Level-01 Chemical Equilibrium.

Answer. 1 We know that, K_c unit $= (\text{conc})^{\Delta n}$

where, $\Delta n = \begin{pmatrix}\text{Total moles of} \\ \text{product}\end{pmatrix} - \begin{pmatrix}\text{Total moles of} \\ \text{reactant}\end{pmatrix}$

for homogeneous reaction.

For reaction, $A + B \rightleftharpoons C$, unit of K_c should be $\left(\frac{\text{mol}}{\text{litre}}\right)^{-1}$ i.e. $\left(\frac{\text{litre}}{\text{mol}}\right)$.

Answer. 3 $\Delta n = (4+6)-(4+5) = 1$

so, unit of $K_c = (\text{conc})^{+1}$

Answer. 4 Equilibrium constant does <u>not</u> change with change in concentrations, pressure and volume. It only changes with temperature and stoichiometry of the reaction.

Answer. 5 If for a chemical reaction, equilibrium constant is K, then the equilibrium constant for the reaction obtained by multiplying a number 'n' with the original equation will be $(K)^n$.

so, $N_2 + O_2 \rightleftharpoons 2NO \quad K_1$

$\frac{1}{2}N_2 + \frac{1}{2}O_2 \rightleftharpoons NO \quad K_2 = (K_1)^{\frac{1}{2}} = \sqrt{K_1}$

Answer.6 (i) Since ΔH is (-)ve, therefore the reaction is an exothermic reaction and thus the reaction will go backward on increasing the temperature.

(ii) On decreasing the pressure, the reaction will go in direction of more number of moles, so in this case the reaction will go in backward direction.

(iii) Removal of ~~R~~ reactant will result in ~~bac~~ backward reaction.

(iv.) Addition of product will favour backward reaction.

Answer.7 An ion exchange reaction with all reactants and products in same phase.

Answer.8 Addition or removal of solid species will <u>not</u> affect the equilibrium. Since, it is a dissociation reaction, hence it must be endothermic, and thus increase in temperature favours forward reaction.

Answer.9 For dissociation of PCl_5, the formula for degree of dissociation will be,

~~An~~

$$x = \frac{D_{theoretical} - D_{observed}}{D_{observed}}$$

$$= \frac{104.16 - 62}{62}$$

$$= 0.68$$

So, degree of dissociation is 68%.

Answer.10 $K_p = K_c (RT)^{\Delta n}$

Here, $\Delta n = 1 - (1+1) = -1$

So, $K_p = 26\,(0.0821 \times 523)^{-1} = 0.61$

Answer.12 $CO + Cl_2 \rightleftharpoons COCl_2$

At equilibrium, $[CO] = \frac{0.1}{1/2} = 0.2$

$[Cl_2] = \frac{0.1}{1/2} = 0.2$

$[COCl_2] = \frac{0.3}{1/2} = 0.6$

So, $\boxed{K_c = \frac{[COCl_2]}{[CO][Cl_2]} = \frac{0.6}{(0.2)^2} = 15}$

Answer.13 Lower the value of K, less will be tendency of the reaction to go forward and thus higher the stability of Oxide. In this case, NO_2 will be most stable oxide of nitrogen.

Answer.14 $2HI \rightleftharpoons H_2 + I_2$

	$2HI$	H_2	I_2
Initial,	1	0	0
At eqm,	$1-x$	$\frac{x}{2}$	$\frac{x}{2}$

Given that, $x = 0.22$, thus,

	$1-0.22$	$\frac{0.22}{2}$	$\frac{0.22}{2}$
At eqm,	0.78	0.11	0.11

$K_c = \frac{[H_2][I_2]}{[HI]^2} = \left(\frac{0.11}{0.78}\right)^2 = 0.0199$

Answer. 15 Initial concentration of $PCl_5 = \frac{2}{2} = 1\,M$

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

	PCl_5	PCl_3	Cl_2
	1	0	0
	$1-x$	x	x
Given, $x=0.4$	$1-0.4$	0.4	0.4
	0.6	0.4	0.4

$$K_c = \frac{(0.4)(0.4)}{0.6} = 0.267$$

Answer. 16 $2HI \rightleftharpoons H_2 + I_2$ $\quad K_1 = 0.25$

$H_2 + I_2 \rightleftharpoons 2HI$ $\quad K_2 = \frac{1}{K_1} = \frac{1}{0.25} = 4.0$

Answer. 19 $HA + OH^- \rightleftharpoons A^- + H_2O$ $\quad K \rightarrow$ ①

② $\longrightarrow H^+ + OH^- \rightleftharpoons H_2O$ $\quad \frac{1}{K_w} = 10^{14}$

③ $\longrightarrow HA \rightleftharpoons H^+ + A^-$ $\quad K_1 = 1 \times 10^{-4}$

Adding ② and ③, we get equation, thus,

$$\boxed{K = \frac{K_1}{K_w} = \frac{10^{-4}}{10^{-14}} = 10^{10}}$$

Answer. 21 In a reaction with $\Delta n = 0$, the equilibrium remains unaffected by pressure change.

Answer. 22 $N_2O_4 \rightleftharpoons 2NO_2$

	N_2O_4	$2NO_2$
Initial moles	1	0
At eqm,	$1-x$	$2x$

Total moles at eqm $= 1-x+2x = 1+x$.

So, partial pressure of N_2O_4 at eqm $= \left(\frac{1-x}{1+x}\right) \times P$

Answer. 25

$$2SO_3 \rightleftharpoons 2SO_2 + O_2$$

	$2SO_3$	$2SO_2$	O_2
Initial,	1	0	0
At equilibrium,	$1-2x$	$2x$	x

Given that, $2x = 0.6 \Rightarrow \boxed{x = 0.3}$

then,

$1-0.6$ $=0.4$	0.6	0.3

$$K_c = \frac{(0.6)^2 \times 0.3}{(0.4)^2} = 0.675$$

Answer. 30 Reaction with Δn (+)ve will be favoured at low pressure.

