

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2007
Advanced Level Examination



ASSESSMENT and
QUALIFICATIONS
ALLIANCE

APPLIED SCIENCE
Unit 11 Controlling Chemical Processes

SC11

Friday 26 January 2007 9.00 am to 10.30 am

<p>For this paper you must have:</p> <ul style="list-style-type: none"> • a pencil and a ruler • a calculator.

For Examiner's Use			
Question	Mark	Question	Mark
1		5	
2			
3			
4			
Total (Column 1)		→	
Total (Column 2)		→	
TOTAL			
Examiner's Initials			

Time allowed: 1 hour 30 minutes

Instructions

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show the working of your calculations.

Information

- The maximum mark for this paper is 80.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.

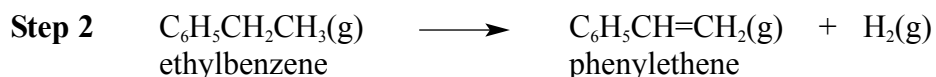
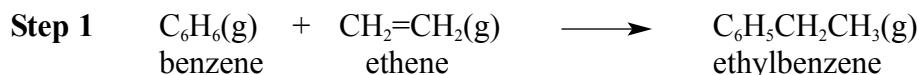
Answer **all** questions in the spaces provided.

- 1 The production of a large range of different plastics forms a major part of the chemical industry that is based on crude oil.

One of the plastics made is polystyrene [poly(phenylethene)].

Phenylethene is used to make the plastic poly(phenylethene).

Phenylethene is made in a two step process from benzene.

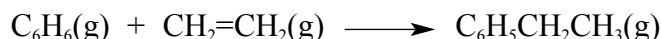


- (a) What name is given to a reaction in which all of the reactants are in the same state?

.....
(1 mark)

- (b) Use the enthalpy of formation, ΔH_f , data to calculate the enthalpy change for **Step 1**.

	$\text{C}_6\text{H}_6(\text{g})$	$\text{CH}_2=\text{CH}_2(\text{g})$	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3(\text{g})$
ΔH_f kJ mol ⁻¹	+82.9	+52.3	+29.8

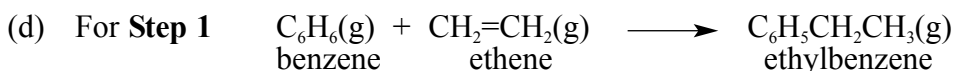


.....
.....
.....
.....
(3 marks)

- (c) Both steps in the reaction are run as batch processes.

Define the term *batch process*.

.....
.....
(2 marks)



A technician was asked to produce 200 kg of ethylbenzene from benzene and ethene.

- (i) Calculate the relative formula mass, M_r , of benzene and ethylbenzene.
 (Relative atomic masses (A_r) C = 12, H = 1)

M_r C_6H_6

M_r $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3$

(2 marks)

- (ii) Use your answers in part (d)(i) to calculate the mass of benzene the technician would need to make 200 kg of ethylbenzene.

.....

(2 marks)

- (e) In **Step 2** high temperatures are used. State and explain the effect of using higher temperatures in reactions.

Effect of using higher temperatures

Explanation

.....

(3 marks)

- (f) Very few chemical reactions give a 100% yield of product. Production workers need to take this into account when they calculate the quantities of reactants they need to produce a desired amount of product.

Suggest **two** reasons why the yield of a reaction is often much less than 100%.

Reason 1

Reason 2

(2 marks)

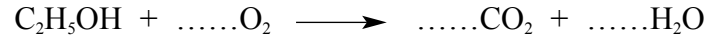
- (g) 400 kg of ethylbenzene is needed to make 392.5 kg of phenylethene in **Step 2** on **page 2**. Calculate the percentage yield when 400 kg of ethylbenzene forms only 320 kg of phenylethene.

.....

(2 marks)

2 Engineers investigating the heat output of engines need to study energy changes. Enthalpy of combustion is the heat energy released when one mole of a compound undergoes complete combustion.

(a) Balance the equation for the complete combustion of ethanol, C₂H₅OH.



(2 marks)

(b) Engineers can measure enthalpy of combustion experimentally by burning fuels in spirit burners. The heat energy released is used to raise the temperature of a known mass of water.

Outline an experiment to measure the enthalpy of combustion of ethanol. Include the necessary apparatus and practical procedure in your method.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(6 marks)

- (c) Explain how you would use the results of the experiment to calculate the enthalpy of combustion for one mole of ethanol.

.....

.....

.....

.....

.....

(3 marks)

- (d) Suggest **two** reasons why the value found by experiment is less than the accepted correct value.

Reason 1

Reason 2

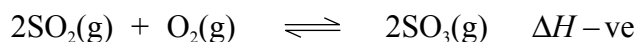
(2 marks)

Turn over for the next question

- 3 Industrial chemists continually investigate the conditions used in manufacturing chemicals. They are concerned about the rate of reaction, the yield produced and the costs involved.

The manufacture of sulphuric acid uses a dynamic equilibrium reaction in one of the steps of the process.

