

Chapter 7: Equilibrium

NCERT Exemplar · Class 11 · Chemistry

Multiple Choice Questions (Type-I)

Question 1

We know that the relationship between K_c and K_p is $K_p = K_c(RT)^{\Delta n}$. What would be the value of Δn for the reaction-



- (i) 1
- (ii) 0.5
- (iii) 1.5
- (iv) 2

Solution

Ans: Δn = number of gaseous moles of products - number of gaseous moles of reactants

$$= 2 - 0 = 2$$

Hence, option(iv) is the correct answer.

Question 2

For the reaction $\text{H}_2 \text{ (g)} + \text{I}_2 \text{ (g)} \rightarrow 2\text{HI (g)}$ the standard free energy is $\Delta G^\ominus > 0$. The equilibrium constant (K) would be _____.

- (i) $K = 0$
- (ii) $K > 1$
- (iii) $K = 1$
- (iv) $K < 1$

Solution

Ans: The given chemical reaction is:



By, thermodynamical equation of equilibrium,

$$\Delta G^\ominus = -RT \ln K > 0$$

$$\Rightarrow -RT \ln K > 0$$

Now, $R > 0$ & $T > 0$

$$\Rightarrow -\ln K > 0$$

$$\Rightarrow K < 1$$

Hence, option(iv) is the correct answer.

Question 3

Which of the following is not a general characteristic of equilibria involving physical processes?

- (i) Equilibrium is possible only in a closed system at a given temperature.
- (ii) All measurable properties of the system remain constant.
- (iii) All the physical processes stop at equilibrium.
- (iv) The opposing processes occur at the same rate and there is dynamic but stable condition.

Solution

Ans: A physical equilibrium is having dynamic nature, both forward and reverse process occur at equal rates. Some kind of motion is always present. The individual molecules continuously move from one phase to another. Hence, option (iii) is the correct answer.

Question 4

PCl_5 , PCl_3 and Cl_2 are at equilibrium at 500K in a closed container and their concentrations are $0.8 \times 10^3 \text{ mol L}^{-1}$, $1.2 \times 10^3 \text{ mol L}^{-1}$ and $1.2 \times 10^3 \text{ mol L}^{-1}$ respectively. The value of K_c for

the reaction-



(i) $1.8 \times 10^3 \text{ mol L}^{-1}$

(ii) 1.8×10^{-3}

(iii) $1.8 \times 10^3 \text{ L mol}^{-1}$

(iv) 0.55×10^4

Solution

Ans: The chemical equation is given as-

$$K_c = \frac{[\text{PCl}_5][\text{PCl}_3]}{[\text{Cl}_2]}$$

$$= 0.8 \times 10^{-3} \text{ mol L}^{-1} \times 1.2 \times 10^{-3} \text{ mol L}^{-1} / 1.2 \times 10^{-3} \text{ mol L}^{-1}$$

$$= 1.8 \times 10^{-3} \text{ mol L}^{-1}.$$

Hence, option (iii) is the correct answer.

Question 5

Which of the following statements is incorrect?

(i) In equilibrium mixture of ice and water kept in perfectly insulated flask mass of ice and water does not change with time.

(ii) The intensity of red colour increases when oxalic acid is added to a solution containing iron (III) nitrate and potassium thiocyanate.

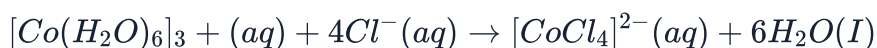
(iii) On addition of catalyst the equilibrium constant value is not affected. (iv) Equilibrium constant for a reaction with negative ΔH value decreases as the temperature increases.

Solution

Ans: Oxalic acid, reacts with ferric ions to form the stable complex ion $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$, thus decreasing the concentration of free ferric ions. Because the concentration of $[\text{Fe}(\text{SCN})]^{2+}$ decreases, as a result the intensity of red colour decreases. Hence, option (ii) is the correct answer.

Question 6

When hydrochloric acid is added to cobalt nitrate solution at room temperature, the following reaction takes place, and the reaction mixture becomes blue. On cooling the mixture, it becomes pink. On the basis of this information mark the correct answer.



- (i) $\Delta H > 0$ for the reaction
- (ii) $\Delta H < 0$ for the reaction
- (iii) $\Delta H = 0$ for the reaction
- (iv) The sign of ΔH cannot be predicted on the basis of this information.

Solution

Ans: On cooling the mixture reaction moves towards backward direction it means it is an endothermic reaction i.e., $\Delta H > 0$. Hence, option (i) is the correct answer.

Question 7

The pH of neutral water at 25°C is 7.0. As the temperature increases, ionisation of water increases, however, the concentration of H^+ ions and OH^- ions are equal. What will be the pH of pure water at 60°C?

- (i) Equal to 7.0
- (ii) Greater than 7.0
- (iii) Less than 7.0
- (iv) Equal to zero

Solution

Ans: As K_w increases Ans: As K_w increases $[H^+][OH^-] > 10^{-14}$. As $[H^+] = [OH^-]$ or $[H^+] = [OH^-]$ $[H^+]^2 = 10^{-14}$ or $[H^+] > 10^{-7}$

∴ pH < 7. Hence, option (iii) is the correct answer.

