Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

For Examiner's Use

General Certificate of Education
June 2008
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Wednesday 11 June 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.
- 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.

For Examiner's Use			
Question	Mark	Question	Mark
1		5	
2		6	
3		7	
4			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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

1 The chloralkali industry produces sodium hydroxide, chlorine and hydrogen by the electrolysis of brine (sodium chloride solution). In the UK, rock salt is the raw material that is used to produce brine.

Sodium hydroxide is important in many manufacturing processes. For example, it is used to hydrolyse the complex esters found in vegetable oils to produce soap.

1 (a) The cost of the vegetable oil used in soap manufacture is a direct cost.

1 (a) (i) Explain the meaning of the term *direct cost*.

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(1 mark)

1 (a) (ii) Identify an indirect cost for this manufacturing process.

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(1 mark)

1 (a) (iii) What type of cost is the cost of building the electrolytic cell?

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(1 mark)

1 (b) Simple esters, such as methyl ethanoate, are hydrolysed by sodium hydroxide in the same way as in soap manufacture.

$$CH_3COOCH_3 + NaOH \rightarrow CH_3COONa + CH_3OH$$

methyl ethanoate

It is important for chemists to control the rate of hydrolysis. The table shows the results of a series of experiments carried out to study the effect of changes in concentration on the hydrolysis of this ester.

Experiment	**Initial concentration of methyl ethanoate ($mol\,dm^{-3}$)**	**Initial concentration of sodium hydroxide ($mol\,dm^{-3}$)**	**Initial rate of reaction ($mol\,dm^{-3}\,s^{-1}$)**
1	1.0	4.0	2.6×10^{-2}
2	0.5	4.0	1.3×10^{-2}
3	2.0	2.0	

Suggest a suitable experimental method that could be used to monitor the rate of this reaction.

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(1 mark)

1 (c) Use the results shown in the table on **page 2** to determine the order of this hydrolysis reaction with respect to methyl ethanoate. Explain your reasoning.

Order .....

Explanation .....

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(2 marks)

1 (d) The reaction is first order with respect to sodium hydroxide at low concentrations.

1 (d) (i) Write the rate equation for the hydrolysis reaction.

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(1 mark)

1 (d) (ii) Calculate the initial rate of reaction when the concentration of methyl ethanoate is 2.0 mol dm^{-3} and the concentration of sodium hydroxide is 2.0 mol dm^{-3}.

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(1 mark)

1 (e) If the concentration of the sodium hydroxide used is increased to a much higher concentration, such as 5 mol dm^{-3}, the order of the reaction with respect to sodium hydroxide becomes zero.

Explain what *zero order* means.

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(1 mark)

Question 1 continues on the next page

1 (f) The rate of this hydrolysis is slow at room temperature, so the industrial production of soap is carried out at higher temperatures.

Explain how increasing the temperature increases the rate of this reaction. You should refer to activation energy in your answer.

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(3 marks)

1 (g) Suggest **one** chemical hazard which might be important to consider in the soap manufacturing process.

Name of chemical .....

Hazard .....

(1 mark)

13

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

2 An analytical chemist at a chemical manufacturing company wants to determine the enthalpy change when phosphoric acid is neutralised with sodium hydroxide.

2 (a) Balance the following equation which represents the neutralisation of phosphoric acid.

$$H_3PO_4 \quad + \quad NaOH \quad \rightarrow \quad Na_3PO_4 \quad + \quad H_2O$$

(1 mark)

2 (b) (i) Describe an experiment you could do to determine the enthalpy of neutralisation of phosphoric acid.

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(5 marks)

2 (b) (ii) How would you use your results to calculate the enthalpy change in your reaction?

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(1 mark)

2 (c) State **two** precautions you would take to improve the accuracy of the experiment.

