HWA CHONG INSTITUTION
C2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**19S**
CENTRE NUMBER		**INDEX NUMBER**	

CHEMISTRY

9729/03

Paper 3 Free Response Questions

15 September 2020

2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your **name**, **CT group, centre number** and **index number** clearly in the spaces above.

Write in dark blue or black pen.

You may use a HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

Section A

Answer **all** the questions.

Section B

Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

No. of sheets of writing paper submitted (write 0 if none)	

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1	**/ 25**
2	**/ 16**
3	**/ 19**
Circle your option below	
4 / 5	**/ 20**
Deductions	
Total	**/ 80**

Section A

Answer **all** the questions in this section.

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1 To date, the COVID-19 pandemic has infected more than 18 million people. The disease is caused by the SARS-CoV-2 coronavirus, whose general structure is shown in Fig. 1.1, with some of its parts labelled.

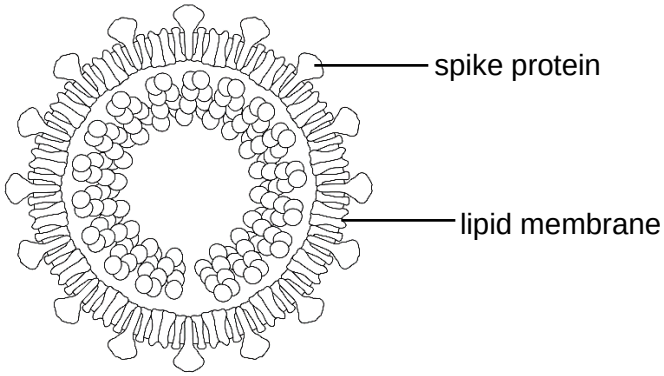
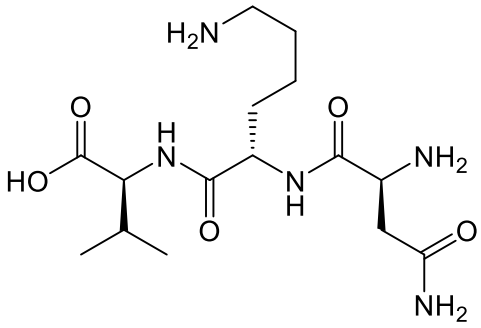


Fig. 1.1

(a) The spike proteins on the surface of the virus' membrane facilitate the entry of the virus into the host cell.

The tripeptide below was obtained from partial hydrolysis of the spike proteins.



(i) Draw the structures of the organic products obtained when the tripeptide is hydrolysed completely by heating with H_2SO_4(aq). [3]

(ii) Using **one** of the products from **(i)** and the aid of a suitable drawing, explain why it exhibits enantiomerism. [2]

(iii) Explain why the virus will no longer be able to enter the host cell if the amino acids in the protein sequence were swapped with their enantiomers. [1]

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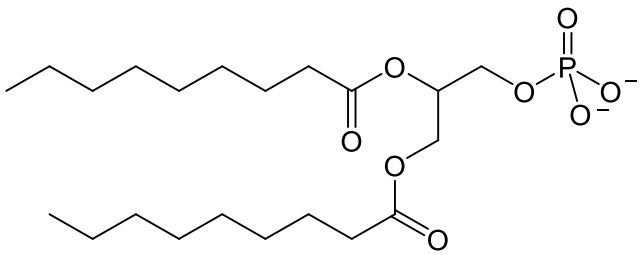
(b) The transmission of COVID-19 may be mitigated by the use of hand sanitisers, frequent washing of hands with soap and water, or wearing of N95 masks.

(i) The structure of the phospholipid particles that make up the lipid membrane of the virus is shown below in Fig. 1.2.



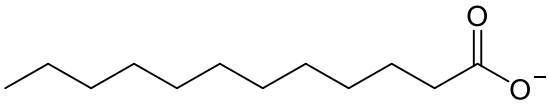
phospholipid

Fig. 1.2

The alcohol content in hand sanitisers destroy the lipid membrane by initially forming hydrogen bonds with it.