Question 8

The ionisation constant of an acid, K_a , is the measure of strength of an acid. The K_a values of acetic acid, hypochlorous acid and formic acid are respectively. Which of the following orders of pH of 0.1 mol dm³ solutions of these acids is correct?

- (i) acetic acid > hypochlorous acid > formic acid
- (ii) hypochlorous acid > acetic acid > formic acid
- (iii) formic acid > hypochlorous acid > acetic acid
- (iv) formic acid > acetic acid > hypochlorous acid

Solution

Ans: Higher the value of K_a higher will be the acidic strength K_a value for formic acid is highest and that will be of hypochlorous acid is lowest. Hence, option(iv) is the correct answer.

Question 9

K_{a_1} , K_{a_2} and K_{a_3} are the respective ionisation constants for the following reactions.

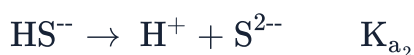


The correct relationship between K_{a_1} , K_{a_2} and K_{a_3}

- (i) $K_{a_3} = K_{a_1} \times K_{a_2}$
- (ii) $K_{a_3} = K_{a_1} + K_{a_2}$
- (iii) $K_{a_3} = K_{a_1} K_{a_2}$
- (iv) $K_{a_3} = K_{a_1} / K_{a_2}$

Solution

Ans:



$$K_{a_1} = \frac{[\text{HS}^-][\text{H}^+]}{[\text{H}_2\text{S}]}$$

$$K_{a_2} = \frac{[\text{H}^+][\text{S}^{2-}]}{[\text{HS}^-]}$$

$$K_{a_3} = K_{a_2} \cdot K_{a_1}$$

Hence, option(i) is the correct answer.

Question 10

Acidity of BF_3 can be explained on the basis of which of the following concepts?

- (i) Arrhenius concept
- (ii) Bronsted Lowry concept
- (iii) Lewis concept
- (iv) Bronsted Lowry as well as Lewis concept.

Solution

Ans: BF_3 is an electron deficient species that is why it is a Lewis acid. (all Lewis acid can accept a pair of electrons). Hence, option (iii) is the correct answer.

Question 11

Which of the following will produce a buffer solution when mixed in equal volumes?

- (i) $0.1 \text{ mol dm}^3 \text{ NH}_4\text{OH}$ and $0.1 \text{ mol dm}^3 \text{ HCl}$
- (ii) $0.05 \text{ mol dm}^3 \text{ NH}_4\text{OH}$ and $0.1 \text{ mol dm}^3 \text{ HCl}$
- (iii) $0.1 \text{ mol dm}^3 \text{ NH}_4\text{OH}$ and $0.05 \text{ mol dm}^3 \text{ HCl}$
- (iv) $0.1 \text{ mol dm}^3 \text{ CH}_3\text{COONa}$ and $0.1 \text{ mol dm}^3 \text{ NaOH}$

Solution

Ans: When $0.1 \text{ mol dm}^{-3} \text{NH}_4\text{OH}$ and $0.05 \text{ mol dm}^{-3} \text{HCl}$ react total amount of HCl reacts with NH_4OH to form NH_4Cl and some NH_4OH will be left unreacted. Thus, the resultant solution contains NH_4Cl and NH_4OH which will produce a buffer solution. Hence, option(iii) is the correct answer.

Question 12

In which of the following solvents is silver chloride most soluble?

- (i) $0.1 \text{ mol dm}^{-3} \text{AgNO}_3$ solution
- (ii) $0.1 \text{ mol dm}^{-3} \text{HCl}$ solution
- (iii) H_2O
- (iv) Aqueous ammonia

Solution

Ans: Aqueous ammonia will absorb chloride ions and thus the equilibria will shift in forward direction and solubility of silver chloride will increase. Hence, option(iv) is the correct answer.

Question 13

What will be the value of pH of $0.01 \text{ mol dm}^{-3} \text{CH}_3\text{COOH}$ ($K_a = 1.74 \times 10^{-5}$)?

- (i) 3.4
- (ii) 3.6
- (iii) 3.9
- (iv) 3.0

Solution

Ans: pH for weak acid is given by the following equation:

$$\begin{aligned} pH &= \frac{1}{2}[pK_a - \log C] \\ &= 21[-\log(1.74 \times 10^{-5}) - \log 0.01] \\ &= 3.4 \end{aligned}$$

Hence, option(i) is the correct answer.

Question 14

K_a for CH_3COOH is 1.8×10^{-5} and K_b for NH_4OH is 1.8×10^{-5} . The pH of ammonium acetate will be-

- (i) 7.005
- (ii) 4.75
- (iii) 7.0
- (iv) Between 6 and 7

Solution

Ans: The equation for weak acid and weak base is given as-

$$pH = 7 + 21(pK_a - pK_b)$$

$$K_a = 1.8 \times 10^{-5}$$

$$pK_a = -\log(1.8 \times 10^{-5}) = 5 - \log 1.8 = 4.744$$

$$pK_b = -\log(1.8 \times 10^{-5}) = 4.744$$

$$pH = 7 + 21(pK_a - pK_b) = 7.$$

Hence, option(iii) is the correct answer.

