OCR
RECOGNISING ACHIEVEMENT

**ADVANCED GCE** **2816/01**

**CHEMISTRY**

Unifying Concepts in Chemistry

**TUESDAY 29 JANUARY 2008** Afternoon

Time: 1 hour 15 minutes

**Additional materials:** Scientific calculator
*Data Sheet for Chemistry* (Inserted)

*CUP/T29639*

| Candidate Forename | | Candidate Surname | |
|---|---|---|---|

| Centre Number | | | | | | Candidate Number | | | | |
|---|---|---|---|---|---|---|---|---|---|---|

**INSTRUCTIONS TO CANDIDATES**

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Do **not** write in the bar codes.
- Do **not** write outside the box bordering each page.
- Write your answer to each question in the space provided.

**INFORMATION FOR CANDIDATES**

- The number of marks for each question is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is **60**.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.

| FOR EXAMINER'S USE | | |
|---|---|---|
| **Qu.** | **Max.** | **Mark** |
| **1** | **12** | |
| **2** | **13** | |
| **3** | **20** | |
| **4** | **15** | |
| **TOTAL** | **60** | |

This document consists of **12** printed pages and a *Data Sheet for Chemistry*.

Answer **all** the questions.

**1** Methanol, $CH_3OH$, is produced by reacting together carbon monoxide and hydrogen. This is a reversible reaction.

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

Equilibrium is achieved in a closed container at 25 °C with a total pressure of 500 kPa.

Under these conditions, the partial pressures of CO(g) and $H_2(g)$ in the equilibrium mixture are shown below.

| component | CO(g) | $H_2(g)$ |
|---|---|---|
| partial pressure / kPa | 3.80 | 7.60 |

**(a) (i)** What is meant by *partial pressure*?

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.....[1]

**(ii)** Determine the partial pressure of $CH_3OH$ in the equilibrium mixture.

[1]

**(b) (i)** Write an expression for $K_p$ for this equilibrium.

[1]

**(ii)** Calculate $K_p$ for this equilibrium. State the units.

$K_p$ = ……. units …….. [2]

**(c)** In this question, one mark is available for the quality of use and organisation of scientific terms.

Industrially, this reaction is carried out at 5000 kPa and 250 °C, with a catalyst.

The value of $K_p$ at 250 °C is less than the value at 25 °C.

Explain the advantages and disadvantages of using each of these industrial conditions for the manufacture of methanol. Assume that equilibrium is reached in this process.

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.....[6]

Quality of Written Communication [1]

[Total: 12]

**2** Acidified bromate(V) ions, $BrO_3^-$, oxidise bromide ions, $Br^-$, to form bromine, $Br_2$.

$$6H^+(aq) + BrO_3^-(aq) + 5Br^-(aq) \longrightarrow 3Br_2(aq) + 3H_2O(l)$$

This reaction was carried out four times using different concentrations of the three reactants. The initial rate of $Br_2$ formation for each reaction was calculated and the results are shown below.

| experiment | $[H^+(aq)]$ / mol dm$^{-3}$ | $[BrO_3^-(aq)]$ / mol dm$^{-3}$ | $[Br^-(aq)]$ / mol dm$^{-3}$ | initial rate / mol dm$^{-3}$ s$^{-1}$ |
|---|---|---|---|---|
| 1 | 0.300 | 0.050 | 0.250 | $1.68 \times 10^{-5}$ |
| 2 | 0.300 | 0.100 | 0.250 | $3.36 \times 10^{-5}$ |
| 3 | 0.600 | 0.050 | 0.250 | $6.72 \times 10^{-5}$ |
| 4 | 0.300 | 0.150 | 0.500 | $1.01 \times 10^{-4}$ |

**(a) (i)** For each reactant, deduce the order of reaction. Show your reasoning.

$H^+(aq)$ .....

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$BrO_3^-(aq)$ .....

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$Br^-(aq)$ .....

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.....[6]

**(ii)** Deduce the rate equation for the reaction.

.....[1]

**(iii)** Calculate the rate constant, *k*, for this reaction. Give your answer to an appropriate number of significant figures and state the units for *k*.

rate constant, *k* = ..... units ..... [4]

**(b)** Suggest how the initial rate of bromine formation would be calculated from a concentration–time graph.

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.....[1]

**(c)** What evidence is there that this reaction proceeds by more than one step?

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.....[1]

[Total: 13]

**3** Ethanoic acid, $CH_3COOH$, is a weak acid.

**(a)** What is meant by a *weak acid*?

.....

.....[1]

**(b)** What is the conjugate base of ethanoic acid?

.....[1]

**(c)** Ethanoic acid takes part in many typical acid reactions.

Complete the equations below for the reactions of ethanoic acid with $Na_2CO_3$ and with Mg.

