Class/ Index Number	Centre Number/ 'O' Level Index Number	Name
/	/	

新加坡海星中学

MARIS STELLA HIGH SCHOOL
PRELIMINARY EXAMINATION
SECONDARY FOUR

CHEMISTRY **6092/02**

Paper 2

15 August 2024

1 hour 45 minutes

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your class, index number, Centre number, O level index number and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.
Write your answers in the spaces provided.

Section B
Answer **one** question.
Write your answers in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page **24.**

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

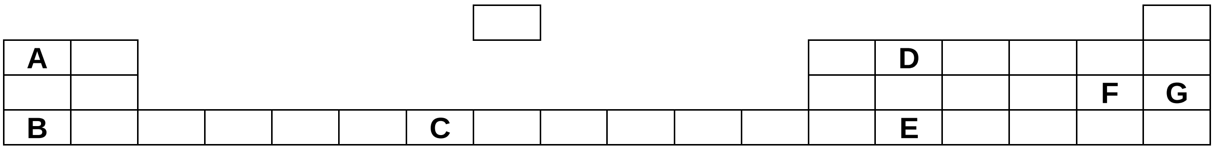
For Examiner's Use	
Section A	70
Section B	10
Total	80

This document consists of **24** printed pages.

Section A

Answer **all** questions in this section in the spaces provided.
The total mark for this section is 70.

1 The position of seven elements from Period 1 to 4 of the Periodic Table is represented by letters **A**, **B**, **C**, **D**, **E**, **F** and **G** as shown below. The letters do not represent the chemical symbols of the elements.



Use the letters, **A** to **G**, to answer the following questions. They can be used once, more than once, or not at all.

(a) Which element contains the smallest number of protons in each atom?

....[1]

(b) Which element combines with element **F** to form a compound which has a low boiling point?

....[1]

(c) Which element is the strongest reducing agent?

....[1]

(d) Which element has common oxidation states of +2, +4, +6 and +7?

....[1]

(e) Which element is important in providing an inert atmosphere for reactions?

....[1]

[Total: 5]

2 A student investigated the change in mass when hydrated cobalt chloride was heated.

The word equation for the reaction is shown below:

hydrated cobalt chloride → anhydrous cobalt chloride + water

2.0 g of hydrated cobalt chloride was heated in a test-tube gently for 30 seconds.
The test-tube and its contents was cooled and the mass of the test-tube and contents was measured.
The experiment was repeated until the mass of the test-tube and contents does not change.

(a) Explain why the mass of the test-tube and contents decreased.

…………………………………………………………………………………………………….[1]

(b) Suggest why the test-tube and contents were heated until the mass did not change.

…………………………………………………………………………………………………….[1]

(c) Energy is taken in from the surroundings when hydrated cobalt chloride is heated.

When 238 g of hydrated cobalt chloride is heated until the mass does not change, 88.1 kJ of energy is taken in.

The student heated 2.00 g of hydrated cobalt chloride until the mass did not change.

Calculate the energy taken in during this reaction.

[2]

(d) What type of reaction takes place when hydrated cobalt chloride is heated?

…………………………………………………………………………………………………….[1]

[Total: 5]

3 A student sets up an experiment as shown in Fig 3.1 to study the effect of graphite and copper electrodes in the electrolysis of aqueous copper(II) sulfate.

