PATHLIGHT SCHOOL
PRELIMINARY EXAMINATION
SECONDARY 4 EXPRESS

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER			

CHEMISTRY 6092/02

Paper 2 **August 2020**

1 hour 45 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Section B
Answer all **three** the questions, the last question is in the form either/or.
Answer **all** questions in the spaces 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.
A copy of the Periodic Table is printed on page 24.

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

Answer **all** questions.

Write your answer in the spaces provided.

1 Seven test-tubes containing different substances are shown in the Table 1.1 below:

Table 1.1

test-tube	substances
A	magnesium and excess dilute butanoic acid
B	iron (II) sulfate crystals and water
C	ethanol and sodium chloride crystals
D	chlorine water and potassium bromide crystals
E	calcium carbonate powder and water
F	ammonium chloride powder and iodine crystals
G	ammonium chloride powder and sodium chloride crystals

Use the letters of the test-tube to answer the following questions. Each letter may be used once, more than once, or not at all.

Which test-tube(s) contain(s)

(a) a reddish-brown solution;

.... [1]

(b) substances which can be separated by sublimation;

.... [1]

(c) substances which can be separated by filtration;

.... [1]

(d) substances which can conduct electricity?

.... [1]

2 A student separates four amino acids by paper chromatography using two different solvents by two-way paper chromatography.

The solvent front of solvent 1 takes five minutes to reach the end of the chromatogram. The chromatogram is then rotated and immersed in solvent 2. The solvent front of solvent 2 takes ten minutes to reach the end of the chromatogram.

Table 2.1 below shows the R_f values she obtained for these amino acids.

Table 2.1

amino acid	**R_f in solvent 1**	**R_f in solvent 2**
A	0.2	0.5
B	0.0	0.4
C	0.8	0.9
D	0.3	0.4

(a) Which amino acid travels fastest in both solvents? Explain your answer.

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

(b) Suggest how the student can make the colourless amino acids become visible to the naked eye.

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

(c) The student writes the following statements about the chromatography.

Conclusion: Solvent 2 gives a better separation than solvent 1.

Source of error: Duration of chromatography for solvent 2 is longer than for solvent 1.

Do you agree with the student statements about his conclusion and source of error? Explain your reasoning for each statement.

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(d) With reference to Table 2.1, complete the chromatogram for amino acids **A**, **B**, **C** and **D** in Fig. 2.2 for the two-way paper chromatography using solvent 1 and 2.

