Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2010

Applied Science SC11

Unit 11 Controlling Chemical Processes

Wednesday 9 June 2010 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. Do not write outside the box around each page or on blank pages.
- 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 marks for questions are shown in brackets.
- The maximum mark for this paper is 80.
- You will be marked on your ability to
  - use good English
  - organise information clearly
  - use specialist vocabulary where appropriate.
- You are expected to use a calculator where appropriate.

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

1 Farmers use ammonium nitrate pellets as a fertiliser. Development chemists try to ensure that the large-scale production of ammonium nitrate is efficient.

Ammonium nitrate, NH_4NO_3, is made on an industrial scale by reacting nitric acid, HNO_3, and ammonia, NH_3.

$$HNO_3(aq) + NH_3(g) \longrightarrow NH_4NO_3(s)$$

1 (a) What term is used to indicate that the reactants and products are in different states?

.....

(1 mark)

1 (b) This reaction produces a 90% yield.

1 (b) (i) Suggest **two** reasons why the yield is less than 100%.

.....

.....

.....

.....

(2 marks)

1 (b) (ii) Calculate the relative formula masses of HNO_3 and NH_4NO_3.
(Relative atomic masses: N = 14, H = 1, O = 16)

M_r HNO_3.....

.....

M_r NH_4NO_3 .....

.....

(2 marks)

1 (b) (iii) Use your answers in part (b)(ii) and the equation above to calculate the mass of HNO_3 that would be required to produce 100 kg of NH_4NO_3 if the yield is 90%.

.....

.....

.....

.....

(3 marks)

1 (c) Ammonium nitrate is used to increase the nitrogen content of soils. It is particularly useful because of its high solubility. Explain why it is useful to make ammonium nitrate fertiliser pellets very small.

.....

.....

(1 mark)

1 (d) Costs involved in manufacturing processes can be classified as

direct costs
capital costs
indirect costs

Classify each of the following costs involved in the manufacture of ammonium nitrate.

1 (d) (i) Cost of ammonia .....

(1 mark)

1 (d) (ii) Maintenance of the plant .....

(1 mark)

1 (d) (iii) Marketing of the ammonium nitrate .....

(1 mark)

1 (d) (iv) Construction of the plant .....

(1 mark)

1 (e) Ammonia is used as the starting material for the production of nitric acid.

1 (e) (i) Calculate the oxidation number of nitrogen in ammonia, NH_3, and in nitric acid, HNO_3.

NH_3 .....

HNO_3 .....

(2 marks)

1 (e) (ii) What type of reaction is the conversion of ammonia to nitric acid? Use your answers to part (e)(i) to help you to decide.

.....

(1 mark)

16

2 Industrial chemists frequently consider the enthalpy changes involved in reactions.

2 (a) Explain what is meant by *enthalpy change of combustion*.

.....

.....

(2 marks)

2 (b) A student on work experience is asked to determine the enthalpy change of combustion of ethanol.

2 (b) (i) Suggest what apparatus could be used to carry out such an experiment. Ethanol is a liquid at room temperature.

.....

.....

.....

.....

.....

(3 marks)

2 (b) (ii) Describe how the student would use the apparatus in part (b)(i) to find the heat energy released when ethanol undergoes combustion. Show how the student would use the results of the experiment to calculate the enthalpy change of combustion for one mole of ethanol.

You will be assessed on the quality of written communication in your answer to this question.

.....

.....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

2 (b) (iii) Suggest **two** ways in which the student could ensure that the experimental results were valid.

1 .....

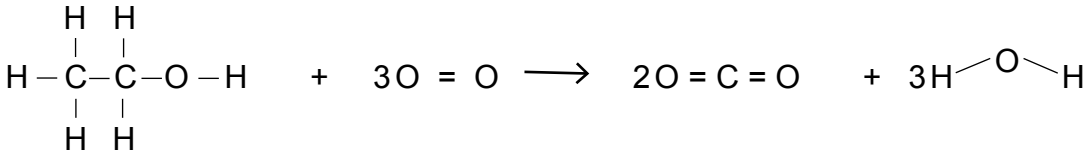
.....

2 .....

.....

(2 marks)

2 (c) (i) The enthalpy change in the combustion of ethanol can be calculated using mean bond enthalpies. Use the following data to calculate the enthalpy change of combustion for ethanol.



ethanol + oxygen ⟶ carbon dioxide + water

	C − C	C − H	O − H	C = O	O = O	C – O
Mean bond enthalpy/kJ mol^{-1}	348	413	463	743	498	360

.....