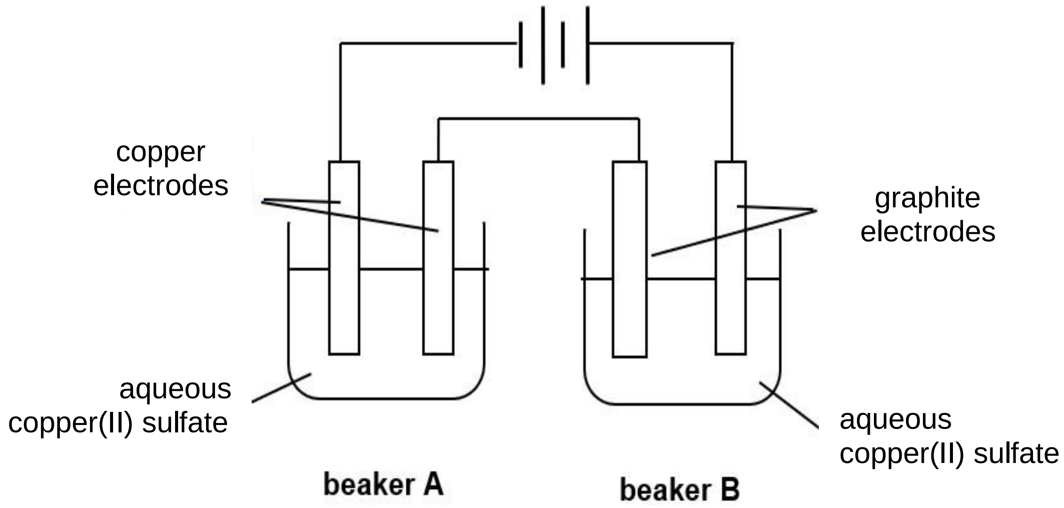


Fig 3.1

(a) With the aid of half equations, describe **one** difference in the observation at the anodes in both beakers.

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………

………

………

………[2]

(b) The mass of the substance (m) deposited or liberated at any electrode is directly proportional to the quantity of electricity or charge (Q) passed. In the experiment, 289500 coulomb of charge (Q) passed through the circuit. These charges are carried by electrons.

Given that the Faraday's constant is 96 500 coulomb per mole and using the following equation:

Q = number of moles of electrons x Faraday's constant

(i) Calculate the number of moles of electrons supplied.

[1]

(ii) Calculate the mass of copper formed in beaker **B**.

[2]

(c) The student repeated the experiment. She replaced copper(II) sulfate solution in beaker **B** with sodium sulfate solution and added a few drops of Universal Indicator at the start of the experiment.

Describe the change you would observe to the colour of solution in beaker **B** near the cathode during the experiment. Explain your answer.

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………………………………………………………………………………………………................

……………………………………………………………………………………………….............[2]

[Total: 7]

4 Titanium is a transition metal. It is extracted from titanium dioxide in a two-stage industrial process as shown below.

Stage 1: $TiO_2 + 2\ C + 2\ Cl_2 \rightarrow TiCl_4 + 2\ CO$

Stage 2: $TiCl_4 + 4\ Na \rightarrow Ti + 4\ NaCl$

(a) Suggest one hazard associated with Stage 1.

…………………………………………………………………………………………………….[1]

(b) Suggest why the reaction in Stage 2 is carried out in an atmosphere of argon and not in air.

……………………………………………………………………………………………………..

…………………………………………………………………………………………………….[2]

(c) Titanium chloride is a liquid at room temperature.

Explain why you would not expect titanium chloride to be a liquid at room temperature.

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……………………………………………………………………………………………………..

…………………………………………………………………………………………………….[2]

(d) In Stage 2, 40 kg of titanium chloride was added to 20 kg of sodium.

(i) Determine the limiting reactant. Show your calculations clearly.

[3]

(ii) For a Stage 2 reaction, the percentage yield was 92.3%. The theoretical maximum mass of titanium produced was 13.5 kg. Calculate the actual mass of titanium produced.

[1]

[Total: 9]

5 This question is about iron and its compounds.

(a) The ease of reduction of four metal oxides by heating with carbon is shown in Table 5.1.

Table 5.1

metal oxide	ease of reduction with carbon
chromium(III) oxide	only reduced above 1700 °C
iron(III) oxide	reduced above 650 °C
magnesium oxide	**not** reduced at 1750 °C
nickel(II) oxide	only reduced above 300 °C

Using information from Table 5.1, state and explain the reactivity of the metals in decreasing order.

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……………………………………………………………………………………………………..[3]

(b) Potassium is a metal in Group 1 of the Periodic Table. Describe **two** properties of iron which differ from those of potassium.

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……………………………………………………………………………………………………..[2]

(c) When iron reacts with dilute hydrochloric acid, iron(II) chloride solution is formed.

(i) Describe a test for iron(II) ions and the expected results.

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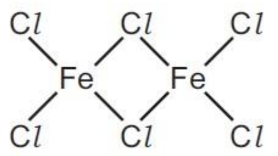
……………………………………………………………………………………………………[2]

(ii) Another chloride of iron has the structure shown below.



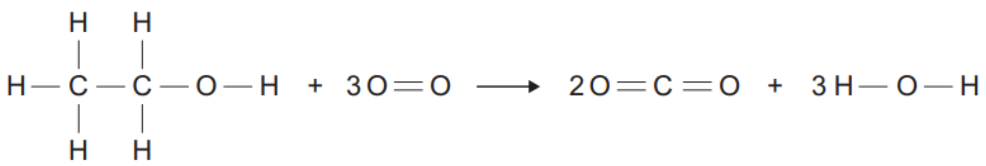
.

