Centre Number						Candidate Number				
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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 2013

Applied Science SC11

Unit 11 Controlling Chemical Processes

Friday 7 June 2013 1.30 pm to 3.00 pm

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

Time allowed
- 1 hour 30 minutes

A

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.

Do not write outside the box

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

1 Metallic compounds are often used in paints and pottery glazes to provide vivid colours.

1 (a) Colour chemists research these metallic compounds to ensure that they are effective when small amounts are used. It is desirable to use small amounts of these powdered compounds because they are toxic.

Suggest **one** safety precaution when handling powdered compounds.

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(1 mark)

1 (b) Cobalt carbonate is used in some blue glazes for pottery. When cobalt carbonate is heated it produces cobalt oxide:

$CoCO_3$	$\longrightarrow$	CoO	+	CO_2
cobalt carbonate		cobalt oxide		carbon dioxide

Name this type of reaction.

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(1 mark)

1 (c) Cobalt aluminate ($CoAl_2O_4$) gives a distinctive deep blue colour to glass, pottery and paints. It is produced when cobalt oxide, CoO, is reacted with aluminium oxide, Al_2O_3:

CoO	+	Al_2O_3	$\longrightarrow$	$CoAl_2O_4$
cobalt oxide		aluminium oxide		cobalt aluminate

Costs involved in industrial processes, such as the production of cobalt aluminate, can be classified as:

capital costs, direct costs, indirect costs

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

sales and marketing.....

cost of cobalt oxide.....

construction of chemical plant .....

buildings insurance .....

(4 marks)

Do not write outside the box

1 (d) (i) Calculate the relative molecular masses, M_r, of cobalt oxide and cobalt aluminate.
(Relative atomic masses: Co = 59, Al = 27, O = 16)

Cobalt oxide .....

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M_r =.....

Cobalt aluminate .....

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M_r =.....
(2 marks)

1 (d) (ii) Calculate the mass of cobalt oxide required to produce 100 kg cobalt aluminate.
Assume 100% yield.

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Mass = ...
(3 marks)

1 (d) (iii) In practice, the yield will be lower than 100%.
Suggest why.

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(1 mark)

1 (e) (i) Given that the oxidation state of aluminium is +3, work out the oxidation state of cobalt in cobalt aluminate $CoAl_2O_4$.

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(1 mark)

Question 1 continues on the next page

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1 (e) (ii) The oxidation state of cobalt in cobalt oxide, CoO is +2. Use this information and your answer from part 1(e)(i) to decide if the production of cobalt aluminate is a redox reaction.

Explain your answer.

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(1 mark)

1 (f) A different reaction requires 320 kg of reactant to make 76 kg of product when there is 100% yield.

Calculate how much reactant will be required to make 76 kg of product if the yield is only 82%.

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(2 marks)

16

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2 Chemical engineers must consider the enthalpy changes that happen during chemical processes. A trainee chemical engineer has been asked to find the enthalpy of combustion of various alcohols.

2 (a) Balance the equation for the complete combustion of ethanol:

$$C_2H_5OH \quad + \quad O_2 \quad \longrightarrow \quad CO_2 \quad + \quad H_2O$$

(2 marks)

2 (b) The trainee decides to determine the enthalpy of combustion of butan-1-ol (C_4H_9OH) by experiment. Butan-1-ol is a liquid at room temperature.

2 (b) (i) Suggest what apparatus the trainee will use.

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(3 marks)

Question 2 continues on the next page

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2 (b) (ii) Describe how the trainee would do the experiment and how the results could be used to determine the enthalpy of combustion.

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

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Extra space (if needed) .....

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(5 marks)

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2 (b) (iii) State what precautions should be taken to ensure that the results of this experiment are reliable if repeated.

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(2 marks)

2 (c) The enthalpy of combustion of butan-1-ol can also be calculated using *enthalpy of formation* data.

2 (c) (i) Explain the meaning of the term enthalpy of formation.