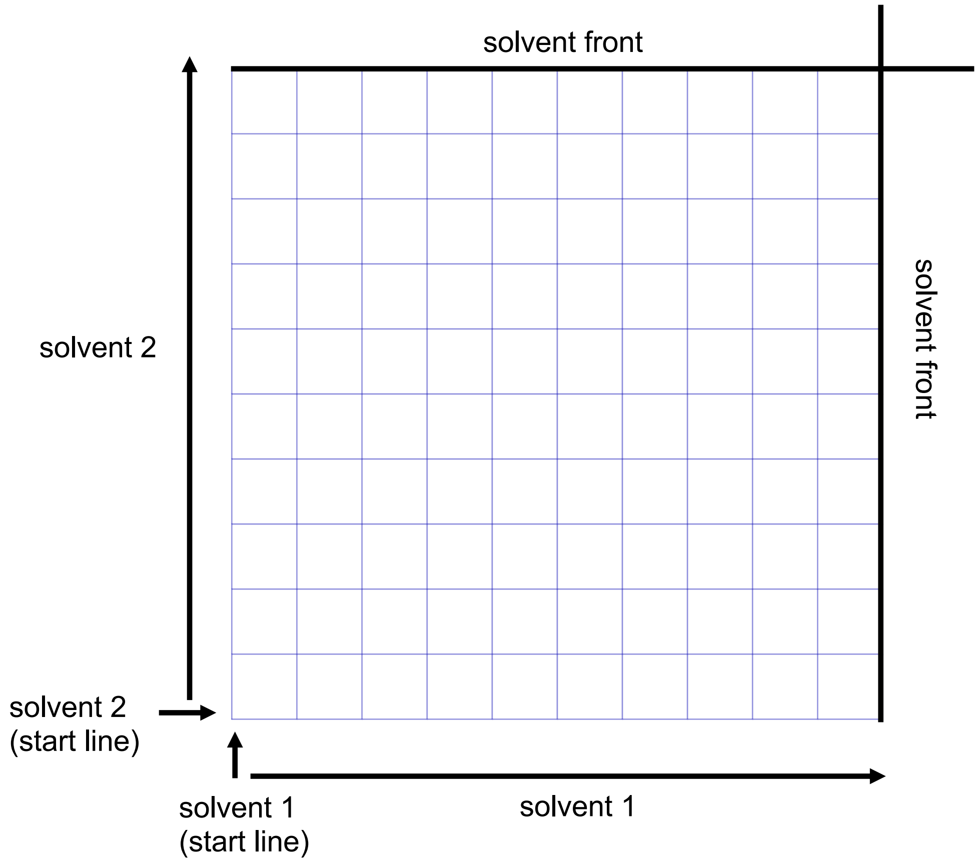

Fig. 2.2

[2]

3 Two scientists, Sir Andre Geim and Sir Kostya Novoselov were awarded the 2010 Nobel Prize in Physics, "for their ground-breaking experiments regarding the two-dimensional material graphene".

Graphene is an allotrope of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice as shown in Fig. 3.1.

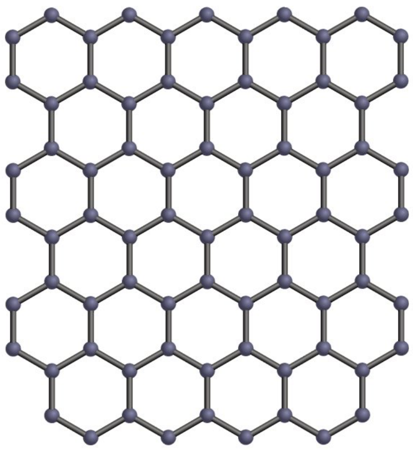

Fig. 3.1

(a) What are *allotropes*?

………………………………………………………………………………………………

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

(b) Graphene is 200 times stronger than steel. Explain this property in terms of its structure and bonding.

………………………………………………………………………………………………

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………………………………………………………………………………………………

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

(c) Graphite is another allotrope of carbon. Describe one similarity in property between graphene and graphite. Explain this property in terms of its structure and bonding.

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

(d) One method of producing graphene involves heating silicon carbide to approximately 1300 °C to burn off the silicon, leaving a thin layer of carbon behind. Silicon carbide, also known as carborundum has a similar structure to diamond.

(i) For each of the physical properties in Table 3.2, circle the correct one that represents the properties of silicon carbide.

Table 3.2

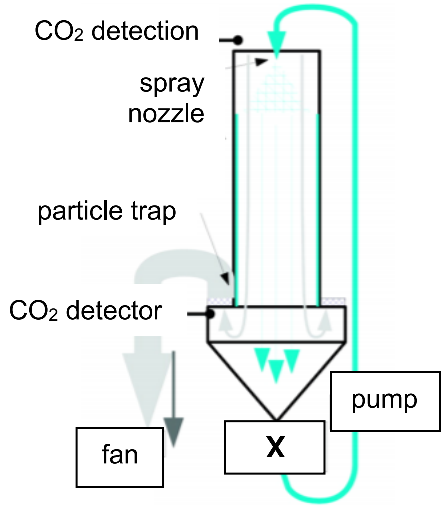
physical property	**circle the correct one**	
melting point and boiling point	high	low
solubility in water	insoluble	soluble
solubility in organic solvents	insoluble	soluble
electrical conductivity	good	poor

[2]

(ii) Silicon carbide can be made by heating pure sand, SiO_2, with carbon at very high temperatures. Carbon dioxide is the other product. Write a balanced chemical equation for the formation of silicon carbide from sand and carbon.