Deduce the molecular formula of this compound.

……………………………………………………………………………………………………[1]

[Total: 8]

6 Alcohols are used as fuels. The equation for the combustion of ethanol is shown below:



The bond energies are shown in Table 6.1

Table 6.1

Bond	Bond energy in kJ/mol
C – H	413
C – C	347
C – O	358
C = O	799
O – H	467
O = O	495

(a) Calculate the overall energy change for this reaction.

[3]

(b) Explain the overall energy change in terms of bonds broken and bonds formed.

……………………………………………………………………………………………………..

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…………………………………………………………………………………………………….[3]

[Total: 6]

7 Milk bottles can be made from glass or polymer.

Table 7.1 shows information about milk bottles of equal volume.

Table 7.1

	glass	polymer
raw materials	limestone sand sodium carbonate	crude oil
energy needed to process raw materials in kilojoules	6750	1710
energy needed to manufacture bottle in kilojoules	750	90
mass of bottle in grams	200	20
mean number of times used during lifetime of bottle	25	1
one disposal method at end of useful life	recycled to make different glass products	recycled to make different polymer products

The life-cycle assessment is a 'cradle to grave' analysis of the impact of a manufactured product on the environment. There are many detailed stages but the main ones are shown below:

1. extracting and processing the raw materials needed
2. manufacturing the product and its packaging
3. using the product during its lifetime
4. disposing of the product at the end of its useful life

(a) State and explain which milk bottle has a greater impact on the environment in terms of extraction and processing of raw materials needed.

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……………………………………………………………………………………………………..[2]

(b) With reference to Table 7.1, state one advantage and one disadvantage of using a glass milk bottle.

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……………………………………………………………………………………………………..

……………………………………………………………………………………………………..[2]

(c) Explain why recycling of polymer has minimal impact on the environment.

……………………………………………………………………………………………………..[1]

[Total: 5]

8 Ethene is an important starting material to produce chemicals such as ethanol, ethanoic acid and ethane-1,2-diol. Ethene is manufactured by the cracking of long chain hydrocarbons such as dodecane, $C_{12}H_{26}$.

(a) Write a chemical equation to show the cracking of dodecane to make ethene and one other product.

…………………………………………………………………………………………………….[1]

(b) Ethene can also be converted into a compound that contains carbon, hydrogen and oxygen. A sample of the compound was analysed and found to contain 1.44 g of carbon, 0.36 g of hydrogen and 0.96 g of oxygen. Show that the empirical formula of the compound is C_2H_6O.

[2]

(c) Name the process in which ethene is converted to the compound formed in **(b)** and suggest the name of the compound.

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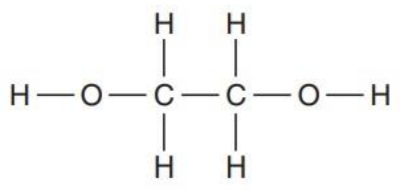
…………………………………………………………………………………………………….[2]

(d) Ethane-1,2-diol has the structure drawn below.



(i) Describe and explain what would be observed when ethane-1,2-diol is warmed with acidified potassium manganate(VII).

……………………………………………………………………………………………………

……………………………………………………………………………………………………[2]

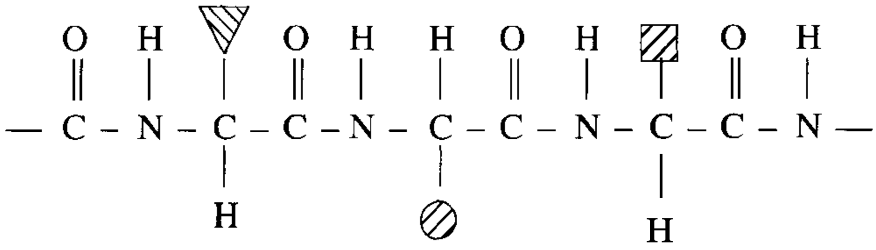
(ii) Draw the full structural formula of the product formed for the reaction in **d(i)**.

[1]

[Total: 8]

9 **(a)** Proteins are natural polymers which can undergo hydrolysis in order to determine its component amino acids. Hydrolysis is the breaking down of protein into its constituent monomers, amino acids. Amino acids contain a carboxyl group and an amine group.

A representation of part of a protein molecule is shown below.