Question 15

Which of the following options will be correct for the stage of half completion of the reaction $A \rightleftharpoons B$.

(i) $\Delta G^\ominus = 0$

(ii) $\Delta G^\ominus > 0$

(iii) $\Delta G^\ominus < 0$

(iv) $\Delta G^\ominus = -RT \ln 2$

Solution

Ans: At the stage of half completion of reaction $[A] = [B]$. Therefore, $K = 1$. Hence, $\Delta G^\ominus = 0$. Hence, option(i) is the correct answer.

Question 16

On increasing the pressure, in which direction will the gas phase reaction proceed to re-establish equilibrium, is predicted by applying the Le Chatelier's principle. Consider the reaction.

$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$ Which of the following is correct, if the total pressure at which the equilibrium is established, is increased without changing the temperature? (i) K will remain same

(ii) K will decrease

(iii) K will increase

(iv) K will increase initially and decrease when pressure is very high.

Solution

Ans: Equilibrium constant K will remain same if temperature is not changed. Hence, option(i) is the correct answer.

Question 17

What will be the correct order of vapour pressure of water, acetone, and ether at 30°C . Given that among these compounds, water has maximum boiling point and ether has minimum boiling point?

(i) Water < ether < acetone

(ii) Water < acetone < ether

(iii) Ether < acetone < water

(iv) Acetone < ether < water

Solution

Ans: Greater the boiling point, lower will be the vapour pressure. Hence, option(ii) is the correct answer.

Question 18

At 500 K, equilibrium constant, K_c , for the following reaction is 5. $\frac{1}{2} \text{H}_2 (\text{g}) + \frac{1}{2} \text{I}_2 (\text{g}) \rightarrow \text{HI} (\text{g})$. What would be the equilibrium constant K_c for the reaction $2\text{HI} (\text{g}) \rightarrow \text{H}_2 (\text{g}) + \text{I}_2 (\text{g})$.

(i) 0.04

(ii) 0.4

(iii) 25

(iv) 2.5

Solution

Ans: If the equation is multiplied by 2, the equilibrium constant for the new equation is the square of K it means we must do the square of 5 that is 25. Then and on reversing the reaction the value of the equilibrium constant is inversed means the value of K comes out to be $1/25 = 0.04$. Hence, option(i) is the correct answer.

Question 19

In which of the following reactions, the equilibrium remains unaffected on addition of small amount of argon at constant volume?

(i) $\text{H}_2 (\text{g}) + \text{I}_2 (\text{g}) \rightleftharpoons 2\text{HI} (\text{g})$

(ii) $\text{PCl}_5 (\text{g}) \rightleftharpoons \text{PCl}_3 (\text{g}) + \text{Cl}_2 (\text{g})$

(iii) $\text{N}_2 (\text{g}) + 3\text{H}_2 (\text{g}) \rightleftharpoons 2\text{NH}_3 (\text{g})$

(iv) The equilibrium will remain unaffected in all the three cases.

Solution

Ans: At constant volume equilibrium remains unaffected with the addition of inert gas. Hence, option(iv) is the correct answer.

Multiple Choice Questions (Type-II)

Question 20

For the reaction the value of K is 50 at 400 K and 1700 at 500 K. Which of the following options is correct?

- (i) The reaction is endothermic.
- (ii) The reaction is exothermic.
- (iii) If $\text{NO}_2(\text{g})$ and $\text{N}_2\text{O}_4(\text{g})$ are mixed at 400 K at partial pressures 20 bar and 2 bar respectively, more $\text{N}_2\text{O}_4(\text{g})$ will be formed.
- (iv) The entropy of the system increases.

Solution

Ans: As, K increases with increase in temperature. K increases, it shows that the reaction must be endothermic. No. of molecules increases thus, there is increase in entropy. Hence, option(i), (iii) and (iv) are the correct answers.

Question 21

At a particular temperature and atmospheric pressure, the solid and liquid phases of a pure substance can exist in equilibrium. Which of the following term defines this temperature?

- (i) Normal melting point
- (ii) Equilibrium temperature
- (iii) Boiling point
- (iv) Freezing point

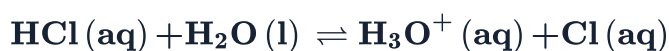
Solution

Ans: Ice and water are in equilibrium only at particular temperature and pressure. For any pure substance at atmospheric pressure, the temperature at which the solid and liquid phases are at equilibrium is called the normal melting point or normal freezing point of the substance. For example, it is 4°C in case of water. The system here is in dynamic equilibrium. Hence, options (i) and (iv) are the correct answers.

Short Answer Questions

Question 22

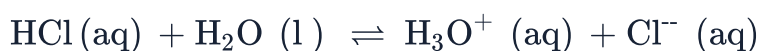
The ionisation of hydrochloric acid in water is given below:



Label two conjugate acid-base pairs in this ionisation.

Solution

Ans: Conjugate acid and conjugate base can be shown as-



acid base conjugate acid conjugate base

Question 23

The aqueous solution of sugar does not conduct electricity. However, when sodium chloride is added to water, it conducts electricity. How will you explain this statement on the basis of ionisation and how is it affected by concentration of sodium chloride?

