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# SRIGAYATRI EDUCATIONAL INSTITUTIONS

## INDIA

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### CHEMICAL EQUILIBRIUM UT-03

- In the system  $\text{CaCO}_3(s) \rightleftharpoons \text{CaO}(s) + \text{CO}_2(g)$ , doubling the mass of CaO will cause the equilibrium concentration of  $\text{CO}_2$  to**
  - become half of its initial value
  - remain unchanged
  - become twice its initial value
  - a value which cannot be predicted unless  $K_c$  is known
- For an equilibrium reaction, which one of the following is not true?**
  - If the reaction quotient of the reaction is greater than  $K_{eq}$ , the reaction has a tendency of move in the backward direction
  - If the reaction quotient of the reaction is greater than  $K_{eq}$ , the reaction has a tendency to move in the forward direction
  - If the reaction quotient of the reaction is equal to  $K_{eq}$ , the reaction is at equilibrium
  - If the reaction quotient of the reaction is smaller than  $K_{eq}$ , the reaction has a tendency to move in the forward direction
- The equilibrium constant of the reaction  $\text{H}_2\text{O}(g) + \text{CO}(g) \rightleftharpoons \text{H}_2(g) + \text{CO}_2(g)$ , is 0.44 at 1259 K. The value of equilibrium constant of the reaction  $\text{H}_2(g) + \text{CO}_2(g) \rightleftharpoons \text{H}_2\text{O}(g) + \text{CO}(g)$  will be**
  - + 0.44
  - 2.27
  - $\sqrt{2.27}$
  - $1.0 - 0.44 = 0.56$
- For the reaction  $\text{A}(g) + \text{B}(g) \rightleftharpoons 2\text{C}(g)$ , one mole of A and 1.5 mol of B are taken in a 2.0 litre vessel. At equilibrium, the concentration of C found to be  $0.35 \text{ mol L}^{-1}$ . The equilibrium constant  $K_c$  of the reaction would be**
  - $0.295 \text{ M}^{-1}$
  - $0.673 \text{ M}^{-1}$
  - $2.36 \text{ M}^{-1}$
  - $1.178 \text{ M}^{-1}$
- For the reaction  $\text{C}_2\text{H}_6(g) \rightleftharpoons \text{C}_2\text{H}_4(g)$ , the  $K_p = 0.05 \text{ atm}$ . The value of  $\Delta G^\circ$  of the reaction at  $627^\circ\text{C}$  would be (take  $p^\circ = 1 \text{ atm}$ )**
  - $11.19 \text{ kJ mol}^{-1}$
  - $22.40 \text{ kJ mol}^{-1}$
  - $33.57 \text{ kJ mol}^{-1}$
  - $22.97 \text{ kJ mol}^{-1}$
- In a system  $\text{A}(s) \rightleftharpoons \text{B}(g) + 2\text{C}(g)$  doubling the equilibrium concentration of B will cause the equilibrium concentration of C to change to**
  - two times its original value
  - one-half its original value
  - $\sqrt{2}$  times the original value
  - $1/\sqrt{2}$  times the original value
- In an equilibrium reaction, the rate constant of the forward and backward reactions are  $3.2 \times 10^{-4} \text{ mol}^{-1}\text{s}^{-1}$  and  $1.2 \times 10^{-5} \text{ mol}^{-1}\text{dm}^3 \text{ s}^{-1}$ , respectively. The equilibrium constant of the reaction is**
  - 0.25
  - 0.37
  - 3.7
  - 26.7
- For the reaction  $2\text{HI}(g) \rightleftharpoons \text{H}_2(g) + \text{I}_2(g)$ , which of the following relations between  $K_p$  and  $K_c$  is true ?**
  - $K_p > K_c$
  - $K_p < K_c$
  - $K_p = K_c$
  - $K_p = K_c^2$