(i) Draw the structural formula of any two amino acids which could be obtained from the hydrolysis of this protein.

[2]

(ii) Suggest a method to separate and identify the three components of amino acids.

……………………………………………………………………………………………....[1]

(b) Chlorine is used in the manufacture of chloroethene (vinyl chloride), CH_2CHCl.
Chloroethene has a similar structure to ethene.
When chloroethene undergoes addition polymerisation, polymer **N** is formed.

Draw the full structural formula of polymer **N**, showing three repeat units.

[1]

(c) State one difference between the polymerisation processes used to manufacture proteins and polymer **N**.

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……………………………………………………………………………………………..[1]

[Total: 5]

10 Production of Ammonia

Ammonia is one of the most widely produced chemicals in the world today, with more than 170 million tonnes being produced each year; more than 85% of this goes into the production of fertiliser.

Ammonia production is a highly energy intensive process consuming around 1.8% of global energy output each year. Over 50% of the current worldwide production of hydrogen is used in the manufacture of ammonia.

The chemical equation for the steam-methane reforming reaction is shown below:

$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2 \qquad \Delta H = +165.2 \text{ kJ/mol}$$

Hydrogen produced from the steam-methane reforming is reacted with nitrogen to form ammonia using the Haber process.
The optimum conditions for steam-methane reforming require a high temperature of 800°C – 900°C, a relatively low pressure of 30 atm and nickel catalyst.

Greenhouse Gas Emissions

The greenhouse gas (GHG) emissions for selected high production volume chemicals for 2010 is shown in Fig 10.1. Along with cement, steel and ethene production, ammonia is one of the 'big four' industrial processes where a decarbonisation plan must be developed and implemented to meet the net-zero carbon emissions target by 2050, a target set during the Paris Agreement in 2016.

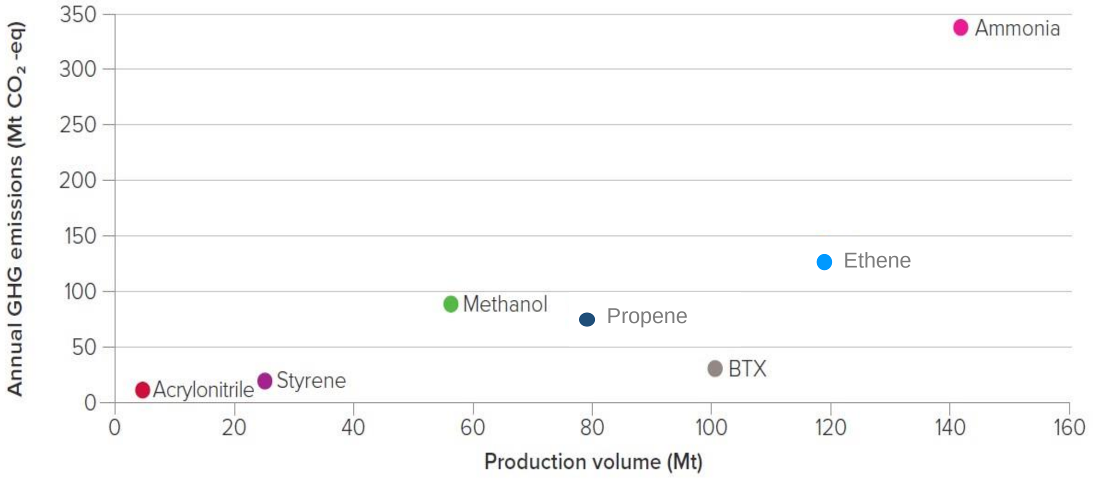

Fig 10.1

Green Ammonia

Green ammonia is zero-carbon ammonia, made using sustainable electricity, water and air. The ammonia produced is the same, it is the carbon emissions from the processes that are different. The production of green ammonia can be achieved by using zero-carbon hydrogen from the electrolysis of water, which is a well-established process. Nitrogen is obtained directly from the fractional distillation of liquid air, which accounts for 2 – 3% of the process energy used. Ammonia produced using the Haber process can be powered by sustainable electrical energy.

Fig 10.2 shows the decarbonisation of the Haber process.

