Surname		Other Names	
Centre Number			Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2008
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

APPLIED SCIENCE **SC11**
Unit 11 Controlling Chemical Procesess

Friday 25 January 2008 9.00 am to 10.30 am

For this paper you must have:
- a pencil and a ruler
- a calculator.

Time allowed: 1 hour 30 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- 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.

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

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

1 In some countries ethanol is used as an alternative fuel for cars. The ethanol is produced by the fermentation of sugar. This is a batch process.

(a) Explain what is meant by a *batch process*.

.....

.....

(2 marks)

(b) The fermentation of sugar can be represented by:

Reaction 1 $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

The table shows some enthalpy of combustion values.

	$C_6H_{12}O_6$	**C_2H_5OH**
Enthalpy of combustion/ (kJ mol^{-1})	–2802.5	–1367.3

(i) Explain why no value has been provided for carbon dioxide in the table.

.....

.....

(1 mark)

(ii) Calculate the enthalpy change for **Reaction 1** using the enthalpy of combustion data above.

.....

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.....

.....

.....

(3 marks)

Ethanol can also be produced by the hydration of ethene. This is a continuous process.

(c) (i) Explain what is meant by a *continuous process*.

.....

.....

(2 marks)

(ii) Give **one** advantage of using a continuous process rather than a batch process.

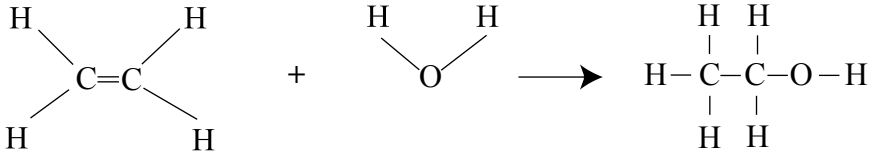
.....

.....

(1 mark)

(iii) The hydration of ethene can be represented by

Reaction 2



Use the mean bond enthalpy data to calculate the enthalpy change when one mole of ethanol is produced in **Reaction 2**.

	C−C	**C=C**	**C−H**	**C−O**	**O−H**
Mean bond enthalpy/ (kJ mol^{-1})	347	612	413	358	464

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(4 marks)

Question 1 continues on the next page

(d) The ethene in **Reaction 2** is obtained from crude oil.

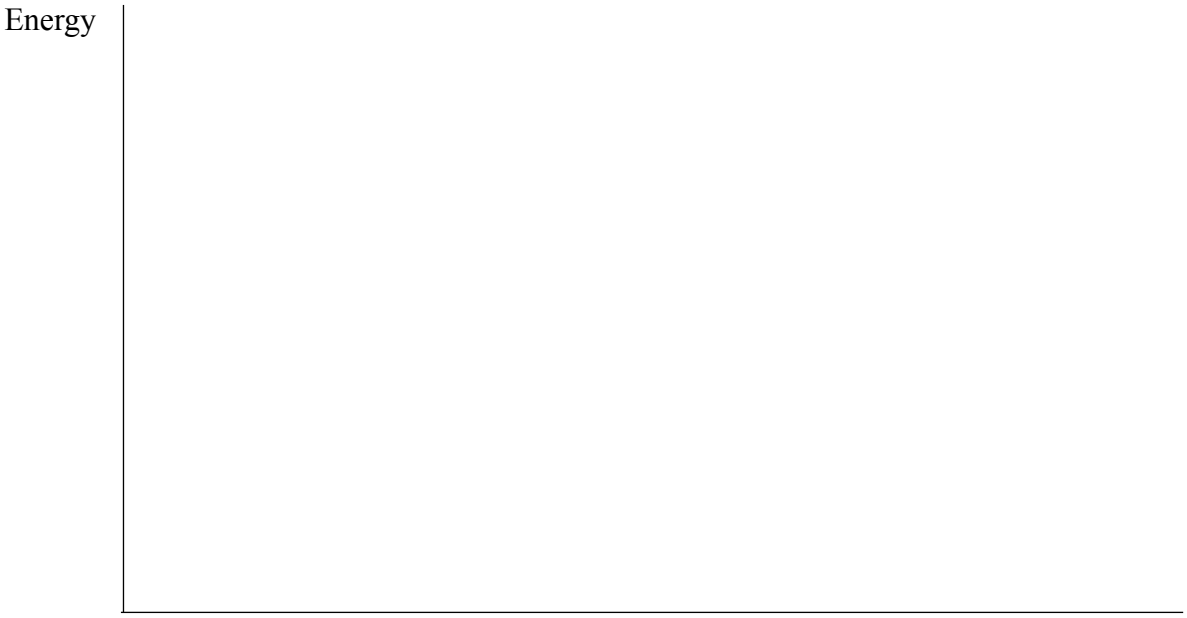
Give **one** environmental advantage of **Reaction 1** (fermentation) compared to **Reaction 2**.