Solution

Ans: Conductance of a solution depends upon the number of ions present in the solution since sodium chloride is an ionic compound when mixed in water it ionizes completely forming an aqueous electrolytic solution. Hence, the solution conducts electricity while sugar being a non-electrolyte does

not ionize in water and when concentration of NaCl is increased, more Na^+ and Cl^- ions will be produced. Hence, conductance increases.

Question 24

BF_3 does not have proton but still acts as an acid and reacts with NH_3 . Why is it so? What type of bond is formed between the two?

Solution

Ans: BF_3 does not have a proton but still it acts as a Lewis acid as it is an electron pair acceptor and reacts with NH_3 by accepting its lone pair of electrons. The reaction can be represented by Coordinate bond is formed between BF_3 and NH_3 . It can be represented as-



Nitrogen acts as lone pair donator in this combination.

Question 25

Ionisation constant of a weak base MOH, is given by the expression $k_b = \frac{[\text{M}^+][\text{OH}^-]}{[\text{MOH}]}$

Values of ionisation constant of some weak bases at a particular temperature are given below:

Base	Dimethylamine	Urea	Pyridine	Ammonia
K_b	5.4×10^{-4}	1.3×10^{-14}	1.77×10^{-9}	1.77×10^{-5}

Arrange the bases in decreasing order of the extent of their ionisation at equilibrium. Which of the above base is the strongest?

Solution

Ans: Higher the value of K_b stronger will be the base.

$$K_b - 5.4 \times 10^{-4} > 1.77 \times 10^{-5} > 1.77 \times 10^{-9} > 1.3 \times 10^{-14}$$

Decreasing order of basic strength.

Dimethylamine > Ammonia > Pyridine > Urea

Hence among the given bases, the strongest base is Dimethylamine.

Question 26

Conjugate acid of a weak base is always stronger. What will be the decreasing order of basic strength of the following conjugate bases? OH^- , RO^- , CH_3COO^- , Cl^- .

Solution

Ans: As the Conjugate acid of a weak base is always stronger and conjugate base of weak acid is always strong.

The weak acids are:

$\Rightarrow \text{H}_2\text{O}, \text{ROH}, \text{CH}_3\text{COOH}, \text{HCl}$

$\Rightarrow \text{HCl} < \text{CH}_3\text{COOH} < \text{ROH} < \text{H}_2\text{O}$

$\Rightarrow$ Conjugate base order $\Rightarrow \text{OH}^- < \text{RO}^- < \text{CH}_3\text{COO}^- < \text{Cl}^-$

Question 27

Arrange the following in increasing order of pH.

KNO_3 (aq), CH_3COONa (aq), NH_4Cl (aq), $\text{C}_6\text{H}_5\text{COONH}_4$ (aq).

Solution

Ans: Correct order of pH is -

$\text{NH}_4\text{Cl} < \text{C}_6\text{H}_5\text{COONH}_4 < \text{KNO}_3 < \text{CH}_3\text{COONa}$

Salts of strong acid and strong base do not hydrolyse and form neutral solution thus, pH will be nearly 7 of KNO_3 .

In sodium acetate, acetic acid remains unionised this results in increase in OH^- concentration and pH will be more than 7.

NH_4Cl formed from weak base, NH_4OH and strong acid, HCl , in water dissociates completely, aq. ammonium ions undergo hydrolysis with water to form NH_4OH and H^+ ions resulting in less pH value.

Question 28

The value of K_c for the reaction $2\text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$ is 1×10^4 . At a given time, the composition of reaction mixture is $[\text{HI}] = 2 \times 1 \times 10^5 \text{ mol}$,

$$[\text{H}_2] = 1 \times 1 \times 10^{-5}$$

mol and $[\text{I}_2] = 1 \times 1 \times 10^5 \text{ mol}$. In which direction will the reaction proceed?

Solution

Ans: We can calculate the reaction quotient Q for the reaction and that will be given by the expression:

$$Q = \frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2} = \frac{(2 \times 10^{-5})(1 \times 10^{-5})}{(2 \times 10^5)^2} = \frac{1}{4}$$

$$= 0.25 = 2.5 \times 10^{-1}$$

As the value of the reaction quotient is greater than the value of K_c that is 1×10^{-4} the reaction will proceed in the reverse direction.

Question 29

On the basis of the equation

$$\text{pH} = -\log[\text{H}^+]$$

, the pH of $10^{-8} \text{ mol dm}^{-3}$ solution of HCl should be 8. However, it is observed to be less than 7.0. Explain the reason.

Solution

Ans: Here concentration of water cannot be neglected since the solution is very dilute. pH will be less than 7.0. Hence, the total concentration is given as -

$$[\text{H}_3\text{O}^+] = 10^{-8} + 10^{-7} \text{ M}$$

Question 30

pH of a solution of a strong acid is 5.0. What will be the pH of the solution obtained after diluting the given solution 100 times?