On Fig. 1.2 above, illustrate a hydrogen bond formed between an ethanol molecule and a phospholipid particle. [2]

(ii) The structure of a soap particle is shown below.



Describe the chemical interactions between the soap particle and the lipid membrane, and hence suggest how soap and water together break up the membrane of the virus. [2]

(iii) Contrary to common belief, N95 masks do not work like filters. Instead the fibers that make up the fabric of the mask are permanently charged on the surface. This allows the fiber to capture dust in the air or droplets that contain the coronavirus.

The surface of the fibers may be positively or negatively charged depending on the manufacturing method. An example of a strand of positively charged fiber is shown in Fig. 1.3.

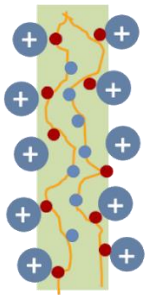


Fig. 1.3

Assuming that dust particles behave like non-polar simple molecules, describe the chemical interactions that form between the fiber and dust particles. Explain how these interactions arise. [2]

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(c) Another area of interest is the study of how long coronaviruses can survive on surfaces. It was found that coronaviruses have a far shorter life span on copper metal than many other surfaces.

Describe the structure and bonding present in copper metal. [2]

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(d) Many falsehoods surfaced during the pandemic, one of which is the claim that malaria drugs chloroquine and hydroxychloroquine are effective against the disease. This claim has not been verified in any controlled studies.

A proposed synthesis route for chloroquine is shown below in Fig. 1.4.

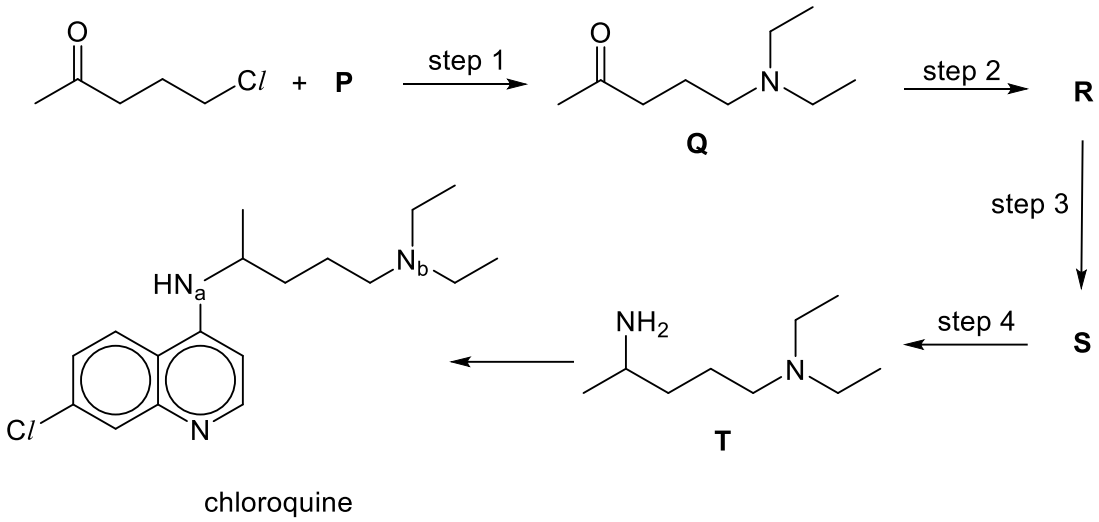


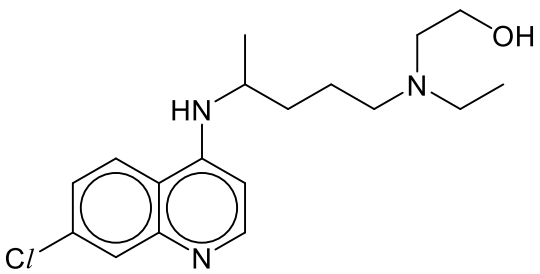
Fig. 1.4

(i) Draw the structure of **P**. [1]

(ii) Suggest reagents and conditions for steps 2 to 4, and draw the structures of compounds **R** and **S**. [5]

(iii) Describe and explain how the basicity of the nitrogen functional group labelled N_a would compare to that labelled N_b. [3]

(iv)



hydroxychloroquine

Describe a simple chemical test to distinguish between chloroquine and hydroxychloroquine, giving observations for each compound. [2]

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[Total: 25]

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2 (a) The Winkler method is used to determine the concentration of dissolved oxygen in water samples. This experiment is conducted in 2 stages.

