SECOND-YEAR HL CHEMISTRY

Final Review: Equilibrium

1 N03

2 M03

3 N02/7

When 1 mole of hydrogen iodide is allowed to dissociate into its elements at 440 °C in a 1.0 dm^3 vessel, only 0.78 moles of hydrogen iodide are present at equilibrium.

(a) Write an equation for the equilibrium reaction, including state symbols. *[2]*

(b) (i) Write the expression for the equilibrium constant K_c for the above reaction and state its units. *[2]*

(ii) Calculate the equilibrium constant for the reaction at 440 °C using the information given above. *[4]*

(c) If $K_c = 0.04$ in the gas phase at 600 °C, deduce whether the dissociation of hydrogen iodide is exothermic or endothermic and explain your answer. *[3]*

(d) Predict and explain the effect on the position of equilibrium of

(i) increasing the total pressure
(ii) adding more hydrogen iodide at constant pressure
(iii) adding a catalyst. *[6]*

(e) The equilibrium constants for the dissociation of hydrogen chloride and hydrogen bromide are given below.

$$K_c(\mathrm{HCl}) = 1.0\times10^{-17}$$
$$K_c(\mathrm{HBr}) = 1.0\times10^{-9}$$

Explain what information these values give about the extent of each dissociation compared to that of hydrogen iodide. *[1]*

(f) Ammonia is manufactured by the Haber Process, for which the reaction is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\ \mathrm{kJ}$$

A *heterogeneous* catalyst of iron is used.

(i) Sketch an enthalpy level diagram showing the enthalpy change and the activation energy of the reaction. *[3]*

(ii) State and explain the effect of the catalyst on the activation energy of the reaction. *[2]*

(iii) Explain the term *heterogeneous* and outline how such catalysts work. *[2]*

4 M02.

5 N01/8. When steam is passed over heated carbon, the following equilibrium is established:

$C(s) + H_2O(g) \rightarrow H_2(g) + CO_2(g)$

The value of the equilibrium constant (K_c) at various temperatures is given in the table below:

Temperature / K	700	1000	1300
Equilibrium constant (K_c)	4.88×10^{-5}	4.51×10^{-2}	1.88

(a) Write the expression for the equilibrium constant and give its units. Deduce whether the forward reaction is endothermic or exothermic and state how you reached this conclusion. [4]

(b) Predict and explain the effect of an increase in temperature, total pressure and surface area of carbon on the:

(i) rate of the forward reaction; [6]

(ii) $[H_2O]$:$[H_2]$ ratio; [6]

(iii) value of the equilibrium constant. [3]

(c) In the above experiment, the surface of the carbon is sprayed with a catalyst. Draw an appropriate energy level diagram for the reaction, showing the effect of the catalyst. State the way in which the catalyst affects the rate of the forward reaction, the rate of the reverse reaction and the overall position of equilibrium. [6]

6 M01/4. When 1.0 mole of ethanoic acid is mixed with 1.0 mole ethanol, and the mixture allowed to reach equilibrium, the following reaction occurs:

$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H\,O(l)$

The amounts of ethyl ethanoate and water at equilibrium are both 0.67 moles.

(a) (i) What is meant by the termequilibrium? [2]

(ii) Write an expression for K_c for this reaction. [1]

(iii) Calculate the value of K_c for this reaction. [2]

(b) For the dissociation $H_2O(l) \rightleftharpoons H^+(aq)\ OH^-(aq)$, the ionic product is given by $K_w = [H^+(aq)][OH^-(aq)]$. The value of K_w is 1.0×10^{-14} mol^2 dm^{-6} at 298 K and 2.4×10^{-14} mol^2 dm^{-6} at 310 K. Using Le Chatelier.s principle, deduce whether the dissociation of water is exothermic or endothermic. [3]

(c) For the system $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ state and explain the effect on the position of equilibrium of

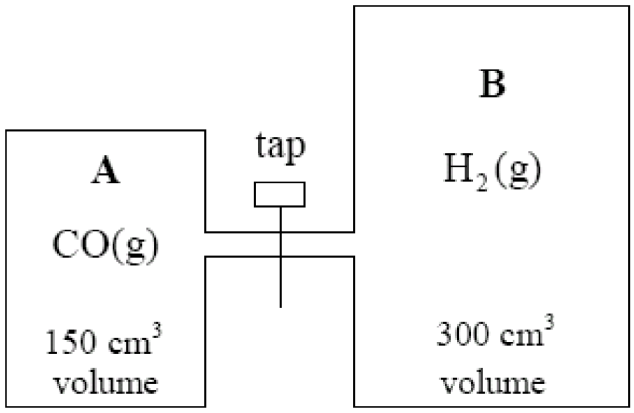
(i) adding a catalyst. [2]

(ii) adding some helium gas but keeping the total gas volume constant. [2]

7 N00/4. Methanol is an important industrial solvent and fuel. It can be produced from carbon monoxide and hydrogen according to the following equation:

$CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)} \qquad \Delta H = -91\ kJ\ mol^{-1}$

The effect of different catalysts on this reaction is investigated using the following apparatus:



A contains 1 mole of carbon monoxide and **B** contains 2 moles of hydrogen. The gases in both containers are at the same temperature and pressure. The tap is closed at the start of the experiment.

(a) What pressure change will occur, if any, in the containers when the tap is opened

(i) and the gases are allowed to mix (but before they start to react)? [1]

(ii) as the reaction takes place? [1]

(b) (i) What will happen to the temperature as the gases begin to react? [1]

(ii) What will happen to the concentration of methanol if the system is allowed to reach equilibrium at a lower temperature? [1]

(c) (i) Write the equilibrium expression for the above reaction, and give the units for K_c. [1]

(ii) Calculate a value for K_c if the maximum yield of methanol is 85 %. [3]

(iii) When this reaction is carried out on an industrial scale, the yield is about 60 %. Suggest a reason for this. [1]

(iv) Copper is a good catalyst for this reaction. What effect, if any, will the addition of copper have on the value of K_c? [1]

8 98/5. (a) [3] State the essential characteristics of chemical and phase equilibria.

Answer the following questions about different equilibrium systems.

(b) [8] A dilute aqueous solution of iodine is continuously stirred.

$$I_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + I^-(aq) + HOI(aq)$$

The solution has a light brown colour due to the reactants, as the products are essentially colourless. Deduce the colour change that would occur upon the addition of a few drops of concentrated solutions of the following to separate samples of the aqueous solution of iodine:

i) hydrochloric acid, (ii) sodium hydroxide, (iii) silver nitrate. Give your reasoning in each case.

(c) [9] The dissociation of N_2O_4 into NO_2 can be represented by the equation $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$. N_2O_4 is colorless and NO_2 is red-brown. A sample of N_2O_4 and NO_2 is enclosed in a transparent 1.0 dm^3 cylinder which is fitted with a frictionless piston. At a temperature T the equilibrium concentrati0ons are N_2O_4 1.0 mol dm^{-3} and NO_2 1.5 mol dm^{-3}.

(i) Calculate the value of the equilibrium constant at T.

(ii) If the temperature is increased the intensity of the colour increases. Deduce whether the reaction is exothermic or endothermic giving your reasoning at each stage.

(iii) At the original temperature T the piston is very rapidly compressed to give a volume of 0.5 dm^3. The intensity of the colour immediately increases and then slowly decreases. Explain clearly what is happening. What happens to the value of K when these changes are complete?