	Class	Register Number
Name		

6092/02
CHEMISTRY

22/4P/6092/2

PAPER 2

Tuesday **30 August 2022** **1 hour 45 minutes**

VICTORIA SCHOOL

PRELIMINARY EXAMINATION
SECONDARY FOUR

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Section B
Answer all **three** questions. The last question is in the form either/or.
Answer all questions in the spaces provided.

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

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

A copy of the Periodic Table is printed on page 22.

Section A	**/ 50**
Section B	**/ 30**
Total	**/ 80**

Deductions	
Presentation	
Significant Figures	
Units	

Section A

Answer all the questions in this section in the spaces provided.
The total mark for this section is 50.

A1 Select substances from the list to answer the following questions.

You may use each substance once, more than once or not at all.

$\mathbf{CaCl_2}$

C

$\mathbf{CO_2}$

$\mathbf{Cu(NO_3)_2}$

$\mathbf{Na_3PO_4}$

$\mathbf{SO_2}$

$\mathbf{ZnSO_4}$

(a) Which substance is an acidic atmospheric pollutant from volcanic eruptions?

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

(b) Which substance is commonly used as an inert electrode?

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

(c) Which substance dissolves in water to form an aqueous solution that gives an insoluble white precipitate on addition of excess aqueous sodium hydroxide?

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

(d) Which substance is likely to be a good catalyst?

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

(e) Which substance will decolourise when used as an electrolyte in an electrolytic cell with inert electrodes?

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

[Total: 5]

A2 The nuclide notation of hydrogen and deuterium are shown.

$$^{1}_{1}H \qquad \qquad ^{2}_{1}D$$

hydrogen deuterium

(a) Suggest a term to indicate the relationship between a hydrogen atom and a deuterium atom.

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

(b) Deuterium reacts with oxygen in the same way as hydrogen. The product of the reaction is known as 'heavy water'.

(i) Using the chemical symbols given above, write the chemical equation for the reaction between deuterium and oxygen.

……..[1]

(ii) Explain why deuterium reacts with oxygen in the same way as hydrogen.

……..[1]

(iii) Sodium can react with water in the following chemical equation.

$$2H_2O + 2Na \rightarrow 2NaOH + H_2$$

7.2 g of water and 6.9 g of sodium are allowed to react.

Determine the limiting reactant and calculate the volume of hydrogen produced.

[3]

[Total: 6]

A3 Table 3.1 shows the melting and boiling points of some substances.

Table 3.1

substance	melting point / °C	boiling point / °C
lead(II) bromide	370	914
lithium	180	1360
methane	–182	–161
methanimine	–93	–6
X	1610	2230

(a) Explain, using ideas about structure and bonding, why methane and lithium have different boiling points.

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

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

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

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

(b) A sample of lead(II) bromide was mixed with chlorine gas in a reaction vessel. However, there was no observable change.

Explain why there was no change observed.

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

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

(c) Substance **X** is a very hard substance that is commonly used on the tips of drill bits.

(i) Suggest the identity of substance **X**.

…………………………………………………………………………………….[1]

(ii) Explain why the substance has poor electrical conductivity.

……………………………………………………………………………………...

…………………………………………………………………………………….[1]

(d) Methanimine has the molecular formula, CH_3N.

Draw a 'dot-and-cross' diagram of methanimine.

Show outer electrons only.

[2]

[Total: 7]

A4 Table 4.1 shows part of a revised version of the original Periodic Table first published by Mendeleev in 1869.

Table 4.1

	Period 1	Period 2	Period 3	Period 4		Period 5	
Group I	H	Li	Na	K	Cu	Rb	Ag
Group II		Be	Mg	Ca	Zn	Sr	Cd
Group III		B	Al			Y	In
Group IV		C	Si	Ti		Zr	Sn
Group V		N	P	V	As	Nb	Sb
Group VI		O	S	Cr	Se	Mo	Te
Group VII		F	Cl	Mn	Br		I

(a) Which group of elements in the modern Periodic Table is missing from the Mendeleev Periodic Table?