.... [1]

(iii) The concentration of carbon dioxide needs to be regulated before releasing it into the environment. Carbon dioxide scrubber is often used to treat the exhaust gas by passing it through a suitable reagent, **X** as shown in Fig. 3.3.



modified image source: https://pubs.acs.org/doi/pdf/10.1021/acs.chemrev.6b00173

Fig. 3.3

Suggest an identity for reagent **X** and with the help of a balanced chemical equation, explain how the carbon dioxide scrubber works.

....

....

.... [3]

4 A reaction was carried out between magnesium and hydrochloric acid. The number of moles of each reactant was monitored over time and the results obtained are shown in Fig. 4.1.

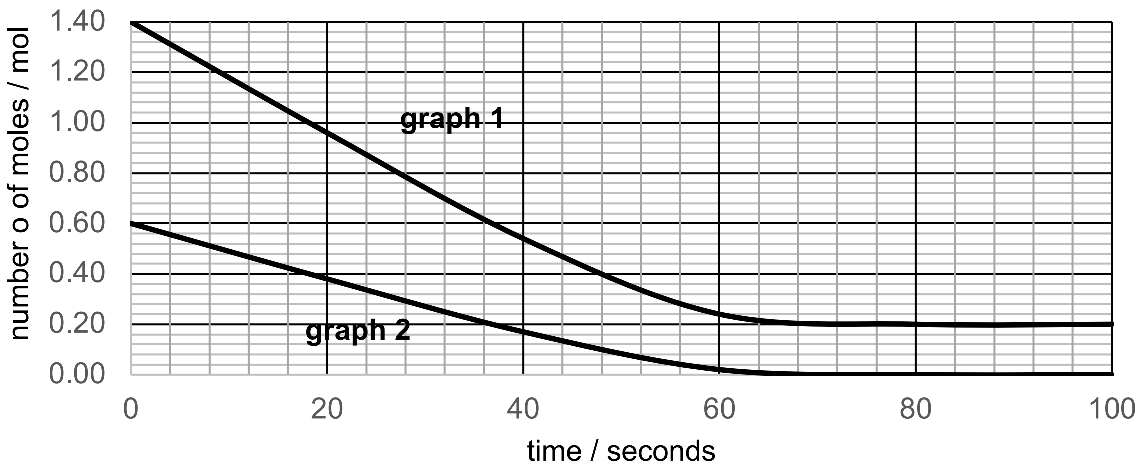


Fig. 4.1

(a) Magnesium is the limiting reactant in this experiment.

(i) Which graph shows the change in moles of magnesium with time? Explain your answer.

……………………………………………………………………………………………….

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

(ii) Using the graph in Fig 4.1, determine the time taken for the reaction to complete.

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

(iii) Sketch a curve on the graph to show how the number of moles of magnesium chloride will change during the reaction. [2]

(b) The time taken for the reaction to complete was reduced when the reaction mixture was heated. Use ideas about particle collisions to explain this observation.

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5 The apparatus in Fig. 5.1 can be used to show how a metal reacts when heated in steam in tube **A** and how the gas produced can reduce a metallic oxide placed in tube **B**.

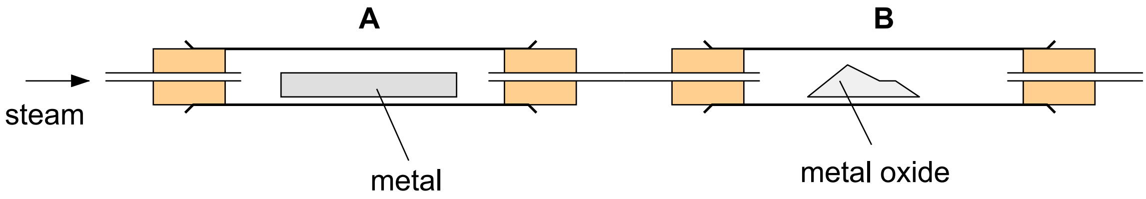

Fig. 5.1

(a) Arrange the following metals in their correct order in the reactivity series with the most reactive metal first.

sodium, copper, iron, lead, magnesium, zinc

.... [1]

(b) Choose from the list in **(a)**

(i) two metals suitable for use in tube **A**, and

.... [1]

(ii) two metals having **oxides** that are suitable for use in tube **B**.