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(3 marks)

Question 2 continues on the next page

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2 (c) (ii) Use the enthalpy of formation data shown in **Table 1** to calculate the enthalpy of combustion for butan-1-ol. The equation for the combustion of butan-1-ol is:

$$\underset{\text{butan-1-ol}}{C_4H_9OH(l)} + 6O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$$

Table 1

Substance	Water	Oxygen	Carbon dioxide	Butan-1-ol
Enthalpy of formation ($kJ\,mol^{-1}$)	−285.8	0	−394.4	−327.4

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Enthalpy of combustion = ...

(4 marks)

2 (c) (iii) Explain why the enthalpy of formation of oxygen is zero.

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(1 mark)

2 (c) (iv) Give **two** reasons why you would expect the calculated enthalpy of combustion to be different from the experimental result.

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2 .....

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(2 marks)

22

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3 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 to find the best conditions.

3 (a) Explain what is meant by the term rate of reaction.

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(2 marks)

3 (b) The initial rate of reaction between the gases nitrogen monoxide, NO, and hydrogen, H_2, was measured in a series of experiments at a constant temperature.
The following rate equation was determined:

$$\text{rate} = k[NO]^2[H_2]$$

3 (b) (i) What is the overall order of the reaction?

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(1 mark)

Question 3 continues on the next page

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3 (b) (ii) **Table 2** shows the data for the reaction between NO and H_2.
Use the rate equation to complete **Table 2**.

Table 2

Experiment	Initial [NO] (mol dm^{-3})	Initial [H_2] (mol dm^{-3})	Initial rate (mol dm^{-3} s^{-1})
1	2.0×10^{-3}	1.5×10^{-3}	1.2×10^{-5}
2	2.0×10^{-3}		6.0×10^{-5}
3	4.0×10^{-3}	1.5×10^{-3}	
4		3.0×10^{-3}	2.4×10^{-5}

(3 marks)

3 (b) (iii) Using the data from Experiment 1 in **Table 2**, calculate a numerical value for the rate constant, *k*.

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k = ...
(3 marks)

3 (b) (iv) What are the units of *k*?

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(1 mark)

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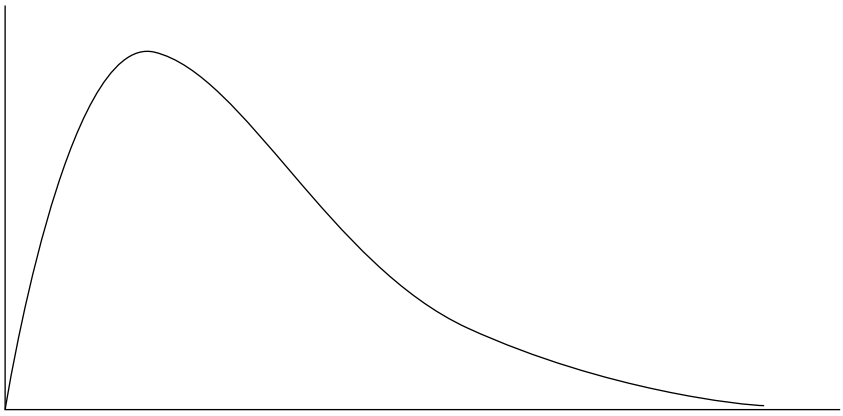
3 (c) Changing the temperature of a reaction mixture can have a significant effect on reaction rate.

Figure 1 shows a Maxwell–Boltzmann curve showing the distribution of energies of particles. This can be used to explain why an increase in temperature increases the rate of a reaction.

Figure 1



3 (c) (i) Add the correct labels to the vertical and horizontal axes on the graph in **Figure 1**.

(2 marks)

3 (c) (ii) On **Figure 1**, sketch the curve you would expect for the same particles at a higher temperature.

(2 marks)

3 (d) (i) Define the term activation energy.

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(2 marks)

3 (d) (ii) Use the idea of activation energy to explain why an increase in temperature increases the rate of a reaction.