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

(b) Identify two other differences between Mendeleev's Periodic Table and the modern Periodic Table.

1. ……………………………………………………………………………………………...

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

2. ……………………………………………………………………………………………...

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

(c) Some elements were left out of the Periodic Table as they had not been discovered.

Fill in the chemical symbol of germanium in Table 4.1. [1]

(d) Mendeleev put elements with similar properties in the same Group.

One of the properties he used was the formula of the oxides of the elements.

Table 4.2 shows the different types of oxides formed when Group I metals tarnish in air.

Table 4.2

element	oxides formed	formula
lithium	lithium oxide	Li_2O
sodium	sodium oxide	Na_2O
	sodium peroxide	Na_2O_2
potassium	potassium superoxide	KO_2
rubidium	rubidium superoxide	RbO_2

(i) Do the formulae of the oxides given in the table show clearly that all of the elements belong in the same Group?

Explain your answer.

…………………………………………………………………………………………………

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

(ii) Do the formulae of the oxides given in the table show a trend down the Group?

Explain your answer.

…………………………………………………………………………………………………

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

(e) What are the formulae of the peroxide and superoxide ions?

peroxide ion ………………………………………

superoxide ion …………………………………… [2]

[Total: 8]

A5 Fig. 5.1 shows the structure of citric acid, one of the polycarboxylic acids commonly present in unripe fruits.

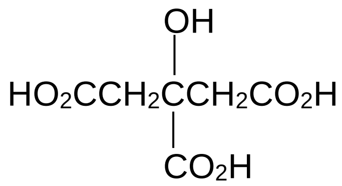


Fig. 5.1

(a) **(i)** Circle the different functional groups present in citric acid. [1]

(ii) The reagents below were added separately to a test-tube containing citric acid.

Record the observations in the table below.

reagent	observation
acidified potassium manganate(VII)	
sodium carbonate	

[2]

(b) Substance **Y**, as shown in Fig. 5.2, undergoes a reaction to produce citric acid.

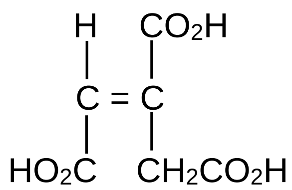


Fig. 5.2

(i) State the reagent and conditions required to produce citric acid from **Y**.

…………………………………………………………………………………………..

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

(ii) Draw the structure of a repeating unit formed by the addition polymerisation of **Y**.

[1]

(c) Another polycarboxylic acid present in unripe fruits exists as a crystalline solid, **Z** with the following composition by mass.

C: 35.8%   H: 4.5%   O: 59.7%

(i) Calculate the empirical formula of **Z**.

[2]

(ii) 1.97 g sample of **Z** (M_r = 134) was dissolved in water and the resulting solution was titrated with 1.00 mol / dm^3 NaOH.

29.4 cm^3 of 1.00 mol / dm^3 NaOH was required for complete neutralisation.

Showing your workings clearly, deduce the number of carboxyl groups present in a molecule of **Z**.

[2]

[Total: 9]

A6 Table 6.1 shows some of the reactions that take place in the blast furnace during the extraction of iron from its ore.

Table 6.1

reaction	equation	ΔH / kJ mol^{-1}
1	$C(s) + O_2(g) \rightarrow CO_2(g)$	-394
2	$C(s) + CO_2(g) \rightarrow 2CO(g)$	+173
3	$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$	-25.5

(a) The temperature at the lower part of the furnace must be hot enough to melt the iron.

Identify the reaction that is responsible for raising the temperature of the furnace.

Explain your answer.

……………………………………………………………………………………………

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

(b) Explain, with the aid of an equation, how silicon dioxide, present as an impurity is removed from the blast furnace.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(c) Calculated quantities of carbon and other elements are then added to pure iron to produce different types of steel.

Explain why different types of steel are produced.

……………………………………………………………………………………………

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

(d) Scrap steel can be recycled to obtain iron metal.

Explain why it takes less energy to make iron from scrap steel than from iron ore.