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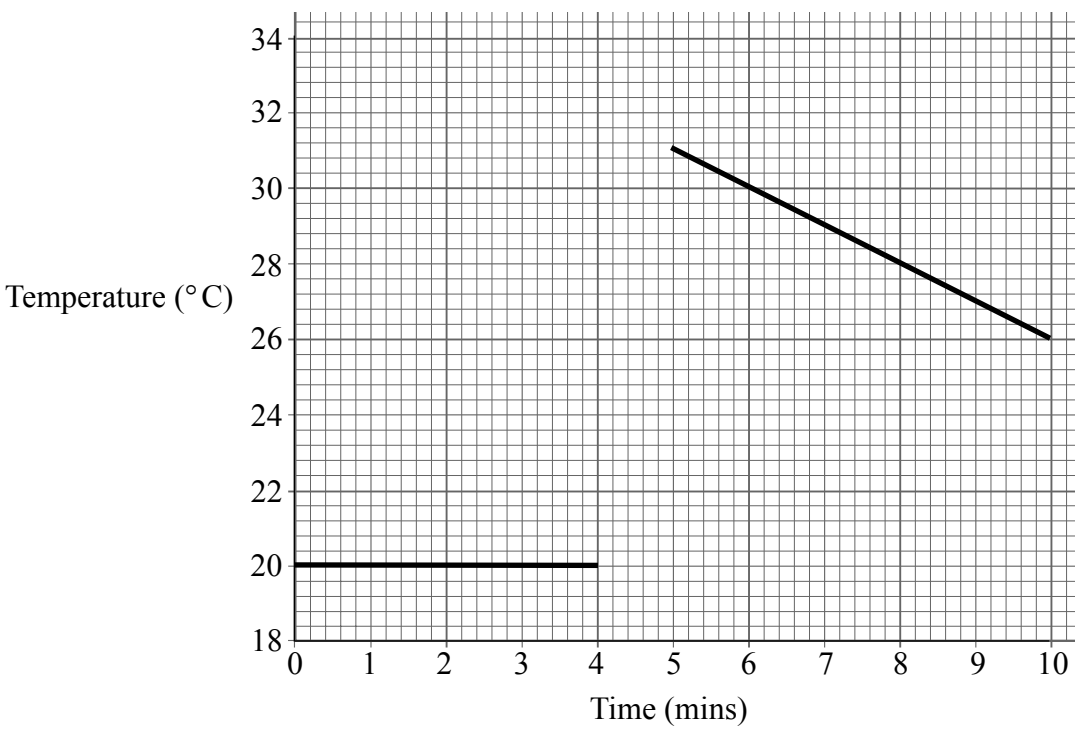
(2 marks)

2 (d) In one experiment, 30 cm^3 of 2 mol dm^{-3} sodium hydroxide was mixed with 30 cm^3 of 1 mol dm^{-3} phosphoric acid. The addition was made after 4.5 minutes. The results have been plotted on the graph below.



2 (d) (i) Use the graph to determine the temperature rise when the solutions were mixed.

.....

(1 mark)

2 (d) (ii) Calculate the heat energy released in this experiment.
Specific heat capacity of water = 4.2 $Jg^{-1}{}^{o}C^{-1}$

.....

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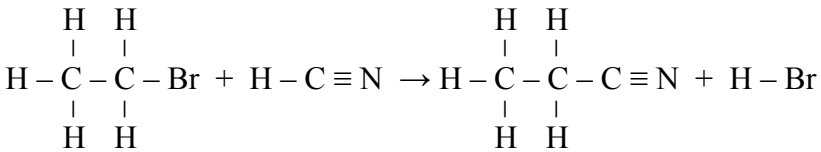
(2 marks)

12

Turn over ▶

3 Hydrocarbons obtained from crude oil are feedstocks for many industrial processes. New substances are often synthesised by extending the carbon chain of these hydrocarbons. One example of this is the production of a nitrile from a haloalkane.

For example, propanenitrile can be formed from the reaction of bromoethane with hydrogen cyanide.



The enthalpy change in this reaction can be determined using mean bond enthalpies or by using enthalpies of formation.

3 (a) Define *bond enthalpy*.

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.....

(1 mark)

3 (b) Use the following mean bond enthalpy data to calculate the enthalpy change when one mole of propanenitrile is produced in the reaction above.

	C – C	C – H	C – Br	C ≡ N	H – Br
Mean bond enthalpy/kJ mol^{-1}	347	413	290	887	366

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(4 marks)

3 (c) Calculate the enthalpy change when one mole of propanenitrile is produced in the same reaction using the following enthalpies of formation.

	CH_3CH_2CN	HCN	CH_3CH_2Br	HBr
Enthalpy of formation/kJ mol^{-1}	15.5	108.9	–90.5	–36.4

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(3 marks)

3 (d) Suggest why the values you have calculated in part (b) and part (c) differ.

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(1 marks)

9

Turn over for the next question

4 A large quantity of the ammonia manufactured is converted to nitric acid, HNO_3. This is neutralised with more ammonia to make ammonium nitrate, often used as a fertiliser.

4 (a) What type of reaction is the conversion of ammonia to nitric acid?

.....

(1 mark)

4 (b) Ammonia is produced industrially in the Haber process.

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

The expression for the equilibrium constant, K_c is

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

4 (b) (i) In a container of volume 400 dm^3, the equilibrium mixture contains 10 moles of N_2, 20 moles of H_2 and 0.9 moles of NH_3. Calculate the value of the equilibrium constant.

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(3 marks)

4 (b) (ii) What are the units of this equilibrium constant?

