1. Ethanol reacts with ethanoic acid as follows:

$$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

1 mole of ethanoic acid was mixed with two moles of ethanol. At equilibrium, 0·858 moles of ethyl ethanoate were present.
Calculate the value of the equilibrium constant, K_c.

2. In the data booklet, the solubility of barium sulphate, shown by the equation

$$BaSO_4(s) + water \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$$

is given as less than 1 g l^{-1}. In a more advanced text book, it is noticed that an equilibrium constant known as the solubility product Ksp, can be written to represent the dissolving process. Ksp is equal to the product of the concentrations of the ions in the solution:

$$Ksp = [Ba^{2+}] \times [SO_4^{2-}]$$

At 298K, Ksp for barium sulphate is equal to 1×10^{-10} $mol^2\ l^{-2}$.

For a saturated solution of barium sulphate at 298K, calculate

(a) The concentration of barium ions dissolved in the solution.
(b) The mass of barium sulphate dissolved in 1 litre of solution.

3. Consider the equilibrium:

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad \Delta H^o = -52kJ$$

When 1 mole of hydrogen iodide is put into a 1 litre container at 713K, 0·78 mole of hydrogen iodide will remain in the equilibrium mixture.

(a) Write an expression for the equilibrium constant, K.
(b) Calculate the value of the equilibrium constant at 713K.
(c) What would be the effect on the equilibrium constant of
  (i) increasing the temperature.
  (ii) increasing the pressure.
  (iii) adding more hydrogen iodide.

(1) $K = \frac{[CH_3COOC_2H_5][H_2O]}{[CH_3COOH][C_2H_5OH]}$

$= \frac{0.858 \times 0.858}{0.142 \times 1.142}$

$= \frac{0.736164}{0.162164}$

$= \underline{4.54}$

(2) (a) $K = [Ba^{2+}][SO_4^{2-}]$

$1 \times 10^{-10} = [Ba^{2+}]^2$

$[Ba^{2+}] = \sqrt{10^{-10}}$

$= \underline{10^{-5} \text{ mol } l^{-1}}$

(b) 1 mol of Ba^{2+} ions = 137.34 g

10^{-5} .. .. $= 137.3 \times 10^{-5}$

$= \underline{0.001373 \text{ g}}$

10^{-5} mol of $BaSO_4$ in sol

137.3 + 32.1 + 64

1 mol = $\underline{233.4 \text{ g}}$ =

10^{-5} mol = 0.002334 g.

$\underline{2.334 \times 10^{-3} \text{ g}}$

Equilibrium Constants

③ (a) $$K = \frac{[H_2][I_2]}{[HI]^2}$$

(b) $$= \frac{0.11 \times 0.11}{(0.78)^2}$$

$$= \frac{0.0121}{0.6084}$$

$$= \underline{1.99 \times 10^{-2}}$$

(c) (i) K would decrease

(ii) No effect

(iii) No effect.

1. For the following reversible reactions, write an expression for Kc or, where appropriate, Kp.

(a) $CO_2(g) + NO(g) \rightleftharpoons CO(g) + NO_2(g)$

(b) $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

(c) $CH_3COOH(l) + C_5H_{11}OH(l) \rightleftharpoons CH_3COOC_5H_{11}(l) + H_2O$

2. Dinitrogen tetraoxide decomposes endothermically on heating as follows :

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

(a) Write an expression for the equilibrium constant, Kp of this reaction.
(b) In what way, if any, would Kp vary if :
(i) the temperature was increased
(ii) the total pressure was increased
(iii) more dinitrogen tetraoxide was added

3. At a certain temperature and a total pressure of 105 Pa, iodine vapour contains 40% by volume of I atoms :

$$I_2(g) \rightleftharpoons 2I(g)$$

Calculate Kp for the equilibrium.

4. Consider the following reaction:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -10\ kJ$$

At a certain temperature, analysis of an equilibrium mixture of the gases yielded the following results:

H_2 = $2{\cdot}5 \times 10^4$ Pa
I_2 = $1{\cdot}6 \times 10^4$ Pa
HI = $4{\cdot}0 \times 10^4$ Pa

(a) Write an expression for the equilibrium constant in terms of partial pressures.
(b) Calculate the equilibrium constant for the reaction.
(c) What effect, if any, will decreasing the temperature have on the value of Kp? Explain your answer.
(d) What effect, if any, will increasing the pressure have on the value of Kp? Explain your answer.

1\. (a) $K_c = \dfrac{[CO][NO_2]}{[CO_{2(g)}][NO]}$ or $\dfrac{P_{CO} P_{NO_2}}{P_{CO_2} P_{NO}} = K_p$

(b) $K_c = \dfrac{[CH_3OH]}{[CO][H_2]^2}$ or $\dfrac{P_{CH_3OH}}{P_{CO} P^2_{H_2}} = K_p$

(c) $K_c = \dfrac{[CH_3COOC_5H_{11}][H_2O]}{[CH_3COOH][C_5H_{11}OH]}$

2\. (a) $K_p = \dfrac{NO_2{}^2}{N_2O_4}$

(b) (i) increase
(ii) no effect
(iii) no effect

3\. $P_{I_g} = \dfrac{40}{100} \times 105 = 42 \text{ Pa}$

$P_{I_2} = 105 - 42 = 63 \text{ Pa}$

$K_p = \dfrac{P^2_{I(g)}}{P_{I_2}} = \dfrac{42^2}{63} = \underline{28}$

4 (a) $$K_p = \frac{P_{HI}^2}{P_{H_2} P_{I_2}}$$

(b) $$K_p = \frac{(4 \times 10^4)^2}{(1 \cdot 6 \times 10^4)(2 \cdot 5 \times 10^4)} = 4$$

(c) K_p will increase as decreasing temp will shift equilibrium to favor exothermic direction, which is to the right ie the products, therefore K_p will increase

(d) no effect, changing total pressure will change the concentration of the reactants and products but by Le Chatelier priciple the equilibrium position will shift to the left or right and the concentrations of the reactants and products will so that K remains constant.

(a) — good mixing

Vol of Thio 22.4 cm^3

Moles Thio = conc × Vol

= 0.05 × 0.0224

= 0.00112 moles ~~of 10 cm³~~ Thio

= ~~0.0056~~ moles in 50 cm^3

~~= 0.112 mol l^{-1}~~

Vol

= 0.00056 moles of Iodine in 10 cm^3

= ~~0.0~~ 0.056 mol l^{-1} I_2 in (aq)

Moles thio = ~~0.00134~~

= 0.025 × 0.0134

= 0.000335 moles

= 0.0001675 moles I_2 in 10 cm^3

= ~~0.00~~ 0.01675 mol l^{-1}

Partition Coeff $K = \frac{0.01675}{0.056} = \underline{0.3}$

(e) No effect

K only dependent on Type of solute / Type of solvent + Temp of system.