Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Friday 14 May 2021 (morning)

1 hour 15 minutes

Candidate session number

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]**.

2221 – 6117

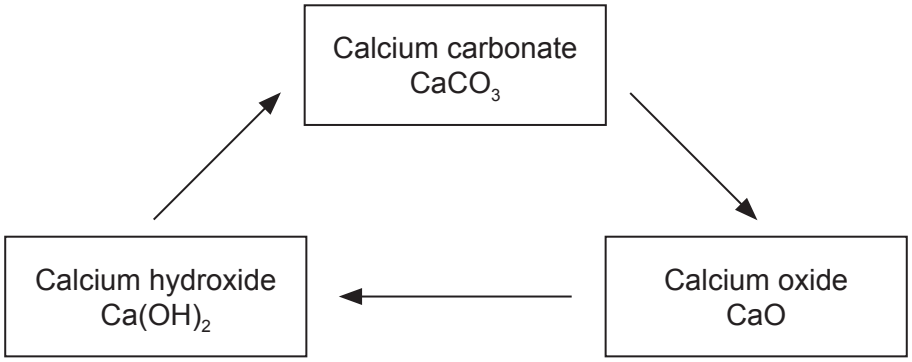
14 pages

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, $CaCO_3$.



(a) Calcium carbonate is heated to produce calcium oxide, CaO.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Calculate the volume of carbon dioxide produced at STP when 555 g 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	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CaCO_3(s)$	–1207
$CaO(s)$	–635
$CO_2(g)$	–393.5

Calculate the enthalpy change of reaction, ΔH, in kJ, for the decomposition of calcium carbonate. [2]

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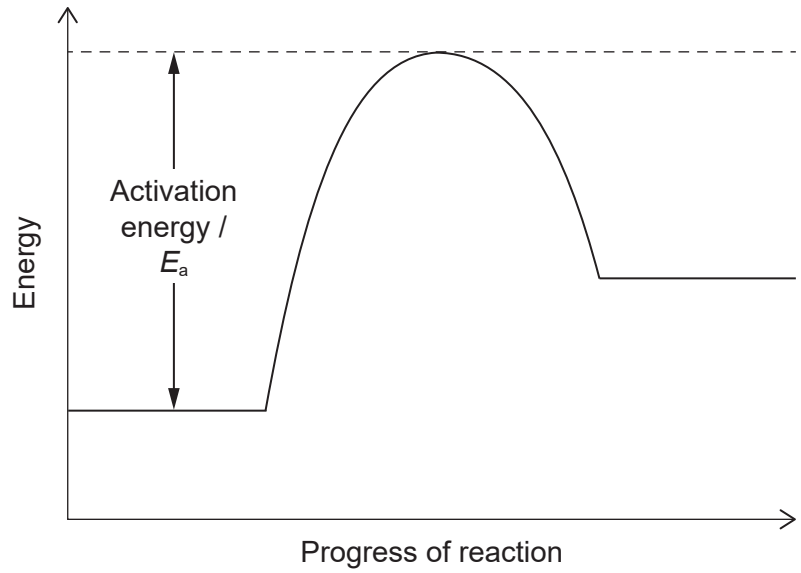
(c) (i) The potential energy profile for a reaction is shown. Sketch a dotted line labelled "Catalysed" to indicate the effect of a catalyst. [1]



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(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, $Ca(OH)_2$.

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

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

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

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(Question 1 continued)

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

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

(i) Determine the mass, in g, of $CaCO_3(s)$ produced by reacting $2.41\,dm^3$ of $2.33 \times 10^{-2}\,mol\,dm^{-3}$ of $Ca(OH)_2(aq)$ with $0.750\,dm^3$ of $CO_2(g)$ at STP. [2]

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(ii) 2.85 g of $CaCO_3$ was collected in the experiment in e(i). Calculate the percentage yield of $CaCO_3$.

(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^+. [2]

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(b) (i) State the condensed electron configurations for Cr and Cr^{3+}. [2]

Cr:

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Cr^{3+}:

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(ii) Describe metallic bonding and how it contributes to electrical conductivity. [3]

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(This question continues on the following page)

(Question 2 continued)

(c) Deduce the Lewis (electron dot) structure and molecular geometry of sulfur dichloride, SCl_2. [2]

Species	**SCl_2**
Lewis structure	
Molecular geometry	. . . . .

