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**N.C.E.R.T EXERCISE**

1. A liquid is in equilibrium with its vapours in a sealed container at a fixed temperature. The volume of the container suddenly increased.
2. What is the initial effect of the change on vapour pressure ?
3. How do rates of evaporation and condensation change initially ?
4. What happen when equilibrium is restored finally and what will be the final vapour pressure ?
5. What is KC for the following equilibrium when the equilibrium concentration of each substance :

[SO2] = 0.6 M , [O2] = 0.82 M and [SO3] = 1.90 M ? 2 SO2 (g) + O2 (g) 2 SO3 (g)

1. At a certain temperature and a total pressure of 105 Pa, iodine vapour contain 40 % by volume of iodine atom in the equilibrium [I2 (g) 2 I (g)]. Calculate KP for the equilibrium.
2. Write the expression for the equilibrium constant, KC for each of the following reactions :
3. 2 NOCl (g) 2 NO (g) + Cl2 (g)
4. 2 Cu (NO3)2 (s) 2 CuO (s) + 4 NO2 (g) + O2 (g)
5. CH3COOC2H5 (aq) + H2O (l) CH3COOH (aq) + C2H5OH (aq)
6. Fe3+ (aq) + 3 OH – (aq) Fe(OH)3 (s)
7. I2 (s) + 5 F2 2 IF5
8. Find out the value of KC for each of the following equilibria from the value of KP :
9. 2 NOCl (g) 2 NO (g) + Cl2 (g) ; KP = 1.8 x 10 – 2 at 500 K
10. CaCO3 (s) CaO (s) + CO2 (g) ; KP = 167 at 1073 K.
11. For the following equilibrium, KC = 6.3 x 1014 at 1000 K : NO (g) + O3 (g) NO2 (g) + O2 (g)

Both the forward and reverse reactions in the equilibrium are elementary bimolecular reactions. What is KC for the reverse reaction ?

1. Explain why pure liquids and solids can be ignored while writing the equilibrium constant expression.
2. Reaction between nitrogen and oxygen takes place as follows :

2N­2 (g) + O2 (g) 2 N2O (g)

If a mixture of 0.482 mol of N2 and 0.933 mol of O­2 is placed in a reaction vessel of volume 10 L and allowed to form N2O at a temperature for temperature for which KC = 2 x 10 – 37. Determine the composition of the equilibrium mixture.

1. Nitric oxide reacts with bromine and gives nitrosyl bromide as per reaction given below :

2 NO (g) + Br2 (g) 2 NOBr (g)

When 0.087 mol of NO and 0.0437 mol of Br2 are mixed in a closed container at constant temperature, 0.0518 mol of NOBr is obtained at equilibrium. Calculate equilibrium amount of nitric oxide and bromide.

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1. At 450 K , KP = 2 x 1010/bar for the given reaction at equilibrium

2 SO­2 (g) + O2 (g) 2 SO3 (g) , What is KC at this temperature ?

1. A sample of HI (g) is placed in a flask at a pressure of 0.2 atm. At equilibrium, the partial pressure of HI (g) is 0.04 atm. What is KP for the given equilibrium ?
2. A mixture of 1.57 mol of N2 , 1.92 mol of H2 and 8.13 mol of NH3 is introduce in a 20 L reaction vessel at 500 K. At this temperature, the equilibrium constant, KC for the reaction,

N­2 (g) + 3 H2 (g) 2 NH3 (g) is 1.7 x 102.

Is the reaction mixture at equilibrium ? if not, what is the direction of the net reaction ?

1. The equilibrium constant expression for a gas reaction is KC =

Write the balanced chemical equation corresponding to this expression.

1. One mole of H2O and one mole of CO are taken in a 10 L vessel and heated at 725 K. At equilibrium 40 % of water (by mass) reacts with CO according to the equation :

H­2O (g) + CO (g) H2 (g) + CO (g) , Calculate the equilibrium constant for the reaction.

1. At 700 K, equilibrium constant for the reaction : H2 (g) + I2 (g) 2 HI (g) is 54.8 .

If 0.5 mol/L of HI (g) is present at equilibrium at 700 K, what are the concentrations of H2 (g) and I­2 (g) assuming that we initially started with HI (g) and allowed it to reach equilibrium at 700 K.