.....

.....

(1 mark)

(e) Both **Reaction 1** and **Reaction 2** are exothermic. Sketch the reaction profile you would expect for an exothermic reaction on the axes below.



(3 marks)

17

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2 Development chemists frequently study rates of reaction.

The reaction between iodine and propanone is as follows:

$$\underset{\text{propanone}}{CH_3COCH_3} + \underset{\text{iodine}}{I_2} \rightarrow CH_3COCH_2I + \underset{\text{hydrogen ion}}{H^+} + I^-$$

The reaction is acid catalysed and is first order with respect to propanone, and also first order with respect to hydrogen ions.

(a) Name **one** experimental technique that could be used to monitor the rate of this reaction.

.....

(1 mark)

(b) What is a catalyst?

.....

.....

(2 marks)

The rate equation for a reaction can be determined by studying rates of reaction. The reaction is first order with respect to propanone, and also first order with respect to hydrogen ions.

(c) (i) Write down the rate equation for this reaction.

.....

(3 marks)

(ii) State the overall order of the reaction.

.....

(1 mark)

(iii) What would happen to the rate of the reaction if the initial concentration of propanone is tripled?

.....

(1 mark)

(d) Development chemists also study rates of reactions when considering how a laboratory experiment might be scaled up for industrial production.
It is important that they find the best conditions.

Two reactants, **X** and **Y**, have been investigated. Both **X** and **Y** are used as solutions in water.

The results of the investigation are shown in the table.

Experiment	Initial concentration of X ($mol\,dm^{-3}$)	Initial concentration of Y ($mol\,dm^{-3}$)	Initial rate of reaction ($mol\,dm^{-3}\,s^{-1}$)
1	0.2	0.2	4×10^{-2}
2	0.1	0.2	1×10^{-2}
3	0.2	0.4	4×10^{-2}

Use the results shown above to determine the order with respect to each of the reactants **X** and **Y**.
Explain your reasoning.

Order with respect to **X** .....

Explanation .....

.....

(2 marks)

Order with respect to **Y** .....

Explanation .....

.....

(2 marks)

(e) Suggest **one** factor that must be kept constant in order to ensure that the investigation, in which concentration is altered, is a fair test.

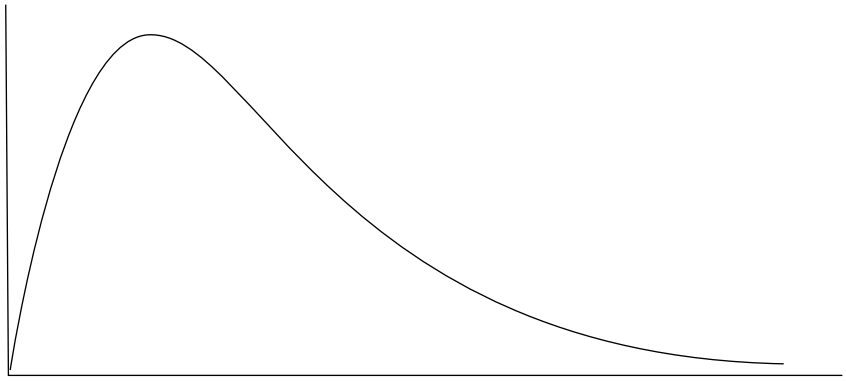
.....