The equation for this dynamic equilibrium reaction is:



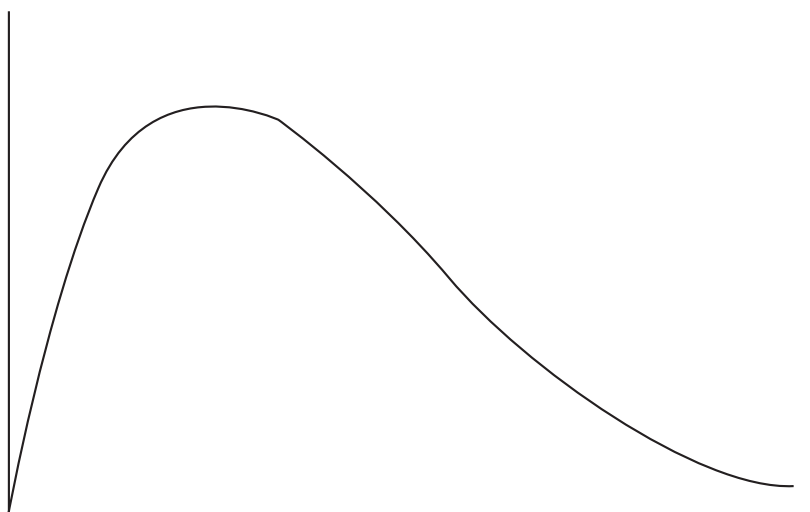
The reaction uses a catalyst of vanadium(V) oxide.

- (a) Define the term *catalyst*.

.....

(2 marks)

- (b) The Maxwell–Boltzmann distribution curve for the distribution of energies of the molecules in a gas is shown below. Label the vertical and horizontal axes on the diagram below.



(2 marks)

- (c) Define the term *activation energy*, E_a .

.....

(2 marks)

- (d) Use the distribution curve in part (b) to explain how a catalyst affects the rate of a reaction.

.....

- (e) In many chemical reactions the catalysts used are solids. Give **two** reasons why the solid is used as a powder rather than as larger lumps.

Reason 1

Reason 2

(2 marks)

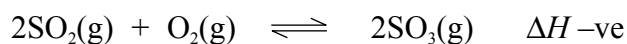
- (f) Many industrial chemical reactions use fluidised-bed reactors. In a fluidised-bed reactor the reacting gases are blown into the catalyst. This agitates the catalyst into a foam.

Give **one** advantage of using a fluidised-bed reactor.

.....

(1 mark)

- (g) The yield obtained in a dynamic equilibrium can be improved by changing some of the operating conditions.



Write an expression for the equilibrium constant, K_c , for this reaction.

.....

.....

(2 marks)

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

.....

.....

(2 marks)

- (i) State Le Chatelier's principle.

.....

.....

(2 marks)

Question 3 continues on the next page

(j) Explain why increasing the pressure results in an increased yield of SO_3 in the equilibrium reaction.

.....
.....
.....
.....
.....

(3 marks)

(k) Give **two** reasons why using a high pressure increases the costs of the process.

Reason 1

Reason 2

(2 marks)

(l) What effect would increasing the temperature have on the yield of SO_3 in this equilibrium reaction. Explain your answer.

Effect on the yield

Explanation

.....
.....

(3 marks)

25

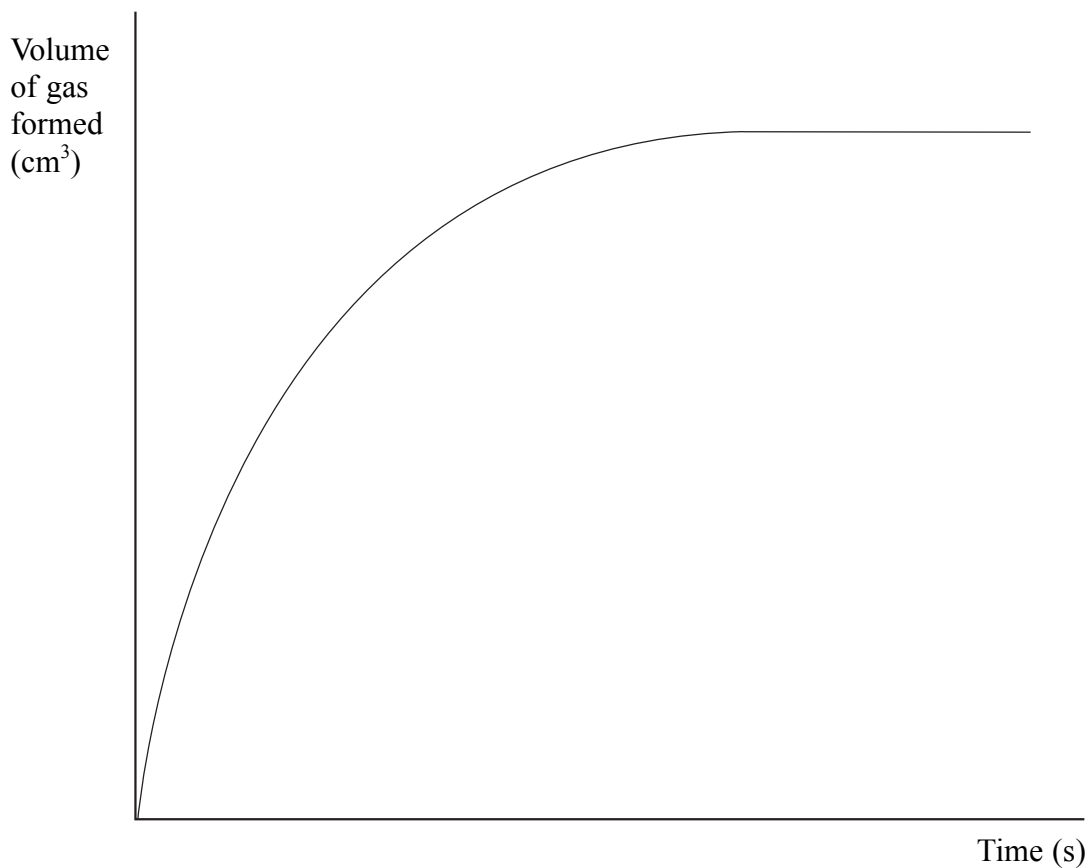
- 4 Laboratory technicians are often asked to investigate the rate of a reaction carried out under different conditions so that the order of reaction can be found.
A technician was asked to investigate the rate of a reaction that produced a gas.