Solution

Ans: Given with the pH = 5 as, $\text{pH} = -\log[\text{H}^+]$

$$[\text{H}^+] = 10^{-5} \text{ M}$$

On 100 times dilution-

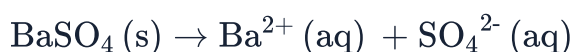
$$[\text{H}^+] = 10^{-7} \text{ M.}$$

Question 31

A sparingly soluble salt gets precipitated only when the product of concentration of its ions in the solution (Q_{sp}) becomes greater than its solubility product. If the solubility of BaSO_4 in water is $8 \times 10^{-4} \text{ mol dm}^{-3}$. Calculate its solubility in 0.01 mol dm^{-3} of H_2SO_4 .

Solution

Ans: The chemical equation is given below-



At $t = 0$ 1 0 0

At equilibrium

in water 1-S S S

At equilibrium in

the presence 1-S S (S+0.01)

of sulphuric acid

$$K_{\text{sp}} \text{ for } \text{BaSO}_4 \text{ in water} = [\text{Ba}^{2+}][\text{SO}_4^{2-}] = (S) (S) = S^2$$

But $S = 8 \times 10^{-4} \text{ mol dm}^{-3}$

$$K_{sp} = (8 \times 10^{-4})^2 = 64 \times 10^{-8} \dots (1)$$

The expression for K_{sp} in the presence of sulphuric acid will be as follows:

$$K_{sp} = (S) (5 + 0.01) \dots (2)$$

Since value of K_{sp} will not change in the presence of sulphuric acid, therefore from (1) and (2)

$$(S) (S + 0.01) = 64 \times 10^{-8}$$

$$S^2 + 0.01 S = 64 \times 10^{-8}$$

$$S^2 + 0.01 S - 64 \times 10^{-8} = 0$$

$$S = \frac{-0.01 \pm \sqrt{(0.01)^2 + (4 \times 64 \times 10^{-8})}}{2}$$

When we solve the above equation, we will get the value of

$$S \text{ is } = 6 \times 10^{-4} \text{ mol}^{-1} \text{ dm}^{-3}$$

Question 32

pH of 0.08 mol dm^{-3} HOCl solution is 2.85. Calculate its ionisation constant.

Solution

Ans: Ionisation constant can be calculated as given below-

pH of HOCl = 2.85

But

$$pH = \log[H^+]$$

$$\therefore -2.85 = \log[H^+]$$

$$\Rightarrow 3^{-.15} = \log[H^+]$$

$$\Rightarrow [H^+] \text{ antilog } 3^{-.15}$$

$$\Rightarrow [H^+] = 1.413 \times 10^{-5}$$

For weak mono basic acid

$$[H^+] = K_a \times C$$

$$\begin{aligned} K_a &= C[H^+]^2 = 0.08(.413 \times 10^{-3})^2 \\ &= 24.957 \times 10^{-6} = 2.4957 \times 10^{-5} \end{aligned}$$

Question 33

Calculate the pH of a solution formed by mixing equal volumes of two solutions A and B of a strong acid having pH = 6 and pH = 4 respectively.

Solution

Ans: we can find the pH of the solution as-

pH of solution A=6

Hence, concentration of $[H^+]$ ion in solution A = $10^{-6} \text{ mol L}^{-1}$

pH of solution B=4

Therefore, concentration of $[H^+]$ ion in solution B = $10^{-4} \text{ mol L}^{-1}$

On mixing one litre of each solution, total volume = 1L+1L=2L.

Amount of H^+ ions in 1L of solution

A = concentration $\times$ Volume(V) = $10^{-6} \text{ mol} \times 1\text{L}$

Amount of H^+ ions in 1L of solution B = $10^{-4} \text{ mol} \times 1\text{L}$

$\therefore$ Total amount of H^+ ions in the solution formed by mixing solutions A and B is $(10^{-5} \text{ mol} + 10^{-4} \text{ mol})$

This amount is present in 2L solution,

$\therefore$ Total



$$= 2 \times 10^{-4} (1 + 0.01) = 21.01 \times 10^{-4} \text{ mol L}^{-1}$$

$$= 21.01 \times 10^{-4} \text{ mol L}^{-1} = 0.5 \times 10^{-4} \text{ mol L}^{-1} = 5 \times 10^{-5} \text{ mol L}^{-1}.$$

$$\text{pH} = -\log[\text{H}^+] = -\log(5 \times 10^{-5}) = -[\log 5 + (-5 \log 10)]$$

$$= -\log 5 + 5 = 5 - \log 5 = 5 - 0.6990 = 4.3010 = 4.3$$

Thus, the pH of the solution will be 4.3.

Question 34

The solubility product of $\text{Al}(\text{OH})_3$ is 2.7×10^{-11} . Calculate its solubility in g L^{-1} and also find out pH of this solution. (Atomic mass of Al = 27 u).

