CHEMICAL EQUILIBRIUM

1. At 1990 K and 1 atm pressure, there are equal number of Cl_2 molecules and Cl atoms in the reaction mixture. The value K_P for the reaction $Cl_{2(g)} \rightleftharpoons 2Cl_{(g)}$ under the above conditions is $x \times 10^{-1}$. The value of x is _____. (Rounded off to the nearest integer)

2. The stepwise formation of $[Cu(NH_3)_4]^{2+}$ is given below

$$Cu^{2+} + NH_3 \overset{K_1}{\rightleftharpoons} [Cu(NH_3)]^{2+}$$

$$[Cu(NH_3)]^{2+} + NH_3 \overset{K_2}{\rightleftharpoons} [Cu(NH_3)_2]^{2+}$$

$$[Cu(NH_3)_2]^{2+} + NH_3 \overset{K_3}{\rightleftharpoons} [Cu(NH_3)_3]^{2+}$$

$$[Cu(NH_3)_3]^{2+} + NH_3 \overset{K_4}{\rightleftharpoons} [Cu(NH_3)_4]^{2+}$$

The value of stability constants K_1, K_2, K_3 and K_4 are 10^4, 1.58×10^3, 5×10^2 and 10^2 respectively. The overall equilibrium constants for dissociation of $[Cu(NH_3)_4]^{2+}$ is $x \times 10^{-12}$. The value of x is _____. (Rounded off to the nearest integer)

3. A homogeneous ideal gaseous reaction $AB_{2(g)} \rightleftharpoons A_{(g)} + 2B_{(g)}$ is carried out in a 25 litre flask at 27°C. The initial amount of AB_2 was 1 mole and the equilibrium pressure was 1.9 atm. The value of K_P is $x \times 10^{-2}$. The value of x is_____.(Integer answer)

4. Consider the reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$. The temperature at which K_C = 20.4 and K_P = 600.1, is_____K. (Round off to the Nearest Integer).

[Assume all gases are ideal and R = 0.0831 L bar K^{-1} mol^{-1}]

5. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

In an equilibrium mixture, the partial pressures are $P_{SO_3} = 43$ kPa ; $P_{O_2} = 530$ Pa and $P_{SO_2} = 45$ kPa. The equilibrium constant K_P = _____ $\times 10^{-2}$. (Nearest integer)

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

6. Value of K_P for the equilibrium reaction $N_2O_{4\,(g)} \rightleftharpoons 2NO_{2(g)}$ at 288 K is 47.9. The K_C for this reaction at same temperature is _____. (Nearest integer)

(R = 0.083 L bar K^{-1} mol^{-1})

7. For the reaction

$$A + B \rightleftharpoons 2C$$

the value of equilibrium constant is 100 at 298 K. If the initial concentration of all the three species is 1 M each, then the equilibrium concentration of C is $x \times 10^{-1}$ M. The value of x is _____ .

(Nearest integer)

8. Presence of which reagent will affect the reversibility of the following reaction, and change it to a irreversible reaction :

$$CH_4 + I_2 \underset{\text{Reversible}}{\overset{h\nu}{\rightleftharpoons}} CH_3 - I + HI$$

(1) HOCl

(2) dilute HNO_2

(3) Liquid NH_3

(4) Concentrated HIO_3

9. $PC1_5 \rightleftharpoons PCl_3 + Cl_3$; $K_c = 1.844$

3.0 moles of PCl_5 is introduced in a 1 L closed reaction vessel at 380 K. The number of moles of PCl_5 at equilibrium is ___ $\times 10^{-3}$.

(Round off to the Nearest Integer)

10. The equilibrium constant for the reaction

$$A(s) \rightleftharpoons M(s) + \frac{1}{2}O_2(g)$$

is $K_p = 4$. At equilibrium, the partial pressure of O_2 is ___ atm. (Round off to the nearest integer)

11. The following data was obtained for chemical reaction given below at 975 K.

$$2NO_{(g)} + 2H_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$$

	[NO]	$[H_2]$	Rate
	mol L^{-1}	mol L^{-1}	mol $L^{-1}s^{-1}$
(A)	8×10^{-5}	8×10^{-5}	7×10^{-9}
(B)	24×10^{-5}	8×10^{-5}	2.1×10^{-8}
(C)	24×10^{-5}	32×10^{-5}	8.4×10^{-8}

The order of the reaction with respect to NO is _____. [Integer answer]

12. The equilibrium constant K_c at 298 K for the reaction $A + B \rightleftharpoons C + D$

is 100. Starting with an equimolar solution with concentrations of A, B, C and D all equal to 1M, the equilibrium concentration of D is _____ $\times 10^{-2}$ M. (Nearest integer)