Answer. 31 Value of K_c should be given as 4 to satisfy the answer given in the booklet.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

	CH_3COOH	C_2H_5OH	$CH_3COOC_2H_5$	H_2O
Initial,	1	1	0	0
Equilibrium,	$1-x$	$1-x$	x	x

$$4 = \left(\frac{x}{1-x}\right)^2$$

$$\Rightarrow \quad 2 = \frac{x}{1-x} \Rightarrow \boxed{x = \frac{2}{3}}$$

Answer. 36 According to the formula, $K_p = K_c(RT)^{\Delta n}$

K_p will be less than K_c when Δn is (−)ve.

$\boxed{\text{Answer. 38}}$ Rate of decomposition of gas $= K_f\,[\text{Gas}]$

$$= 1\times10^{-4}\times5\times10^{-2}$$

$$= 5\times10^{-6}\ \frac{\text{mol}}{\text{min litre}}$$

$\boxed{\text{Answer. 40}}$

$$2HI \rightleftharpoons H_2 + I_2$$

Initial moles, $\frac{0.96}{128}$ $\quad 0 \quad 0$

At equilibrium, $\frac{0.96}{128}(1-\alpha) \quad \frac{0.96}{128\times2}\alpha \quad \frac{0.96}{128\times2}\alpha$

Now, milliequivalents of $Na_2S_2O_3 = 14\times\frac{1}{10} = 1.4$

Equivalents of $Na_2S_2O_3 = 1.4\times10^{-3}$

According to the law of equivalence, equivalents of I_2 should be equal to equivalents of $Na_2S_2O_3$.

So, Equivalents of $I_2 = 1.4\times10^{-3}$

no. of moles of $I_2 = \frac{1.4\times10^{-3}}{2}$

So,

$$\frac{0.96}{128\times\cancel{2}}\alpha = \frac{1.4\times10^{-3}}{\cancel{2}} \Rightarrow \boxed{\alpha = 18.6\ \%}$$

$\boxed{\text{Answer. 41}}$

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

Initial moles, $a \quad b \quad 0 \quad 0$

At equilibrium, $a-x \quad b-x \quad x \quad x$

Concentration $\frac{a-x}{2} \quad \frac{b-x}{2} \quad \frac{x}{2} \quad \frac{x}{2}$

$$K = \frac{\left(\frac{x}{2}\right)^2}{\left(\frac{a-x}{2}\right)\left(\frac{b-x}{2}\right)} = \frac{x^2}{(a-x)(b-x)}$$

Answer. 42 Since N_2 will not react with any of the gases in the mixture, therefore it is an inert gas with respect to the given reaction. Now, addition of inert gas at constant pressure will result in an increase in volume, thus the reaction will go in direction of more no. of moles. So, reaction will go in forward direction with $\underline{\alpha > 0.2}$.

Answer. 43

$$\begin{array}{ccccc} Cl_2 & + & PCl_3 & \rightleftharpoons & PCl_5 \\ 0.1 & & 0.1 & & 0.2 \end{array}$$

$$K_P = \frac{0.2}{(0.1)^2}$$

For new equilibrium, $K_P = \dfrac{p_{PCl_5}}{(p_{PCl_3})(p_{Cl_2})}$

$$\Rightarrow \frac{0.2}{(0.1)^2} = \frac{p_{PCl_5}}{\left(\frac{0.1}{2}\right)\left(\frac{0.1}{2}\right)}$$

$$\Rightarrow \frac{0.2}{\cancel{(0.1)^2}} = \frac{4\,p_{PCl_5}}{\cancel{(0.1)^2}}$$

$$\Rightarrow \boxed{p_{PCl_5} = \left(\frac{1}{4}\right)0.2}$$

So, Partial pressure of PCl_5 is $\frac{1}{4}$ times of the p_{PCl_5} in the first experiment.

Answer. 44 $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

Initial moles, $1 \quad 0 \quad 0$

At equilibrium, $1-\alpha_1 \quad \alpha_1 \quad \alpha_1$

Concentration, $\frac{1-\alpha_1}{V_1} \quad \frac{\alpha_1}{V_1} \quad \frac{\alpha_1}{V_1}$

$$K_c = \frac{\left(\frac{\alpha_1}{\cancel{V_1}}\right)\left(\frac{\alpha_1}{V_1}\right)}{\left(\frac{1-\alpha_1}{\cancel{V_1}}\right)} = \frac{\alpha_1^2}{V_1(1-\alpha_1)}$$

Now, after volume is doubled, the reaction will move in the direction of more no. of moles. So,

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$

Initial moles, $1 \quad 0 \quad 0$

At equilibrium, $1-\alpha_2 \quad \alpha_2 \quad \alpha_2$

Concentration, $\frac{1-\alpha_2}{2V_1} \quad \frac{\alpha_2}{2V_1} \quad \frac{\alpha_2}{2V_1}$

$$K_c = \frac{\left(\frac{\alpha_2}{\cancel{2V_1}}\right)\left(\frac{\alpha_2}{2V_1}\right)}{\left(\frac{1-\alpha_1}{\cancel{2V_1}}\right)} = \frac{\alpha_2^2}{2V_1(1-\alpha_2)}$$

Given that α_1 and α_2 are very small, so, $1-\alpha_1 \simeq \alpha_1$ and $1-\alpha_2 \simeq \alpha_2$. Then,

$$\frac{\alpha_1^2}{\cancel{V_1}} = \frac{\alpha_2^2}{2\cancel{V_1}} \Rightarrow \boxed{\alpha_2 = \sqrt{2}\,\alpha_1}$$

~~Answer.34~~

Answer. 45

$$A \rightleftharpoons nB$$

Initial mole, $1 \qquad 0$

At equilibrium, $1-x \qquad nx$

Total moles at equilibrium $= 1-x+nx = 1+(n-1)x$

Due to conservation of mass,

$$M_A \times 1 = M_{(A+B)} \times \{1+(n-1)x\}$$

Dividing this equation by 2, we get,

$$\frac{M_A}{2} \times 1 = \frac{M_{A+B}}{2}\{1+(n-1)x\}$$

$$\Rightarrow \quad D_A \times 1 = D_{(A+B)}\{1+(n-1)x\}$$

$$\Rightarrow \quad D_A = D_{(A+B)} + D_{(A+B)}(n-1)x$$

$$\Rightarrow \quad \boxed{x = \frac{D_A - D_{(A+B)}}{D_{A+B}(n-1)}}$$

Answer. 47 $Cu(NH_3)_4^{2+} + SO_3^{2-} \rightleftharpoons Cu(NH_3)_3SO_3 + NH_3$

With addition of NH_3, the reaction will go backward i.e. concentration of reactants will ~~de~~ increase and that of products will ~~incr~~ decrease. Thus, $[Cu(NH_3)_3SO_3]$ would decrease.

