

Dr Clays A-level Chemistry

UNIT 1 TOPIC 6

EQUILIBRIA & REDOX

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Unit 1 Topic 6 – EQUILIBRIA & REDOX

EXERCISE 1 – Equilibrium Constants

1. State the three features of a dynamic equilibrium

2. For each of the following equilibria, write the expression for the equilibrium constant K_c and state its units:

i) $2NO_2(g) \leftrightarrow N_2O_4(g)$

ii) $CH_3CH_2CO_2H(l) + CH_3CH_2OH(l) \leftrightarrow CH_3CH_2CO_2CH_2CH_3(l) + H_2O(l)$

iii) $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$

iv) $2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$

v) $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$

3. For the equilibrium $PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$

   the equilibrium concentrations of PCl_5, PCl_3 and Cl_2 are 1.0, 0.205 and 0.205 $moldm^{-3}$ respectively. Calculate the value of K_c.

4. For the equilibrium $2N_2O_5(g) \leftrightarrow 2N_2O_4(g) + O_2(g)$
   The equilibrium concentrations are $[N_2O_5]$ = 1.0 $moldm^{-3}$, $[N_2O_4]$ = 0.11 $moldm^{-3}$, $[O_2]$ = 0.11 $moldm^{-3}$.

   Calculate the value of K_c.

5. The reaction for the formation of hydrogen iodide does not go to completion but reaches an equilibrium: $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$
   A mixture of 1.9 mol of H_2 and 1.9 mol of I_2 was prepared and allowed to reach equilibrium in a closed vessel on 250 cm^3 capacity. The resulting equilibrium mixture was found to contain 3.0 mol of HI. Calculate the value of Kc.

6. Consider the equilibrium: $N_2O_4(g) \leftrightarrow 2NO_2(g)$.

   1 mol of dinitrogen tetroxide, N_2O_4, was introduced into a vessel of volume 10 dm^3. At equilibrium 50% had dissociated. Calculate Kc for the reaction.

7. In an experiment, 9.0 moles of nitrogen and 27 moles of hydrogen were placed into a vessel of volume 10 dm^3 and allowed to reach equilibrium. It was found that two thirds of the nitrogen and hydrogen were converted into ammonia. Calculate Kc for the reaction.

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

8. Hydrogen chloride can be oxidised to chlorine by the Deacon process:

   $4HCl(g) + O_2(g) \leftrightarrow 2Cl_2(g) + 2H_2O(g)$

   0.800 mol of hydrogen chloride was mixed with 0.200 mol of oxygen in a vessel of volume 10 dm^3. At equilibrium it was found that the mixture contained 0.200 mol of hydrogen chloride. Calculate Kc for the reaction.

9. A 0.04 sample of SO_3 is introduced into a 3.04 litre vessel and allowed to reach

   equilibrium. The amount of SO_3 present at equilibrium is found to be 0.0284 mole. Calculate the value of K_c for the reaction $2SO_3(g) \leftrightarrow 2SO_2(g) + O_2(g)$.

10. The reaction between carbon monoxide and hydrogen proceeds according to the equilibrium $CO(g) + 2H_2(g) \leftrightarrow CH_3OH(g)$ A 1 litre flask maintained at 700K contains 0.1 mole of carbon monoxide. After 0.3 mole of hydrogen is added, 0.06 mol of ethanol are formed. Calculate the equilibrium constant K_c.

11. When 1.0 mole each of ethanoic acid and ethanol were allowed to reach equilibrium in a sealed vessel of volume 500 cm^3, the amount of ethanoic acid present at equilibrium was found to be 0.33 mole. Calculate the value of K_c for the reaction $CH_3COOH + CH_3CH_2OH \leftrightarrow CH_3COOCH_2CH_3 + H_2O(l)$

12. At 723K, hydrogen and iodine react together and the following equilibrium is established: $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$

    The value of K_c for this equilibrium is 64. In an experiment, equal amounts of hydrogen and iodine were mixed together, and the equilibrium mixture of the three gases in a container of volume 1 dm^3 at 723K was found to contain 1.5 moles of iodine. Calculate the concentration of hydrogen iodide in the mixture at 723K.

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EXERCISE 2 – Changing the Position of Equilibrium

1. Consider the following exothermic reaction:

$4HCl(g) + O_2(g) == 2Cl_2(g) + 2H_2O(g)$

State, with a reason, what would happen to the amounts of chlorine and hydrogen chloride in the system if the following changes were made after equilibrium had been established in a sealed container:

a) water is removed from the system;

b) extra oxygen is added to the system;

c) the volume of the container was reduced;

d) the temperature of the container was increased;

e) a catalyst was added.

2. For each of the following reactions, state and explain whether a high or low temperature and a high or low pressure should be used to maximize the yield of product:

a) $2SO_2(g) + O_2(g) == 2SO_3(g)$, ΔH = -ve

b) $PCl_5(g) == PCl_3(g) + Cl_2(g)$, ΔH = +ve

c) $H_2(g) + I_2(g) == 2HI(g)$, ΔH = -ve

d) $HCOOH(l) + CH_3OH(l) == HCOOCH_3(l) + H_2O(l)$, ΔH = 0

3. The manufacture of ammonia by the Haber process is an important example of an industrial process which involves an equilibrium reaction:

$$N_2(g) + 3H_2(g) == 2NH_3(g), \Delta H = -ve$$

The reaction is carried out at 450 °C and 250 atm with an iron catalyst.

a) Give one reason why a higher temperature is not used.

b) Give one reason why a lower temperature is not used.

c) Give one reason why a higher pressure is not used.

d) Give two reasons why a lower pressure is not used.

e) Explain why a catalyst is used.

EXERCISE 3 – redox reactions

1. Define the terms:
a) Oxidation
b) Reduction
c) Oxidising agent
d) Reducing agent
e) Redox reaction
2. Deduce the oxidation numbers of the following atoms:

a)	Si in SiF_4	k)	Tl in TlCl
b)	S in H_2S	l)	C in CaC_2
c)	Pb in PbO_2	m)	H in AlH_3
d)	S in H_2SO_4	n)	C in $C_2O_4^{2-}$
e)	N in NO_3^-	o)	I in IO_3^-
f)	N in NO_2^-	p)	Cl in Cl_2O_7
g)	I in I_2	q)	O in OF_2
h)	S in $S_2O_3^{2-}$	r)	Fe in Fe_3O_4
i)	Cl in ClO^-	s)	S in $S_4O_6^{2-}$
j)	Cl in ClO_3^-	t)	C in HCN

3. Turn the following processes into redox reactions by writing out half-equations and combining them:

a) $PbO_2 \rightarrow Pb^{2+}$, $Cl^- \rightarrow Cl_2$

b) $S_2O_3^{2-} \rightarrow S_4O_6^{2-}$, $I_2 \rightarrow 2I^-$

c) $IO_3^- \rightarrow I_2$, $I^- \rightarrow I_2$

d) $ClO^- \rightarrow ClO_3^-$, $ClO^- \rightarrow Cl^-$

e) $H_2SO_4 \rightarrow SO_2$, $Br^- \rightarrow Br_2$

f) $H_2SO_4 \rightarrow S$, $I^- \rightarrow I_2$

g) $H_2SO_4 \rightarrow H_2S$, $I^- \rightarrow I_2$

h) $ClO^- \rightarrow Cl^-$, $I^- \rightarrow I_2$

i) $PbO_2 \rightarrow Pb^{2+}$, $SO_3^{2-} \rightarrow SO_4^{2-}$

4. Identify the oxidising and reducing agents in the equations in question 2.

5. Identify any disproportionation reactions in question 2.