……………………………………………………………………………………………

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

(e) Fig. 6.1 shows the reaction between iron and chlorine gas to produce gaseous iron(III) chloride, Fe_2Cl_6.

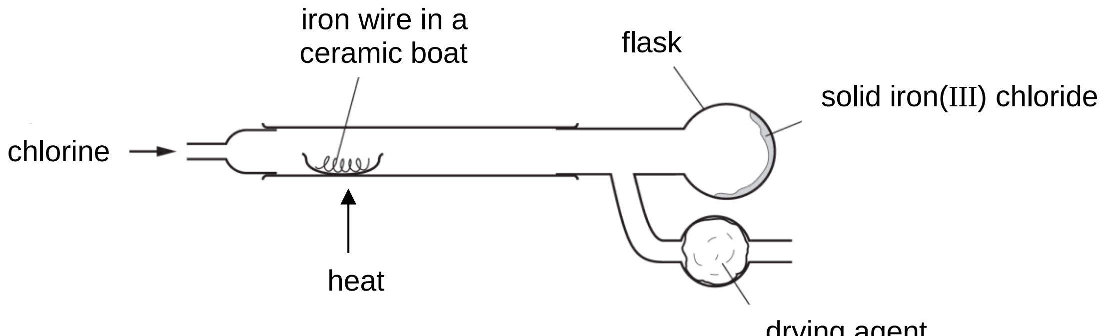


Fig. 6.1

(i) Identify a suitable drying agent for the reaction above.

……………………………………………………………………………………….[1]

(ii) Suggest why the iron(III) chloride is collected in the flask and not in the ceramic boat.

……………………………………………………………………………………….

……………………………………………………………………………………….[1]

[Total: 8]

A7 Butadiene is an organic compound that can be used to produce synthetic rubber.

It is a gas at room temperature and pressure that can be produced via a process known as steam cracking. Fig. 7.1 shows the structure of butadiene.

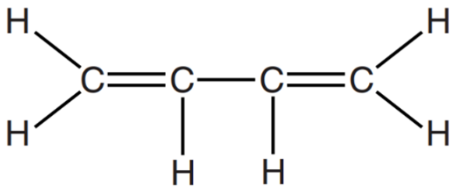


Fig. 7.1

(a) Which petroleum fraction would butadiene be found?

Explain your answer.

…………………………………………………………………………………………………

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

(b) Butadiene is an unsaturated hydrocarbon.

Describe a chemical test to test for an unsaturated hydrocarbon.

…………………………………………………………………………………………………

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

(c) Describe the arrangement and motion of the particles in butadiene at room temperature and pressure.

…………………………………………………………………………………………………

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

(d) A sample of butadiene undergoes hydrogenation reaction with excess hydrogen.

(i) State the reaction conditions for hydrogenation reaction to take place.

……..[1]

(ii) Draw the full structural formula of the product formed after the hydrogenation reaction.

[1]

[Total: 7]

Section B

Answer all the questions in this section in the spaces provided.

The last question is in the form of an either/or and only one of the alternatives should be attempted.

B8 Hess's Law

Hess's Law is a law of Physical Chemistry, which states that the heat absorbed or evolved in a chemical process is the same regardless of whether the entire chemical process is completed in one or multiple steps.

For example, Fig. 8.1 shows that the total energy change for Reaction 3 is the sum of the energy change for both Reactions 1 and 2.

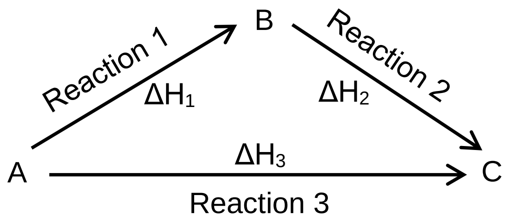


Fig. 8.1

Hess's Law can be used to determine the energy change between the different reactants using the following formula:

$$\Delta H_3 = \Delta H_1 + \Delta H_2$$

Combustion of Methane

Methane is a commonly used fuel in science laboratories to generate heat required for experiments. Methane is channelled through a gas tap to the Bunsen burner, which is lighted up to produce a flame.