.....

.....

.....

.....

(4 marks)

2 (c) (ii) How would you expect your answer to part (c)(i) to compare to the experimentally determined value? Explain your answer.

.....

.....

.....

.....

(2 marks)

18

Turn over ▶

3 The manufacture of sulphuric acid involves several stages. One stage is the oxidation of sulphur dioxide, SO_2. This is a reversible reaction and therefore a dynamic equilibrium is established.

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

3 (a) (i) Explain the meaning of the term *dynamic equilibrium*.

.....

.....

.....

(2 marks)

3 (a) (ii) Suggest what type of container should be used for the reversible reaction if a dynamic equilibrium is to be established.

.....

(1 mark)

3 (b) (i) Write an expression for the equilibrium constant, K_c, for this equilibrium.

.....

.....

.....

(2 marks)

3 (b) (ii) A reaction vessel contains the following concentrations of reactants at equilibrium

$SO_2 = 24.0 \text{ mol dm}^{-3}$
$O_2 = 18.5 \text{ mol dm}^{-3}$

The value of K_c is $1.2 \times 10^5 \text{ mol}^{-1}\text{dm}^3$. Calculate the equilibrium concentration of sulphur trioxide, SO_3.

.....

.....

.....

.....

.....

.....

(3 marks)

3 (c) Chemical engineers try to achieve the best yield of sulphur trioxide in the most economical way.

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

3 (c) (i) What effect will increasing the temperature have on the yield of sulphur trioxide?

State and use le Chatelier's principle to explain your answer.

You will be assessed on the quality of written communication in your answer to this question.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

3 (c) (ii) Suggest why the production of sulphur trioxide is not carried out at very high pressure despite the fact that, according to le Chatelier's principle, the yield of sulphur trioxide would increase as pressure increases.

.....

.....

(1 mark)

Question 3 continues on the next page

3 (d) The production of sulphur trioxide requires a catalyst of vanadium(V) oxide.

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

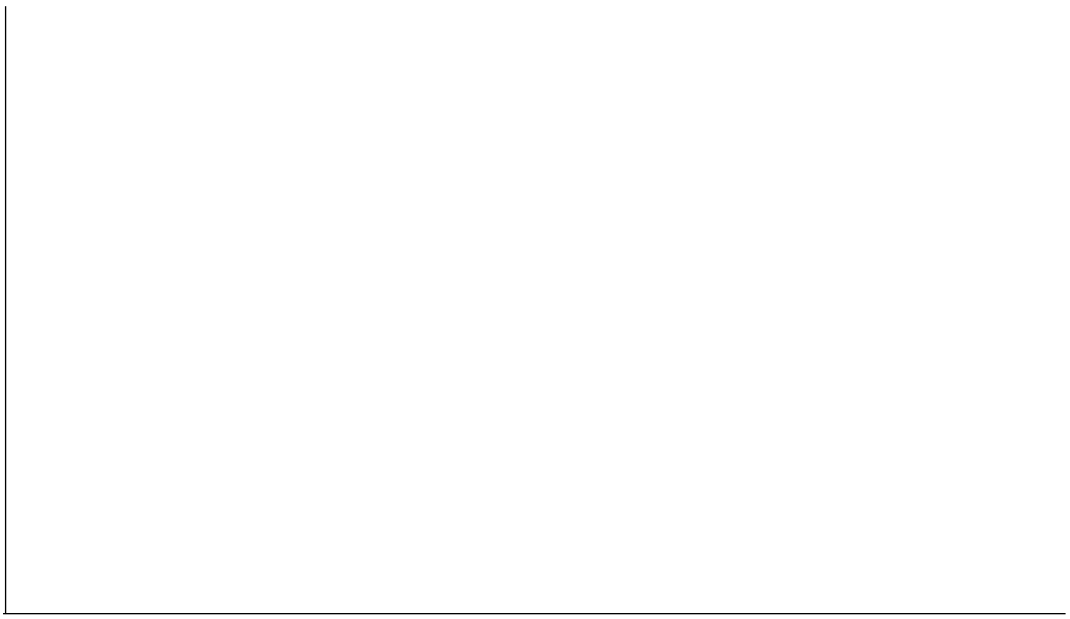
3 (d) (i) What is a *catalyst*?