Stage 1

An excess of manganese(II) ions and hydroxide ions are added to a water sample, causing a precipitate of manganese(II) hydroxide to form.

This precipitate is then oxidised by the dissolved oxygen in the water sample into a manganese(III) hydroxide precipitate.

$$4Mn(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Mn(OH)_3(s)$$

Stage 2

An excess of acidified potassium iodide is then added to dissolve the manganese(III) hydroxide precipitate to form manganese(III) ions, which oxidise iodide ions to iodine. Iodine is then titrated against a standard solution of 0.0100 mol dm^{-3} sodium thiosulfate.

$$2Mn^{3+}(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Mn^{2+}(aq)$$

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

(i) With the aid of the *Data Booklet*, describe an observation which would suggest that the reaction in Stage 1 has occurred. [1]

(ii) Fish require oxygen concentrations of at least 3 mg dm^{-3} to survive.

A 500 cm^3 sample of pond water was analysed using the Winkler method. It took 12.60 cm^3 of sodium thiosulfate solution to react completely with the iodine.

Calculate the concentration of dissolved oxygen in mg dm^{-3}, and comment if fish can survive in this pond. [3]

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(b) Water samples taken near mines are often contaminated with heavy metal ions such as copper(II) ions.

The solubility of copper(II) hydroxide in water is 3.00×10^{-6} mol dm^{-3}.

(i) Write an expression for the solubility product, K_{sp}, of copper(II) hydroxide and calculate its value, giving its units. [3]

(ii) The maximum contaminant level goal (MCLG) is the concentration of a contaminant in drinking water below which there is no known or expected risk to health.

The MCLG for copper(II) ions is 1.3 mg dm^{-3}. On the basis of the concentration of copper(II) ions alone, determine if a water sample whose pH was found to be 8.73, is safe for consumption. [2]

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(c) A breathalyser is a device to estimate the concentration of ethanol vapour in a breath sample.

In the newer models, fuel cell sensors rely on an electrochemical process that oxidises ethanol into ethanoic acid and produces an electrical current. The strength of the current corresponds to the concentration of ethanol present in the sample. The fuel cell set-up shown in Fig. 2.1 consists of two platinum electrodes that are partitioned by a porous acid-electrolyte material.

(i) On Fig. 2.1, indicate the polarity of each electrode and the direction of electron flow through the wires. [2]