.... [1]

(c) Write equations for

(i) the reaction of one metal listed in **(b)(i)** with steam, and

.... [1]

(ii) the reduction of one oxide listed in **(b)(ii)**.

.... [1]

6 You are provided with three solutions.

Solution **X** is hydrogen peroxide, H_2O_2.
Solution **Y** is potassium iodide, KI.
Solution **Z** is potassium manganate(VII), $KMnO_4$.

The following tests were carried out and the observations were recorded in Table 6.1.

Table 6.1

	test	**observation**
1	Add about 2 cm depth of solution **Y** into a clean test-tube. To this test-tube, add about 1 cm depth of dilute sulfuric acid. Then add about 2 cm depth of solution **X**. Place the tube in the test-tube rack to allow its contents to settle.	The colourless solution turns yellow and darkens gradually to brown. On standing, black solids settle to the bottom of the reddish-brown solution.
2	Add about 2 cm depth of solution **X** into a clean test-tube. To this test-tube, add about 2 cm depth of dilute sulfuric acid. Add 5 drops of solution **Z** and shake the test-tube.	The purple solution **Z** is decolourised rapidly as effervescence is observed. Solution gradually decolourised. The colourless, odourless gas given out relights a glowing splint.

(a) Deduce the role played by solution **X** (hydrogen peroxide) in **test 1**.
Explain your deduction using evidence from your observations.

role played by solution **X** ....

explanation ....

....

.... [2]

(b) Deduce the role played by solution **X** (hydrogen peroxide) in **test 2**.
Explain your deduction using evidence from your observations.

role played by solution **X** ....

explanation ....

....

.... [2]

(c) Name the following products in the observations.

(i) black solids in **test 1** ……………………………………..………………………

(ii) colourless, odourless gas in **test 2** ………………………………………….… [2]

7 Nitric acid used in industry is produced using the Ostwald Process, consisting of three steps:

Step 1: Ammonia gas reacts with oxygen gas to produce nitrogen monoxide and water vapour.

Step 2: Nitrogen monoxide reacts with oxygen gas to produce nitrogen dioxide.

Step 3: Nitrogen dioxide is passed through water to form nitric acid and nitrogen monoxide.

$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

(a) By using oxidation state, show that the reaction in step 3 is a redox reaction.

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

(b) 1080 dm^3 of nitrogen dioxide is used in step 3. However only 567 g of HNO_3 is produced.

(i) Calculate the percentage yield.

percentage yield = …………………………………% [3]

(ii) The concentration of the nitric acid produced is 15 mol/dm^3. Calculate the volume of water added to dilute the nitric acid to 5 mol/ dm^3.

volume of water = ……………………………..dm^3 [2]

(c) The Haber process is the main industrial procedure for the commercial synthesis of ammonia gas today using nitrogen gas and hydrogen gas as raw materials.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

A graph showing the yield of ammonia gas obtained at different pressures and temperatures is shown in Fig. 7.1.

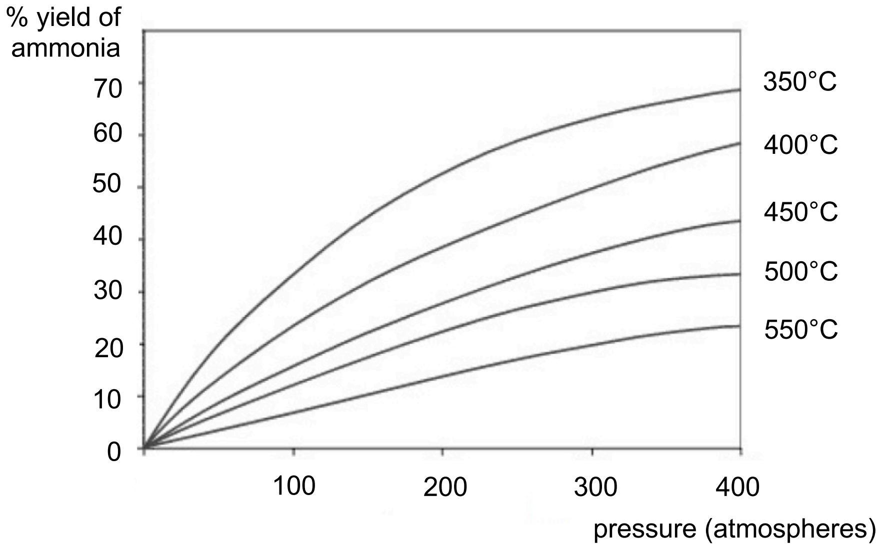

Fig. 7.1

(i) Deduce from the graph the best conditions for obtaining the best yield of ammonia.