Answer, 48 $I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$.

Since the given reaction is an irreversible reaction, hence the addition of BaI_2 will not effect the rate as well as extent of this reaction. According to the stoichiometry of the reaction, the number of moles of $S_2O_4^{2-}$ formed at the end of the reaction would be equal to $\frac{1}{2}$ the moles of $S_2O_3^{2-}$ reacted.

Answer. 49 $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$ $\underline{K_c = 16}$

	$SO_2(g)$	$NO_2(g)$	$SO_3(g)$	$NO(g)$
Initial moles,	1	1	1	1
At equilibrium,	$1-x$	$1-x$	$1+x$	$1+x$

$$K_c = \left(\frac{1-x}{1+x}\right)^2 = 16$$

Taking square root on both sides, we get,

$$\frac{1-x}{1+x} = 4 \Rightarrow \underline{x = 0.6}$$

Thus, $[NO_2] = 1 - 0.6 = 0.4$

$[NO] = 1 + 0.6 = 1.6$

Answer. 50 $SCN^-(aq) + Fe^{+3}(aq) \rightleftharpoons [Fe(SCN)]^{-2}$

Addition of reactant SCN^- ion will shift the reaction in forward direction, so more product will be formed. Thus, the solution will become deeper red.

Level – 02

Answer.3 Molar mass of Urea(NH_2CONH_2) = 60

Moles of urea = $\frac{120}{60}$ = 2 moles

Molarity of urea = $\frac{2}{5}$ = 0.4 M

~~An~~

Answer.4 $K_p = K_c$, when $\Delta n_g = 0$.

Answer.5 At low pressure, reaction will move in the direction of more no. of moles.

Answer.6 $K_p > K_c \Rightarrow \Delta n_g > 0$.

Answer.7 Since more of product is added, therefore, the reaction should move towards reactants; Hence, more cis-2-pentene is formed.

Answer.9 Value of equilibrium constant will not change with change in volume.

Answer.12 $N_2 + 3H_2 \rightleftharpoons 2NH_3$

Since according to Le-Chatelier's principle, with increase in pressure, the reaction will move in ~~less~~ direction of less no. of ~~molecules~~ moles. So, reaction will move in forward direction.

Answer.13 Increase in volume results in the movement of reaction in the direction of more number of moles. So, the answer is,

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

~~**Answer.14**~~ ~~$2SO_3 \rightleftharpoons 2SO_2 + O_2$ $K_c = 100$~~

Answer.17 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -45$

Since it is an exothermic reaction, hence it should be favoured ~~in~~ at <u>low temperature</u>

Answer.18 $K_p = K_c$ only when $\Delta n = 0.$

For $N_2 + O_2 \rightleftharpoons 2NO$, $\Delta n = 0$

Answer.20 There will be no effect of addition of inert gas ~~on the eq~~ at constant volume on the equilibrium.

Answer.23 Equilibrium constant does not change with concentration of reactants.

Answer.24 $K_p < K_c$ only when Δn_g is (-)ve.

For $2SO_2 + O_2 \rightleftharpoons 2SO_3$ $\underline{\Delta n_g < 0 \Rightarrow K_p < K_c}$

Answer.25 For $CO(g) + \frac{1}{2} O_2(g) \rightleftharpoons CO_2(g)$

$$\Delta n_g = 1 - (1 + \tfrac{1}{2}) = -\frac{1}{2}$$

$$K_p = K_c (RT)^{\Delta n_g} \Rightarrow \frac{K_p}{K_c} = (RT)^{-\frac{1}{2}}$$

$$\Rightarrow \boxed{\frac{K_p}{K_c} = \frac{1}{\sqrt{RT}}}$$

Self - Practice Question

Answer. 5 The value of equilibrium constant does not depend on the initial concentrations of the reactants.

Answer. 6 If $\Delta n_g \neq 0$, then equilibrium constant unit will depend on the units of concentration. In reaction, $CoCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$

~~$\Delta n_g \neq$~~ $\cdot \Delta n_g = 1$, thus the unit of K_c will be $(atm)^1$.

Answer. 7 Greater the value of equilibrium constant, greater will be the tendency of the reaction for completion. Thus, with ~~equi~~ $K = 9 \times 10^{-3}$, production of AB is most favoured.

Answer. 8 Since $\Delta n_g = 0$, therefore there will be no effect of addition of an inert gas. or increase of pressure. The degree of dissociation will be affected by increase of temperature.

Answer. 9 $N_2 + O_2 \rightleftharpoons 2NO$

Initial concentration, 1M 1M 0

At equilibrium, $1-x$ $1-x$ $2x$

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

Taking square root on both sides, we get

$$\Rightarrow \quad \sqrt{2} = \frac{2x}{1-x} \quad \Rightarrow \quad \boxed{x = \frac{1}{1+\sqrt{2}}}$$

Answer. 10 When a system is compressed, it means pressure is increased. When pressure is increased, according to Le Chatelier's principle, reaction will move in direction of less no. of moles. So, PCl_3 and Cl_2 will combine to form PCl_5.

Answer. 13 Since the value of equilibrium constant is decreasing with increase in temperature, therefore we can say that the reaction is exothermic.

