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**Chemistry**  
**Standard level**  
**Paper 2**

Friday 14 May 2021 (morning)

Candidate session number

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1 hour 15 minutes

**Instructions to candidates**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.



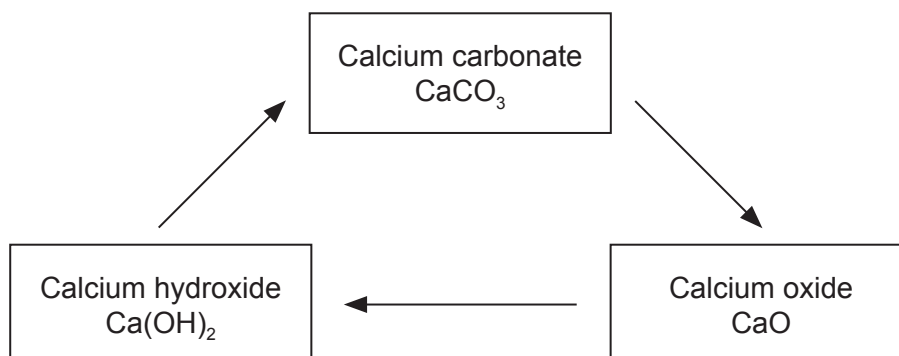
Please **do not** write on this page.

Answers written on this page  
will not be marked.



Answer **all** questions. Answers must be written within the answer boxes provided.

1. Limestone can be converted into a variety of useful commercial products through the lime cycle. Limestone contains high percentages of calcium carbonate,  $\text{CaCO}_3$ .



- (a) Calcium carbonate is heated to produce calcium oxide,  $\text{CaO}$ .



Calculate the volume of carbon dioxide produced at STP when 555g of calcium carbonate decomposes. Use sections 2 and 6 of the data booklet.

[2]

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**(Question 1 continued)**

(b) Thermodynamic data for the decomposition of calcium carbonate is given.

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
$\text{CaCO}_3(\text{s})$	-1207
$\text{CaO}(\text{s})$	-635
$\text{CO}_2(\text{g})$	-393.5

Calculate the enthalpy change of reaction,  $\Delta H$ , in kJ, for the decomposition of calcium carbonate. [2]

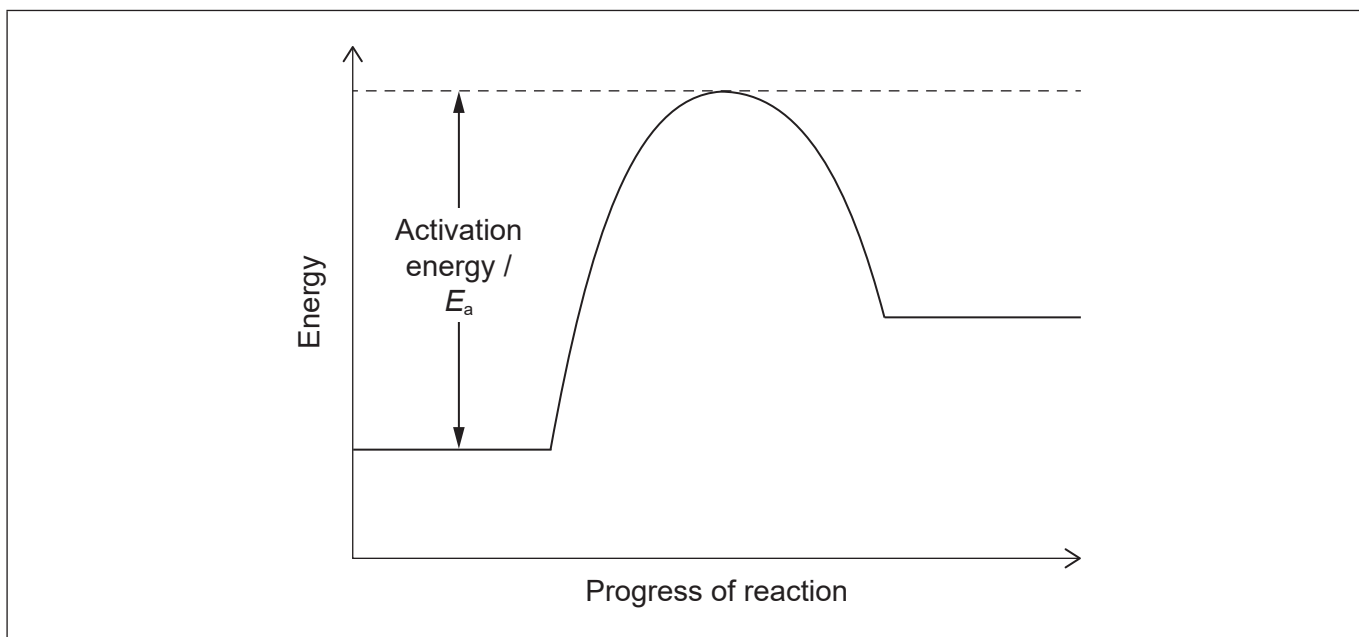
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(c) (i) The potential energy profile for a reaction is shown. Sketch a dotted line labelled "Catalysed" to indicate the effect of a catalyst. [1]



**(This question continues on the following page)**



**(Question 1 continued)**

- (ii) Outline why a catalyst has such an effect. [1]

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- (d) The second step of the lime cycle produces calcium hydroxide,  $\text{Ca(OH)}_2$ .