Solution

Ans: Let us assume S be the solubility of $\text{Al}(\text{OH})_3$.

$$K_{\text{sp}} = [\text{Al}^{3+}] [\text{OH}^-]^3 = (S) (3S)^3 = 27S^4$$

$$S^4 = 27K_{\text{sp}} = 27 \times 10^{-27} \times 10^{-11} = 1 \times 10^{-12}$$

$$S = 1 \times 10^{-3} \text{ mol L}^{-1}.$$

(i) Solubility of $\text{Al}(\text{OH})_3$: Molar mass of $\text{Al}(\text{OH})_3$ is 78g. Hence, solubility of $\text{Al}(\text{OH})_3$ in $\text{g L}^{-1} = 1 \times 10^{-3} \times 78 \text{ g L}^{-1} = 78 \times 10^{-3} \text{ g L}^{-1} = 7.8 \times 10^{-2} \text{ g L}^{-1}$

(ii) pH of the solution: $S = 1 \times 10^{-3} \text{ mol L}^{-1}$

$$[\text{OH}] = 3S = 3 \times 1 \times 10^{-3} = 3 \times 10^{-3}$$

$$\text{p}[\text{OH}] = 3 - \log 3$$

$$\text{pH} = 14 - \text{pOH} = 11 + \log 3 = 11.4771.$$

Question 35

Calculate the volume of water required to dissolve 0.1 g lead (II) chloride to get a saturated solution. (K_{sp} of $\text{PbCl}_2 = 3.2 \times 10^{-8}$, atomic mass of Pb = 207 u).

Solution

Ans:

$$K_{sp} = 3.2 \times 10^{-8}$$



$$K_{sp} = (S) (2S)^2$$

$$K_{sp} = 4S^3$$

$$S^3 = 43.2 \times 10^{-8}$$

$$S^3 = 8 \times 10^{-9}$$

$$S = 2 \times 10^{-3}$$

$$\text{Molar mass of PbCl}_2 = 278 \text{ g/mol}$$

By using Molarity formula,

$$2 \times 10^{-3} = 278 \times x 0.1$$

$$x = \frac{0.1}{278 \times 2 \times 10^{-3}}$$

$$= \frac{100}{278 \times 2}$$

$$x = 0.18 \text{ L}$$

Question 36

A reaction between ammonia and boron trifluoride is given below: $\text{NH}_3 + \text{BF}_3 \rightarrow \text{H}_3\text{N} : \text{BF}_3$

Identify the acid and base in this reaction. Which theory explains it? What is the hybridisation of B and N in the reactants?

Solution

Ans: As, NH_3 is Lewis base while BF_3 is Lewis acid. Lewis electronic theory of acids and bases explains it. Hybridisation state: N in NH_3 is sp^3 hybridised and Boron in BF_3 is sp^2 hybridised.

Question 37

Following data is given for the reaction: $\text{CaCO}_3 (\text{s}) \rightarrow \text{CaO} (\text{s}) + \text{CO}_2 (\text{g})$

$$\Delta_f H^\ominus [\text{CaO (s)}] = 635.1 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\ominus [\text{CO}_2 \text{ (g)}] = 393.5 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\ominus [\text{CaCO}_3 \text{ (s)}] = 1206.9 \text{ kJ mol}^{-1}$$

Predict the effect of temperature on the equilibrium constant of the above reaction.

Solution

Ans: As, enthalpy of formation is given by-

$$\Delta_r H^\ominus = \Delta_f H^\ominus [\text{CaO (s)}] + \Delta_f H^\ominus [\text{CO}_2 \text{ (g)}] - \Delta_f H^\ominus [\text{CaCO}_3 \text{ (s)}]$$

$$\Delta_r H^\ominus = 178.3 \text{ kJ mol}^{-1}.$$

The reaction is endothermic. Therefore, according to Le Chatelier's principle, reaction will proceed in forward direction on increasing temperature.

Matching Type

Question 38

Match the following equilibria with the corresponding condition.

(i) Liquid $\rightleftharpoons$ Vapour	(a) Saturated solution
(ii) Solid $\rightleftharpoons$ Liquid	(b) Boiling point
(iii) Solid $\rightleftharpoons$ Vapour	(c) Sublimation point
(iv) Solute $\rightleftharpoons$ Solute(solution)	(d) Melting point
	(e) Unsaturated solution

Solution

Ans: (i) $\rightarrow$ (b); (ii) $\rightarrow$ (d); (iii) $\rightarrow$ (c); (iv) $\rightarrow$ (a).

Question 39

For the reaction: $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$

Equilibrium constant $K_c = \frac{[\text{NH}_3]^2}{[\text{N}]^2[\text{H}]^3}$. Some reactions are written below in Column I and their equilibrium constants in terms of K_c are written in Column II. Match the following reactions with the corresponding equilibrium constant-

Column I (Reaction)

Column II (Equilibrium constant)

(i) $2\text{N}_2(\text{g}) + 6\text{H}_2(\text{g}) \rightleftharpoons 4\text{NH}_3(\text{g})$	(a) $2K_c$
(ii) $2\text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$	(b) $\frac{1}{2} K_c$
(iii) $\frac{1}{2}\text{N}_2(\text{g}) + \frac{3}{2}\text{H}_2(\text{g}) \rightleftharpoons \text{NH}_3(\text{g})$	(c) K_c
	(d) K_c

Solution

Ans: (i) $\rightarrow$ (d); (ii) $\rightarrow$ (c); (iii) $\rightarrow$ (b).