(d) Suggest, giving reasons, the relative volatilities of SCl_2 and H_2O. [3]

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(Question 2 continued)

(e) Consider the following equilibrium reaction:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

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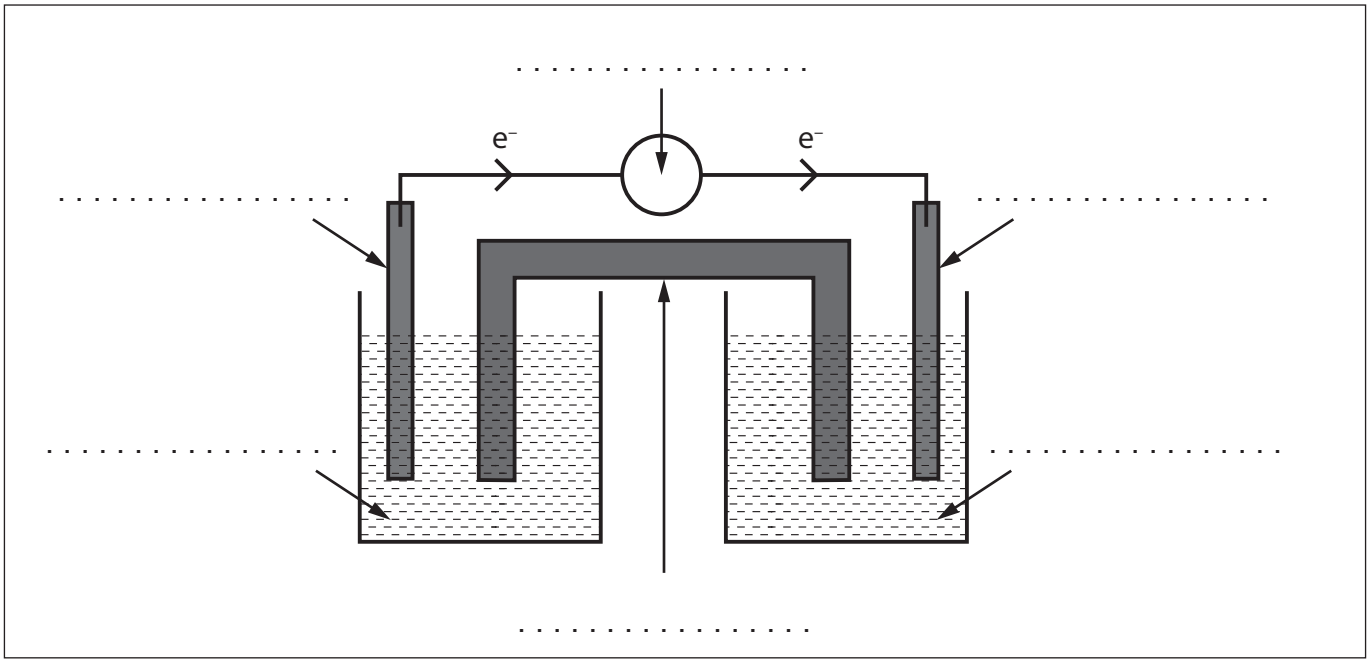
3. Oxidation and reduction reactions can have a variety of commercial uses.

(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, $Al(NO_3)_3(aq)$ and tin(II) nitrate, $Sn(NO_3)_2(aq)$.

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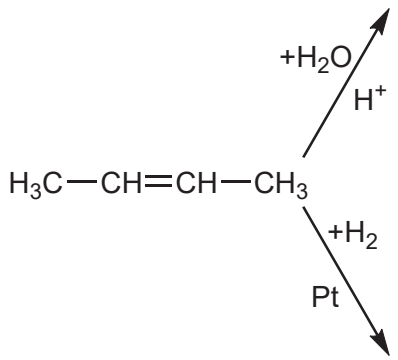
4. Organic chemistry can be used to synthesize a variety of products.

(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]



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

$$CH_3CH{=}CHCH_3(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$$

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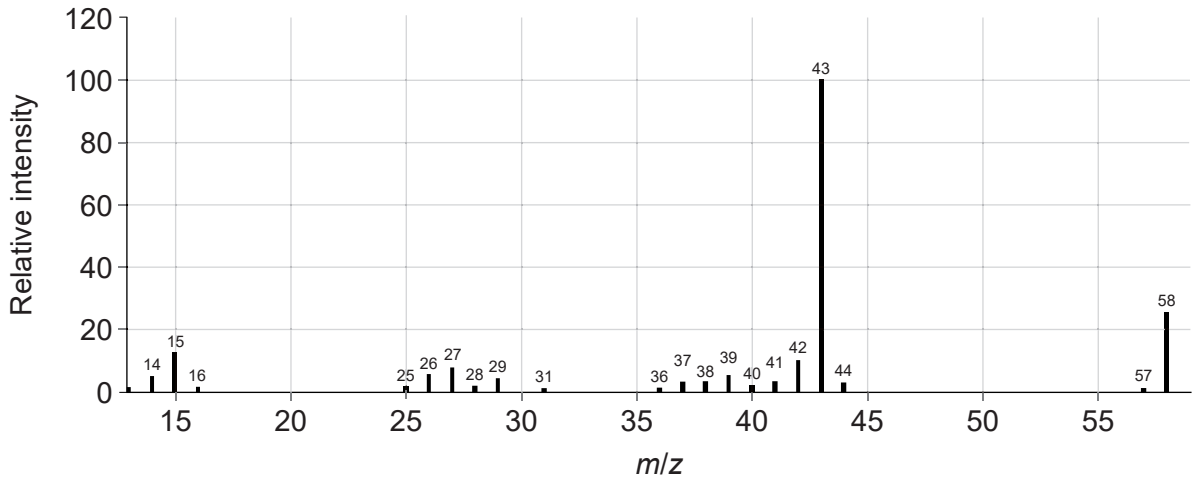
(e) Combustion analysis of an unknown organic compound indicated that it contained only carbon, hydrogen and oxygen.