- (i) Write the equation for the reaction of  $\text{Ca(OH)}_2(\text{aq})$  with hydrochloric acid,  $\text{HCl}(\text{aq})$ . [1]

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- (ii) Determine the volume, in  $\text{dm}^3$ , of  $0.015 \text{ mol dm}^{-3}$  calcium hydroxide solution needed to neutralize  $35.0 \text{ cm}^3$  of  $0.025 \text{ mol dm}^{-3}$   $\text{HCl}(\text{aq})$ . [2]

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- (iii) Saturated calcium hydroxide solution is used to test for carbon dioxide. Calculate the pH of a  $2.33 \times 10^{-2} \text{ mol dm}^{-3}$  solution of calcium hydroxide, a strong base. [2]

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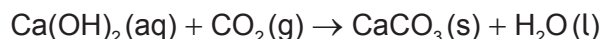
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(Question 1 continued)

(e) Calcium hydroxide reacts with carbon dioxide to reform calcium carbonate.



(i) Determine the mass, in g, of  $\text{CaCO}_3(\text{s})$  produced by reacting  $2.41 \text{ dm}^3$  of  $2.33 \times 10^{-2} \text{ mol dm}^{-3}$  of  $\text{Ca(OH)}_2(\text{aq})$  with  $0.750 \text{ dm}^3$  of  $\text{CO}_2(\text{g})$  at STP. [2]

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(ii) 2.85 g of  $\text{CaCO}_3$  was collected in the experiment in e(i). Calculate the percentage yield of  $\text{CaCO}_3$ .

(If you did not obtain an answer to e(i), use 4.00 g, but this is not the correct value.) [1]

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(f) Outline how **one** calcium compound in the lime cycle can reduce a problem caused by acid deposition. [1]

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2. The properties of elements can be predicted from their position in the periodic table.

(a) (i) Explain why Si has a smaller atomic radius than Al. [2]

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(ii) Explain the decrease in radius from Na to Na<sup>+</sup>. [2]

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(b) (i) State the condensed electron configurations for Cr and Cr<sup>3+</sup>. [2]

Cr:  
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Cr<sup>3+</sup>:  
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(ii) Describe metallic bonding and how it contributes to electrical conductivity. [3]

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**(Question 2 continued)**

(c) Deduce the Lewis (electron dot) structure and molecular geometry of sulfur dichloride,  $\text{SCl}_2$ . [2]

Species	$\text{SCl}_2$
Lewis structure	
Molecular geometry	.....

(d) Suggest, giving reasons, the relative volatilities of  $\text{SCl}_2$  and  $\text{H}_2\text{O}$ . [3]

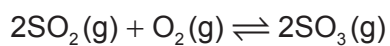
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**(Question 2 continued)**

(e) Consider the following equilibrium reaction:



State and explain how the equilibrium would be affected by increasing the volume of the reaction container at a constant temperature.

[3]