1. What is the equilibrium constant of each of the substances in the equilibrium when the initial concentration of ICl was 0.78 M ? 2 ICl (g) I2 (g) + Cl2 (g) , KC = 0.14
2. KP = 0.04 atm at 899 K for the equilibrium shown below. What is the equilibrium concentration of C2H6 when it is placed in a flask at 4 atm pressure and allowed to come in equilibrium ?

C2H6 (g) C2H4 (g) + H2 (g)

1. The ester, ethyl acetate is formed by the reaction is formed by the reaction of ethanol and acetic acid and the equilibrium is represented as : CH3COOH (l) + C2H5OH (l) CH3COOC2H5 (l) + H2O (l)
2. Write the concentration ratio (concentration quotient) Q for this reaction. Note that water is not in excess and is not a solvent in this reaction.
3. At 293 K, if one starts with 1 mol of acetic acid and 0.18 mol of ethanol, there is 0.171 mol of ethyl acetate in the final equilibrium mixture. Calculate the equilibrium constant.
4. Starting with 0.5 mol of ethanol and 1 mol of acetic acid and maintaining it at 293 K, 0.214 mol of ethyl acetate is found after sometime. Has equilibrium been reached ?
5. A sample of pure PCl5 was introduced into a evacuated vessel at 473 K. After equilibrium was reached , the concentration of PCl5 was found to be 0.5 x 10 – 1 mol/L. If KC is 8.3 x 10 – 3 what are the concentrations of PCl3 and Cl2 at equilibrium ?
6. One of the reactions that takes place in producing steel from iron ore is the reduction of iron (II) oxide by carbon monoxide to give iron metal and CO2 ; FeO (s) + CO (g) Fe (s) + CO2 (g) : KP = 0.265 atm at 1050K. What are the equilibrium partial pressures of CO and CO2 at 1050 K if the initial pressures are :

PCO = 1.4 atm and Pco2 = 0.8 atm ?

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1. Equilibrium constant KC for the reaction : N­2 (g) + 3 H2 (g) 2 NH3 (g) at 500 K is 0.061. At a particular time , the analysis shows that composition of the reaction mixture is 3 mol/L N2 , 2 mol/L H2 and 00.5 mol/L NH3 . Is the reaction at equilibrium ? If not, in which direction does the reaction tend to proceed to reach equilibrium ?
2. Bromine monochloride (BrCl) decomposes into bromine and chlorine and attains the equilibrium

2 BrCl (g) Br2 (g) + Cl2 (g) for which KC = 32 at 500 K. If initially pure BrCl is present at a concentration of 3.3 x 10 – 3 mol/L, what is its molar concentration in the mixture at equilibrium ?

1. At 1127 K and 1 atm pressure, a gaseous mixture of CO and CO2 in equilibrium with solid carbon has 90.55% CO by mass in the reaction ; C (s) + CO2 (g) 2 CO (g). Calculate KC for this reaction at the above temperature.
2. Calculate (a) G0 and (b) the equilibrium constant for the formation of NO2 from NO and O2 at 298 K .

NO (g) + O2 (g) → NO2 (g) ,

where G0 (NO2) = 52 KJ/mol , G0 (NO) = 87 KJ/mol , G0 (O2) = 0 KJ/mol

1. Does the number of moles of reaction products increase, decrease or remain same when each of the following equilibria is subjected to a decrease in pressure by increasing the volume ?

a) PCl5 (g) PCl3 (g) + Cl2 (g) b) CaO (s) + CO2 (g) CaCO3 (g)

c) 3 Fe (s) + 4 H2O (g) Fe3O4 (g) + 4 H2 (g)

1. Which of the following reactions will get affected by increasing the pressure ? Also mention whether change will cause the reaction to go into forward or backward direction ?

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| a) COCl2 (g) CO (g) + Cl2 (g) | b) CH4 (g) + 2 S2 (g) CS2 (g) + 2 H2S (g) |
| c) C (s) + CO2 (g) 2 CO (g) | d) 2 H2 (g) + CO (g) CH3OH (g) |
| e) CaCO3 (g) CaO (s) + CO2 (g) | f) 4 NH3 (g) + 5 O2 (g) 4 NO (g) + 6 H2O (g) |