Answer. 14 $N_2(g) + 3H_2 \rightleftharpoons 2NH_3(g)$

	$N_2(g)$	$3H_2$	$2NH_3(g)$
Initial moles,	0.2	0.6	0
At equilibrium,	0.2 − 0.08 = 0.12	0.6 − 0.24 = 0.36	2 × 0.08 = 0.16

Given that 40% of mixture reacts, it means 0.32 moles of mixture react. So, according to stoichiometry of reaction, 0.08 moles of N_2 and 0.24 moles of H_2 reacts. Now, since temperature and pressure are constant, hence, $V \propto n$. So, volume ratio is same as mole ratio. So,

Final moles of gases = 0.12 + 0.36 + 0.16 = 0.64

Initial moles of gases = 0.2 + 0.6 = 0.80

$$\boxed{\text{So, molar ratio} = \text{Volume ratio} = \frac{0.64}{0.80} = \frac{4}{5}}$$

$\boxed{\text{Answer.15}}$ $$2CN^- + Ag^+ \rightleftharpoons [Ag(CN)_2]^+$$

At t = 0, $0.1M$ $0.03M$ 0

At equilibrium, $(0.1-0.06)M = 0.04M$ $0.0\,M$ $0.03\,M$

In this reaction, concentration of Ag^+ is zero, so this equilibrium is shifted towards left. Hence by dissociation some Ag^+ is formed.

$$[Ag(CN)_2]^+ \rightleftharpoons Ag^+ + 2CN^-$$

At equilibrium, $0.03M$ 0 $0.04\,M$

At new equilibrium, $(0.03-x)M$ $x\,M$ $(0.04+2x)M$

$$K = \frac{[Ag^+]\,[CN^-]^2}{[Ag(CN)_2]^+}$$

Hence, $$4\times10^{-19} = \frac{x \times (0.04+2x)^2}{(0.03-x)}$$

where, $0.03 - x \simeq 0.03$

so, $$4\times0.03\times10^{-19} = x \times (0.04+2x)^2$$

$$1.2\times10^{-20} = x \times (16\times10^{-4} + 4x^2 + 0.16x)$$

$$= (16\times10^{-4})x + 4x^3 + 0.16x^2$$

On neglecting the higher power of x,

$$16\times10^{-4}x = 1.2\times10^{-20}$$

$$x = 7.5\times10^{-18}M$$

Hence, $$\boxed{[Ag^+] = 7.5\times10^{-18}\,M}$$

Answer. 16 Le Chatelier's principal is not applicable to solid - solid equilibria. So, answer is

$$Fe(s) + S(s) \rightleftharpoons FeS(s)$$

Answer. 17 Since with increase in temperature, the value of K_{eq} is also increasing, hence the reaction is an endothermic reaction.

Answer. 18 Let the mass of N_2 in the mixture be x, then mass of H_2 will be $340 - x$. In right ratio means $(n_{N_2}) \times 3 = n_{H_2}$, then, $3 \times \left(\frac{x}{28}\right) = \frac{340 - x}{2} \Rightarrow x = 280$ gram.

According to the reaction, $N_2 + 3H_2 \rightleftharpoons 2NH_3$

	N_2	$3H_2$	$2NH_3$
Initially, ~~Totally,~~	280 gram	60 g	0
Finally,	0	0	340 gram

But it is given that yield is 20%, so the mass of NH_3 produced will $\boxed{\frac{20}{100} \times 340 = 68 \text{ gram.}}$

Answer. 19 $2AB_3(g) \rightleftharpoons A_2(g) + 3B_2(g)$

	$2AB_3(g)$	$A_2(g)$	$3B_2(g)$
Initial moles,	8	0	0
At equilibrium,	$8(1-\alpha)$	$\frac{8\alpha}{2}$	$3 \times \frac{8\alpha}{2}$

Given that, $\frac{8\alpha}{2} = 2 \Rightarrow \boxed{\alpha = \frac{1}{2}}$

then, $8(1 - \frac{1}{2}) = 4$ $\quad 2 \quad$ $3 \times \frac{8}{2} \times \frac{1}{2} = 6$

$$\boxed{K_c = \frac{2 \times (6)^3}{(4)^2} = 27 \text{ mol}^2 L^{-2}}$$

Answer. 23 moles of O_2 in 5.6 litre of O_2 at STP $= \frac{5.6}{22.4} = 0.25$

So, active mass $= \frac{\text{moles}}{\text{Volume}} = \frac{0.25}{5.6}$

Answer. 24 $N_2 + 3H_2 \rightleftharpoons 2NH_3$ $V = 1\ dm^3 = 1\ litr$

Initial moles, 1 2 0

At equilibrium, $1-x$ $2-3x$ $2x$

Given that, $2x = 0.8 \Rightarrow \boxed{x = 0.4}$

So, $[H_2] = 2 - 3(0.4) = 2 - 1.2 = \underline{0.8}$

Answer. 25 $2A(g) + B(g) \rightleftharpoons 3C(g) + D(g)$

Initial moles, 2 2 0 0

At equilibrium, $2-2x$ $2-x$ $3x$ x

So, $[A] < [B]$ at equilibrium

Answer. 27

$N_2 + 3H_2 \rightleftharpoons 2NH_3$ K_1

$N_2 + O_2 \rightleftharpoons 2NO$ K_2

$H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O$ K_3

Reversing reaction ①, multiplying reaction ③ by 3, and adding the resulting reactions with reaction 2, we get the reaction,

$$2NH_3 + \frac{5}{2}O_2 \rightleftharpoons 2NO + 3H_2O$$

with $\boxed{K = \frac{K_2 K_3^3}{K_1}}$

~~Answer.29~~ ~~$2H_2S \rightleftharpoons$~~

Answer.31

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

Initial moles, 1 0 0

At equilibrium, $1-x$ x x

Total moles at equilibrium $= 1+x$

Let the molar mass of mixture be M_x.

