

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



General Certificate of Education
Advanced Level Examination
January 2013

Applied Science

SC11

Unit 11 Controlling Chemical Processes

Friday 18 January 2013 9.00 am to 10.30 am

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



J A N 1 3 S C 1 1 0 1

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

1 Industrial chemists must consider the rates of reactions. It is important that they find the conditions that provide the required product in a reasonable time.

1 (a) Three reactants, **A**, **B** and **C**, have been investigated by industrial research chemists. All are used dissolved in ethanol. The results of the investigation are shown in **Table 1**.

Table 1

Expt	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	0.20	0.20	0.20	0.30
2	0.40	0.20	0.20	1.20
3	0.20	0.10	0.20	0.15
4	0.20	0.20	0.05	0.30

1 (a) (i) The reaction is *zero order* with respect to **C**.

Explain what zero order with respect to **C** means.

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(2 marks)

1 (a) (ii) Use the results shown in **Table 1** to determine the order of reaction with respect to the reactants **A** and **B**. Explain how you arrive at your answers.

Order with respect to **A**.....

Explanation

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

Explanation

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(4 marks)



1 (b) Two factors that affect the rate of a reaction are temperature and the *activation energy* of that reaction.

1 (b) (i) Define activation energy.

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(2 marks)

1 (b) (ii) What effect will an increase in temperature have on the activation energy?

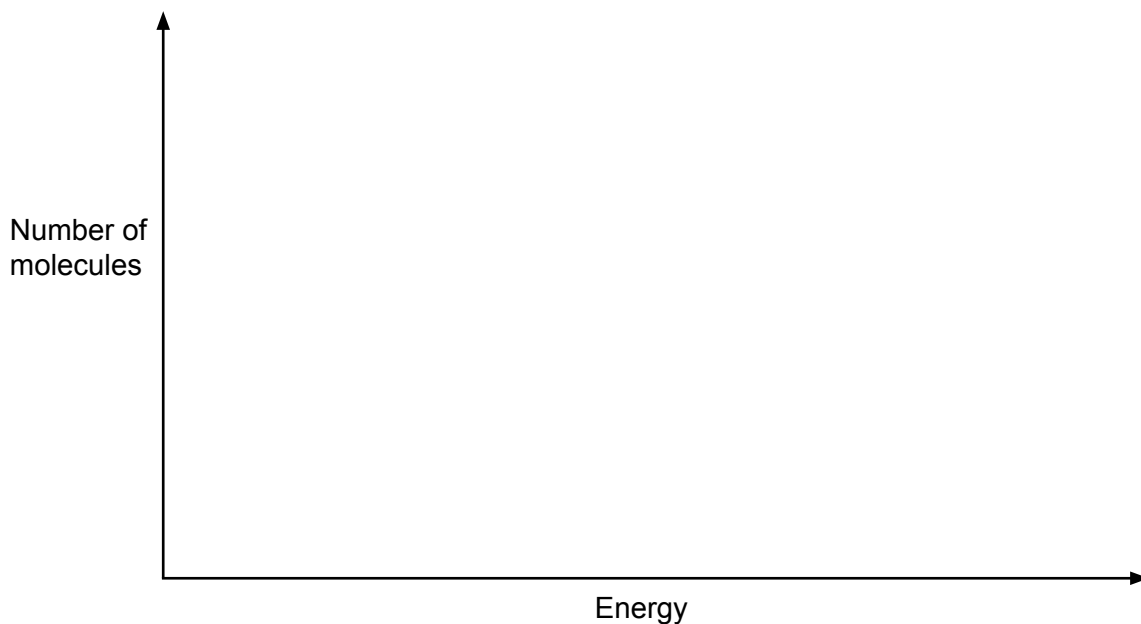
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(1 mark)

1 (c) Chemists often use a Maxwell-Boltzmann curve showing the distribution of energies of particles to explain changes in the rate of a reaction.

1 (c) (i) On the axes in **Figure 1** sketch a Maxwell-Boltzmann distribution.

Figure 1



(3 marks)

1 (c) (ii) On the Energy axis, indicate:

- the activation energy without a catalyst. Label this E_a
- the activation energy with a catalyst. Label this $E_a(\text{cat})$.

(2 marks)

Turn over ►



1 (c) (iii) What effect will a catalyst have on the rate of a reaction?
Use your Maxwell-Boltzmann curve to explain why.