(a) Suggest a method that the technician could use to follow the rate of such a reaction.

.....
.....

(2 marks)

(b) The technician produced the following graph from the results of the investigation.



How would the technician use the graph to find the rate of reaction at any given time in the reaction?

.....
.....
.....

(2 marks)

Question 4 continues on the next page

- (c) The technician investigated the rate of reaction between two compounds, **A** and **B**. He measured the rate using different concentrations of compound **A**, and then measured the rate using different concentrations of compound **B**.

State **two** factors which must be kept constant when measuring the rate of a reaction using different concentrations of a reactant.

Factor 1

Factor 2

(2 marks)

- (d) The results of the investigation are shown in the table below.

Run	Initial concentration of A (mol dm ⁻³)	Initial concentration of B (mol dm ⁻³)	Initial rate (mol dm ⁻³ s ⁻¹)
1	0.20	0.20	2×10^{-3}
2	0.20	0.40	4×10^{-3}
3	0.40	0.20	8×10^{-3}

Show how the technician would use these results to find the order of reaction with respect to compound **A** and compound **B**. In each case explain your reason.

- (i) Order with respect to compound **A**

Reason

(2 marks)

- (ii) Order with respect to compound **B**

Reason

(2 marks)

- (e) Once the order of reaction is found for each reactant, then a rate equation can be constructed.

The rate equation for the reaction of compound **X** and compound **Y** might be:

$$\text{rate} = k [\mathbf{X}][\mathbf{Y}]$$

- (i) Define the term k in the rate equation.

(1 mark)

- (ii) State **one** change in conditions that would alter the value of k .

.....

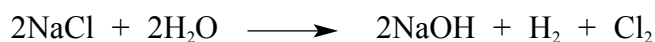
- 5 A technician works at a large chlor-alkali plant. He is hoping to gain promotion in the electrolytic cell department. He has been asked to develop a series of questions for new employees at the plant. The new employees are to carry out research that will enable them to answer the questions.

These are the questions he set for the new employees to answer. Imagine that you are one of the new employees. Answer the questions.

Rock salt is the major source of sodium chloride. Sodium chloride is the feedstock for a large range of useful chemicals.

Sodium chloride solution undergoes electrolysis in an electrolytic cell to form hydrogen gas, chlorine gas and sodium hydroxide solution.

An equation to represent this reaction is:



- (a) Give the oxidation state for chlorine in each of the following:

Sodium chloride, NaCl

.....

Chlorine, Cl₂

.....

(2 marks)

- (b) State the hazard associated with each of the following products of the electrolysis of sodium chloride.

(i) Concentrated sodium hydroxide

.....

(1 mark)

(ii) Chlorine

.....

(1 mark)

- (c) Give **one** safety precaution you should take when using concentrated sodium hydroxide.

.....

.....

(1 mark)

(d) Costs involved in manufacturing chemicals can be classified as:

capital costs, direct costs, indirect costs

Classify each of the following costs involved in the electrolysis of sodium chloride.

(i) Cost of sodium chloride
(1 mark)

(ii) Building the electrolysis cell
(1 mark)

(iii) Cost of electricity used in the electrolysis cell
(1 mark)

(iv) Sales and advertising
(1 mark)

(e) The electrolysis of sodium chloride is run as a continuous process.

Explain what is meant by the term *continuous process*.

.....
.....
.....
(2 marks)

(f) Give **two** advantages of using a continuous process rather than a batch process when manufacturing chemicals.

Reason 1

Reason 2
(2 marks)

END OF QUESTIONS