Equilibria

Question Paper 5

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 5

Time Allowed: **64 minutes**

Score: **/53**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 Concern over the ever-increasing use of fossil fuels has led to many suggestions for alternative sources of energy. One of these, suggested by Professor George Olah, winner of a Nobel Prize in chemistry, is to use methanol, CH_3OH, which can be obtained in a number of different ways.

Methanol could be used instead of petrol in a conventional internal combustion engine or used to produce electricity in a fuel cell.

(a) Construct a balanced equation for the **complete** combustion of methanol.

.... [1]

When hydrocarbon fuels are completely burned in an internal combustion engine, several toxic pollutants may be formed.

(b) State **two toxic** pollutants that can be produced after **complete** combustion of a hydrocarbon fuel in an internal combustion engine.

....

.... [2]

Methanol may be manufactured catalytically from *synthesis gas*, a mixture of CO, CO_2 and H_2. The CO is reacted with H_2 to form methanol, CH_3OH.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

(c) From your understanding of Le Chatelier's principle, state **two** conditions that could be used in order to produce a high yield of methanol.

In **each** case, explain why the yield would increase.

condition 1 ....

explanation ....

....

condition 2 ....

explanation ....

.... [4]

Carbon monoxide, which can be used to make methanol, may be formed by reacting carbon dioxide with hydrogen.

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g) \qquad K_c = 1.44 \text{ at } 1200\text{ K}$$

(d) **(i)** It has been suggested that, on a large scale, this reaction could be helpful to the environment.

Explain, with reasons, why this would be the case.

....

....

(ii) A mixture containing 0.50 mol of CO_2, 0.50 mol of H_2, 0.20 mol of CO and 0.20 mol of H_2O was placed in a 1.0 dm^3 flask and allowed to come to equilibrium at 1200 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1200 K.

	CO_2	+	H_2	$\rightleftharpoons$	CO	+	$_2O$
initial moles	0.50		0.50		0.20		0.20

[6]

[Total: 13]

2 **(a)** Explain what is meant by the *Bronsted-Lowry* theory of acids and bases.

....

....

.... [2]

(b) The K_a values for some organic acids are listed below.

acid	K_a/mol dm^{-3}
CH_3CO_2H	1.7×10^{-5}
$ClCH_2CO_2H$	1.3×10^{-3}
Cl_2CHCO_2H	5.0×10^{-2}

(i) Explain the trend in K_a values in terms of the structures of these acids.

....

....

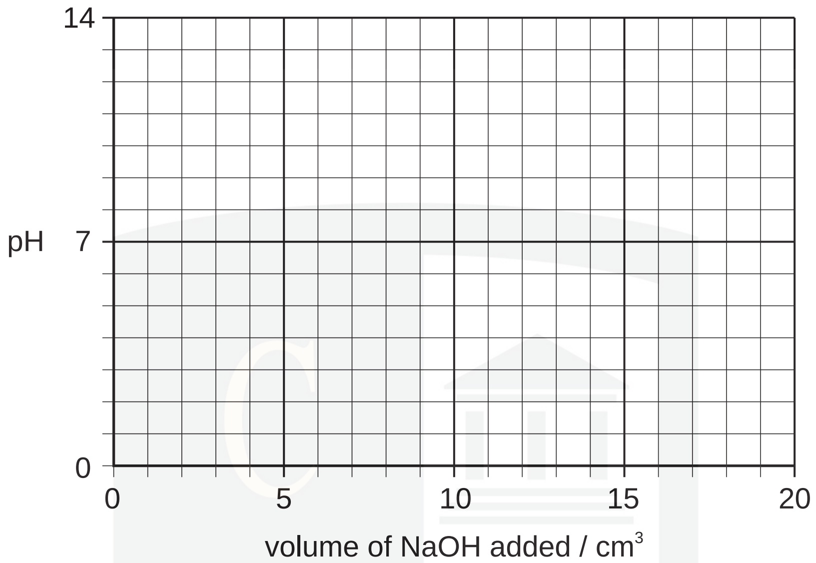
....

....

(ii) Calculate the pH of a 0.10 mol dm^{-3} solution of $ClCH_2CO_2H$.

pH = ...