The combustion of methane can proceed via two pathways.

Pathway 1: Methane undergoes complete combustion with sufficient oxygen.
Pathway 2: Methane first undergoes incomplete combustion before converting to the final products.

Both pathways are illustrated in Fig. 8.2.

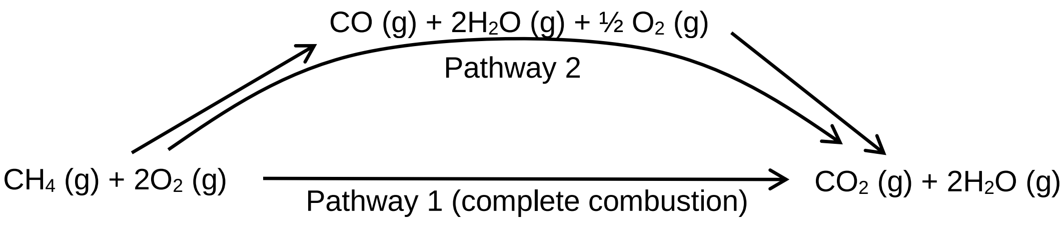


Fig. 8.2

The chemical equations for the respective combustion reactions at 298 K are shown below.

Incomplete combustion:

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO\ (g) + 2H_2O\ (g) + \tfrac{1}{2}\ O_2\ (g) \qquad \Delta H = -607\ kJ/mol$$

Complete combustion:

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g) \qquad \Delta H = -890\ kJ/mol$$

Gibbs Free Energy

Gibbs free energy is a thermodynamic potential that uses the enthalpy change of a system to calculate the work done in the system.

The equation $\Delta G = \Delta H - T\Delta S$, can be used to predict if a chemical reaction can take place spontaneously.

ΔG is the Gibbs free energy change in kJ / mol
ΔH is the enthalpy change of the reaction
T is the temperature in Kelvin, K
ΔS is the entropy change of the reaction

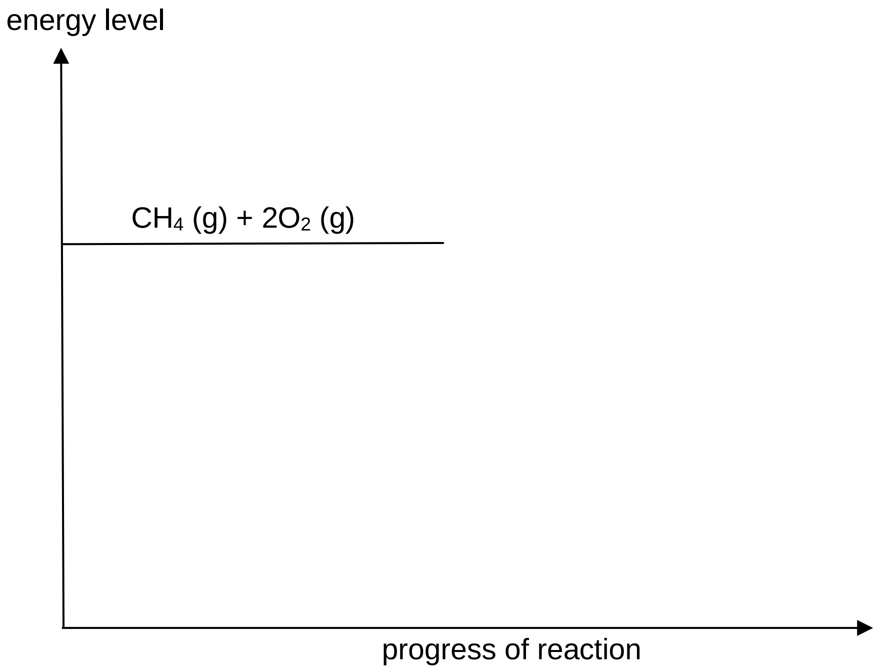
If $\Delta G < 0$, the reaction is able to proceed and will occur naturally.
If $\Delta G > 0$, the reaction is unable to proceed and will not occur naturally.
If $\Delta G = 0$, the reaction is at equilibrium.