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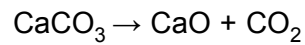
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(3 marks)

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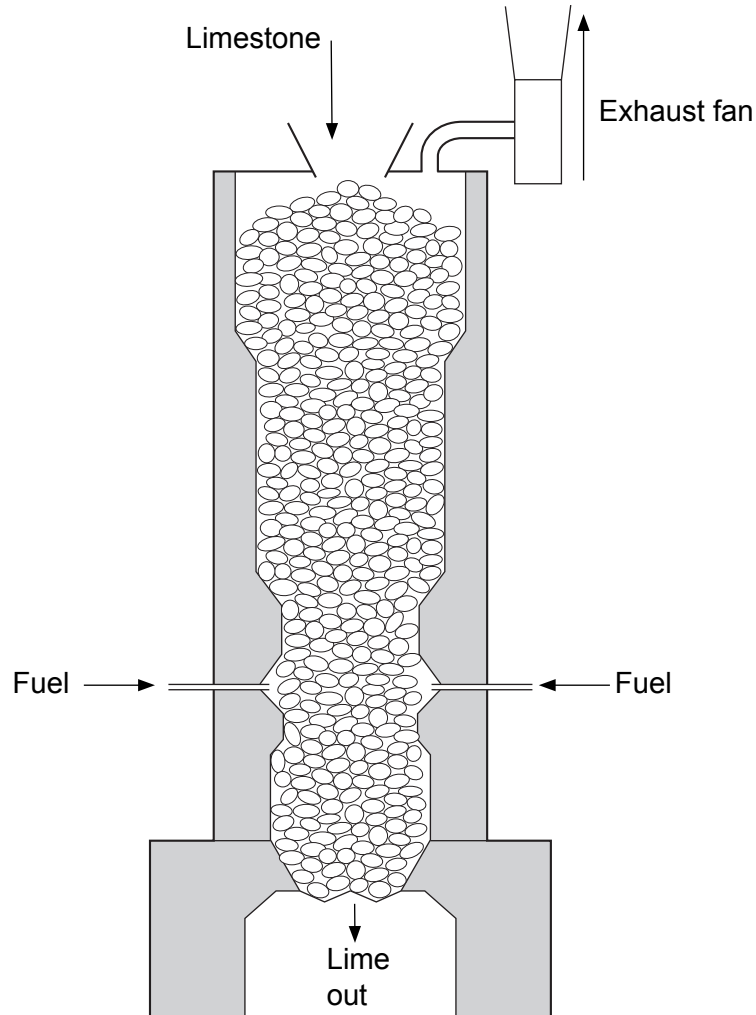


- 2 Calcium oxide (often called 'lime') is produced commercially by heating limestone at temperatures over 900°C :



This is often carried out in a lime kiln as shown in **Figure 2**.

Figure 2



- 2 (a) Costs involved in industrial processes can be classified as:

capital costs, direct costs, indirect costs

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

cost of limestone

cost of fuel

construction of the kiln

rental of site

(4 marks)

Turn over ▶



2 (b) Archaeologists have found many examples of lime kilns at historical sites in areas of the UK where the *raw materials* were available.

Explain what is meant by a raw material.

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(1 mark)

2 (c) Modern lime kilns operate as *continuous processes*, whereas lime kilns that have been found by archaeologists used a *batch process*.

2 (c) (i) What is meant by a batch process?

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(2 marks)

2 (c) (ii) What is meant by a continuous process?

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(2 marks)

2 (c) (iii) Give **two** advantages, other than cost, of a continuous process compared with a batch process.

Advantage 1.....
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Advantage 2.....
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(2 marks)

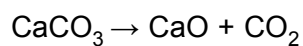


- 2 (d) The reaction that occurs in a lime kiln involves reactants and products that are in different states. What chemical term describes this?