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(3 marks)

19

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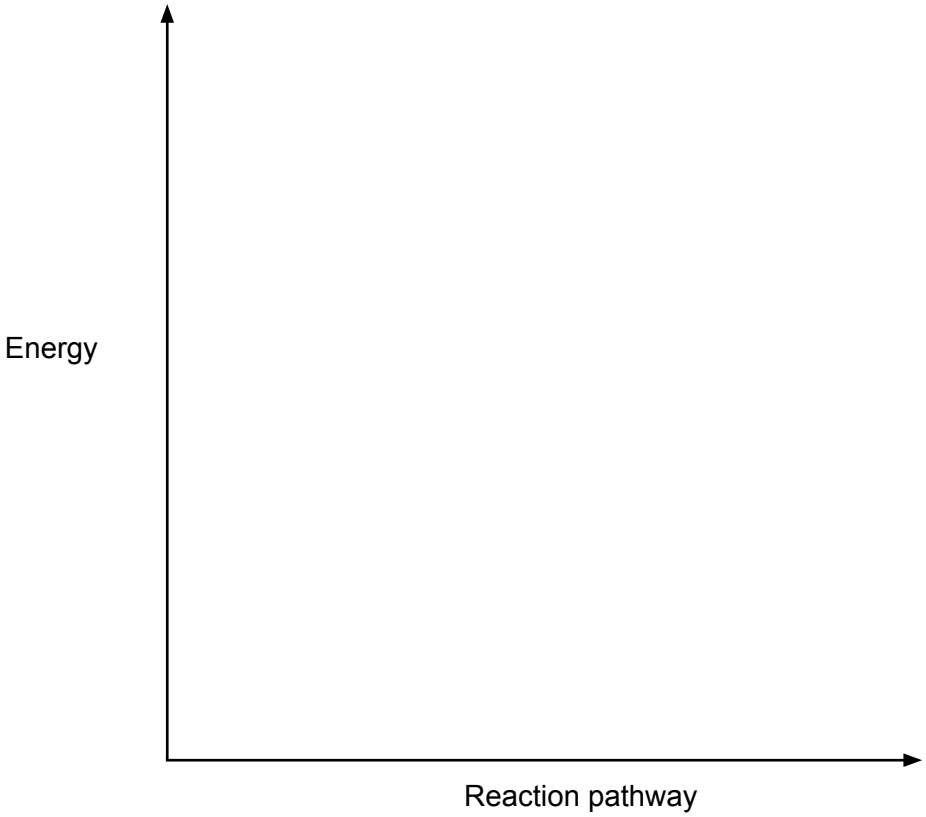
4 A research chemist measured the enthalpies of combustion of the three alcohols with the smallest molecules.
These are shown in **Table 3**.

Table 3

Alcohol	Formula	Enthalpy of combustion ($kJ\,mol^{-1}$)
methanol	CH_3OH	−726.0
ethanol	C_2H_5OH	−1367.3
propan-1-ol	C_3H_7OH	−2021.0

4 (a) On **Figure 2** sketch the reaction profile you would expect for the complete combustion of methanol.

Figure 2



(3 marks)

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4 (b) The enthalpies of combustion of alcohols increase as the number of carbon atoms in the molecules increases.
Explain why. You will need to use the concept of bond enthalpies in your answer.

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

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Extra space (if needed) .....

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(5 marks)

8

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5 The Haber process is used to make ammonia on an industrial scale. Ammonia is used in making fertilisers and in manufacturing pharmaceuticals.
The Haber process is a *continuous process*.

5 (a) (i) What is meant by a continuous process*?*

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(2 marks)

5 (a) (ii) *Batch processes* are often used to manufacture pharmaceuticals.
What is meant by a batch process?

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(2 marks)

5 (a) (iii) Give **two** reasons why a batch process may be considered to be better than a continuous process.

1 .....

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2 .....

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(2 marks)

5 (b) The Haber process involves a reversible reaction and so a *homogeneous* dynamic equilibrium will be established.

Explain what is meant by homogeneous.

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(1 mark)

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5 (c) The Haber process uses nitrogen and hydrogen to form ammonia:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

5 (c) (i) State Le Chatelier's principle.

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(2 marks)

5 (c) (ii) Use Le Chatelier's principle to determine what effect increasing the pressure will have on the yield of ammonia.

Explain your answer.

Effect.....

Explanation .....

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(3 marks)

5 (c) (iii) What effect will a catalyst have on the yield of ammonia?

Explain your answer.

Effect.....

Explanation .....

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(3 marks)

15

END OF QUESTIONS

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There are no questions printed on this page

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