1. The equilibrium constant for the reaction, H­2 (g) + Br2 (g) 2 HBr (g) at 1024 K is 1.6 x 105. Find the equilibrium pressure of all gases if 10 bar of HBr is introduced into a sealed container at 1024 K.
2. Dihydrogen gas is obtained from natural gas by partial oxidation with steam as per the endothermic reaction : CH4 (g) + H2O (g) CO (g) + 3 H2 (g)
3. Write an expression for KP for the above reaction.
4. How will the value of KP and composition of the equilibrium mixture be affected by (a) increasing the pressure (b) increasing the temperature and (c) using a catalyst ?
5. Describe the effect of : (a) addition of H2O (b) addition of CH3OH (c) removed of CO (d) removal of CH3OH, on the equilibrium of the reaction : 2 H2 (g) + CO (g) CH3OH (g).
6. At 473 K, equilibrium constant KC for the decomposition of phosphorus pentachloride, PCl5 is 8.3 x 10 – 3.If the decomposition is depicted as : PCl5 (g) PCl3 (g) + Cl2 (g) ; H0 = 124 KJ mol – 1
7. Write an expression for KC for the reaction ?
8. What is the value of KC for the reverse reaction at the same temperature ?
9. What would be the effect on KC if (i) more PCl5 is added (ii) pressure in increased (iii) temperature is increased ?

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1. Dihydrogen gas used in Haber’s process is produced by reacting methane from natural gas with high temperature steam. The first stage of two stage reaction involves the formation of CO and H2. In second stage, CO formed in first stage is reacted with more steam in water gas shift reaction,

CO (g) + H2O (g) CO2 (g) + H2 (g). If a reaction vessel at 400˚C is charged with an equimolar mixture of CO and steam such that Pco = P(water)  = 4 bar, what will be the partial pressure of H2 at equilibrium ? KP = 0.1 at 400˚C.

1. Predict which of the following reaction will have appreciable concentrations and products :

a) Cl2 (g) 2 Cl (g) ; KC = 5 x 10 – 39  b) 2 NO (g) + Cl2 (g) 2 NOCl (g) ; KC = 3.7 x 108

c) 2 NO2 (g) + Cl2 (g) 2 NO2Cl (g) ; KC = 1.8

1. The value of KC for the reaction : 3 O2 (g) 2 O3 (g) is 2 x 10 – 50 at 25˚C. If the equilibrium concentration of O2 in air at 25˚C is 1.6 x 10 – 2 , what is the concentration of O3 ?
2. The reaction CO (g) + 3 H2 (g) CH4 (g) + H2O (g) , is at equilibrium at 1300 K in a 1 L flask. It also contain 0.3 mol of CO , 0.1 mol of H2 and 0.02 mol of H2O and an unknown amount of CH4 in the flask. Determine the concentration of CH4 in the mixture. The equilibrium constant, KC for the reaction at a given temperature is 3.9 .

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**Answers**

2. 12.229 L/mol 3. 2.67 x 104 Pa

4. (i) Kc = (ii) Kc = [NO2 (g)]4 [O2 (g)]

(iii) Kc = (iv) Kc = (v) Kc =

5. (i) 4.33 x 10 – 4 (ii) 1.87 6. 1.59 x 10 – 15  8. 6.6 x 10 – 21 mol/L

9. [Br2] = 0.0178 mol , [NO] = 0.0352 mol 10. 7.48 x 1011 L/mol 11. 4 12. No, backward direction

13. 4 NO (g) + 6 H2O (g) 4 NH3 (g) + 5 O2 (g) 14. 0.444 15. [H2] = [I2] = 0.06 mol/L

16. [I2] = [Cl2] = 0.167 M , [ICl] = 0.446 M 17. [C2H6]eq. = 3.6 atm 18. (ii) Kc = 3.92 (iii) Q = 0.204 , No

19. [PCl3]eq. = [Cl2]eq. = 0.02 M 20. [Pco] = 1.739 atm [Pco2]eq. = 0.461 atm

21. Q = 0.0104 , Reaction will proceed in the forward direction 22. [BrCl] = 2.68 x 10 – 4 mol/L

23. Kc = 0.153 24. K = 1.36 x 106 25. (a) increase (b) decrease (c) remain same

26. a) Reaction will go in the backward direction b) Reaction will not be affected by pressure

c) Reaction will go in the backward direction d) Reaction will go in the forward direction.

e) Reaction will go in the backward direction f) Reaction will go in the backward direction

27. = = 2.5 x 10 – 2 bar , = 10 bar 28. (i) =

(ii) (a) Backward direction (b) Forward direction (c) No effect, but equilibrium attained quickly

29. a) Reaction will shift in the forward direction b) Reaction will shift in the backward direction

c) Reaction will shift in the backward direction d) Reaction will shift in the forward direction.