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

(ii) Suggest why the conditions deduced in **(c)(i)** above are **not** adopted for the industrial production of ammonia.

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…………………………………………………………………………………………

…………………………………………………………………………………………

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

[Turn over

Section B

Answer **three** questions.

Question **10** is in the form of an **Either/Or** question. Only one part should be answered.

8 Read the information below about fuel cells.

A fuel cell is a chemical cell in which reactants are continuously supplied to produce electricity.

Two such cells are the ***Molten carbonate fuel cells (MCFCs)*** and the ***Proton Exchange Membrane Fuel Cell (PEMFC).***

Molten carbonate fuel cells (MCFCs)

MCFC uses a molten carbonate salt suspended in a porous ceramic matrix as the electrolyte. Salts commonly used include lithium carbonate, potassium carbonate and sodium carbonate.

They operate at high temperature, around 650ºC and noble metal catalyst is not required to improve reaction kinetics.

The higher temperature also makes the cell less prone to carbon monoxide poisoning than lower temperature systems.

Anode:

$H_2(g) + CO_3^{2-}(l) \rightarrow H_2O(l) + CO_2(g) + 2e-$

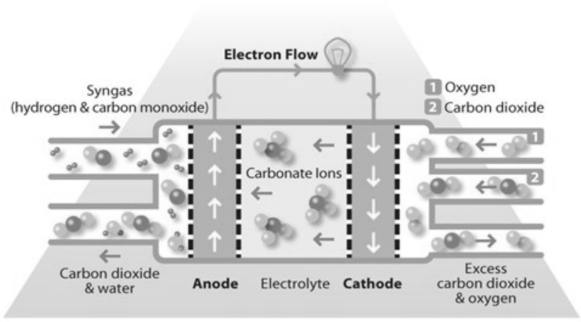
Cathode:

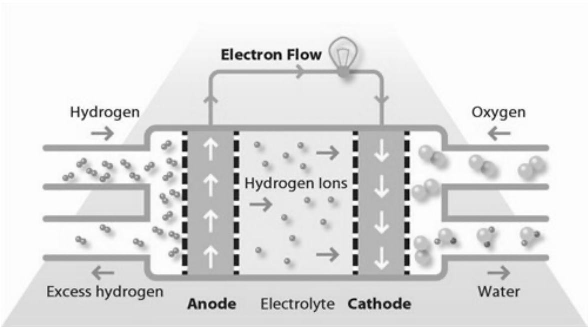
$\frac{1}{2}O_2(g) + CO_2(g) + 2e^- \rightarrow CO_3^{2-}(l)$

Proton Exchange Membrane Fuel Cell (PEMFC)

The ***PEMFC*** uses a water-based, acidic polymer membrane as its electrolyte, with platinum-based electrodes. PEMFC cells operate at relatively low temperatures (below 100°C). Due to the relatively low temperatures and the use of precious metal-based electrodes, these cells must operate on pure hydrogen.

Hydrogen fuel is processed at the anode where electrons are separated from protons on the surface of a platinum-based catalyst. The protons pass through the membrane to the cathode side of the cell while the electrons travel in an external circuit, generating the electrical output of the cell. On the cathode side, another precious metal electrode combines the protons and electrons with oxygen to produce water, which is expelled as the only waste product.





[Source: http://www.fuelcelltoday.com/about-fuel-cells/introduction]

(a) With the help of overall equation for the reaction in ***MCFC***, explain how ***Molten carbonate fuel cells (MCFCs)*** generate electricity.