Due to conservation of mass,

$$(208.5 \times 1) = (1+x) \times M_x$$

Dividing this equation by 2, we get,

$$\frac{208.5}{2} = (1+x) \times \frac{M_x}{2}$$

$$104.25 = (1+x) \times d_0 \quad \left(\because V.D = \frac{M.W.}{2}\right)$$

Given that, $d_0 = 70.2$, then,

$$104.25 = (1+x) \times (70.2)$$

$$\Rightarrow \boxed{x = 0.485}$$

Answer.33

$$A \rightleftharpoons 2B$$

Initial moles, 1 0

At equilibrium, $1-x$ $2x$

Given that, $x = 0.4$, then,

$1-0.4 = 0.6$ $2 \times 0.4 = 0.8$

Equilibrium concentration, $\frac{0.6}{2} = 0.3$ $\frac{0.8}{2} = 0.4$

$$\boxed{K = \frac{(0.4)^2}{0.3} = 0.53}$$

Assertion and Reason Questions

Answer. 2 $K_P = K_c (RT)^{\Delta n_g}$

So, for reactions where $\Delta n_g \neq 0$, $K_p \neq K_c$. At constant temperature,

$P = \left(\frac{nRT}{V}\right)$ ~~where,~~

$\Rightarrow P = CRT$ or $\boxed{P \propto C}$

Answer. 3 We don't take concentrations of solids in K_c expression.

Answer. 4

$$\underset{\text{(Pink)}}{Co(H_2O)_6^{2+}(aq)} + 4Cl^-(aq) \rightleftharpoons \underset{\text{(Deep blue)}}{CoCl_4^{2-}(aq)} + 6H_2O(l)$$

~~For endothermic, K_c depends~~

For endothermic reactions, K_c decreases with decrease in temperature, so reaction moves backward.

Answer. 5 If Q_c (reaction quotient) < K_c (equilibrium constant) reaction moves in direction of products.

Answer. 6

$$\overleftarrow{\underline{\underline{NaCl}}_{(s)} \rightarrow Na^+(aq.) + \boxed{Cl^-}(aq)}$$

$$HCl_{(g)} \rightarrow H^+(aq.) + Cl^-(aq.)$$

Brine is an aq. dil. NaCl solⁿ.

Since the reaction is not at equilibrium in brine solution, hence Le-Chatelier principle is not applicable.

Answer. 7 Addition of heat to the equilibrium solid $\rightleftharpoons$ liquid results in decrease in the amount of solid because the reaction is endothermic, and thus heating favours forward reaction.

Answer. 12 For the reaction,

$$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$$

$$\Delta n = (1+3) - 2 = 2$$

So, unit of K_p is $(atm)^2$.

Answer. 13 $\log\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H}{2.303R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$ where, $T_2 > T_1$

For exothermic ΔH is (−)ve, thus $K_2 < K_1$ ~~the~~ which implies reaction is favoured at <u>lower</u> temperature.

For endothermic ΔH is (+)ve, thus $K_2 > K_1$, which implies reaction is favoured at <u>higher</u> temperature.

Answer. 15 There is no relation between ~~st~~ assertion and reason. Reason statement is true because of Le-Chatelier principle. But in assertion statement there are no gases, ~~so no~~ but water in liquid form. Increase in pressure will favour forward reaction because of decrease in volume in going from ice to water.

Answer. 16 Since the reaction is exothermic with (−)ve Δn_g, hence forward reaction is favoured at low temperature and high pressure.

Answer. 17 Equilibrium constant is independent of the ~~a~~ volume of the reaction vessel.

Previous Years Questions

Answer. 2 We have, $\log\left(\frac{K'_P}{K_P}\right) = -\frac{\Delta H}{2.303R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$

Since the reaction is exothermic, hence $\underline{\Delta H = (-)ve}$.
Assuming $T_2 > T_1$, we see that right hand side of this equation will be (−)ve. Thus, $\boxed{K_P > K'_P}$

Answer. 3

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \rightarrow ① \quad K_1$$

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \rightarrow ② \quad K_2$$

Adding ① and ②, we get,

$$N_2 + 2O_2 \rightleftharpoons 2NO_2 \rightarrow ③ \quad K_3 = K_1K_2$$

Reversing equation ③, we get,

$$2NO_2 \rightleftharpoons N_2 + 2O_2 \rightarrow ④ \quad K_4 = \frac{1}{K_1K_2}$$

Multiplying equation ④ with $\left(\frac{1}{2}\right)$, we get,

$$NO_2 \rightleftharpoons \frac{1}{2}N_2 + O_2 \rightarrow ⑤, \quad \boxed{K = \left(\frac{1}{K_1K_2}\right)^{\frac{1}{2}}}$$

Answer. 7

$$\alpha\text{-(D) glucose} \rightleftharpoons \beta\text{(D) glucose} \qquad \underline{K = 1.8}$$

Initially, 1 $\qquad 0$

At equilibrium, $1 - x$ $\qquad x$

So, $K = \frac{x}{1-x} \Rightarrow 1.8 = \frac{x}{1-x} \Rightarrow \boxed{x = 0.643}$

Thus, $1 - x = 1 - 0.643 = 0.357 = \underline{35.7\%}$

Answer. 10 $C(s) + CO_2(g) \longrightarrow 2CO(g)$ $K_p = \frac{(p_{CO})^2}{(p_{CO_2})} = 63$

Given that, at equilibrium, $p_{CO} = 10p_{CO_2}$, then,

$$K_p = 63 = \frac{(10\,p_{CO_2})^2}{(p_{CO_2})} \Rightarrow p_{CO_2} = 0.63 \text{ atm}$$

and $p_{CO} = 10 \times 0.63 = 6.3$ atm

Total pressure at equilibrium, $\boxed{P = p_{CO} + p_{CO_2} = 6.93 \text{ atm}}$