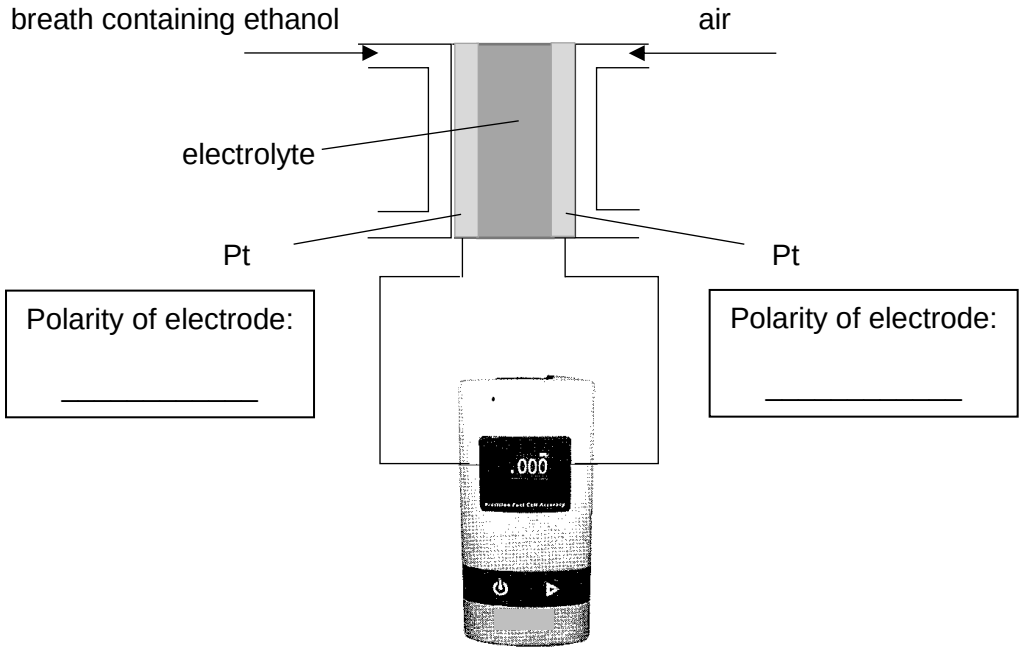

Fig. 2.1

(ii) Write an ion-electron equation to show the oxidation of ethanol to form ethanoic acid. [1]

(iii) Write an equation to show the overall reaction taking place inside the fuel cell. [1]

(iv) Given the data in Table 2.1, calculate $\Delta G^{\ominus}_{r}$ of the reaction in **(iii)**, and hence find the standard cell potential of this cell.

Table 2.1

compound	$\Delta G^{\ominus}_{f}$ / kJ mol^{-1}
$CH_3CH_2OH(g)$	–174
$CH_3CO_2H(l)$	–389
$H_2O(l)$	–237

[2]

(v) Suggest a reason why a person who has just smoked might give a false positive test when using this breathalyser. [1]

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[Total: 16]

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3 (a) Cyclobutane can decompose to form ethene as shown in the following equation.

$$\square\,(g) \longrightarrow 2\ CH_2{=}CH_2(g) \qquad \Delta H_1$$

To determine ΔH_1, the enthalpy change of combustion of cyclobutane is first determined by the following experiment.

A sample of cyclobutane was burned under laboratory conditions in an apparatus that trapped 80% of the heat evolved by heating a container of water. The burning of 1.00 g of cyclobutane raised the temperature of 200 g of water from 20.0 °C to 67.0 °C.

(i) Define the term *standard enthalpy change of combustion*. [1]

(ii) Calculate the experimental enthalpy change of combustion of cyclobutane. [2]

(iii) Given that the enthalpy change of combustion of ethene is −1422 kJ mol^{-1} and using your answer in **(ii)**, calculate ΔH_1. [1]

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(b) (i) Ethene reacts readily with aqueous bromine under room temperature. Describe the mechanism for this reaction, giving the major organic product. In your answer, you should show all charges, lone pairs and show the movement of electrons by curly arrows. [3]

(ii) In some circumstances, double bonds may undergo a nucleophilic addition reaction.

Use the concepts of electronic effect and delocalisation to explain the following in Fig. 3.1.

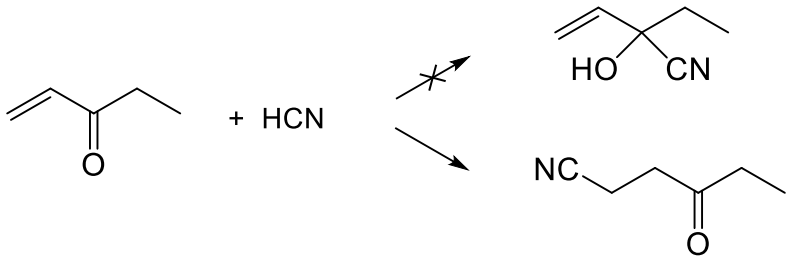

Fig. 3.1 [2]

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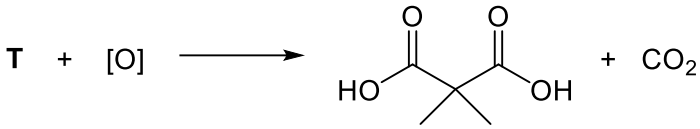
(c) This question involves ketoacids of the form $RCOCO_2H$ which can be oxidised in the following way.

$$RCOCO_2H + [O] \rightarrow RCO_2H + CO_2$$

Ketoacid **T**, $C_6H_8O_5$, can be oxidised as shown below to form 2,2-dimethylpropan-1,3-dioic acid.