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

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

(b) Explain why the operation of ***MCFC*** is more economical than that of ***PEMFC*** in terms of reaction kinetics.

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

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

(c) One of disadvantage of the operation of ***MCFC*** is the need to inject carbon dioxide continuously at cathode. Explain why.

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

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

(d) For the ***PEMFC***, the half equation at the anode is:

$$2H_2(g) \rightarrow 4H^+(aq) + 4e^-$$

Write the half equation for the reaction occurring at the cathode.

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

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

(e) Some people think that using hydrogen fuel cells eliminate the production of greenhouse gases. However, there are other people that argue that this is incorrect. Explain why.

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

(f) Most of the hydrogen produced today is made via steam-methane reforming. In this process, high temperature steam reacts with methane, in the presence of a catalyst to produce hydrogen and carbon monoxide. The equation for the reaction is shown below.

$$CH_4(g) + H_2O(g) \rightarrow 3H_2(g) + CO(g)$$

(i) Use the information in the table below to determine the enthalpy change for the reaction.

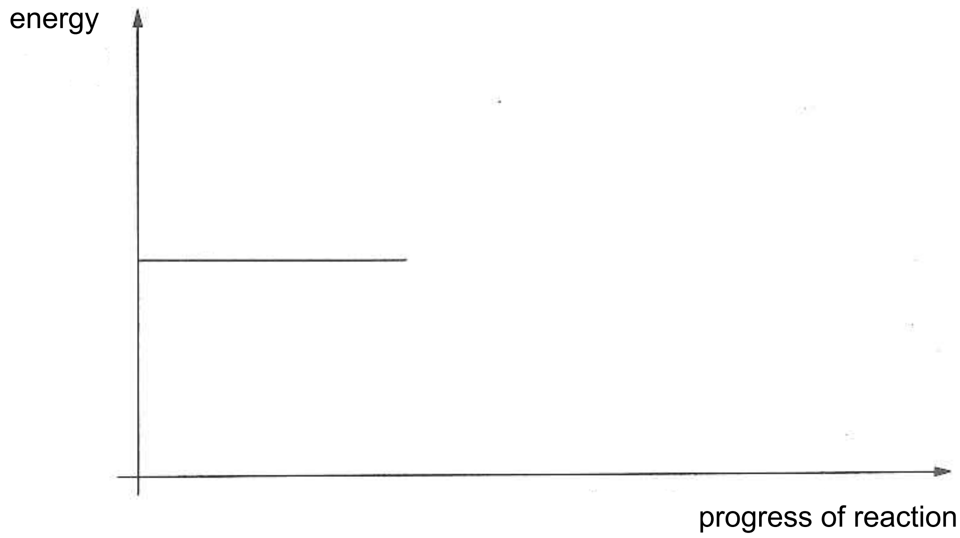
bond	bond energy (kJ/mol)
C−H	413
C≡O	1077
H−H	436
O−H	463

enthalpy change for the reaction = ...kJ/mol [2]

(ii) Complete the energy profile diagram for the reaction in steam-methane reforming.

Your diagram should include

- the **formulae of the reactants and products** of the reaction,
- a label and value for **the activation energy**,
- a label and value for **the enthalpy change of reaction**



[3]

9 *Carbon sequestration* is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change. There are two types of *carbon sequestration* – *biological* and *geological*.

Biological sequestration refers to storage of atmospheric carbon in vegetation, soils, woody products, and aquatic environments. For example, by encouraging the growth of plants, particularly larger plants like trees, advocates of biologic sequestration hope to help remove carbon dioxide from the atmosphere.

Geological sequestration is the process of storing carbon dioxide in underground geologic formations. The carbon dioxide is usually pressurized until it becomes a liquid, and then it is injected into porous rock formations.

In 2016, a research project called the *CarbFix* project, led by Columbia University adopted the following approach to pump heat-trapping carbon dioxide gas into the ground and turning it into stone.

The approach involves dissolving carbon dioxide gas with water and pumping the resulting mixture – essentially, **soda water** – down into certain kinds of rocks, where the carbon dioxide gas reacts with the rocks to form a mineral stones called calcite*. By turning the carbon dioxide gas into calcite, scientists can then lock it away permanently.

