OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced Subsidiary GCE

CHEMISTRY 2813/01

How Far, How Fast?

Wednesday **29 MAY 2002** Morning 45 minutes

Candidates answer on the question paper.
Additional materials:
Data Sheet for Chemistry
Scientific Calculator

Candidate Name	Centre Number	Candidate Number

TIME 45 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

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

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	5	
2	7	
3	5	
4	14	
5	7	
6	7	
TOTAL	45	

This question paper consists of 10 printed pages and 2 blank pages.

Registered Charity Number: 1066969
[Turn over

Answer **all** questions.

1 The enthalpy change for the reaction between hydrochloric acid, HC*l*(aq), and sodium hydroxide, NaOH(aq), can be determined in the following way.

- 50.0 cm^3 of 2.00 mol dm^{-3} HC*l*(aq) is placed in a plastic cup, and its temperature recorded.
- 50.0 cm^3 of 2.00 mol dm^{-3} NaOH(aq) is placed in another plastic cup, and its temperature recorded.
- The two solutions are mixed with stirring, and the final temperature recorded.

The following results were obtained from one such experiment:

initial temperature of both HC*l*(aq) and NaOH(aq) = 18.0 °C

final temperature after mixing = 31.9 °C

(Take the specific heat capacity of all solutions to be 4.18 J g^{-1} K^{-1}, and the densities of all solutions to be 1.00 g cm^{-3}.)

(a) Calculate the heat evolved in the above experiment. Include units in your answer.

heat evolved = ... [3]

(b) Calculate how many moles of HC*l* were used.

moles of HC*l* = ... [1]

(c) Hence calculate the enthalpy change, in kJ, for the reaction of 1 mol of HC*l* with 1 mol of NaOH.

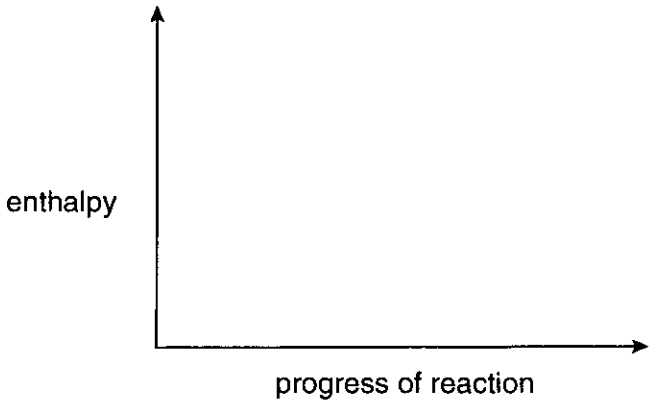
enthalpy change =..... kJ [1]

[Total : 5]

2 On heating in a lime kiln at 1000 °C, limestone decomposes according to the following equation.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g) \qquad \Delta H = +178\,kJ\,mol^{-1}$$

(a) Using the axes below, sketch the enthalpy profile of this reaction. Label the activation energy E_A and the enthalpy change ΔH.



[3]

(b) Suggest **two** reasons why this reaction needs heating to a high temperature.

1. .....

.....

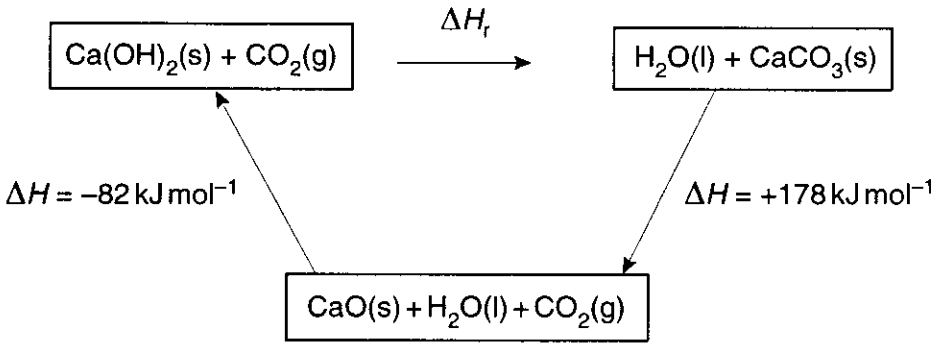
2. .....

..... [2]

(c) When water is added to calcium oxide, CaO, it becomes 'slaked' to give calcium hydroxide, $Ca(OH)_2$.

$$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s) \qquad \Delta H = -82\,kJ\,mol^{-1}$$

Calculate the enthalpy change ΔH_r in the following cycle.



ΔH_r = ... $kJ\,mol^{-1}$ [2]

[Total : 7]

[Turn over

3 The chlorination of methane in the gas phase involves the following two steps.

$CH_4 + Cl \longrightarrow CH_3 + HCl$ **reaction 3.1**

$CH_3 + Cl_2 \longrightarrow CH_3Cl + Cl$ **reaction 3.2**

Table 3.1 lists some relevant average bond enthalpies.