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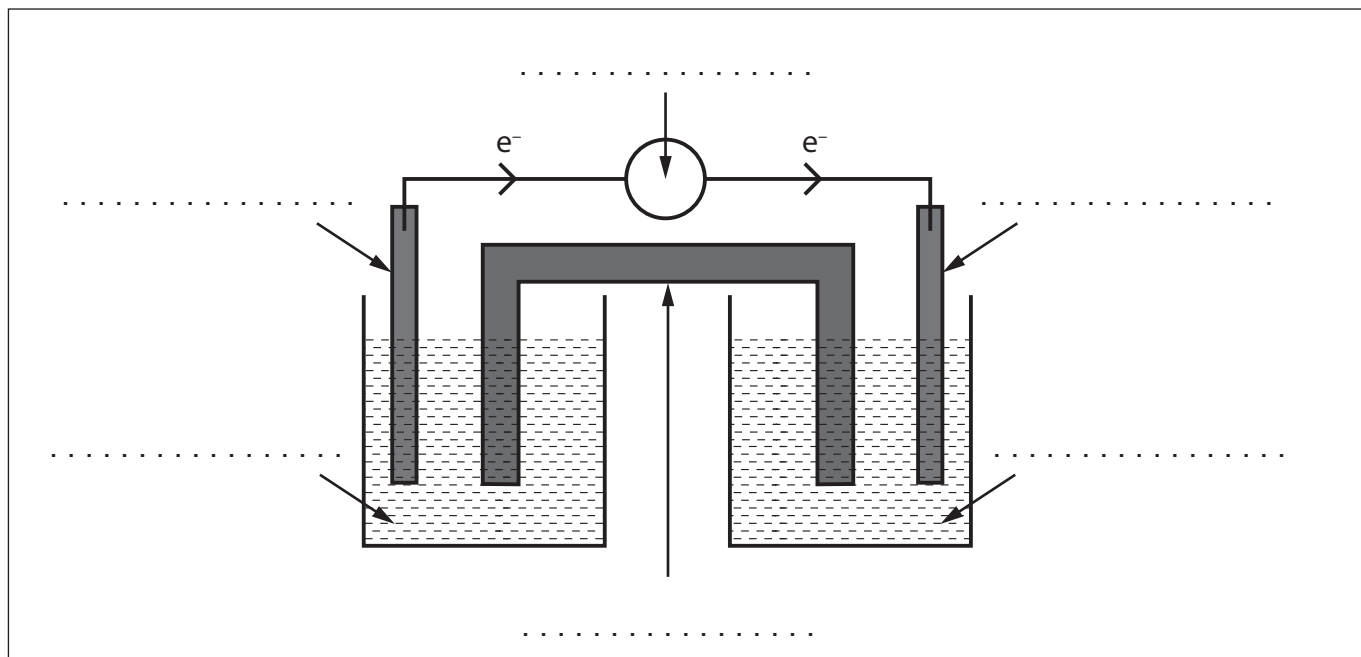
3. Oxidation and reduction reactions can have a variety of commercial uses.

- (a) A student decides to build a voltaic cell consisting of an aluminium electrode, Al(s), a tin electrode, Sn(s), and solutions of aluminium nitrate, Al(NO<sub>3</sub>)<sub>3</sub>(aq) and tin(II) nitrate, Sn(NO<sub>3</sub>)<sub>2</sub>(aq).

Electron flow is represented on the diagram.

Label each line in the diagram using section 25 of the data booklet.

[3]



- (b) Write the equation for the expected overall chemical reaction in (a).

[1]

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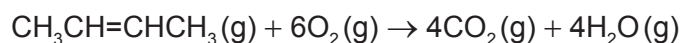


4. Organic chemistry can be used to synthesize a variety of products.

- (a) Several compounds can be synthesized from but-2-ene. Draw the structure of the final product for each of the following chemical reactions. [2]



- (b) Determine the change in enthalpy,  $\Delta H$ , for the combustion of but-2-ene, using section 11 of the data booklet. [3]



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- (c) Write the equation and name the organic product when ethanol reacts with methanoic acid. [2]

Equation:

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Product name:

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**(Question 4 continued)**

- (d) Oxidation of ethanol with potassium dichromate,  $K_2Cr_2O_7$ , can form two different organic products. Determine the names of the organic products and the methods used to isolate them. [2]

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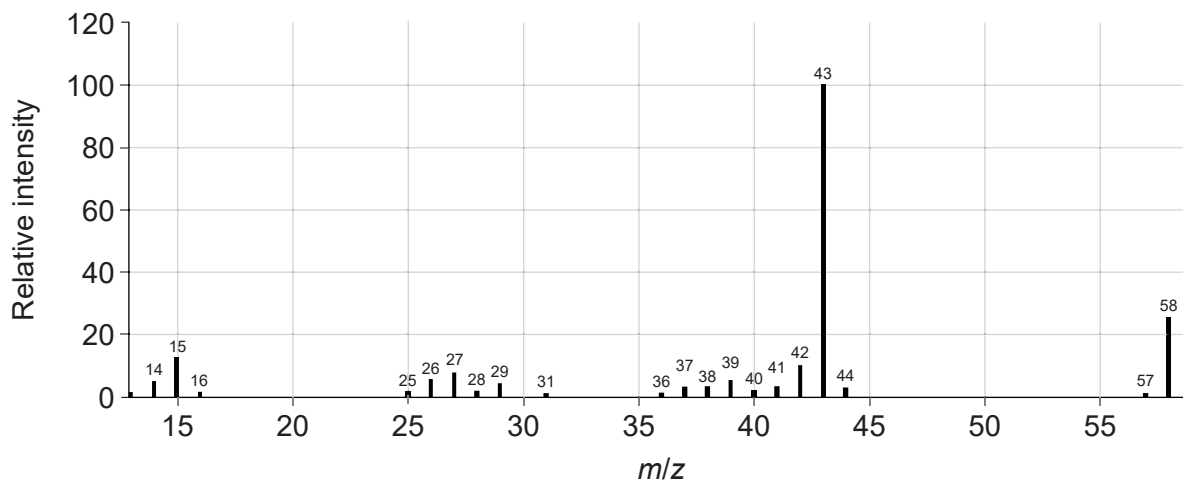
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- (e) Combustion analysis of an unknown organic compound indicated that it contained only carbon, hydrogen and oxygen.