Question 40

Match standard free energy of the reaction with the corresponding equilibrium constant

(i) $\Delta G^\circ > 0$	(a) $K > 1$
(ii) $\Delta G^\circ < 0$	(b) $K = 1$
(iii) $\Delta G^\circ = 0$	(c) $K = 0$
	(d) $K < 1$

Solution

Ans: (i) $\rightarrow$ (d); (ii) $\rightarrow$ (a); (iii) $\rightarrow$ (b).

Question 41

Match the following species with the corresponding conjugate acid Species Conjugate -

(i) NH_3	(a) CO_3^{2-}
(ii) HCO_3^-	(b) NH_4^+
(iii) H_2O	(c) H_3O^+
(iv) HSO_4^-	(d) H_2SO_4
	(e) H_2CO_3

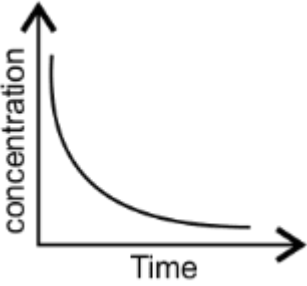
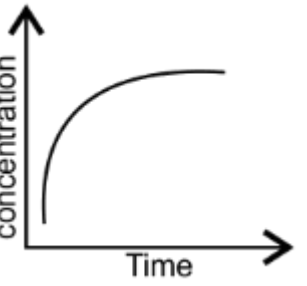
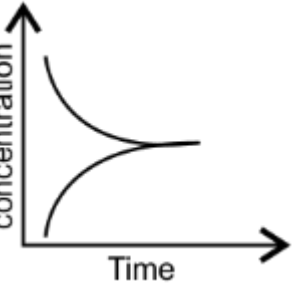
Solution

Ans: (i) $\rightarrow$ (b); (ii) $\rightarrow$ (e); (iii) $\rightarrow$ (c); (iv) $\rightarrow$ (d)

Question 42

Match the following graphical variation with their description-

A	B
(i)	(a) Variation in product concentration with time

	
(ii) 	(b) Reaction at equilibrium
(iii) 	(c) Variation in reactant concentration with time

Solution

Ans: (i) $\rightarrow$ (c); (ii) $\rightarrow$ (a); (iii) $\rightarrow$ (b).

Question 43

Match Column (I) with Column (II). Column I Column II-

(i) Equilibrium	(a) $\Delta G > 0$, $K < 1$
(ii) Spontaneous reaction	(b) $\Delta G = 0$
(iii) Nonspontaneous reaction	(c) $\Delta G^\ominus = 0$
	(d) $\Delta G < 0$, $K > 1$

Solution

Ans: (i) $\rightarrow$ c; (ii) $\rightarrow$ (d); (iii) $\rightarrow$ (a).

Assertion and Reason Type

In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

Question 44

Assertion (A): Increasing order of acidity of hydrogen halides is $\text{HF} < \text{HCl} < \text{HBr} < \text{HI}$

Reason (R): While comparing acids formed by the elements belonging to the same group of periodic table, H-A bond strength is a more important factor in determining acidity of an acid than the polar nature of the bond. (i) Both A and R are true and R is the correct explanation of A.

(ii) Both A and R are true but R is not the correct explanation of A.

(iii) A is true but R is false.

(iv) Both A and R are false.

Solution

Ans: As, H-A bond strength is a more important factor in determining acidity than its polar nature. As the size of A increases down the group, H-A bond strength decreases. Hence, option(i) is the correct answer.

Question 45

Assertion (A): A solution containing a mixture of acetic acid and sodium acetate maintains a constant value of pH on addition of small amounts of acid or alkali.

Reason (R): A solution containing a mixture of acetic acid and sodium acetate acts as a buffer solution around pH 4.75.

- (i) Both A and R are true and R is correct explanation of A.
- (ii) Both A and R are true but R is not the correct explanation of A.
- (iii) A is true but R is false.
- (iv) Both A and R are false.

Solution

Ans: The solutions which resist change in pH on dilution or with the addition of small amounts of acid or alkali are called buffer solutions. Hence, option(ii) is the correct answer.

Question 46

Assertion (A): The ionisation of hydrogen sulphide in water is low in the presence of hydrochloric acid.

Reason (R): Hydrogen sulphide is a weak acid.

- (i) Both A and R are true and R is correct explanation of A.
- (ii) Both A and R are true but R is not correct explanation of A.
- (iii) A is true but R is false.
- (iv) Both A and R are false.

Solution

Ans: In presence of H^+ ion, equilibrium shifts in backward direction. Hence, option(ii) is the correct answer.

Question 47

Assertion (A): For any chemical reaction at a particular temperature, the equilibrium constant is fixed and is a characteristic property.

Reason (R): Equilibrium constant is independent of temperature.

- (i) Both A and R are true and R is correct explanation of A.
- (ii) Both A and R are true but R is not correct explanation of A.
- (iii) A is true but R is false.
- (iv) Both A and R are false.

Solution

Ans: The equilibrium constant for an exothermic reaction (negative H) decreases as the temperature increases. The equilibrium constant for an endothermic reaction (positive H) increases as the temperature increases. Hence, option(iii) is the correct answer.