13. The reaction rate for the reaction

$$[PtCl_4]^{2-} + H_2O \rightleftharpoons [Pt(H_2O)Cl_3]^- + Cl^-$$

was measured as a function of concentrations of different species. It was observed that

$$\frac{-d\left[[PtCl_4]^{2-}\right]}{dt} = 4.8 \times 10^{-5}\left[[PtCl_4]^{2-}\right] - 2.4 \times 10^{-3}\left[[Pt(H_2O)Cl_3]^-\right]\left[Cl^-\right].$$

where square brackets are used to denote molar concentrations. The equilibrium constant K_c=_____. (Nearest integer)

14. When 5.1 g of solid NH_4HS is introduced into a two litre evacuated flask at 27°C, 20% of the solid decomposes into gaseous ammonia and hydrogen sulphide. The K_p for the reaction at 27°C is $x \times 10^{-2}$. The value of x is _____. (Integer answer)

[Given R = 0.082 L atm K^{-1} mol^{-1}]

SOLUTION

1. Official Ans. by NTA (5)

Sol. $Cl_2 \rightleftharpoons 2Cl$

Let mol of both of Cl_2 and Cl is x

$$P_{Cl} = \frac{x}{2x} \times 1 = \frac{1}{2}$$

$$P_{Cl_2} = \frac{x}{2x} \times 1 = \frac{1}{2}$$

$$K_p = \frac{\left(\frac{1}{2}\right)^2}{\frac{1}{2}} = \frac{1}{2} = 0.5 \Rightarrow 5 \times 10^{-1}$$

2. Official Ans. by NTA (1)

Sol. $Cu^{2+} + NH_3 \overset{K_1}{\rightleftharpoons} [Cu(NH_3)]^{2+}$

$[Cu(NH_3)]^{2+} + NH_3 \overset{K_2}{\rightleftharpoons} [Cu(NH_3)_2]^{2+}$

$[Cu(NH_3)_2]^{2+} + NH_3 \overset{K_3}{\rightleftharpoons} [Cu(NH_3)_3]^{2+}$

$[Cu(NH_3)_3]^{2+} + NH_3 \overset{K_4}{\rightleftharpoons} [Cu(NH_3)_4]^{2+}$

$Cu^{2+} + 4NH_3 \overset{K}{\rightleftharpoons} [Cu(NH_3)_4]^{2+}$

So

$K = K_1 \times K_2 \times K_3 \times K_4$

$= 10^4 \times 1.58 \times 10^3 \times 5 \times 10^2 \times 10^2$

$K = 7.9 \times 10^{11}$

Where K → Equilibrium constant for formation of $[Cu(NH_3)_4]^{2+}$

So equilibrium constant (K') for dissociation of $[Cu(NH_3)_4]^{2+}$ is $\frac{1}{K}$

$$K' = \frac{1}{K}$$

$$K' = \frac{1}{7.9 \times 10^{11}}$$

$= 1.26 \times 10^{-12} = (x \times 10^{-12})$

So the value of x = 1.26

OMR Ans = 1 (After rounded off to the nearest integer)

3. Official Ans. by NTA (73)

Sol.

AB_2 =	A	+	2B
1	–		–
1–α	α		2α
= 0.535	0.465		0.93

$1.9 \times 25 = n_T \times 0.08206 \times 300$

$n_T = 1.93 = 1 + 2\alpha$

$\alpha = 0.465$

$$Kp = \frac{\left(\frac{0.465}{1.93} \times 19\right)\left(\frac{0.93}{1.93} \times 1.9\right)^2}{\left(\frac{0.535}{1.93} \times 1.9\right)}$$

$\simeq 73 \times 10^{-2}$ atm^2

4. Official Ans. by NTA (354)

Sol. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$; $\Delta n_g = 2 - 1 = 1$

Now, $K_p = K_c \cdot (RT)^{\Delta ng}$

or, $600.1 = 20.4 \times (0.0831 \times T)^1$

$\therefore$ T = 353.99 K = 354K

5. Official Ans. by NTA (172)

Sol. $2SO_{2(g)} + O_{2(g)} = 2SO_{3(g)}$

$$K_P = \frac{(pSO_{3(g)})^2}{pSO2(g)} \times pO_{2(g)}$$

$$= \frac{43 \times 43}{45 \times 45} \times 530 \text{ Pa}^{-1}$$

$= 172.28 \times 10^{-5}$ Pa^{-1}

= 172.28 atm

$= 17228 \times 10^{-2}$ atm

Ans is 17228

6. Official Ans. by NTA (2)

$$K_C = \frac{K_P}{RT} = \frac{47.9}{0.083 \times 288} = 2$$

7. Official Ans. by NTA (25)

Sol.

$$A + B \rightleftharpoons 2C$$

1	1	1
– x	–x	2x
1 –x	1–x	1 + 2x

$$K = \frac{[C]^2_{eq}}{[A]_{eq}[B]_{eq}} = \frac{(1+2x)^2}{(1-x)(1-x)}$$

$$100 = \left(\frac{1+2x}{1-x}\right)^2$$

$$\left(\frac{1+2x}{1-x}\right) = 10$$

$$x = \frac{3}{4}$$

$[C]e_{q.} = 1 + 2x$

$= 1 + 2\left(\frac{3}{4}\right)$

$= 2.5$ M

25×10^{-1} M

8. Official Ans. by NTA (4)

Sol. Iodination of alkane is reversible reaction.