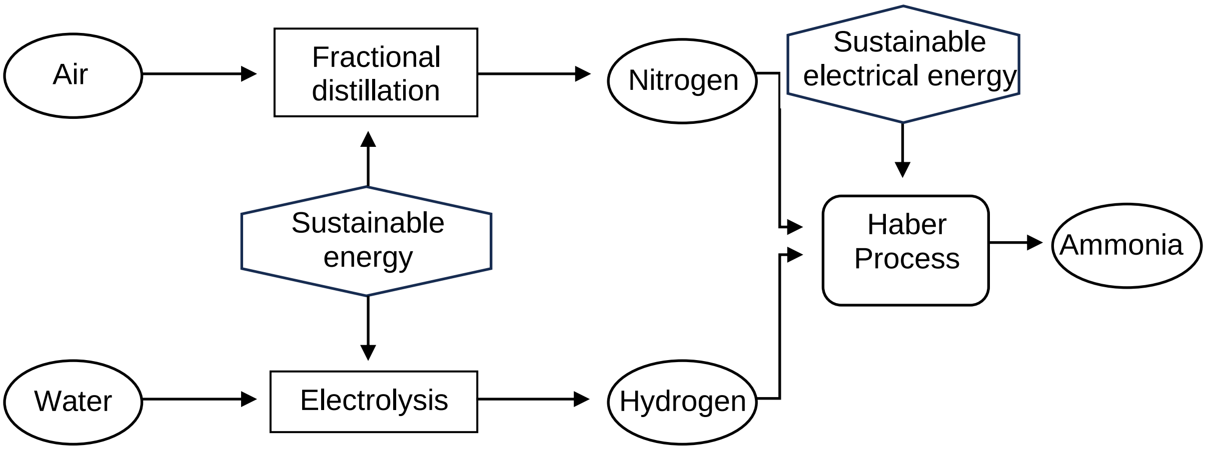

Fig 10.2

One aspect of sustainability includes environmental responsibility, which ensures that natural resources are used efficiently and preserved for future generations. This includes minimising pollution, reducing waste, conserving biodiversity, and reducing the impact of climate change.

The production of green ammonia has the capability to impact the transition towards zero-carbon through the decarbonisation of its current major use in fertiliser production.

Potential Uses of Green Ammonia

In addition to decarbonising the existing use of ammonia in the production of fertilisers for agriculture, the production of green ammonia from green hydrogen offers further options in the drive to reduce greenhouse gas emissions.

Ammonia can be stored in large quantities as a liquid at moderate pressures or refrigerated temperatures. It serves as an efficient energy storage medium with its energy density approximately 40% that of petroleum.

As a zero-carbon fuel, ammonia can be used in fuel cells, internal combustion engines, industrial burners, and gas turbines. It can be used to generate electricity to supply power to grids or remote areas. The maritime industry is expected to be an early adopter of ammonia as a fuel, and it has the potential to decarbonise rail, heavy road transport, and aviation.

While ammonia has a well-established track record for safe transportation and use, new applications will require additional control measures to reduce potential risks to health and the environment.

Source : https://royalsociety.org/news-resources/projects/low-carbon-energy-programme/green-ammonia/

(a) Draw the energy level diagram to show the steam-methane reforming reaction. Your diagram should include:

- the reactants and products of the reaction,
- label to show the enthalpy change of reaction.

[3]

(b) Write a chemical equation to show the manufacture of ammonia by the Haber process. State the effect of temperature on the yield of ammonia.

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……………………………………………………………………………………………………..

……………………………………………………………………………………………………..[2]

(c) Explain why the production of ammonia results in high levels of greenhouse gas emission.

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……………………………………………………………………………………………………..

……………………………………………………………………………………………………..[2]

(d) Suggest a source of sustainable electrical energy for electrolysis and fractional distillation.

……………………………………………………………………………………………………..[1]

(e) The table below shows the boiling points of hydrogen and ammonia.

	hydrogen	ammonia
boiling point/^{o}C	– 252.9	– 33.3

Hydrogen gas can be stored as a gas in high-pressure tanks or as a liquid under very low temperature. Ammonia is stored as a liquid under relatively low pressure at room temperature.

(i) Explain why it is easier to transport ammonia as a liquid than to transport hydrogen as a liquid.

………………………………………………………………………………………………………..

……………………………………………………………………………………………………..[1]

(ii) Explain why it is more costly to transport hydrogen as a gas.

……………………………………………………………………………………………………..[1]

(f) Suggest two likely products when ammonia is burned. Explain why ammonia is considered a zero-carbon fuel.

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……………………………………………………………………………………………………..[2]

[Total: 12]

Section B

Answer **one** question from this section.

11 A colorimeter measures light absorbed when the light passes through a coloured solution. The diagram shows how a colorimeter works.