- (i) Deduce two features of this molecule that can be obtained from the mass spectrum. Use section 28 of the data booklet. [2]



*m/z* 58:

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*m/z* 43:

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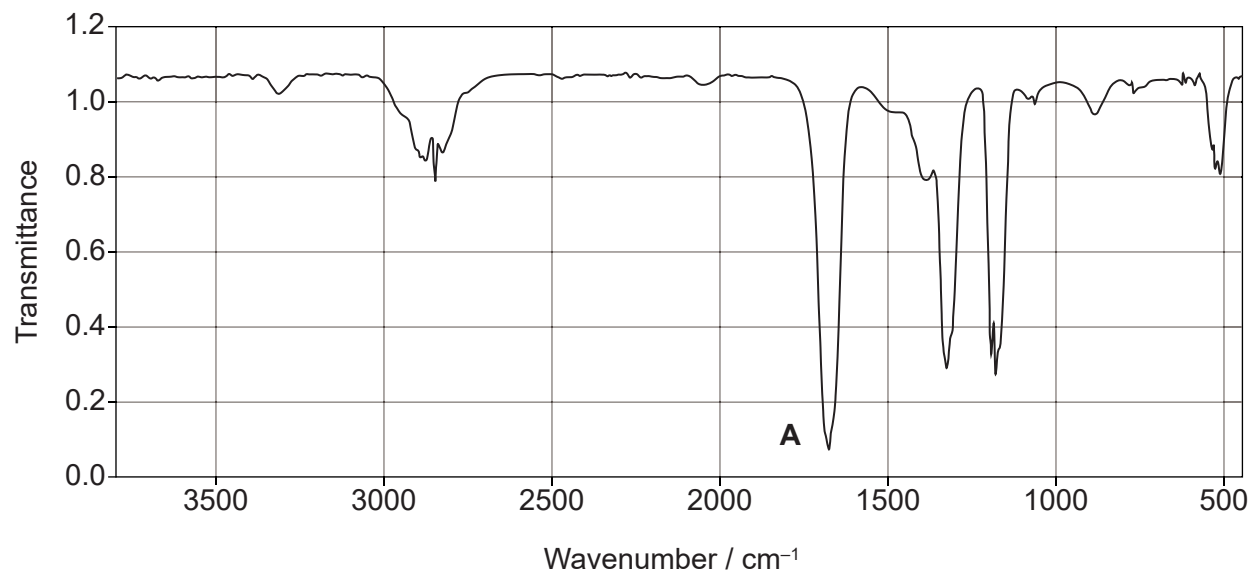
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(Question 4 continued)

- (ii) Identify the bond responsible for the absorption at **A** in the infrared spectrum.  
Use section 26 of the data booklet.

[1]



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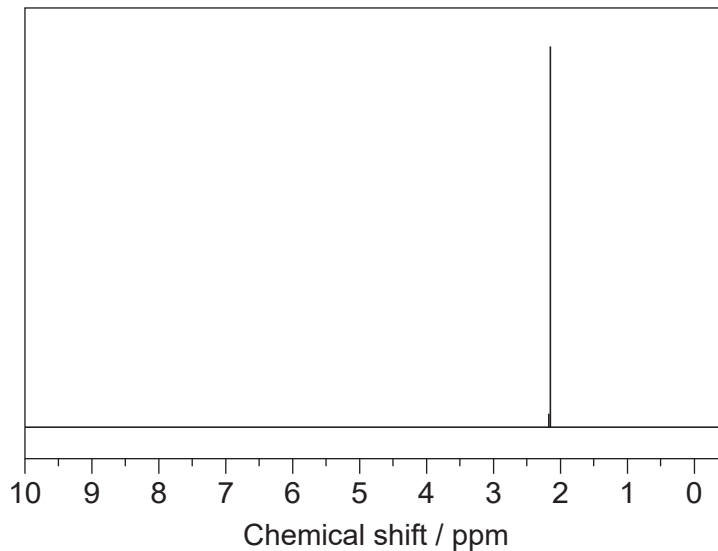
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**(Question 4 continued)**

- (iii) Deduce the identity of the unknown compound using the previous information, the  $^1\text{H}$  NMR spectrum and section 27 of the data booklet. [2]

$^1\text{H}$  NMR spectrum



Information deduced from  $^1\text{H}$  NMR:

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Compound:

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**References:**

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16EP16