2,2-dimethylpropan-1,3-dioic acid

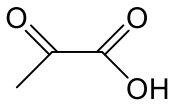
(i) Draw the structure of **T**. [1]

P, $C_9H_{12}O$, reacts with $NaBH_4$ in methanol to give **Q**, $C_9H_{14}O$.

P also reacts with hydrogen in the presence of Ni catalyst to give **R**, $C_9H_{18}O$.

On warming **P** with Tollens' reagent, followed by acidification, **S**, $C_9H_{12}O_2$, is formed. **S** contains a five-membered ring of carbon atoms.

When heated with acidified $KMnO_4$, **S** forms the ketoacid **T** in **(i)**, and **U**.



U

(ii) Deduce the structures of **P**, **Q**, **R**, **S** and explain the observations described above. [9]

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Section B

Answer **one** question from this section

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4 (a) The pH values of the solutions of three Period 3 chlorides are given in Table 4.1.

Table 4.1

compound	pH of 1.0 mol dm^{-3} solution
NaCl	7.0
$AlCl_3$	3.0
$SiCl_4$	1.0

(i) Suggest explanations for the pH values of the three chloride solutions. Include appropriate equation(s) in your answer. [4]

(ii) Using suitable data from the *Data Booklet*, suggest the pH value of 1.0 mol dm^{-3} solution of $FeCl_3$. Explain your answer. [2]

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(b) Although iron is a widely used metal, it has a major disadvantage in that it readily corrodes in the presence of oxygen and water. The corrosion is a multi-step electrochemical process which occurs on the surface of the iron. Iron is first oxidised to iron(II) ions, which then precipitates as iron(II) hydroxide under mildly alkaline conditions. Iron(II) hydroxide readily gets oxidised and eventually forms rust.

(i) Calculate the standard cell potential for the oxidation of iron to iron(II) ions in the rusting process described above. [1]

(ii) Explain how the cell potential in **(i)** is affected by the precipitation of iron(II) ions as iron(II) hydroxide. [3]

(iii) Using data from the *Data Booklet*, explain why iron(II) hydroxide readily gets oxidised. Write a balanced equation for the reaction that occurs. [2]

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(c) A student suggested the synthesis in Fig. 4.1 for 4-aminosalicylic acid, a drug that was widely used against tuberculosis.