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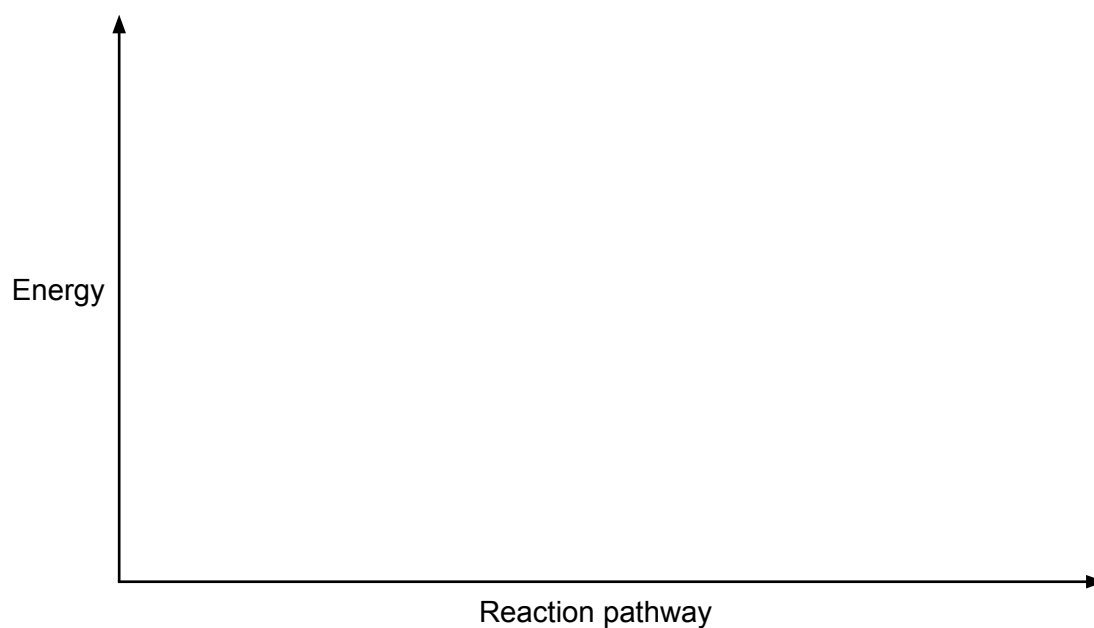
(1 mark)

- 2 (e) The decomposition of calcium carbonate is endothermic:



On **Figure 3**, sketch the reaction profile you would expect for this reaction.

Figure 3



(3 marks)

- 2 (f) Identify **one** environmental problem that the production of calcium oxide contributes to.

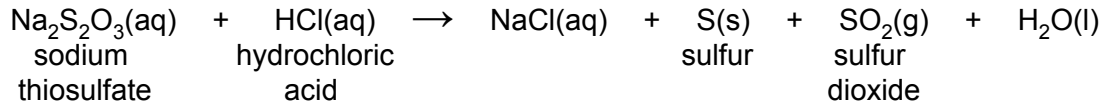
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(1 mark)



3 A chemistry teacher is designing a rate of reaction experiment. The acid decomposition of sodium thiosulfate is to be studied at different temperatures.

3 (a) (i) Balance the equation for the reaction between sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, and hydrochloric acid (HCl):



(2 marks)

3 (a) (ii) Chemical equations must always be balanced. Explain why.

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(1 mark)

3 (b) If 5 cm^3 of 2 mol dm^{-3} hydrochloric acid is added to 50 cm^3 of 0.1 mol dm^{-3} sodium thiosulfate a precipitate of sulfur will form. The precipitate appears as a pale yellow solid and increases over time.

The reaction is therefore usually monitored by measuring how much light can be transmitted through the reaction vessel or by measuring how long it takes for an object to be obscured.

3 (b) (i) Suggest what apparatus the teacher could use to carry out this reaction at different temperatures.

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(3 marks)

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

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(2 marks)



3 (b) (iii) Describe how the experiment to determine the rate of reaction between sodium thiosulfate and hydrochloric acid at different temperatures would be carried out.

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

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(5 marks)

Turn over ▶



3 (b) (iv) 2 mol dm^{-3} hydrochloric acid is an *irritant*.
Explain what irritant means.

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(1 mark)

3 (b) (v) One of the products of the reaction, sulfur dioxide, is toxic.
Suggest a suitable safety precaution for this experiment.

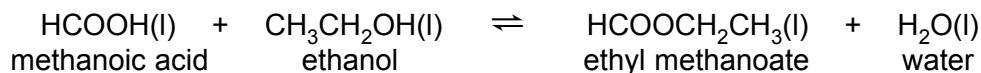
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(1 mark)

15



- 4 Ethyl methanoate, $\text{HCOOCH}_2\text{CH}_3$, is used as solvent. It is produced in the reaction of methanoic acid with ethanol. Industrial chemists must control the reaction to get the best yield.



- 4 (a) This reaction is reversible and therefore, after some time, a *dynamic equilibrium* is established.

- 4 (a) (i) Explain what is meant by a dynamic equilibrium.

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(2 marks)

- 4 (a) (ii) Write an expression for the equilibrium constant, K_c , for this reaction.