.....

.....

(2 marks)

3 (d) (ii) On the axes provided, sketch the reaction profile you would expect for the production of sulphur trioxide. Label this reaction profile **A**.



(3 marks)

3 (d) (iii) On the same axes, draw the reaction profile you would expect to see if no catalyst was used. Label this reaction profile **B**. *(2 marks)*

21

4 Development chemists study the rates of reactions when they are considering how a laboratory experiment might be used on an industrial scale. It is important that they find the best conditions.

Three reactants, **A**, **B** and **C**, are involved in a process. All three reactants are used as solutions in water. The results of the investigation are shown in the table below.

Experiment	Initial concentration of A ($mol\,dm^{-3}$)	Initial concentration of B ($mol\,dm^{-3}$)	Initial concentration of C ($mol\,dm^{-3}$)	Initial rate of reaction ($mol\,dm^{-3}s^{-1}$)
1	0.2	0.2	0.2	3.6×10^{-3}
2	0.1	0.2	0.2	1.8×10^{-3}
3	0.2	0.2	0.1	9.0×10^{-4}
4	0.2	0.1	0.2	3.6×10^{-3}

4 (a) Use the results shown in the table to determine the order with respect to the reactants **B** and **C**. Explain how you arrive at your answers.

Order with respect to **B**.....

Explanation .....

.....

(2 marks)

Order with respect to **C**.....

Explanation .....

.....

(2 marks)

4 (b) Use the results in the table and your answers to part (a) to write the rate equation for the reaction.

.....

.....

(3 marks)

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

.....

(1 mark)

Question 4 continues on the next page

4 (d) Another reaction involving three substances **X**, **Y** and **Z** was studied and was found to have the rate equation:

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

Calculate the units of k for this reaction.

.....

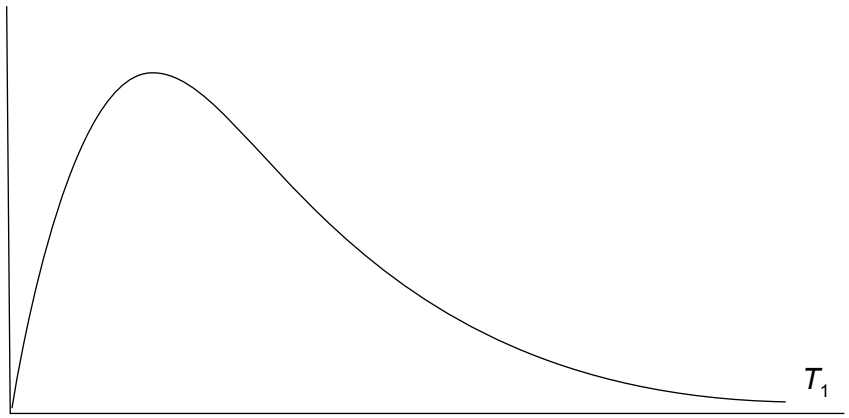
.....

(1 mark)

9

5 In industry, chemical engineers consider rates of reactions as well as yields. This is to ensure that a product is made economically.

The graph below shows the Maxwell–Boltzmann distribution of the energies at temperature T_1 for the particles in a gaseous system.



5 (a) (i) Label the axes, and mark the activation energy on the Maxwell–Boltzmann distribution. *(3 marks)*

5 (a) (ii) Sketch the curve you would expect for the same gas at a higher temperature T_2 and label this curve **X**. *(3 marks)*

5 (b) Use your answer to part (a)(ii) and the idea of activation energy to explain why an increase in temperature increases the rate of a reaction.

.....

.....

.....

.....

.....

(3 marks)

Question 5 continues on the next page

5 (c) Explain why an increase in pressure increases the rate of a gaseous reaction.

.....

.....

(1 mark)

5 (d) Some products are made in a continuous process, others using a batch process. The advantages and disadvantages of each process must be considered if the product is to be made economically.

5 (d) (i) Explain what is meant by the term *batch process*.

.....

.....

.....

.....

(2 marks)

5 (d) (ii) Explain what is meant by the term *continuous process.*

.....

.....

.....

.....

(2 marks)

5 (d) (iii) Give **two** advantages of a continuous process compared to a batch process.

.....

.....

.....

.....

(2 marks)

16

END OF QUESTIONS