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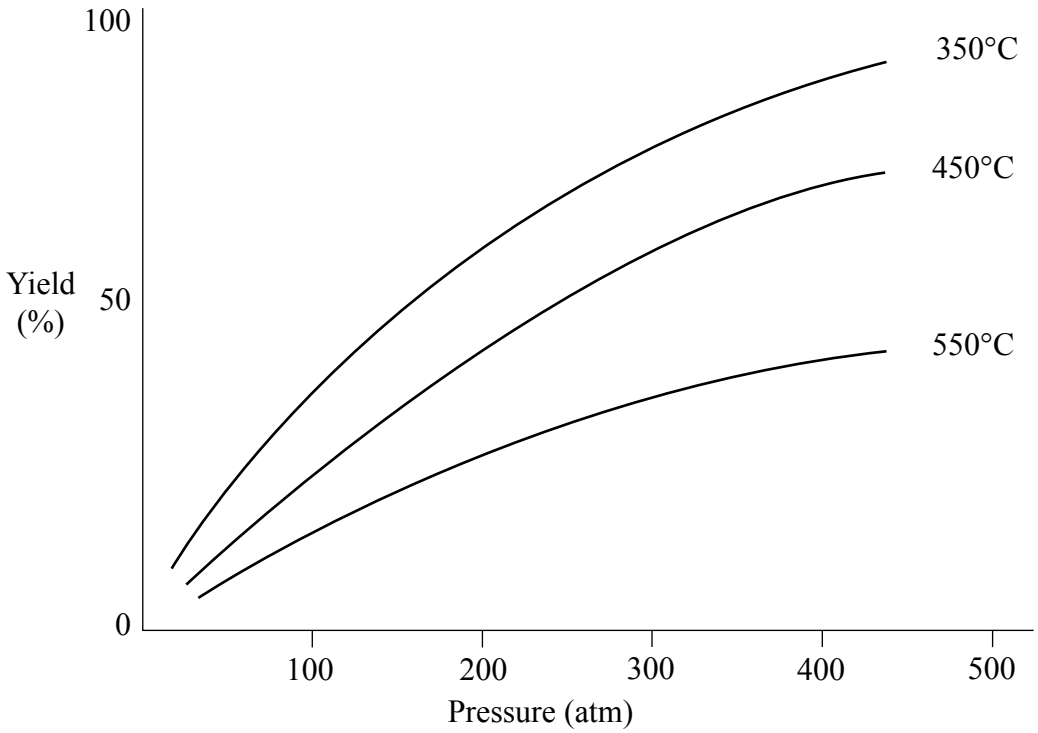
(1 mark)

4 (c) The graph shows the equilibrium yield of ammonia in the Haber process over a range of temperatures and pressures.



4 (c) (i) How does the yield of ammonia change as temperature increases? Explain why this change occurs.

How the yeild changes .....

Explanation .....

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(4 marks)

4 (c) (ii) In practice a temperature of about 450 °C is usually chosen. Explain why this can be considered as a compromise temperature.

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(2 marks)

11

5 Chemical engineers can control reactions by cooling the reaction vessels. This can make the overall production process more economical, as the heat energy that is removed can be used elsewhere.

5 (a) Suggest why it may be necessary to cool a reaction mixture.

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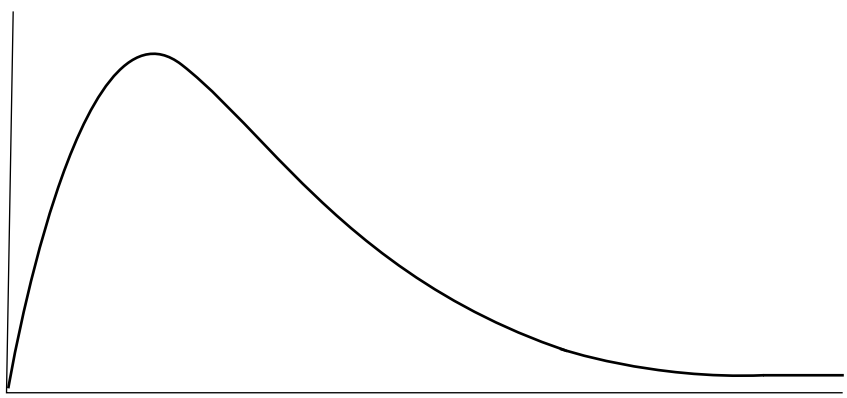
(1 mark)

5 (b) The graph shows the Maxwell–Bolzmann distribution curve for a gaseous system.