30. (a) Kc = , (b) 120.48 (c) (i) No effect as Kc is constant at constant temperature

(ii) No effect (iii) As given reaction is endothermic, on increasing the temperature Kf will increase. As Kc = .

Kc will increase with increase of temperature.

31. ()eq. = 0.96 bar 32. For reaction (c) , as Kc is neither high nor very low , reactants and products will be present in comparable amounts.

33. [O3] = 2.86 x 10 – 28 M 34. [CH4] = 0.0585 M = 5.85 x 10 – 2 M

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**Assignment – I**

1. **Fill in the blanks :**
2. A bulb containing N2O4 is colourless in ice. Its colour in boiling water is …………………….. while in water at 298 K, it is …………………….. .
3. According to Law of Mass Action, the rate at which a substance reacts is proportional to its …………………….
4. In terms of rate constants for forward and backward reactions ( kf and kb ), equilibrium constant of a reaction is equal to ………………….. .
5. Ratio of KP/KC of a reaction : 2 SO2 + O2 2 SO3 is equal to ………………… .
6. Equilibrium constant of a reaction does not change with ………………… but changes with ……………………
7. The equilibrium constant of an endothermic reaction ………………………. will increase on temperature.
8. On adding a catalyst to a reaction, the equilibrium constant …………………………… .
9. If concentration quotient of reaction is less than its equilibrium constant, then the reaction will proceed in the …………………… direction.
10. N2 gas is added to the reaction equilibrium PCl5 (g) PCl3 (g) + Cl2 (g) at constant temperature. If pressure is kept constant, equilibrium constant will ………………. and equilibrium will shift in the ……………. direction.
11. Exothermic reaction are favoured by ………………………. Temperature.
12. If pressure is applied on the ice water equilibrium, more of ………………….. will be formed.
13. **True / False**
14. If concentration of the reactants in the reaction, A + B C + D was doubled, equilibrium constant is also doubled.
15. It is insignificant whether we start with reactants or products to attain equilibrium.
16. A catalyst increases the speed of an equilibrium reaction and hence the amount of product formed increases.
17. In the equilibrium mixture N­2 (g) + 3 H2 (g) 2 NH3 (g) is compressed to half the volume, the concentration quotient will become ¼ th of equilibrium constant.
18. Equilibrium constant of vaporisation equilibrium of water at a particular temperature is equal to its vapour pressure.
19. At 700 K, the equilibrium constant Kp for the reaction : 2 SO3 (g) 2 SO2 (g) + O2 (g) is 1.8 x 10 – 3 kPa. What is the numerical value of KC in moles per litre for this reaction at the same temperature ?
20. At 773 K, the equilibrium constant Kc for the reaction : N­2 (g) + 3 H2 (g) 2 NH3 (g) is 6.02 x 10 – 2 L2/mol2. Calculate the value of KP at the same temperature.
21. For the equilibrium ; 2 NOCl (g) 2 NO (g) + Cl2 (g), the value of the equilibrium constant, KC is 3.75 x 10 – 6 at 1069 K. Calculate KP for the reaction at this temperature.
22. KP for the reaction N2O4 (g) 2 NO­2 (g) is 0.157 atm at 27˚C and 1 atm pressure. Calculate KC for the reaction.
23. For the reaction : A (g) + B (s) C (g) + D (g) , KC = 49 mol/dm3 at 127˚C. Calculate KP.

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**Answers**

Q.1 1. Reddish brown , pale brown 2. Active mass or molar concentration 3. Kf/Kb 4. 1/RT

5. initial concentrations of reactants , change in temperature 6. Increases 7. Remain unchanged

8. forward 9. Remain constant, forward 10. Low 11. Water

Q.2 1. False 2. True 3. False 4. True 5. True Q.3 3.09 x 10 – 7 mol/L

Q.4 1.5 x 10 – 5atm – 2  Q.5 3.33 x 10 – 4  Q.6 6.37 x 10 – 3 mol/L Q.7 1.61 x 103 atm

**Assignment – II**

1. Two moles of PCl5 were heated to 327˚C in a closed 2 L vessel and when equilibrium was achieved, PCl5 was found to be 40 % dissociated into PCl3 and Cl2. Calculate the equilibrium constant KP and K­C for this reaction.
2. For the reaction, N­2 (g) + 3 H2 (g) 2 NH3 (g) , the partial pressure of N2 and H2 are 0.8 and 0.4 atm respectively at equilibrium. The total pressure of the system is 2.8 atm. What is KP for the above reaction.
3. The value of KP for the reaction :

CO2 (g) + C (s) 2 CO (g)

is 3 at 1000 K. If initially, Pco2 = 0.48 bar and Pco = 0 bar and pure graphite is present, Calculate the equilibrium partial pressure of CO and CO2 .