Answer. 11 $AB(g) \rightleftharpoons A(g) + B(g)$ $K_p = 2.56 \times 10^{-2}$

Initial moles, 1 0 0

Equilibrium, $1-x$ x x

Total moles at equilibrium $= 1 - \cancel{x} + \cancel{x} + x = 1 + x$

So, $p_{AB} = \frac{1-x}{1+x}$, $p_A = \frac{x}{1+x}$, $p_B = \frac{x}{1+x}$

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

$$\Rightarrow \quad x^2 = \frac{K_p}{1+K_p} \Rightarrow x = \sqrt{\frac{K_p}{1+K_p}}$$

$$\Rightarrow \quad x = \sqrt{\frac{2.56 \times 10^{-2}}{1 + 2.56 \times 10^{-2}}}$$

$$\Rightarrow \quad x = 0.16$$

$\Rightarrow$ percentage dissociation $= x = 16\%$

Answer.12 Increase in pressure implies that there is an increase in no. of moles of products. Since the concentration of products is greater than reactants, then $\underline{K > 1.0}$

Answer.14 $AB(g) \rightleftharpoons A(g) + B(g)$

	$AB(g)$	$A(g)$	$B(g)$
Initial,	1	0	0
Equilibrium,	$1-x$	x	x
Given that, $x=0.33$	$1-0.33$ $=0.67$	0.33	0.33

Total moles at equilibrium $= 1 + 0.33 = 1.33$

$$p_{AB} = \frac{0.67}{1.33} p \quad , \quad p_A = p_B = \frac{0.33}{1.33} p$$

$$K_p = \frac{\left(\frac{0.33}{1.33} p\right)^2}{\left(\frac{0.67}{1.33} p\right)} = \frac{(0.33)^2}{1.33 \times 0.67} p$$

$$\Rightarrow K_p \simeq \frac{0.1}{0.8} p \Rightarrow \boxed{p = 8K_p}$$

Answer.16 $K = \frac{K_f}{K_b} = \frac{2.38 \times 10^{-4}}{8.15 \times 10^{-5}} = 2.92$

Answer.19 For given reaction, $\Delta n = -1$

So, $K_p = K_c (RT)^{-1} \Rightarrow K_c = K_p (RT)$

$\Rightarrow K_c = 2 \times 10^{10} \times (0.0821 \times 450) = 73.8 \times 10^{10} = 7.38 \times 10^{11}$

Answer. 24

	$A(g)$	$+\ B(g) \rightleftharpoons$	$C(g)$	$+\ D(g)$
Initial moles,	2	2	0	0
Equilibrium,	$2-x$	$2-x$	x	x
Concentration,	$\frac{2-x}{V}$	$\frac{2-x}{V}$	$\frac{x}{V}$	$\frac{x}{V}$

~~Then / [A] = [B]~~ Given, $\frac{x}{V} = \frac{3(2-x)}{V} \Rightarrow \boxed{x = 1.5}$

Then, $[A] = [B] = \frac{2-1.5}{V} = \frac{0.5}{V}$, $[C] = [D] = \frac{1.5}{V}$

$$K_c = \frac{\left(\frac{1.5}{V}\right)^2}{\left(\frac{0.5}{V}\right)^2} = \frac{\overset{3}{\cancel{1.5}} \times \overset{3}{\cancel{1.5}}}{\cancel{0.5} \times \cancel{0.5}} = 9$$

Answer. 26 Since $\Delta G° < 0$, thus forward reaction is favoured, thus concentration of products is always greater than concentration of reactants. Therefore, equilibrium constant will be greater than unity

Answer. 27

	$2SO_2(g)$	$+\ O_2(g) \rightleftharpoons$	$2SO_3(g)$
Initial moles,	5	5	0
At equilibrium,	$5-2x$	$5-x$	$2x$

Given that, $2x = \frac{60}{100} \times 5 \Rightarrow \boxed{x = 1.5}$

So,

$5-3$ $=2$	$5-1.5$ $=3.5$	$2 \times (1.5) = 3$

Total moles at equilibrium $= 2 + 3.5 + 3 = 8.5$

$$p_{O_2} = \frac{3.5}{8.5} \times 1 = 0.41 \text{ atm}$$

Answer-36 $2AB_2 \rightleftharpoons 2AB(g) + B_2(g)$

Initial moles, $1 \quad 0 \quad 0$

At equilibrium, $1-\alpha$

$\alpha \quad \frac{\alpha}{2}$

Total moles at equilibrium $= 1 - \cancel{\alpha} + \cancel{\alpha} + \frac{\alpha}{2}$

$= 1 + \frac{\alpha}{2}$

$$p_{AB_2} = \frac{1-\alpha}{1+\frac{\alpha}{2}}p \quad , \quad p_{AB} = \frac{\alpha}{1+\frac{\alpha}{2}}p$$

$$p_{B_2} = \frac{\alpha/2}{1+\alpha/2}p$$

$$K_p = \frac{(p_{AB})^2 (p_{B_2})}{(p_{AB_2})^2} = \frac{\left(\frac{\alpha}{1+\frac{\alpha}{2}}p\right)^2 \left(\frac{\alpha/2}{1+\frac{\alpha}{2}}p\right)}{\left(\frac{1-\alpha}{1+\frac{\alpha}{2}}p\right)^2}$$

$$\Rightarrow \quad K_p = \frac{\alpha^3 p}{2\left(1+\frac{\alpha}{2}\right)(1-\alpha)}$$

Since α is much less than 1, therefore α can be neglected with respect to 1 in denominator. Then,

$$K_p = \frac{\alpha^3 p}{2}$$

$$\Rightarrow \quad \alpha^3 = \frac{2K_p}{p}$$

$$\Rightarrow \quad \boxed{\alpha = \left(\frac{2K_p}{p}\right)^{\frac{1}{3}}}$$

Answer. 37

$$X \rightleftharpoons Y + Z \qquad K_{P_1}$$

$$A \rightleftharpoons 2B \qquad K_{P_2}$$

Given that, $\boxed{\dfrac{K_{p_1}}{K_{p_2}} = \dfrac{9}{1}} \longrightarrow ①$

For reaction

$$\begin{array}{ccccc} X & \rightleftharpoons & Y & + & Z \\ 1 & & 0 & & 0 \\ 1-x & & x & & x \end{array}$$

$$\boxed{K_{p_1} = \frac{x^2}{1-x^2} p_1} \longrightarrow ②$$

For reaction,

$$\begin{array}{ccc} A & \rightleftharpoons & 2B \\ 1 & & 0 \\ 1-x & & 2x \end{array} \qquad K_{p_2}$$

$$\boxed{K_{p_2} = \frac{4x^2}{1-x^2} p_2} \longrightarrow ③$$

Dividing ② by ③ and using ①, we get,

$$\frac{9}{1} = \frac{p_1}{4p_2}$$

$$\Rightarrow \boxed{\frac{p_1}{p_2} = \frac{36}{1}}$$

Answer.41

	PCl_5 $\rightleftharpoons$	PCl_3 +	Cl_2
Initial moles,	3	3	2
At equilibrium,	$3-x$	$3+x$	$2+x$