5 (b) (i) Add the correct label to the vertical axis. *(1 mark)*

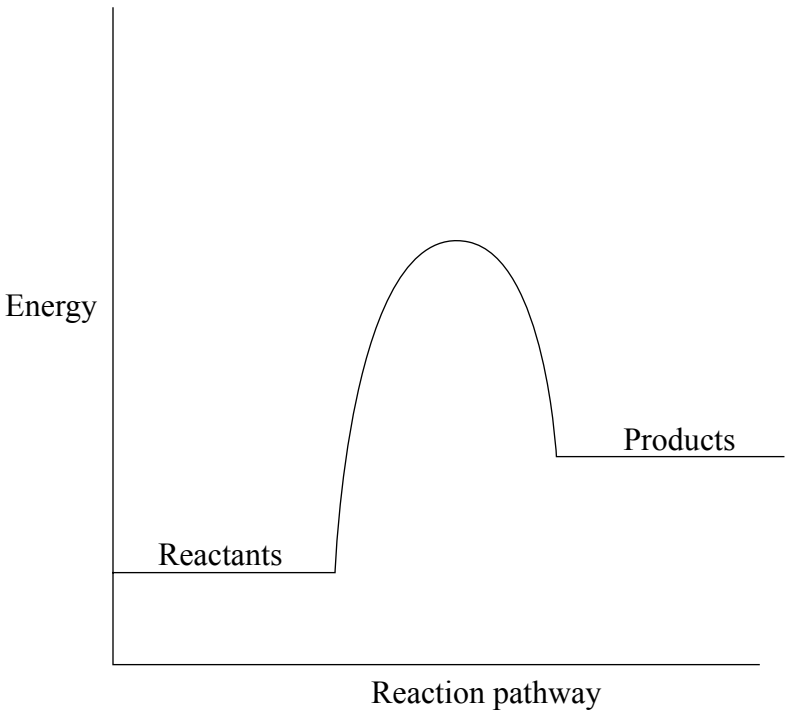
5 (b) (ii) What does the area under this curve represent?

.....

(1 mark)

5 (b) (iii) On the graph above sketch the Maxwell–Bolzmann distribution curve for the same system at a lower temperature. *(2 marks)*

5 (c) A typical reaction profile for a reaction that uses a catalyst is shown.



5 (c) (i) State the sign of the enthalpy change of this reaction and explain your answer.

Sign .....

Explanation .....

.....

(2 marks)

5 (c) (ii) On the graph above, draw the reaction profile you would expect to see if the reaction was carried out without a catalyst. *(1 mark)*

5 (d) (i) Define the term *activation energy*.

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(2 marks)

5 (d) (ii) Explain, in terms of activation energy, how a catalyst works.

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(2 marks)

6 Paracetamol is a common pharmaceutical. It is made by a batch process.

6 (a) (i) Explain what is meant by the term *batch process.*

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(2 marks)

6 (a) (ii) Give **one** advantage and **one** disadvantage of a batch process.

Advantage .....

.....

Disadvantage .....

.....

(2 marks)

6 (a) (iii) Many processes are continuous. Explain what is meant by the term *continuous process*.

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(2 marks)

Paracetamol can be manufactured from 4-aminophenol. The overall reaction can be summarised by:

$$\underset{\text{4-aminophenol}}{C_6H_4(OH)NH_2} + (CH_3CO)_2O \rightarrow \underset{\text{paracetamol}}{C_6H_4(OH)NHCOCH_3} + CH_3COOH$$

6 (b) (i) Calculate the relative molecular masses of 4-aminophenol and paracetamol. (Relative atomic masses: N=14, O=16, C=12, H=1)

M_r 4-aminophenol .....

.....

M_r paracetamol .....

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(2 marks)

6 (b) (ii) Calculate the mass of 4-aminophenol required to make 302 kg of paracetamol.

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(3 marks)

6 (b) (iii) If the percentage yield of paracetamol is 80%, calculate what mass of paracetamol would be produced instead of 302 kg.

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(1 mark)

12

Turn over for the next question

7 Sulphuric acid is an important industrial chemical. It is used to manufacture many materials including fertilisers, paints, detergents, plastics and dyes.
The manufacture of sulphuric acid occurs in several stages.
Chemists need to control conditions in order to maximise yield.

One stage is the oxidation of sulphur dioxide, SO_2, to form sulphur trioxide, SO_3.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -98\,kJ\,mol^{-1}$$

Small pellets of vanadium(V) oxide are used as a catalyst. This process is reversible and therefore a dynamic equilibrium is established.

7 (a) Explain the meaning of

7 (a) (i) *reversible* .....

.....

7 (a) (ii) *dynamic equilibrium* .....

.....

(2 marks)

7 (b) All the reactants and products are in the same state. What word describes this?

.....

(1 mark)

7 (c) Describe how the equilibrium yield of sulphur trioxide would be affected by an increase in pressure. Explain your answer.

Effect on yield .....

Explanation .....

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(3 marks)

7 (d) (i) Write an expression for the equilibrium constant, K_c, for this reaction.

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(2 marks)

7 (d) (ii) What would happen to the value of K_c if the temperature was increased?

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(1 mark)

7 (e) Explain why the solid catalyst is used in the form of small pellets rather than large lumps.

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(2 marks)

11

END OF QUESTIONS

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