1. The equilibrium constant at 278 K for :

Cu (s) + 2 Ag+ (aq) Cu2++ 2 Ag (s)

is 2 x 1015. In a solution in which copper has displaced some silver ions from the solution, the concentration of Cu2+ ions is 1.8 x 10 – 2 mol/L and the concentration of Ag+ ions is 3 x 10 – 9 mol/L. Is this system at equilibrium ?

1. The value of KC for the reaction : 2 A B + C , is 2 x 10 – 3 . At a given time, the composition of the reaction mixture is [A] = [B] = [C] = 3 x 10 – 4 M. In which direction, the reaction will proceed ?
2. AB2 (g) AB (g) + B (g) : if initial pressure of AB2 (g) is 500 mm of Hg and the total pressure at equilibrium is 700 mm of Hg , calculate KP for the reaction.
3. Determine the concentration of CO2 which will be in equilibrium with 2.5 x 10 – 2 mol/L of CO at 100˚C for the reaction : FeO (s) + CO (g) Fe (s) + CO2 (g) , KC = 50.
4. The value of KC = 4.24 at 800 K for the reaction :

CO (g) + H2O (g) CO2 (g) + H2 (g)

Calculate equilibrium concentrations of CO2 , H2 , CO and H2O at 800 K, if only CO and H2O are present initially at concentration of 0.1 M each ?

1. 3 mol of PCl5 kept in 1 L closed reaction vessel was allowed to attain equilibrium at 380 K. Calculate the composition of the mixture at equilibrium , KC = 1.8

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1. 13.8 g of N2O­4 was placed in 1 L reaction vessel at 400 K and allowed to attain equilibrium :

N2O4 (g) 2 NO­2 (g). The total pressure at equilibrium was found to be 9.15 bar. Calculate Kc , KP and partial pressure at equilibrium.

1. For the reaction : N2O4 (g) 2 NO­2 (g), the concentration of an equilibrium mixture at 298 K are N2O­4 = 4.5 x 10 – 2 mol/L and NO2 = 1.61 x 10 – 2 mol/L. What is the value of equilibrium constant?
2. At equilibrium, the concentration of N2 = 3 x 10 – 3 M , O2 = 4.2 x 10 – 3 M and NO = 2.8 x 10 – 3 M in a sealed vessel at 800 K. What will be Kc for the reaction :

N­2 (g) + O2 (g) 2 NO (g)

1. For the reaction ; 2 NO (g) + Cl2 (g) 2 NOCl, if partial pressure = 0.32 atm, = 0.22 atm and = 0.11 atm, then find KP.
2. Calculate the equilibrium constant KP and Kc for the reaction ; CO (g) + O2 (g) CO2 (g). Given that partial pressures at equilibrium in a vessel at 3000 K are Pco = 0.4 atm , Pco2 = 0.6 atm and Po2 = 0.2 atm.
3. A reaction mixture containing N2 at 0.5 atm, H2 at 3 atm and NH3 at 0.5 atm is heated to 450˚C. In which direction the reaction : N­2 (g) + 3 H2 (g) 2 NH3 (g) will go if KP is 4.8 x 10 – 5 ?

**Answers**

1. Kc = 0.267 mol/L , KP = 13.13 atm 2. KP = 50 3. Pco2 = 0.15 bar , Pco = 0.66 bar 4. Yes

5. In backward direction 6. 133.3 mm 7. 12.5 x 10 – 2 M 8. [CO2]eq. = 0.067 M , [CO]eq. = 0.033 M

9. [PCl5] = 1.41 M , [PCl3] = [Cl2] = 1.59 M 10. KP = 85.87 , Kc = 2.6 11. 5.76 x 10 – 3  12. 0.622

13. 19.23 atm – 1  14. KP = 3.354 , Kc = 52.64 15. In backward direction

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