Given that $3-x=1.5 \Rightarrow \boxed{x=1.5}$

$$\Rightarrow n_{PCl_3}=3+1.5=4.5$$

Answer.42

	H_2 +	I_2 $\rightleftharpoons$	$2HI$
Initial concentration,	c	c	0
At equilibrium,	$c(1-x)$	$c(1-x)$	$2cx$

Given, $\boxed{K_c=\frac{K_f}{K_b}=1}$.

Thus, $K_c=\left(\frac{2cx}{c(1-x)}\right)^2=1$

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

Taking square root on both sides, we get,

$$\frac{2x}{1-x}=1 \Rightarrow x=\frac{1}{3}=0.33$$

or $\boxed{x=33\%}$

Answer.43 $6HCHO \rightleftharpoons C_6H_{12}O_6$ $K=6\times10^{22}$

then,

$C_6H_{12}O_6$ $\rightleftharpoons$	$6HCHO$
1	0
$1-x$	$6x$

$K_1=\frac{1}{6\times10^{22}}$

So, $\frac{1}{6 \times 10^{22}} = \frac{(6x)^6}{1-x}$

Since equilibrium constant is very low, therefore degree of dissociation will be much less than 1, so $1-x \simeq 1$. Then,

$$\frac{10^{-22}}{6} = 6^6 x^6$$

$$\Rightarrow \quad x^6 = \frac{1}{6} \times \frac{10^{-22}}{6^6}$$

$$\Rightarrow \quad x^6 = \frac{100}{6} \times \left(\frac{10^{-24}}{6^6}\right)$$

$$\Rightarrow \quad (x^6)^{\frac{1}{6}} = \left(\frac{100}{6}\right)^{\frac{1}{6}} \left(\frac{10^{-24}}{6^6}\right)^{\frac{1}{6}}$$

$$\Rightarrow \quad x = \cancel{100}\,(16.66)^{\frac{1}{6}} \times \frac{10^{-4}}{6}$$

~~Now~~, $\Rightarrow \quad x = 1.6 \times \frac{10^{-4}}{6}$

Now, concentration of HCHO at equilibrium is $6x$.

$$[HCHO] = 6 \times \left(1.6 \times \frac{10^{-4}}{6}\right)$$

$$\Rightarrow \quad \boxed{[HCHO] = 1.6 \times 10^{-4}}$$

Answer.44

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

Initial moles, $\frac{9.2}{92} = 0.1$ $\qquad$ 0

At equilibrium, $0.1(1-\alpha)$ $\qquad$ $2 \times 0.1\alpha$

Given that, $\alpha = 0.5$, then,

$0.1(1-0.5)$ $\qquad$ $2 \times 0.1 \times 0.5$

$= 0.05$ $\qquad$ $= 0.1$

$$\boxed{K_c = \frac{(0.1)^2}{0.05} = \frac{0.01}{0.05} = 0.2}$$

Answer.45

$$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$$

$p_{CO_2} = 2$ atm $\qquad$ $p_{CO} = 4$ atm

$$K_p = \frac{(p_{CO})^2}{(p_{CO_2})} = \frac{(4)^2}{2} = 8.$$

Answer.48

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \quad K_p = 1.16$$

But, K_p = Pressure of CO_2

$$\Rightarrow \boxed{P_{CO_2} = 1.16}$$

Let x moles of CO_2 are formed. Then, by using $PV = nRT$, we get,

$$1.16 = \frac{x \times 0.0821 \times 1073}{5}$$

$$\Rightarrow x = 0.065 \quad \text{or} \quad \boxed{x = 6.5\%}$$

Answer. 49

$$H_2O(g) \rightleftharpoons H_2(g) + \frac{1}{2}O_2(g)$$

Initial moles, $\quad 1 \qquad 0 \qquad 0$

At equilibrium, $\quad 1-\alpha \qquad \alpha \qquad \frac{\alpha}{2}$

Total moles at equilibrium $= 1-\cancel{\alpha}+\cancel{\alpha}+\frac{\alpha}{2} = 1+\frac{\alpha}{2}$

$$p_{H_2O} = \frac{1-\alpha}{1+\frac{\alpha}{2}}p \quad , \quad p_{H_2} = \frac{\alpha}{1+\frac{\alpha}{2}}p$$

$$p_{O_2} = \frac{\alpha/2}{1+\frac{\alpha}{2}}p$$

$$K_p = \frac{\left(\frac{\alpha}{1+\frac{\alpha}{2}}p\right)\left(\frac{\alpha/2}{1+\frac{\alpha}{2}}p\right)^{\frac{1}{2}}}{\frac{1-\alpha}{1+\frac{\alpha}{2}}p}$$

$$= \frac{\left(\frac{\cancel{2}\alpha}{2\cancel{+\alpha}}\cancel{p}\right)\left(\frac{\alpha}{2+\alpha}p\right)^{\frac{1}{2}}}{\frac{\cancel{2}(1-\alpha)}{2\cancel{+\alpha}}\cancel{p}}$$

$$\boxed{K_p = \frac{\alpha^{\frac{3}{2}}\,p^{\frac{1}{2}}}{(1-\alpha)(2+\alpha)^{\frac{1}{2}}}}$$

Answer. 51 $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ $K_p = 1.6$ atm