9. The equilibrium constants  $K_p$  and  $K_c$  for a gaseous reactions are related to each other through the expression

a)  $K_p (RT)^{\Delta_{\text{vg}}} = K_c$       b)  $K_p = K_c (RT)^{\Delta_{\text{vg}}}$       c)  $K_p = K_c R$       d)  $K_c = R K_p$

10. For the reaction  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ ;  $\Delta H = -93.6 \text{ kJ mol}^{-1}$ , the formation of  $NH_3$  is expected to increase at

- a) High pressure and low temperature      b) Low pressure and low temperature  
c) High pressure and high temperature      d) Low pressure and high temperature

11. For a given equilibrium reaction, an increase in temperature will

- (a) increase the rate of the exothermic direction more than the endothermic direction  
(b) increase the rate of endothermic direction more than the exothermic direction  
(c) increase both rates equally  
(d) decrease both rates equally

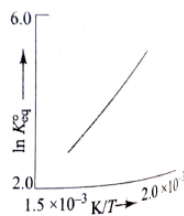
12. For the reaction  $Cl_2(g) \rightleftharpoons 2Cl(g)$ , the formation of  $Cl(g)$  is favoured at

- a) high temperature and low pressure      b) high temperature and high pressure  
c) low temperature low pressure      d) low temperature and low pressure

13. What is the equilibrium expression for the reaction  $P_4(S) + 5O_2(g) \rightleftharpoons P_4O_{10}(S)$ ?

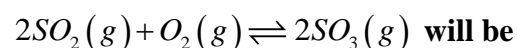
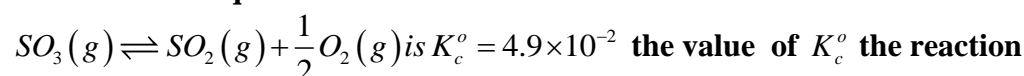
a)  $K_c = \frac{[P_4O_{10}]}{[P_4][O_2]^5}$       b)  $K_c = \frac{[P_4O_{10}]}{5[P_4][O_2]}$   
c)  $K_c = [O_2]^5$       d)  $K_c = \frac{1}{[O_2]^5}$

14. The schematic plot of  $\ln K_{eq}$  versus inverse of temperature for a reaction is shown in the figure the reaction must be



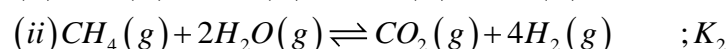
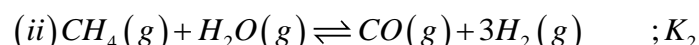
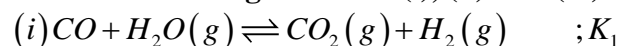
- a) One with negligible enthalpy change      b) highly spontaneous at ordinary temperature  
c) exothermic      d) endothermic

15. The standard equilibrium constant for the reaction



- a)  $4.9 \times 10^{-2}$       b) 416  
c)  $9.8 \times 10^{-3}$       d)  $2.40 \times 10^{-2}$

16. For the following reactions (i), (ii) and (iii)



Which of the following expressions is correct

- a)  $K_1^2 = K_3 K_2^3$       b)  $K_3 = K_1 \sqrt{K_2}$   
c)  $K_1 = K_1 K_3$       d)  $K_3 = K_1 K_2$



## SOLUTIONS

1.  $K_{eq} = p(CO_2)$ . It is independent of mass of CaO.

2. Conceptual

3.  $K_{new} = 1 / K_{old} = 1 / 0.44 = 2.27$

4.  $A(g) + 2B(g) \rightleftharpoons 2C(g)$   
 $\begin{matrix} 1\text{mol}-x & 1.5\text{mol}-2x & 2x \end{matrix}$

Hence,  $\frac{2x}{2L} = 0.35 \text{ mol L}^{-1} \rightarrow x = 0.35 \text{ mol}$

$$K_c = \frac{[C]^2}{[A][B]^2} = \frac{(0.70 \text{ mol} / 2L)^2}{(0.6 \text{ mol} / 2L)(0.8 \text{ mol} / 2L)^2} = 2.36 \text{ mol}^{-1} L$$