**calcite has the chemical formula of* $CaCO_3$.

One key to the approach is to find the right kind of rocks. Volcanic rocks called basalts are excellent for the process, because basalts are rich in calcium, which react with carbon dioxide gas.

The research was conducted for years in Iceland, a volcanic island made up mainly of basalt. Scientists found that the conversion yield was about 95%; meaning that 95% of the carbon dioxide was converted into calcite. More importantly, the conversion happened relatively quickly – in less than two years, instead of ten years as previously predicted by scientists using computer.

Source: https://www.usgs.gov/faqs/what-s-difference-between-geologic-and-biologic-carbon-sequestration?qt-news_science_products=0#qt-news_science_products

(a) Explain why sequestration is important in protecting the environment.

....

.... [1]

(b) Describe one advantage of geological sequestration over biological sequestration.

....

.... [1]

[Turn over

(c) "Soda water" mentioned in the article is actually weak carbonic acid. Explain with the help of an ionic equation, what is meant by the term weak acid.

....

....

....

.... [2]

(d) A researcher in the *CarbFix* project decided to investigate the presence of calcium ions in calcite. He was given the following four reagents:

dilute sulfuric acid	dilute hydrochloric acid
aqueous ammonia	aqueous sodium hydroxide

Describe the tests that he should carry out. Your answer should include

- the reactions involved using some of the given reagents;
- how the observations showed the presence of calcium ions in calcite.

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....

.... [3]

(e) Suggest a reason why

(i) The conversion of carbon dioxide gas into calcite happened relatively quickly in Iceland.

....

.... [1]

(ii) Conversion yield of carbon dioxide gas into calcite may not reach 100%.

....

.... [1]

Either

10 **(a)** The first ionisation energy is defined as the energy required to remove the valence electron in an atom to form an ion with a +1 charge. Table 10.1 below shows the first ionisation energy for the elements in Group I.

Table 10.1

element	Ionisation energy/ kJ mol^{-1}
lithium	0.526
sodium	0.502
potassium	0.425
rubidium	0.409
caesium	0.382

(i) Describe the trend of the first ionisation energies as shown in Table 10.1.

....

.... [1]

(ii) Using ideas of atomic structures, suggest how the ionisation energy affects the reactivity of Group I metals.

....

....

....

.... [2]

(b) The graph in Fig.10.2 below show the first ionisation energy and atomic radius for the first 20 elements in the Periodic Table.