(iii) Use the following axes to sketch the titration curve you would obtain when 20 cm^3 of 0.10 mol dm^{-3} NaOH is added gradually to 10 cm^3 of 0.10 mol dm^{-3} $ClCH_2CO_2H$.



[8]

(c) (i) Write suitable equations to show how a mixture of ethanoic acid, CH_3CO_2H, and sodium ethanoate acts as a buffer solution to control the pH when either an acid or an alkali is added.

....

....

(ii) Calculate the pH of a buffer solution containing 0.10 mol dm^{-3} ethanoic acid and 0.20 mol dm^{-3} sodium ethanoate.

pH = ...

[4]

[Total: 14]

3 When hydrocarbons such as petrol or paraffin wax are burned in an excess of air in a laboratory, carbon dioxide and water are the only products.
When petrol is burned in a car engine, nitrogen monoxide, NO, is also formed.

(a) Explain how NO is formed in an internal combustion engine but not formed when a small sample of petrol is burnt in an evaporating basin.

....

....

....[2]

The engines of modern motor cars have exhaust systems which are fitted with catalytic converters in order to reduce atmospheric pollution from substances such as NO.

(b) **(i)** State **three more** pollutants, other than CO_2 and H_2O, that are present in the exhaust gases of a car engine.

.... and .... and ....

(ii) What is the active material present in the catalytic converter?

....

(iii) Write **one** balanced equation to show how NO is removed from the exhaust gases of a car engine by a catalytic converter.

....

[4]

NO is also formed when nitrosyl chloride, NOC*l*, dissociates according to the following equation.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

Different amounts of the three gases were placed in a closed container and allowed to come to equilibrium at 230 °C. The experiment was repeated at 465 °C.

The equilibrium concentrations of the three gases at each temperature are given in the table below.

	concentration / mol dm^{-3}		
temperature / °C	NOC*l*	NO	Cl_2
230	2.33×10^{-3}	1.46×10^{-3}	1.15×10^{-2}
465	3.68×10^{-4}	7.63×10^{-3}	2.14×10^{-4}

(c) **(i)** Write the expression for the equilibrium constant, K_c, for this reaction. Give the units.

(ii) Calculate the value of K_c at each of the temperatures given.

230 °C

465 °C

(iii) Is the forward reaction endothermic or exothermic? Explain your answer.

....

....

[5]

(d) The temperature of the equilibrium was then altered so that the equilibrium concentrations of NOC*l* and NO were the same as each other.

What will be the effect on the equilibrium concentration of NOC*l* when the following changes are carried out on this new equilibrium? In each case, explain your answer.

(i) The pressure of the system is halved at constant temperature.

....

....

(ii) A mixture of NOC*l*(g) and NO(g) containing equal numbers of moles of each gas is introduced into the container at constant temperature.

....

....

[4]

[Total: 15]

4 Alcohols and esters are important organic compounds which are widely used as solvents.

Esters such as ethyl ethanoate can be formed by reacting carboxylic acids with alcohols.

$$CH_3CO_2H + C_2H_5OH \rightleftharpoons CH_3CO_2C_2H_5 + H_2O$$

This reaction is an example of a dynamic equilibrium.

(a) Explain what is meant by the term *dynamic equilibrium*.

....

....[1]

(b) Write the expression for the equilibrium constant for this reaction, K_c.

[1]

(c) For this equilibrium, the value of K_c is 4.0 at 298 K.
A mixture containing 0.5 mol of ethanoic acid, 0.5 mol ethanol, 0.1 mol ethyl ethanoate and 0.1 mol water was set up and allowed to come to equilibrium at 298 K. The final volume of solution was V dm^3.

Calculate the amount, in moles, of each substance present at equilibrium.

[4]

Alcohols may be classified into primary, secondary and tertiary. Some reactions are common to all three types of alcohol. In other cases, the same reagent gives different products depending on the nature of the alcohol.

(d) In the empty squares below give the structural formula of the organic compound formed in each of the reactions indicated.

If no reaction occurs, write 'no reaction' in the space.

reagent(s) and conditions \ alcohol	$CH_3CH_2CH_2CH_2OH$	$CH_3CH_2CH(OH)CH_3$	$(CH_3)_3COH$
red phosphorus and iodine heat under reflux			
concentrated H_2SO_4 heat			
$Cr_2O_7^{2-}/H^+$ heat under reflux			

[5]

[Total: 11]