5.  $\Delta G^0 = -RT \ln K_k^0 = -(8.314 \text{ K}^{-1} \text{ mol}^{-1})(900 \text{ K})(2.303) \log(0.05) = 22400 \text{ J mol}^{-1}$

6.  $[B]_1 [C]_1^2 = [B]_2 [C]_2^2$

It is given that  $[B]_2 = 2[B]_1$ . Hence  $[C]_2 = \frac{[C]_1}{\sqrt{2}}$

7.  $K_{eq} = K_f / K_b = 3.2 \times 10^{-4} \text{ mol}^{-1} \text{ dm}^3 \text{ S}^{-1} / 1.2 \times 10^{-5} \text{ mol}^{-1} \text{ dm}^3 \text{ S}^{-1} = 26.7$

8.  $K_p = K_c (RT)^{\Delta v_g}; \Delta v_g \Rightarrow K_p = K_c$

9. Conceptual

10. Conceptual

11. Conceptual

12. Conceptual

13. For the reaction  $P_4(s) + 5O_2(g) \rightleftharpoons P_4O_{10}(s)$ , the expression of equilibrium constant is  $K_c = 1/[O_2]^5$  as only gaseous species (and not condensed phases) is considered

14. The variation of standard equilibrium constant with temperature is given by

$$\frac{d \ln K_{eq}^0}{dT} = \frac{\Delta H^0}{RT^2} \text{ which on integration gives } \ln K_{eq}^0 = -\frac{\Delta H^0}{RT} + \text{constant}$$

The slope of the graph between  $\ln K_{eq}^0$  and  $1/T$  shown in the figure is positive. The slope as given by the above equations is  $-\Delta H / R$ . This means  $\Delta H$  is negative, hence, the reaction is exothermic

15. The reaction  $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$  is obtained by reversing the reaction

$SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$  followed by multiplication by 2. Hence

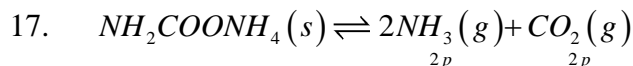
$$K_c^0 = \frac{1}{(K_c^0)^2} = \frac{1}{(4.9 \times 10^{-2})^2} = 416$$

16. Equation (iii) is obtained by adding Eqs (i) and (ii). Hence

$$\Delta G_{(iii)} = \Delta G_{(i)} + \Delta G_{(ii)} \quad \text{or} \quad -RT \ln k_3^0 = -RT \ln K_1^0 - RT \ln K_2^0$$

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This leads to  $K_3 = K_1 K_2$

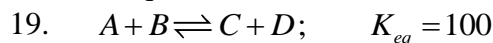


$$K_p = (p_{NH_3})^2 (p_{CO_2}) = (2p)^2 (p) = 4p^3$$

$$p = \left(\frac{K_p}{4}\right)^{1/3} = \left(\frac{2.9 \times 10^{-5} \text{ atm}^3}{4}\right)^{1/3} = 0.01935 \text{ atm}$$

$$P_{total} = p_{NH_3} + p_{CO_2} = 2p + p = 3p = 3 \times 0.01935 \text{ atm} = 5.81 \times 10^{-2} \text{ atm}$$

18. Increase in pressure shifts the equilibrium towards the lesser volume side. Since the molar volume of liquid water is smaller than that of ice, equilibrium will shift in the forward direction.