**(i)** $Na_2CO_3$ + .....

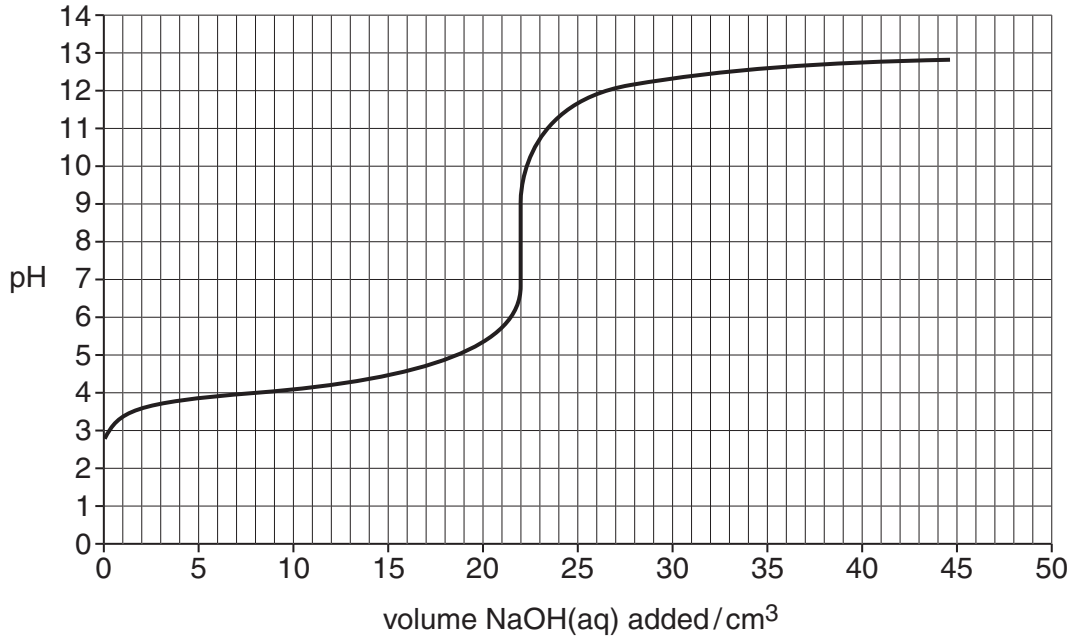
**(ii)** Mg + .....[3]

**(d)** The concentration of ethanoic acid can be found by titrating against a standard solution of NaOH(aq).

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$$

A student titrated 25.0 $cm^3$ of ethanoic acid with 0.200 $mol\,dm^{-3}$ NaOH(aq). The NaOH(aq) was added from a burette and the pH was monitored throughout.

The titration pH curve is shown below.



**(i)** Use the information on page 6 to calculate the concentration, in mol $dm^{-3}$, of the ethanoic acid.

concentration = …….. mol $dm^{-3}$ [2]

**(ii)** The pH ranges in which the colour changes for three indicators are shown below.

| indicator | pH range |
|---|---|
| metacresol purple | 7.4–9.0 |
| bromophenol blue | 3.6–4.6 |
| indigo carmine | 11.4–13.0 |

Explain which of the three indicators is most suitable for this titration.

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.....[1]

**(e)** Vinegar is an aqueous solution of ethanoic acid. It can be prepared by oxidising the ethanol in wine with oxygen gas.

$$CH_3CH_2OH(aq) + O_2(g) \longrightarrow CH_3COOH(aq) + H_2O(l)$$

A 750 $cm^3$ bottle of wine was taken containing 79.2 g of ethanol. All of the ethanol in the wine was oxidised to ethanoic acid using oxygen gas to make vinegar.

Calculate the pH of the vinegar at 25 °C, showing all your working.

Assume that the only component in the wine having an effect on pH is ethanoic acid.

$K_a$ for ethanoic acid at 25 °C = $1.70 \times 10^{-5}$ mol $dm^{-3}$.

pH = …….. [6]

**(f)** Ethanoic acid can be used to make buffer solutions.

**(i)** State a compound that could be added to ethanoic acid to make a buffer solution.

.....[1]

**(ii)** Explain how this solution acts as a buffer. Include equations in your answer.

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.....[5]

[Total: 20]

**4** 'Sour gas' is natural gas that is contaminated with small amounts of hydrogen sulphide, $H_2S$. The hydrogen sulphide can be removed by the Claus reaction. This converts the hydrogen sulphide in sour natural gas into sulphur.

The Claus reaction takes place in two steps.

Step 1: Some of the hydrogen sulphide is reacted with oxygen to form sulphur dioxide.

Step 2: The remaining hydrogen sulphide reacts with the sulphur dioxide to produce sulphur.

The sulphur can now be oxidised to sulphuric acid that has many uses.

**(a)** A sour natural gas stream contains 1.8% hydrogen sulphide by mass. The pipeline moves 100 tonnes of sour gas each day.

Calculate the mass, in tonnes, of sulphuric acid that could be obtained each day by completely processing this hydrogen sulphide. 1 tonne = $10^6$ g

mass of sulphuric acid = ..... tonnes [3]

**(b)** Construct an equation for each step, Step 1 and Step 2, of the Claus reaction and use these to construct an overall equation for the Claus reaction.

[3]

**(c)** Explain what happens in the two steps of the Claus reaction in terms of the oxidation states of sulphur.

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.....[3]

**(d)** The hydrogen sulphide can also be removed in an acid-base reaction by bubbling the sour gas through an aqueous solution containing carbonate ions, $CO_3^{2-}$. Two ions are formed.

Write a balanced equation for the reaction that takes place and identify the conjugate acid-base pairs.

[3]

**(e)** After removal of the hydrogen sulphide, the purified natural gas is odourless. A small amount of organic sulphur compounds called thiols is added. The thiols give natural gas its characteristic smell, without which a gas leak would be difficult to detect.

Thiols react in a similar way to alcohols and their composition is such that the oxygen atom in the alcohol has been replaced by a sulphur atom. The thiol most frequently added to natural gas is butane-1-thiol.

Draw the structure of butane-1-thiol and suggest a balanced equation for one reaction of this compound.

[3]

[Total: 15]

**END OF QUESTION PAPER**

**PLEASE DO NOT WRITE ON THIS PAGE**