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(2 marks)

Question 4 continues on the next page

Turn over ▶



4 (b) What effect will an increase in the concentration of ethanol have on the equilibrium yield of ethyl methanoate?

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

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

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(5 marks)



- 4 (c)** Use Le Chatelier's principle to decide what effect increasing the pressure will have on the yield of ethyl methanoate.
Explain your answer.

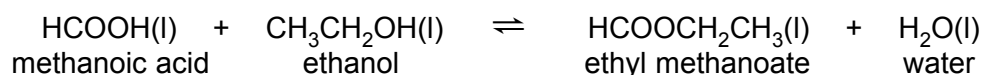
Effect.....

Explanation

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(3 marks)

- 4 (d)** Chemical engineers must know the enthalpy change for the reaction that occurs. Both enthalpy of formation data and *mean bond enthalpy* data can be used to calculate an enthalpy change.



- 4 (d) (i)** Use the enthalpy of formation data in **Table 2** to calculate the enthalpy change when one mole of ethyl methanoate is made from ethanol and methanoic acid.

Table 2

	HCOOH	CH ₃ CH ₂ OH	HCOOCH ₂ CH ₃	H ₂ O
Enthalpy of formation/ kJ mol ⁻¹	-425.0	-277.1	-371.0	-237.2

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Enthalpy change =

(4 marks)

Turn over ▶



4 (d) (ii) Explain the meaning of the term mean bond enthalpy.

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(2 marks)

4 (d) (iii) Use the mean bond enthalpy data in **Table 3** to calculate the enthalpy change when one mole of ethyl methanoate is made from ethanol and methanoic acid:

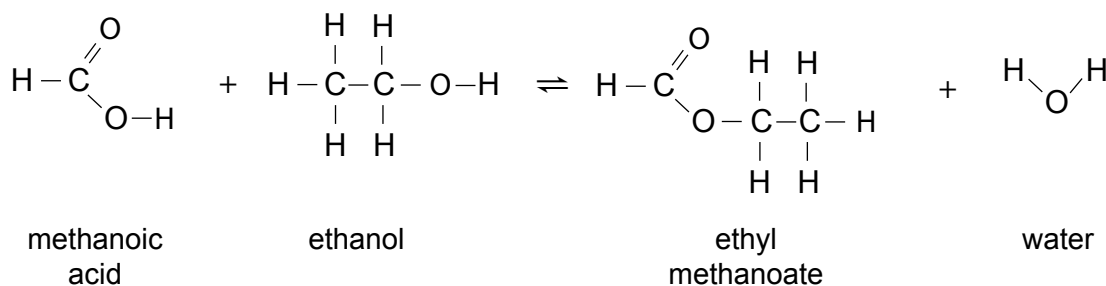


Table 3

	C-C	C=O	C-O	H-C	O-H
Mean bond enthalpy/kJ mol ⁻¹	347	749	358	413	464

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Enthalpy change =

(4 marks)



4 (d) (iv) Explain why the value calculated in part (d) (iii) is not the same as that calculated in (d) (i).

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(1 mark)

23

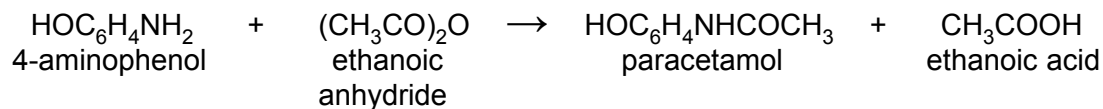
Turn over for the next question

Turn over ▶



- 5** The manufacture of pharmaceuticals often involves reactions that have a relatively low yield. This is often because the syntheses involve several stages.

4-aminophenol and ethanoic anhydride are reacted in the final stage of the synthesis of paracetamol:



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

M_r 4-aminophenol

.....

M_r paracetamol

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(2 marks)

- 5 (a) (ii)** Paracetamol is often sold as 500 mg tablets. There are usually 16 in a pack. How many packs of tablets would a manufacturer be able to produce from 8 kg paracetamol?

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(2 marks)

- 5 (a) (iii)** Calculate the mass of 4-aminophenol required to produce 8 kg paracetamol. Assume 100% yield is achieved.

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Mass =

(3 marks)



5 (b) Many of the stages in the production of paracetamol produce a yield much lower than 100%.

5 (b) (i) Suggest why.

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(1 mark)

5 (b) (ii) Calculate the percentage yield of a reaction in which the theoretical yield was 20.4 kg but the actual yield was 7.3 kg.

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Percentage yield =

(1 mark)

9

END OF QUESTIONS



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