(1 mark)

Question 2 continues on the next page

If development chemists decide that the laboratory scale experiment is going to be too slow to be an economic industrial process they may consider an increase in temperature.

A Maxwell-Boltzmann curve showing the distribution of energies of particles can be used to explain why an increase in temperature increases the rate of a reaction.



(f) (i) On the Maxwell-Boltzmann distribution label the axes.

(2 marks)

(ii) Sketch the curve you would expect for the same particles at a higher temperature.

(2 marks)

(g) Define the term *activation energy*.

.....

.....

(2 marks)

(h) Use your answers to part (f)(ii) and part (g) to explain why an increase in temperature increases the rate of a reaction.

.....

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(3 marks)

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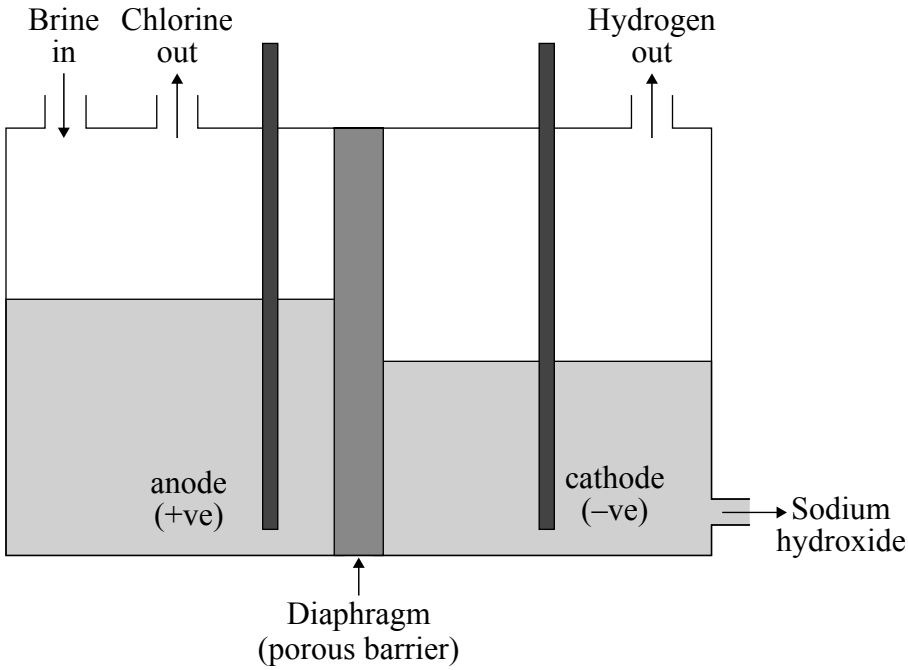
3 Large underground deposits of salt are found in Cheshire. Most of the salt extracted from the Cheshire deposits is dissolved in water to form brine.

The electrolysis of brine produces three useful substances – sodium hydroxide, chlorine and hydrogen.

The diagram below shows a cell used for this electrolysis.



(a) Balance the following half equations showing the formation of hydrogen and chlorine.

$$H^+ + \quad e^- \rightarrow \quad H_2$$

$$Cl^- \rightarrow \quad Cl_2 + \quad e^-$$

(2 marks)

(b) (i) State a hazard presented by hydrogen.

.....

(1 mark)

(ii) Identify the toxic substance produced in this electrolysis.

.....

(1 mark)

(iii) Suggest **one** appropriate safety precaution required when handling chlorine.

.....

(1 mark)

The overall equation for the electrolysis process is

$$2NaCl + 2H_2O \rightarrow 2NaOH + Cl_2 + H_2$$

(c) (i) Calculate the relative molecular masses of sodium chloride and sodium hydroxide (relative atomic masses: Na = 23, Cl = 35.5, O = 16, H = 1)

M_r NaC1 .....

.....

M_r NaOH .....

.....