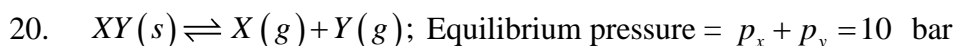
$$1M - x \quad 1M - x \quad 1M + x \quad 1M + x$$

$$K_{eq} = \frac{[C][D]}{[A][B]} = \frac{(1M + x)^2}{(1M - x)^2} = 100$$

$$\text{Thus } \frac{1M + x}{1M - x} = 10 \text{ i.e. } 1M + x = 10(1M - x)$$

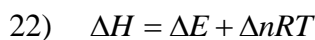
$$\text{Or } 11x = 9M \text{ or } x = (9/11)M = 0.818 M$$

$$\text{Equilibrium concentration of D is } D_{is} [D]_{eq} = 1M + x = 1M + 0.818M = 1.818M$$



Since  $p_x + p_y$  we have  $p_x + p_y = 5$  bar The value of equilibrium constant will be

$$K_p = p_x p_y = (5 \text{ bar}) = 2$$



$$\Delta H - \Delta E = \Delta nRT$$

$$-1190 \text{ cal} = \Delta n \times 2 \times 298 \Rightarrow \Delta n = \frac{-1190}{2 \times 298} = -2$$

$$\text{Also } K_p = K_c (RT)^{\Delta n}$$

$$\frac{K_p}{K_c} \times 10^4 = (RT)^{\Delta n} = (0.0821 \times 298)^{-2} = 1.67 \times 10^{-3}$$

$$= 1.67 \times 10^{-3} \times 10^4 = 1.67 \times 10 = 16.7 = 17 \text{ (nearest integer value)}$$

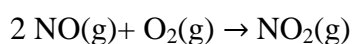


Molecular weight of  $O_2 = 32$  g

Given weight of  $O_2 = 16$  g

$$\text{No. of moles of } O_2 = O_2 = \frac{\text{Given weight}}{\text{Mol.wt}} = \frac{16}{32} = 0.5 \text{ mol}$$

Given amount of  $NO = 2$  mol



From the above reaction.

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2 moles of NO react with 1 mole of O<sub>2</sub> to produce 2 mole of NO<sub>2</sub>.

But the given amount of O<sub>2</sub> is 0.5 mole.

Thus, O<sub>2</sub> is limiting reagent.

Now again from the above reaction,

1 mole of O<sub>2</sub> produces 2 moles of NO<sub>2</sub>.

Therefore, 0.5 mole of O<sub>2</sub> will produce 1 mole of NO<sub>2</sub>.

From ideal gas equation PV=nRT

$$P = n R T / V$$

$$PV = nRT$$

$$\Rightarrow P = \frac{nRT}{V}$$

Initially:-

2 mole of NO and 0.5 mole of O<sub>2</sub> were present.

Total no. of moles initially = 2 + 0.5 = 2.5

Therefore,

$$\text{Initial pressure } (P_i) = 2.5 R T / V$$

After reaction:-

1 mole of NO<sub>2</sub> formed and 1 mole of NO left.

Total no. of moles after reaction = 1 + 1 = 2

Therefore,

$$\text{Final pressure } (P_f) = 2RT/V$$

Therefore,

$$\text{Change in pressure } (\Delta P) = P_i - P_f \Rightarrow \Delta P$$

$$= \frac{2.5RT}{V} - \frac{2RT}{V} = \frac{RT}{2V}$$

Given that T = 27°C = (27 + 273) = 300 K

V = 6.25 L

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$$\text{Initial pressure } (P_i) = \frac{2.5RT}{V}$$

After reaction:-

1 mole of  $\text{NO}_2$  formed and 1 mole of  $\text{NO}$  left.

Total no. of moles after reaction = 1+1=2

Therefore,

$$\text{Final pressure } (P_f) = \frac{2RT}{V}$$

Therefore,

$$\text{Change in pressure } (\Delta P) = P_i - P_f$$

$$\Rightarrow \Delta P = \frac{2.5RT}{V} - \frac{2RT}{V} = \frac{RT}{V}$$

Given that  $T=27^\circ\text{C}=(27+273)=300\text{ K}$

$V=6.25\text{ L}$

$$\therefore \Delta P = \frac{0.0821 \times 300}{2 \times 6.25} = 2\text{ atm}$$

Hence the change in pressure is 2 atm.