Table 3.1

bond	bond enthalpy / kJ mol^{-1}
C—H	+413
C—Cl	+327
H—Cl	+432
Cl—Cl	+243

(a) **(i)** Use these bond enthalpies to calculate the enthalpy changes of reactions **3.1** and **3.2**.

reaction 3.1

Answer ..... kJ mol^{-1}

reaction 3.2

Answer ..... kJ mol^{-1} [2]

(ii) Suggest which might be the faster of these two reactions. Give a reason for your answer.

.....

..... [1]

(b) An alternative reaction route has been suggested for this reaction, which involves the following two steps.

$CH_4 + Cl \longrightarrow CH_3Cl + H$ **reaction 3.3**

$H + Cl_2 \longrightarrow HCl + Cl$ **reaction 3.4**

Use Table 3.1 to suggest why this reaction route is unlikely to take place.

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.....

..... [2]

[Total : 5]

4 It has been suggested that using methane, CH_4, as a fuel for cars rather than petrol would decrease the amount of carbon dioxide produced per mile. This question looks at how much this reduction in CO_2 emission might be. You may assume that petrol is pure octane, C_8H_{18}.

The combustion of methane can be represented by the following equation.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O \qquad \Delta H_c^{\ominus} = -890\ \text{kJ mol}^{-1}$$

(a) Balance the following equation for the combustion of octane.

$$C_8H_{18} + \ldots\ldots\ldots O_2 \longrightarrow \ldots\ldots\ldots CO_2 + \ldots\ldots\ldots H_2O$$ [1]

(b) The enthalpy change of combustion, $\Delta H_c^{\ominus}$, of octane is –5472 kJ per mole of octane.

Use your balanced equation and the given $\Delta H_c^{\ominus}$ data to calculate for each fuel:

(i) the enthalpy change **per mole of CO_2 produced**, and hence

(ii) the number of moles of CO_2 produced per kJ of heat energy given out.

Write your answers in the Table below.

fuel	$\Delta H_c^{\ominus}$ per mole of alkane burned / kJ	$\Delta H_c^{\ominus}$ per mole of CO_2 produced / kJ	moles of CO_2 produced per kJ of heat given out
methane	–890		
octane	–5472		

[4]

(iii) Hence calculate a value for the ratio:

$$\frac{\text{moles of } CO_2 \text{ produced per kJ from methane}}{\text{moles of } CO_2 \text{ produced per kJ from octane}}$$

Ratio ..... [1]

(c) Both methane and octane undergo incomplete combustion in a car engine. As a result of this, unburned hydrocarbons and carbon monoxide, CO, occur in the exhaust gases. Nitrogen monoxide, NO, is also formed inside the engine. All three pollutants can be removed by fitting a catalytic converter to the exhaust system.

(i) State **one** environmental consequence of **each** of the following emissions.

unburned hydrocarbons

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CO

.....

NO

..... [3]

(ii) How is the NO formed in a car engine?

.....

..... [1]

(iii) NO and CO react together on the surface of the catalyst. Write an equation for this reaction.

..... [1]

(iv) What is the catalyst made of?

..... [1]

(v) The catalyst is a heterogeneous catalyst. What is the meaning of *heterogeneous*?

.....

..... [1]

(vi) The catalytic converter is positioned as close to the engine as possible, so that it heats up quickly. Why does the converter work best when it is hot?

.....

..... [1]

[Total : 14]

[Turn over

5 Methanol is an important industrial organic chemical. It is used as a solvent and a feedstock for the manufacture of several other compounds such as ethanoic acid. A two-stage process to make methanol from natural gas, methane, is summarised in the following equations.

reaction 5.1 $CH_4(g) + H_2O(g) \xrightleftharpoons{\text{Ni at } 700\,^\circ\text{C}} CO(g) + 3H_2(g)$ $\Delta H = +207\ \text{kJ mol}^{-1}$

reaction 5.2 $CO(g) + 2H_2(g) \xrightleftharpoons{\text{Cr at } 300\,^\circ\text{C and } 30\ \text{MPa}} CH_3OH(g)$ $\Delta H = -129\ \text{kJ mol}^{-1}$

(a) Describe and explain the effect of increasing the pressure on the **rate** of reaction 5.1.

.....

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..... [2]

(b) Describe and explain how the **equilibrium position** of reaction 5.1 is affected by

(i) increasing the temperature,

.....

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..... [2]

(ii) increasing the pressure.

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..... [2]

(c) Reaction 5.2 uses the products from reaction 5.1. Suggest a reason why these two reactions cannot proceed one after the other in the same reaction vessel.

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..... [1]

[Total : 7]

6 What do you understand by the term *acid*? Describe **three** different types of reaction of hydrochloric acid in which it behaves as an acid. Give any relevant observations, and write both full equations and ionic equations.

In this question, 1 mark is available for the quality of written communication.

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QWC [1]

[Total : 7]

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