(2 marks)

(ii) Use your answers in part (c)(i) to calculate the mass of sodium hydroxide produced when electrolysis is carried out on 585 kg of sodium chloride.

.....

.....

.....

(2 marks)

(d) (i) How many moles of chlorine would be produced if 50 000 moles of sodium hydroxide were made?

.....

(1 mark)

(ii) Use your answer to part (d)(i) to calculate the volume of chlorine gas that would be produced when 50 000 moles of sodium hydroxide were made.

Assume that 1 mole of any gas occupies 22.4 dm^3 at standard temperature and pressure.

.....

(1 mark)

Question 3 continues on the next page

Costs involved in manufacturing processes can be classified as

Capital costs
Direct costs
Indirect costs

Classify each of the following as **one** of the above costs.

(e) (i) Maintenance of the electrolysis cell.....
(1 mark)

(ii) Electricity used in the electrolysis cell.....
(1 mark)

(iii) Construction of the chemical plant (i.e. pipework, pumps, etc.)

.....
(1 mark)

(iv) Cost of salt.....
(1 mark)

Some of the chlorine and sodium hydroxide are used to make sodium chlorate (I), NaClO which is a substance found in bleaches.

$$Cl_2 + 2NaOH \rightarrow NaCl + NaClO + H_2O$$

What is the oxidation number of chlorine in

(f) (i) NaClO.....
(1 mark)

(ii) NaCl ?.....
(1 mark)

(g) If there was 100% yield, 160 tonnes of sodium hydroxide (NaOH) would produce 149 tonnes of sodium chlorate(I), NaClO.

In practice this process does not give 100% yield.

Calculate the mass of sodium hydroxide required to make 149 tonnes of sodium chlorate(I), NaClO, if the yield is only 80%.

.....

.....

.....
(2 marks)

19

4 One of the hydrocarbons obtained from crude oil is called butane. It is marketed as a fuel for camping stoves. A chemist is investigating the uses of butane. She wants to find out the enthalpy change when butane is burnt completely in oxygen.

The chemist uses a small camping gas burner to conduct a laboratory investigation to determine the enthalpy of combustion. The heat energy released by the combustion is used to raise the temperature of a known mass of water.

(a) Suggest the apparatus that could be used to conduct such an investigation.

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.....

.....

(3 marks)

(b) What measurements should the chemist take during the investigation? Ensure that you state how the chemist will know the amount of fuel used.

.....

.....

.....

(3 marks)

(c) Suggest **two** ways the chemist could ensure that her results were accurate and reliable.

.....

.....

.....

(2 marks)

(d) Explain how the results from this experiment could be used to determine the enthalpy of combustion for the butane used. Make sure you include the mathematical expression you would use and what values would need to be substituted into this expression.

.....

.....

.....

(2 marks)

10

5 Chemical engineers are employed to improve the efficiency of industrial processes. They attempt to maximise yield. Yield is often much lower than 100% because many reactions establish a dynamic equilibrium.

(a) Suggest **one** other reason why a reaction may **not** give a maximum yield.

.....

(1 mark)

(b) Explain **fully** what *dynamic equilibrium* means.

.....

.....

.....

(2 marks)

The production of ammonia, NH_3, is extremely important industrially. Ammonia is used in the manufacture of a wide range of substances such as dyes, fertilisers and pharmaceuticals.
Chemical engineers consider Le Chatelier's principle when deciding how they can obtain the best yield. The production of ammonia uses hydrogen and nitrogen as reactants.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -93.2 \text{ kJ mol}^{-1}$$

(c) (i) What type of energy change occurs during the above reaction?

.....

(1 mark)

(ii) State Le Chatelier's principle.

.....

.....

(2 marks)

(iii) What effect would a decrease in pressure have on the yield of ammonia. Explain your answer.

Effect .....

Explanation .....

.....

.....

.....

(3 marks)

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

.....

.....

(2 marks)

(v) Equilibrium concentrations are measured in mol dm^{-3}.
Use your answer to part (c)(iv) to work out the units for K_c.

.....

(1 mark)

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END OF QUESTIONS

There are no questions printed on this page