Question 48

Assertion (A): Aqueous solution of ammonium carbonate is basic. **Reason (R):** Acidic/basic nature of a salt solution of a salt of weak acid and weak base depends on K_a and K_b value of the acid and the base forming it. (i) Both A and R are true and R is correct explanation of A.

- (ii) Both A and R are true but R is not correct explanation of A.
- (iii) A is true but R is false.
- (iv) Both A and R are false.

Solution

Ans: K_a and K_b values are responsible for acidic and basic characters of substances. Hence option (i) is the correct answer.

Question 49

Assertion (A): An aqueous solution of ammonium acetate can act as a buffer. **Reason (R):** Acetic acid is a weak acid and NH_4OH is a weak base. (i) Both A and R are true and R is correct explanation of A.

(ii) Both A and R are true but R is not correct explanation of A.

(iii) A is false but R is true.

(iv) Both A and R are false.

Solution

Ans: Salt of weak acid and weak base can form buffer solution. Hence option (iii) is the correct answer.

Question 50

Assertion (A): In the dissociation of PCl_5 at constant pressure and temperature addition of helium at equilibrium increases the dissociation of PCl_5 .

Reason (R): Helium removes Cl_2 from the field of action.

(i) Both A and R are true and R is correct explanation of A.

(ii) Both A and R are true but R is not correct explanation of A.

(iii) A is true but R is false.

(iv) Both A and R are false.

Solution

Ans: If the volume is kept constant and an inert gas such as argon is added which does not take part in the reaction, the equilibrium remains undisturbed. Hence, option(iv) is the correct answer.

Long Answer Questions

Question 51

How can you predict the following stages of a reaction by comparing the value of K_c and Q_c ?

- (i) Net reaction proceeds in the forward direction.
- (ii) Net reaction proceeds in the backward direction.
- (iii) No net reaction occurs.

Solution

Ans: The values of K_c and Q_c are itself sufficient to explain the direction of reaction and less than or greater than one another decides the direction in which reaction will proceed as follows-

- (i) As $Q_c < K_c$, the reaction proceeds in the forward direction.
- (ii) If $Q_c > K_c$, the reaction will proceed in the direction of reactants (reverse reaction).
- (iii) If $Q_c = K_c$, no net reaction occurs.

Question 52

On the basis of Le Chatelier principle explain how temperature and pressure can be adjusted to increase the yield of ammonia in the following reaction.

$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H = -92.38 \text{ kJ mol}^{-1}$. What will be the effect of addition of argon to the above reaction mixture at constant volume?

Solution

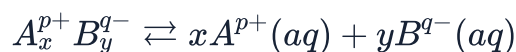
Ans: According to Le Chatelier's principle, when we raise the temperature, it shifts the equilibrium to left and decreases the equilibrium concentration of ammonia since it is an exothermic reaction. In other words, low temperature and high pressure is favourable for high yield of ammonia. There will be no change in equilibria on addition of argon (Ar).

Question 53

A sparingly soluble salt having general formula $A_x^{p+}B_y^{q-}$ and molar solubility S is in equilibrium with its saturated solution. Derive a relationship between the solubility and solubility product for such salt.

Solution

Ans: The equation can be written as-



S moles of A and B dissolves to give xS moles of A^{p+} and yS moles of B^{q-} .

$$\begin{aligned} K_{sp} &= [A^{p+}]^x [B^{q-}]^y = [xS]^x [yS]^y \\ &= x^x y^y S^{x+y} \end{aligned}$$

Question 54

Write a relation between ΔG and Q and define the meaning of each term and answer the following:

- (a) Why a reaction proceeds forward when $Q < K$ and no net reaction occurs when $Q = K$.
- (b) Explain the effect of increase in pressure in terms of reaction quotient Q for the reaction:
 $\text{CO (g)} + 3\text{H}_2 \text{ (g)} \rightarrow \text{CH}_4 \text{ (g)} + \text{H}_2\text{O (g)}.$

Solution

Ans: (a) As we know,

$$\Delta G = \Delta G^\ominus + RT \ln Q$$

$\Delta G^\ominus$ = Change in free energy as the reaction proceeds,

ΔG = Standard free energy change,

Q = Reaction quotient,

R = Gas constant,

T = Absolute temperature.

Since, $\Delta G^\ominus = -RT \ln K$

$$\therefore \Delta G = -RT \ln K + RT \ln Q = RT \ln \frac{Q}{K}$$

If $Q < K$, ΔG will be negative. Reaction proceeds in the forward.

If $Q = K$, $\Delta G = 0$, reaction is in equilibrium and no net reaction is there.

Ans: When we increase the pressure equilibrium will shift in forward direction it means $Q < K$.

Types of Chemical Reactions :

There are 4 main types of chemical reactions. These are-

1. Combination Reactions- Combination Reactions are chemical reactions with 2 or more substances combining to form one single compound.
2. Decomposition Reactions- Decomposition Reactions are chemical reactions with one compound decomposing to produce 2 or more different substances. The digestion process of food in our body is a Decomposition reaction.
3. Displacement Reactions- Displacement reactions are reactions that involve the displacement of 1 element or group by another.
4. Double Displacement- Displacement reactions are reactions with 2 compounds that react to form 2 new compounds. In the displacement reaction, no change in oxidation state occurs.