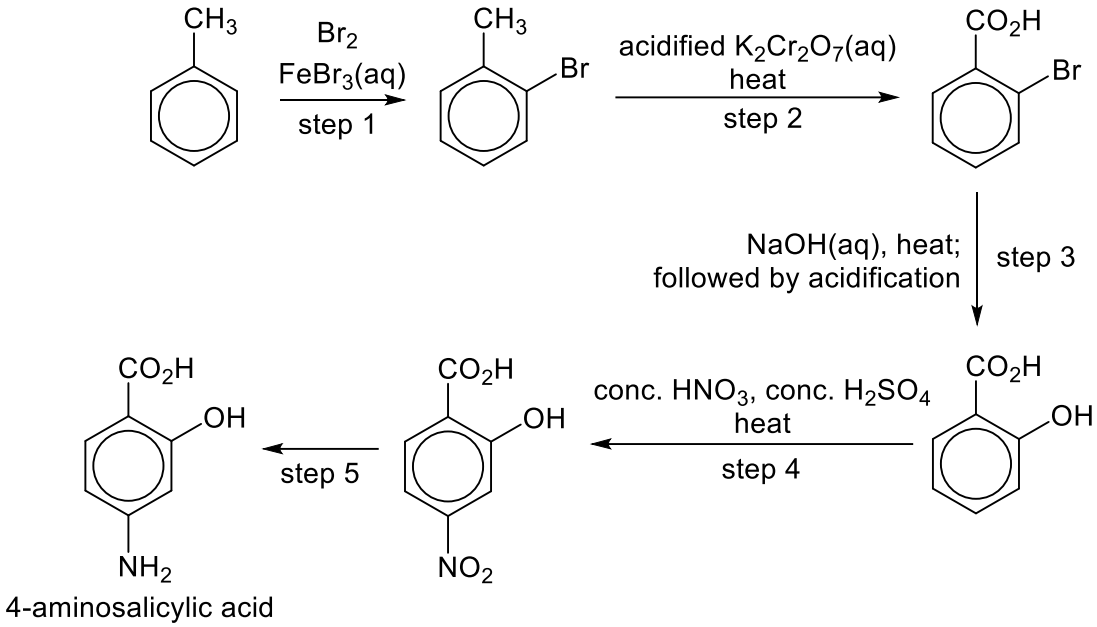

Fig. 4.1

(i) Explain why steps 1 to 4 are **not** ideal. [4]

(ii) Suggest reagents and conditions for step 5. [1]

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(d) Iron is an essential element for all forms of life, mainly found in haemoglobin in the blood. The pH of blood is maintained at 7.35 by a H_2CO_3/HCO_3^- buffer.

With the aid of equations, explain how the H_2CO_3/HCO_3^- buffer helps to maintain the pH of the blood. [3]

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[Total: 20]

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5 (a) (i) The acid-base behaviour of aluminium oxide, Al_2O_3, shows similarities to that of magnesium oxide, MgO, on the one hand, and phosphorus(V) oxide, P_4O_{10}, on the other.
Describe what these similarities are, and write balanced equations for all the reactions you choose to illustrate your answer. [3]

(ii) Kaolinite is an aluminosilicate clay with the formula $xAl_2O_3.ySiO_2.zH_2O$ and a molar mass of 258 g mol^{-1}.

When 1.80 g of kaolinite was heated to complete dryness, a mass loss of 0.251 g was detected.

35.0 cm^3 of 1.20 mol dm^{-3} solution of hydrochloric acid was found to react completely with the remaining residue.

Determine the values of *x*, *y* and *z*. [4]

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(b) Alumina, Al_2O_3 and silica, SiO_2 have very high melting points which make them good refractory materials to withstand the very high temperatures in industrial processes. Explain the high melting points of Al_2O_3 and SiO_2 in terms of their structures and bondings. [3]

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(c) Bauxite is an ore which contains aluminium oxide and other solid impurities.
Aluminium is extracted by electrolysis, using purified molten aluminium oxide as an electrolyte.

(i) Write equations for the reactions that occur at the anode and cathode respectively in this electrolysis. [2]

(ii) By selecting appropriate $E^{\ominus}$ values from the *Data Booklet*, explain why extraction of aluminium cannot be achieved by the electrolysis of aqueous aluminium salt. [2]

(iii) An aluminium plant consumed an average of 2.28×10^6 kg bauxite per year.
Assuming bauxite contains only 60% by mass of aluminium oxide, calculate the charge that runs through the electrolytic cell and the mass of aluminium produced per year. [3]

(d) The reaction of powdered aluminium with iron(III) oxide, known as the thermite reaction, generates an enormous amount of heat, enough to melt steel. The balanced chemical equation for this reaction is as follows.

$$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(s) + Al_2O_3(s) \qquad \Delta H_r$$

Table 5.1

	$\Delta H^{\ominus}$ / kJ mol^{-1}
$Al(s) + \frac{1}{2} Fe_2O_3(s) \rightarrow \frac{1}{2} Al_2O_3(s) + Fe(l)$	-366.3
$Fe(s) \rightarrow Fe(l)$	+59.3

Using the data in Table 5.1, draw an energy level diagram to calculate ΔH_r. [3]

[Total: 20]

Additional answer space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

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