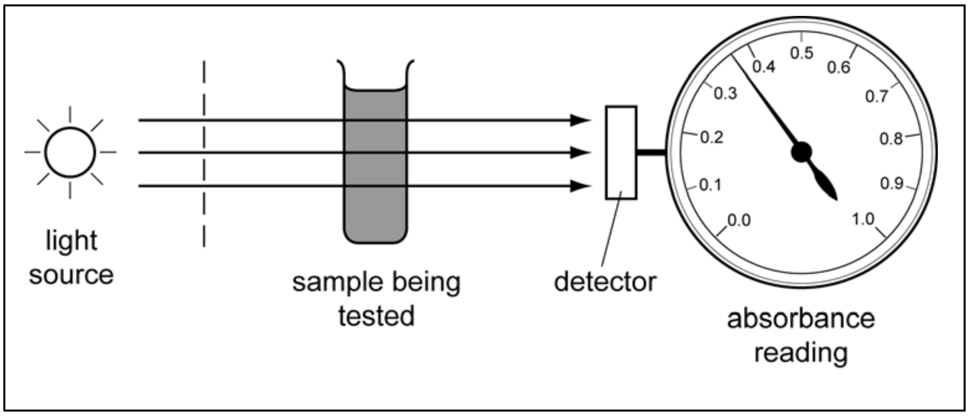


Table 11.1 shows the absorbance reading of aqueous solutions of chlorine, bromine and iodine, each of concentration 0.0100 mmol/dm^3. (1 mol = 1000 mmol)

Table 11.1

halogen	**absorbance reading**
chlorine	0.00
bromine	0.22
iodine	0.34

An experiment is carried out to investigate the reaction between aqueous potassium iodide and chlorine solution.

1 cm^3 of aqueous potassium iodide was added to chlorine solution of concentration 0.0100 mmol/dm^3 and the mixture was shaken.

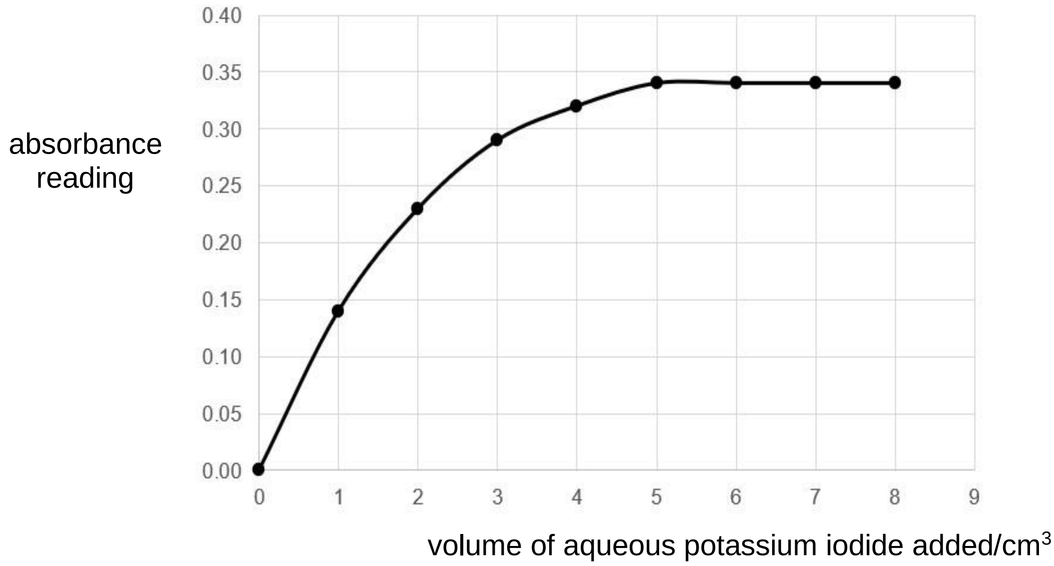
The absorbance reading was taken after each 1 cm^3 of aqueous potassium iodide was added. The final absorbance reading after 8 cm^3 of potassium iodide was added was 0.34.

(a) Using the data in Table 11.1, explain the relationship between the colour of the solution and the absorbance reading of the solution.

....[1]

Graph 1 shows the results of the experiment.