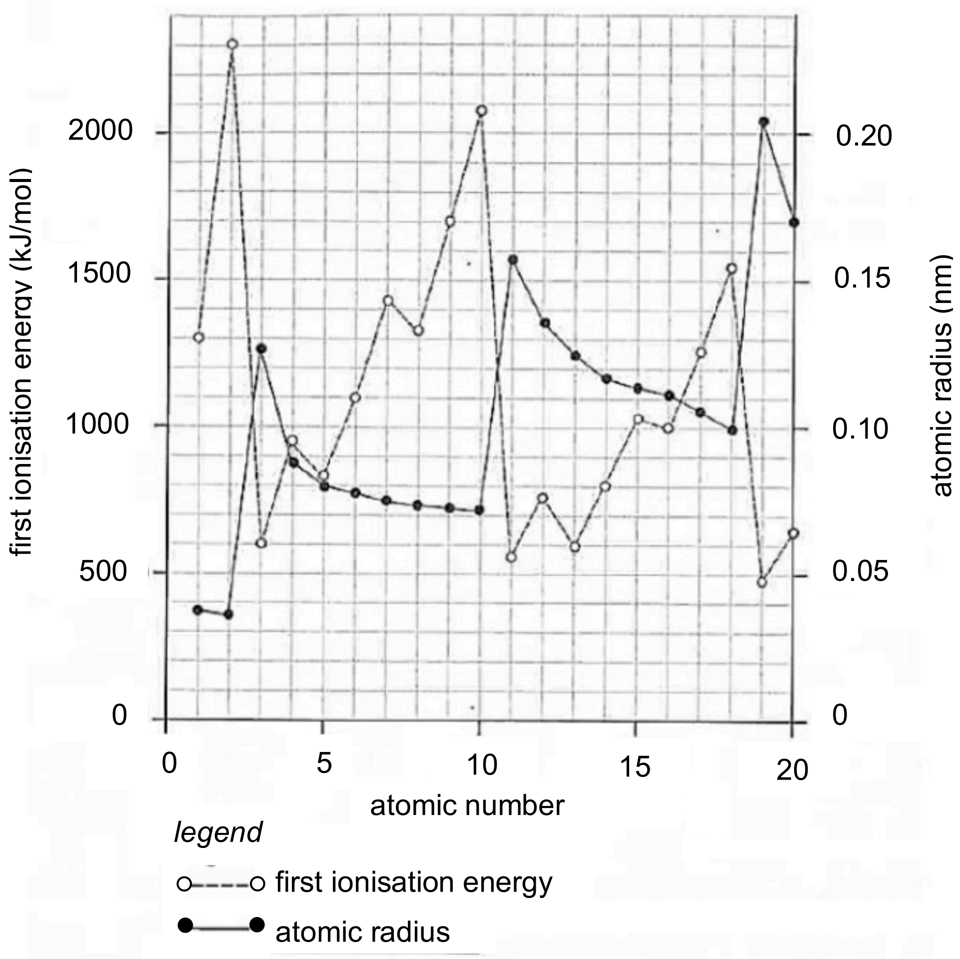

Fig. 10.2

(i) Describe the trend in terms of atomic radius for Group II elements shown in Fig. 10.2.

....

.... [1]

(ii) Based on Fig.10.2 and its electronic structure, explain why helium is the least reactive element.

....

....

....

.... [2]

(c) Hydrogen fluoride attacks glass and is used to draw on glass. It is prepared by adding concentrated sulfuric acid to form calcium fluoride. The reaction takes place at room temperature.

$$CaF_2(s) \;+\; H_2SO_4 \;\rightarrow\; 2HF(g) \;+\; CaSO_4(s)$$

When 15.6 g of a sample of calcium fluoride was reacted with 12.5 cm^3 of 20.0 mol/dm^3 of sulfuric acid at room temperature and pressure, 10.0 dm^3 of gas was collected. [1 mole of any gas occupies 24.0 dm^3 at room temperature and pressure.]

(i) Deduce the limiting reagent used in this reaction. Show your workings clearly.

[1]

(ii) It was found that the volume of hydrogen fluoride formed is actually less than the stated volume.

Support the finding with suitable calculation and suggest a reason why this could be so.

……………………………………………………………………………………………

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

OR

10 A student carried out some experiments between various metals with excess hydrochloric acid at room conditions to study the reactivity of metals. Table 10.3 summarises these reactions.

Table 10.3

metal added	rise in temperature / °C	total volume of hydrogen given off / cm^3	observations
A	15	144	reaction very slow at first. Sudden rise and violent reaction after 20 minutes.
B (strips)	0	0	no visible reaction.
B (powdered)	1	0	red-brown powder forms a very pale blue solution over time.
C	5	96	slow reaction at first, then fairly rapidly towards the end.
D	6	144	fairly rapid reaction.
E	9	96	moderately rapid reaction

(a) Arrange these five metals in increasing reactivity.

.... [1]

(b) **(i)** Suggest an identity of metal **B**.

.... [1]

(ii) Explain the difference in observation when metal strip **B** and powdered metal **B** are both added to dilute hydrochloric acid separately.

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

(c) Explain the observations for metal **A**.

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(d) Instead of using the reaction between acids and metals to study reactivity of metals, the student carried out another set of experiment to verify if his reactivity series of metals are arranged in the correct order.

Describe the experiment that the student carried out. Your answer should include

- how he should carry out his investigation,
- the measurements that he made,
- how the results showed that the reactivity of the five metals are arranged in correct order.

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…………………………………………………………………………………………………

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

The Periodic Table of Elements

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

Group																	
I	II											III	IV	V	VI	VII	0
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											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 –		114 Fl flerovium –		116 Lv livermorium –		

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.).