Initial moles, 1 0 0

At equilibrium, $1-x$ x x

Given, $x=0.5$, $1-0.5 = 0.5$ 0.5 0.5

Total moles at equilibrium $= 1.5$

$$p_{PCl_5} = p_{PCl_3} = p_{Cl_2} = \frac{\cancel{0.5}}{\cancel{1.5}} p = \frac{1}{3} p$$

$$K_p = \frac{\left(\cancel{\tfrac{1}{3}p}\right)^2}{\left(\cancel{\tfrac{1}{3}p}\right)} = \frac{1}{3} p$$

$$\Rightarrow \boxed{p = 3 \times 1.6 = 4.8 \text{ atm}}$$

Answer. 53 $NH_4COONH_2(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$

At equilibrium, — $2p$ p

Then, $2p + p = 3$ atm $\Rightarrow \boxed{p = 1 \text{ atm}}$

$$\boxed{K_P = (2)^2 (1) = 4}$$

Answer. 55 $X(g) \rightleftharpoons Y(g) + Z(g)$ $K_p = 1$ atm

Initial moles, 1 0 0

At equilibrium, $1-x$ x x

$x = 0.5$, then, $1-0.5 = 0.5$ 0.5 0.5

Total moles at equilibrium $= 1.5$

$$p_X = p_Y = p_Z = \frac{0.5}{1.5} p = \frac{1}{3} p$$

$$K_p = \frac{(\frac{1}{3}\cancel{p})^{2}}{(\frac{1}{\cancel{3}}\cancel{p})} \Rightarrow \frac{1}{3}p = 1 \Rightarrow \boxed{p = 3\text{ atm}}$$

$$\boxed{p_X = \frac{1}{3}\times 3 = 1\text{ atm}}$$

Answer. 56 $A(s) + B(g) + \text{heat} \rightleftharpoons 2C(g) + 2D(g)$

$$K = \frac{[C]^2[D]^2}{[B]}$$

K will remain same, on re-establishment of ~~reaction~~ equilibrium. So,

$$\frac{[\cancel{C}]^2[D]^2}{[\cancel{B}]} = \frac{[\cancel{C}]^2[D]^2_{new}}{2[\cancel{B}]} \Rightarrow \boxed{[D]_{new} = \sqrt{2}[D]}$$

Answer. 57 $N_2 + 3H_2 \rightleftharpoons 2NH_3$

	N_2	$3H_2$	$2NH_3$
Initial moles,	$\frac{\cancel{56}}{\cancel{28}} = 2$	$\frac{\cancel{8}}{\cancel{2}} = 4$	0
At equilibrium,	$2-x$	$4-3x$	$2x$

Now, $2x = \frac{\cancel{34}^{2}}{\cancel{17}} \Rightarrow \boxed{x = 1}$

Then,

$2-1$ $=1$	$4-3$ $=1$	2 2

Answer. 59 $P_4(s) + 6Cl_2(g) \rightleftharpoons 4PCl_3(g)$

$P_4(s)$	$6Cl_2(g)$	$4PCl_3(g)$
a	a	0
$a-x$	$a-6x$	$4x$

So, we can see that at equilibrium $[P_4] > [Cl_2]$.

Answer. 62

$$AB + CD \longrightarrow AD + CB$$

Initial moles, $1 \quad 1 \quad 0 \quad 0$

At equilibrium, $1-\frac{3}{4} = \frac{1}{4} \quad 1-\frac{3}{4} = \frac{1}{4} \quad \frac{3}{4} \quad \frac{3}{4}$

$$\boxed{K = \frac{\left(\frac{3}{4}\right)^2}{\left(\frac{1}{4}\right)^2} = 9}$$

Answer. 66 Exothermic reactions means ΔH is (−)ve so, we can say that the backward reaction has higher activation energy than the forward reaction.

Answer. 68 Since for the given reaction Δn_g is (−)ve, therefore increase in pressure will result in formation of more ~~reactants~~ products. It is a formation reaction therefore it is an exothermic reaction.

Answer. 78 There will be no effect of addition or removal of any solid species on the equilibrium. So, only change in temperature will change the partial pressure of O_2.

Answer. 83

$$CaCO_3 \rightleftharpoons CaO + CO_2$$

Since lime kiln is an open system hence CO_2 formed escapes out. Due to continuous removal of one product, the reaction goes to completion.

Answer. 90 $H_2 + I_2 \rightleftharpoons 2HI$

Initial moles, $1 \quad 2 \quad 0$

At equilibrium, $1-x \quad 2-x \quad 2x$

Given that, $1 - x = 0.2 \Rightarrow \boxed{x = 0.8}$

So, $0.2 \quad 2 - 0.8 = \underline{1.2} \quad 2 \times 0.8 = \underline{1.6}$

Answer. 92 $CH_3COOH \rightleftharpoons CH_3COO^- + H^+ \quad K_1 = 1.5 \times 10^{-5}$

$HCN \rightleftharpoons CN^- + H^+ \quad K_2 = 4.5 \times 10^{-10}$

Reversing reaction ② and then adding both the reactions, we get,

$$CN^- + CH_3COOH \rightleftharpoons HCN + CH_3COO^- \quad K = \frac{K_1}{K_2}$$

$$\Rightarrow \boxed{K = \frac{1.5 \times 10^{-5}}{4.5 \times 10^{-10}} = 3 \times 10^4}$$

Answer. 94 $N_2O_4 \rightleftharpoons 2NO_2$

Initial moles, $\frac{9.2}{92} = 0.1 \quad 0$

At equilibrium, $0.1 - x \quad 2x$

For 50% dissociation, $0.1 - 0.05 = 0.05 \quad 2(0.05) = 0.1$

$$\boxed{K = \frac{(0.1)^2}{0.05} = 0.2}$$

Answer. 95 $A + B \rightleftharpoons C + D$

Initial concn, $3n \quad n \quad 0 \quad 0$

At eqm, $3n - x \quad n - x \quad x \quad x$

Given that, $n - x = x \Rightarrow \boxed{x = \frac{n}{2}}$

So, $\underline{[D] = x = \frac{n}{2}}$