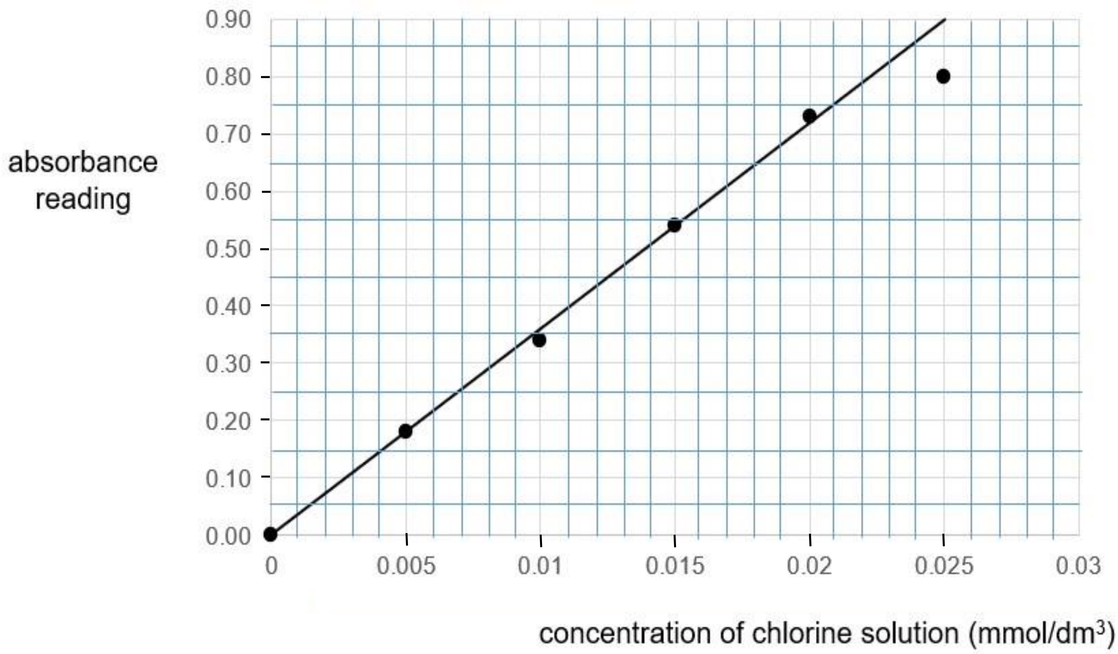
Graph 1



The experiment was then repeated for four other chlorine solutions of known concentrations.

Graph 2 shows the results of the final absorbance readings for the chlorine solutions after 8 cm^3 of potassium iodide was added.

Graph 2



(b) With the aid of a chemical equation for the reaction between chlorine solution and aqueous potassium iodide, describe and explain the shape of Graph 1.

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....[5]

(c) One of the absorbance readings in Graph 2 appears to be lower than the expected value.

Identify the concentration that this absorbance reading occurs and suggest an error in the procedure that may have caused this lowered reading.

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....[2]

(d) Chlorine is a disinfectant for swimming pools as it reacts with contaminants such as bacteria and other organic matter. Swimming pool operators need to maintain a range of 1.0 – 1.5 mg/L of chlorine for proper sanitation.
(1 L = 1 dm^3, 1mol = 1000mmol)

To determine if a swimming pool meets the sanitation requirement, a sample of swimming pool water was collected.

The experiment was conducted on the sample with 8 cm^3 of potassium iodide added and the absorbance reading obtained was 0.45.

Determine if the sample of swimming pool water meets the desired sanitation requirement. Show your working.

[2]

[Total: 10]

12 When hydrochloric acid is added to sodium thiosulfate solution, the mixture gradually becomes cloudy.

The equation for the reaction is shown below:

$$Na_2S_2O_3(aq) + 2\ HCl(aq) \rightarrow 2\ NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$$

A student investigated the effect of changing the concentration of sodium thiosulfate solution on the rate of the reaction.

Fig 12.1 shows the apparatus used.

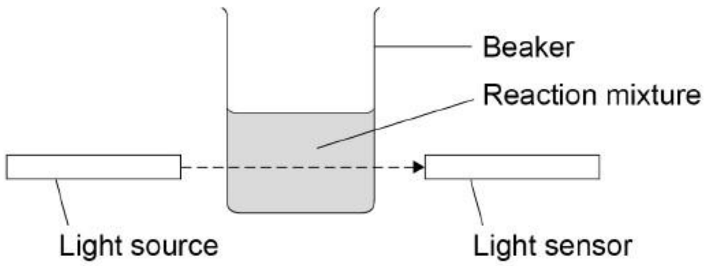

Fig 12.1

A smaller percentage of light from the light source reaches the light sensor as the mixture becomes more cloudy.

