in the system, R = Number of independent chemical reactions and

Z = Number of restricting conditions. Therefore, $C = 3 - 1 - 0 = 1$, $F = 2 - 2 + 2 - 1 = 1$

Q12. Discuss the effect of the use of D_2O in place of water in phenol -water system in determining CST?

Ans:

In a partially miscible system, where water is one of the components, then CST changes by changing the isotopic ratio hydrogen in water e.g., in the phenol-water system, the CST is raised by using D_2O in place of water.

Problems based on Phase Rule:

Number of components for a non – reactive system = Number of constituents.
 Number of components for a reactive system $C = S - R - Z$; where C = Number of components,
 S = Number of chemical species present in the system, R = Number of independent chemical reactions,
 Z = Number of restricting conditions.

I.

Calculate the number of components and degrees of freedom for the following equilibria:

(i) An aqueous solution of glucose. (ii) An aqueous solution of NaCl. (iii) An aqueous solution of mixture of NaCl and KBr in equilibrium with the vapour phase. (iv) $\text{NH}_4\text{Cl} \rightleftharpoons \text{NH}_3(\text{g}) + \text{HCl}(\text{g})$ system in which

(a) $P_{\text{NH}_3} = P_{\text{HCl}}$; (b) $P_{\text{NH}_3} \neq P_{\text{HCl}}$

Ans: (i) $F = C - P + 2 = 2 - 1 + 2 = 3$ (Temperature, Pressure and Concentration of solution)

(ii) $F = 2 - 1 + 2 = 3$ (T, P and concentration of solution)

(iii)

$$F = C - P + 2$$

Here $C = S - R - Z$ where C = Number of components, S = Number of chemical species present in the system, R = Number of independent chemical reactions, Z = Number of restricting conditions.

Thus $C = 10 - 5 - 1 = 4$

$\therefore F = 4 - 1 + 2 = 5$

(iv)

(a) $F = C - P + 2$

Here $C = S - R - Z$ where C = Number of components, S = Number of chemical species present in the system, R = Number of independent chemical reactions, Z = Number of restricting conditions.

$\therefore C = 3 - 1 - 1 = 1$

$\therefore F = 1 - 2 + 2 = 1$

(b)

$$F = C - P + 2$$

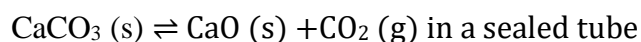
Here $C = S - R - Z$ where C = Number of components, S = Number of chemical species present in the system, R = Number of independent chemical reactions, Z = Number of restricting conditions.

$$\therefore C = 3 - 1 - 0 = 2$$

$$\therefore F = 2 - 2 + 2 = 2$$

II.

Calculate the number of components, phases and degrees of freedom in the following equilibrium:



Ans:

$$F = C - P + 2$$

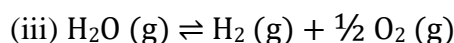
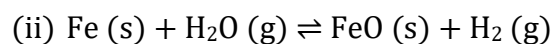
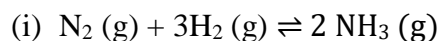
Here $C = S - R - Z$ where C = Number of components, S = Number of chemical species present in the system, R = Number of independent chemical reactions, Z = Number of restricting conditions.

$$\therefore C = S - R - 0 = 3 - 1 - 0 = 2$$

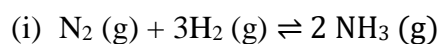
$$F = C - P + 2 = 2 - 3 (2 \text{ solid} + 1 \text{ gas}) + 2 = 1$$

III.

Write down the number of components, number of phases and degrees of freedom for the following equilibria:



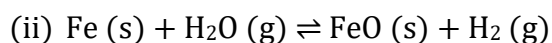
Ans:



For this type of reaction $C = S - R + Z$; Here $S = 3, R = 1, Z = 0$

$$\therefore C = 3 - 1 - 0 = 2$$

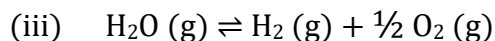
$$P = 1; F = C - P + 2 = 2 - 1 + 2 = 3$$



For this type of reaction $C = S - R + Z$; Here $S = 4, R = 1, Z = 0$;

$$C = 4 - 1 + 0 = 3$$

$$F = 3 - 3 + 2 = 2$$



For this type of reaction $C = S - R - Z$; Here $S = 3, R = 1, Z = 1$;

$$C = 3 - 1 - 1 = 1$$

$$F = 1 - 1 + 2 = 2$$

IV.

Calculate the number of components and the degrees of freedom in

- (i) An aqueous solution of acetic acid
- (ii) Pure partly frozen acetic acid
- (iii) A dilute solution of sulphuric acid in water

Ans:

$$(i) C = S - R + Z; \text{ here } C = 2 - 0 - 0 = 2; F = 2 - 1 + 2 = 3$$

$$(ii) C = S - R + Z; \text{ here } C = 1 - 0 - 0 = 1; F = 1 - 2 + 2 = 1$$

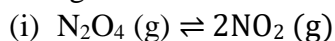
(iii) $C = S - R + Z$; a dilute solution of sulphuric acid in water gives itself $\text{H}_2\text{SO}_4, \text{H}_2\text{O}, \text{H}_3\text{O}^+,$

$\text{HSO}_4^-, \text{SO}_4^{2-}$. Therefore, $S = 5, R = 2$ and $Z = 1$

$$\therefore C = 5 - 2 - 1 = 2; F = 2 - 1 + 2 = 3$$

V.

Write down the number of components, number of phases and degrees of freedom for the followings:



(ii) Solid carbon in equilibrium with gases $\text{CO (g)}, \text{CO}_2 \text{(g)}$ and $\text{O}_2 \text{(g)}$ at 373 K.

(iii) $\text{NH}_4\text{Cl (s)}$ partially dissociated into $\text{NH}_3\text{(g)} + \text{HCl(g)}$

Ans:

$$(i) C = S - R - Z = 2 - 1 - 0 = 1; F = 1 - 1 + 2 = 2$$

$$(ii) C = S - R - Z = 4 - 2 - 1 = 1; F = 1 - 2 + 2 = 1$$

$$(iii) C = S - R - Z = 3 - 1 - 0 = 2; F = 2 - 2 + 2 = 2$$