It can be irreversible in the presence of strong oxidising agent like conc. HNO_3 or conc. HIO_3

9. Official Ans. by NTA (1396)

Sol. $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ $K_2 = 1.844$

$t = 0$ 3 moles

$t = \infty$ x x

$$\Rightarrow \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{x^2}{3-x} = 1.844$$

$\Rightarrow x^2 + 1.844 - 5.532 = 0$

$$\Rightarrow x = \frac{-1.844 + \sqrt{(1.844)^2 + 4 \times 5.532}}{2}$$

$\cong 1.604$

$\Rightarrow$ Moles of $PCl_5 = 3 - 1.604 \cong 1.396$

10. Official Ans. by NTA (16)

Sol. $k_p = Po_2^{1/2} = 4$

$\therefore$ $Po_2 = 16$ bar $= 16$ atm

11. Official Ans. by NTA (1)

Sol. $7 \times 10^{-9} = K \times (8 \times 10^{-5})^x (8 \times 10^{-5})^y$ …(1)

$2.1 \times 10^{-8} = K \times (24 \times 10^{-5})^x (8 \times 10^{-5})^y$ …(2)

$$\frac{1}{3} = \left(\frac{1}{3}\right)^x \Rightarrow x = 1$$

12. Official Ans. by NTA (182)

Sol. $A + B \rightleftharpoons C + D : K_{eq} = 100$

1M 1M 1M 1M

First check direction of reversible reaction.

Since $Q_C = \frac{[C][D]}{[A][B]} = 1 < K_{eq.} \Rightarrow$ reaction will move in forward direction to attain equilibrium state.

$\Rightarrow A + B \rightleftharpoons C + D : K_{eq} = 100$

to 1 1 1 1

$t_{eq.}$ 1–x 1–x 1+x 1+x

Now : $K_{eq} = 100 = \frac{(1+x)(1+x)}{(1-x)(1-x)}$

$$\Rightarrow \boxed{100 = \left(\frac{1+x}{1-x}\right)^2}$$

(i) $10 = \left(\frac{1+x}{1-x}\right)$

$\Rightarrow 10 - 10x = 1+x$ $\Rightarrow 11x = 9$

$$\Rightarrow \boxed{x = \frac{9}{11}}$$

(ii) $-10 = \frac{1+x}{1-x}$

$\Rightarrow -10 + 10x = 1 + x$ $\Rightarrow -9x = -11$

$$\Rightarrow \boxed{x = \frac{11}{9}}$$

$\rightarrow$ 'x' cannot be more than one, therefore not valid.

therefore equation concretion of (D) = 1 + x

$$= 1 + \frac{9}{11} = \frac{20}{11}$$

$= 1.8181 = 181.81 \times 10^{-2}$

$\simeq 182 \times 10^{-2}$

13. Official Ans. by NTA (50)

Sol. $[PtCl_4]^{-2} + H_2O \rightleftharpoons [Pt(H_2O)Cl_3]^- + Cl^-$

$$\frac{-d[Pt\ Cl_4]^{-2}}{dt} = 4.8 \times 10^{-5}\,[PtCl_4^{-2}] - 2.4 \times 10^{3}$$

$[Pt(H_2O)Cl_3][\overset{0}{u}]$

$$\Rightarrow K_{eq} = \frac{k_f}{k_b} = \frac{4.8\times10^{-5}}{2.4\times10^{-3}} = 0.02$$

14. Official Ans. by NTA (6)

Sol. moles of NH_4HS initially taken = $\dfrac{5.1g}{51g/mol}$

= 0.1 mol

volume of vessel = 2ℓ

$$NH_4HS_{(s)} \rightleftharpoons NH_{3(g)} + H_2S_{(g)}$$

t = 0	0.1 mol		
t = ∞	0.1(1–0.2)	0.1×0.2	0.1×0.2

$\Rightarrow$ partial pressure of each component

$$P = \frac{nRT}{V} = \frac{0.1\times0.2\times0.082\times300}{2}$$

= 0.246 atm

$$\Rightarrow k_P = P_{NH_3} \times P_{H_2S} = (0.246)^2 = 0.060516$$

$= 6.05 \times 10^{-2}$ $\Rightarrow$ 6