(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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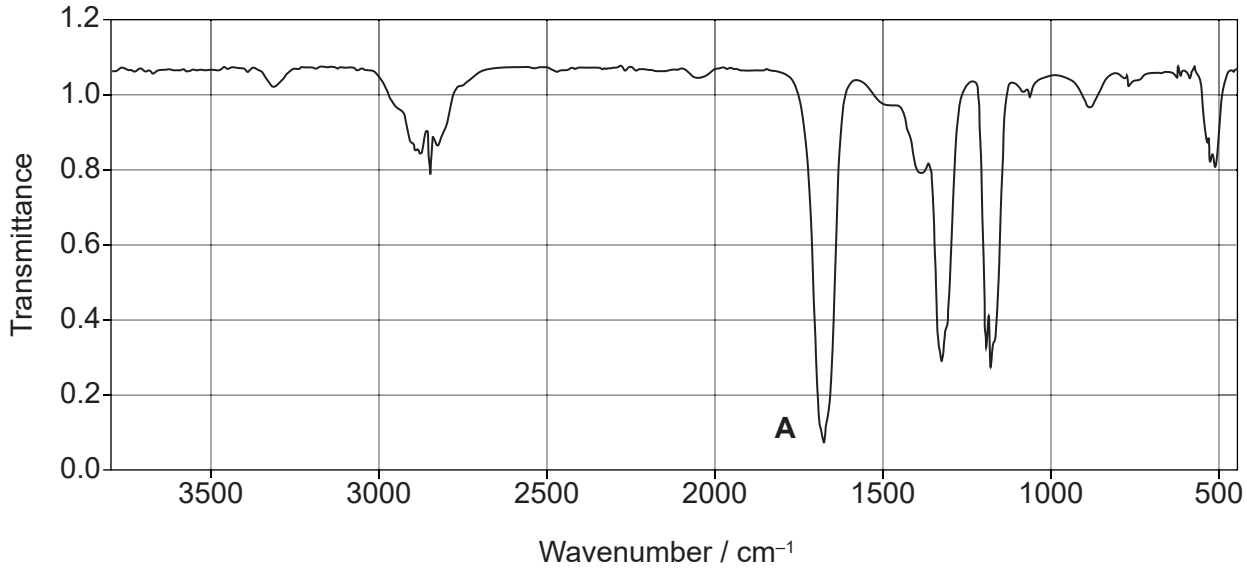
(Question 4 continued)

(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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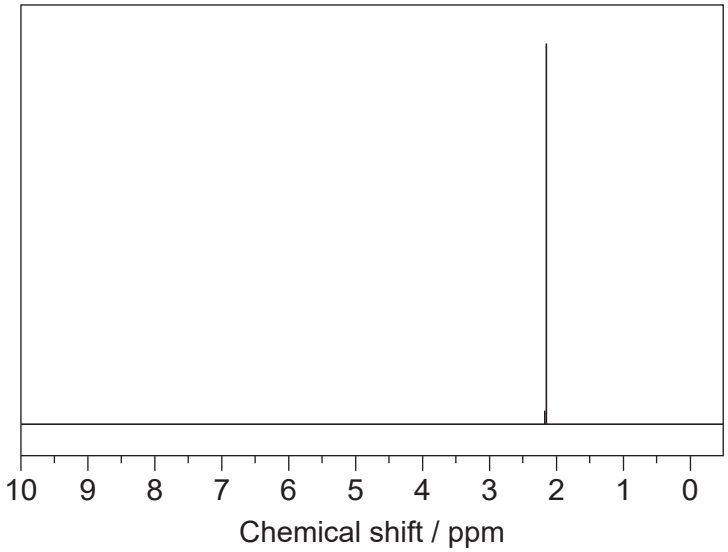
(Question 4 continued)

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

^{1}H NMR spectrum



Information deduced from ^{1}H NMR:

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Compound:

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References:

4.(e)(i) NIST Mass Spectrometry Data Center Collection © 2014 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved.

4.(e)(ii) NIST Mass Spectrometry Data Center Collection © 2014 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved.

4.(e)(iii) SDBS, National Institute of Advanced Industrial Science and Technology (AIST).

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