10 cm^3 of dilute hydrochloric acid was added to excess 50 cm^3 of 0.10 mol/dm^3 sodium thiosulfate solution in the beaker.

The percentage of light from the light source that reaches the light sensor was recorded every 20 seconds for 120 seconds.

The experiment was repeated using 0.20 mol/dm^3 sodium thiosulfate solution.

(a) Explain why the mixture becomes cloudy.

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……………………………………………………………………………………………............[2]

(b) The same student did the investigation again the next day.

The student found that the same method produced different results for the percentage of light reaching the light sensor.

Suggest an improvement to the method so that the same percentages of light reached the light sensor.

……………………………………………………………………………………………............[1]

(c) Fig 12.2 shows the results for 0.10 mol/dm^3 sodium thiosulfate solution.

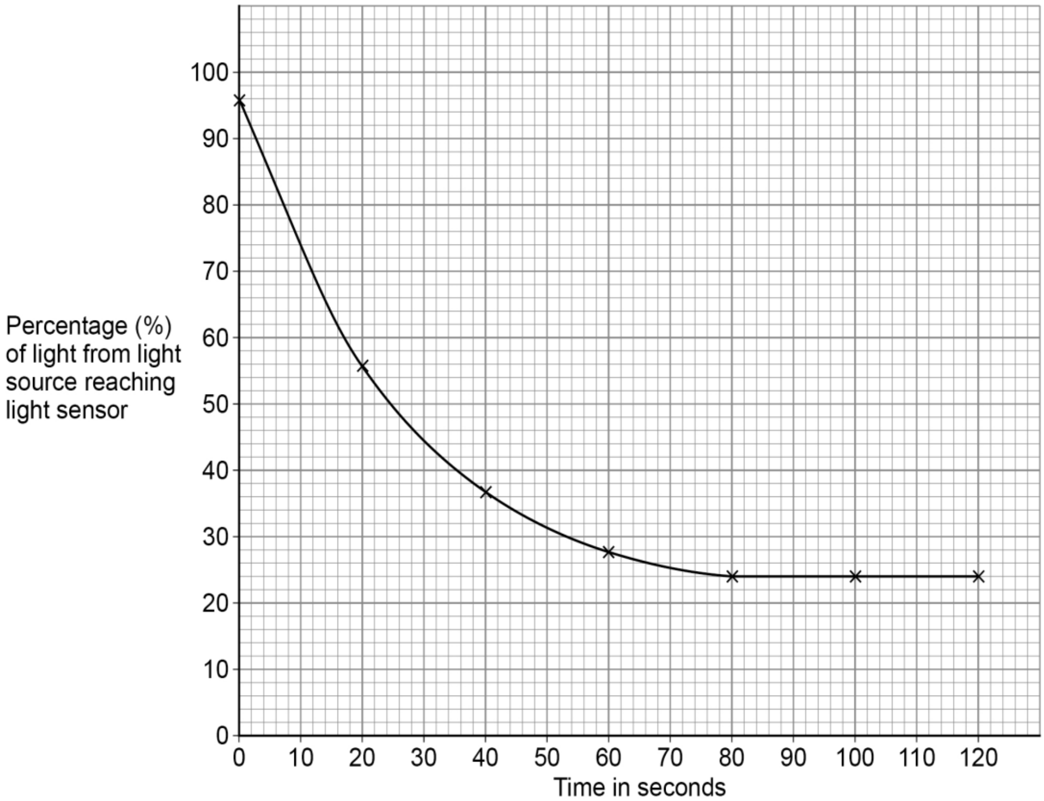

Fig 12.2

How would you use the graph to determine the rate of reaction for the production of sulfur at time 30 seconds?

…………………………………………………………………………………………………..............[1]

(d) **(i)** Sketch a graph on Fig 12.2 to show the results you would predict for 0.20 mol/dm^3 of sodium thiosulfate solution.

[1]

(ii) Explain why the rate changes between 0 to 120 seconds. Use collision theory to explain how the rate of reaction changes when the experiment is repeated with 0.20 mol/dm^3 of sodium thiosulfate solution.

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....[5]

[Total: 10]

END OF PAPER

The Periodic Table of Elements

Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9		**Key** proton (atomic) number atomic symbol name relative atomic mass									5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).
The Avogadro constant, $L = 6.02 \times 10^{23}\ mol^{-1}$