(a) Use Hess's Law to calculate the enthalpy change of the formation of the products of complete combustion from the products of the incomplete combustion of methane.

[2]

(b) Complete the energy level diagram for both the complete and incomplete combustion, on the same diagram.

Your diagram should also include the values of the respective energy changes of both pathways for the combustion of methane.



[3]

(c) Suggest reasons why the enthalpy change of combustion of complete combustion is more negative than the enthalpy change of combustion of incomplete combustion.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(d) Explain, in terms of oxidation states, whether the complete combustion of methane is a redox reaction.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(e) **(i)** Given that the ΔS of complete combustion of methane is –0.242 kJ / mol K, calculate the Gibbs free energy change of the complete combustion of methane and predict whether the reaction would take place naturally.

[2]

(ii) The conversion of diamond to graphite at room temperature and pressure is calculated to have a negative Gibbs free energy change.

Suggest why a sample of diamond at room temperature and pressure does not visibly convert to graphite.

……………………………………………………………………………………

……………………………………………………………………………………[1]

[Total: 12]

B9 The Clark Sensor, as shown in Fig. 9.1, is an electrolytic cell that is used to measure the concentration of oxygen gas dissolved in samples of water such as from rivers and seas.

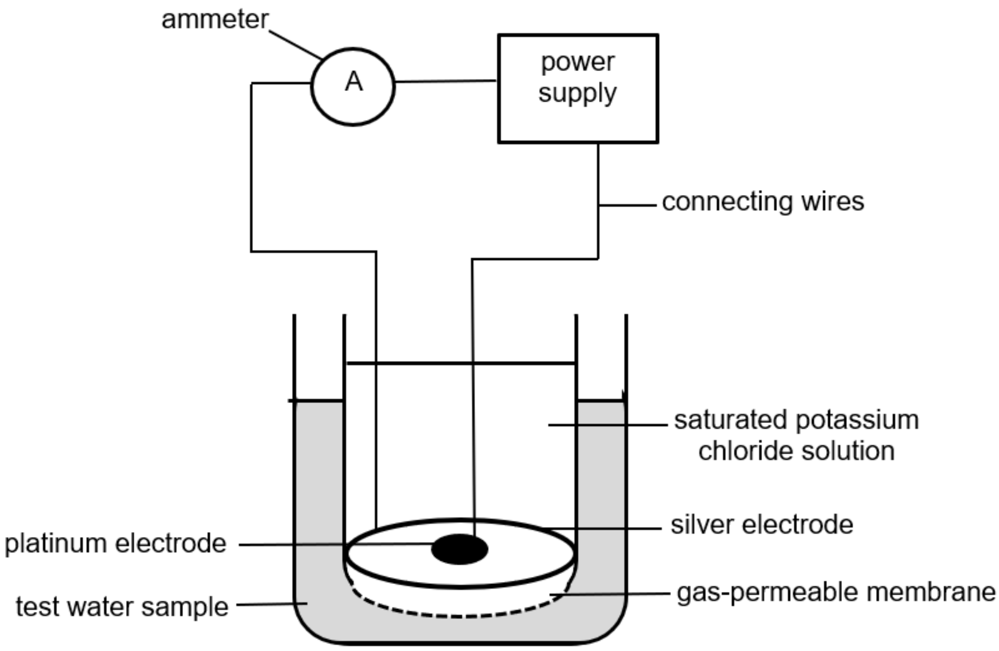


Fig. 9.1

Oxygen gas dissolved in the water sample can diffuse across the gas-permeable membrane.

A constant voltage is applied and the rate of flow of electrons produced is measured by the ammeter. The rate of flow of electrons is proportional to the number of oxygen molecules used up per minute in the water sample.

The half-equations at the electrode reactions are:

$$Ag \rightarrow Ag^+ + e^-$$

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

(a) Write the overall equation for the reaction in the electrolytic cell.

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

(b) Identify the direction of electron flow in the cell.

Place a tick (✓) beside the correct option.

platinum to silver	
silver to platinum	

[1]

(c) Given that the number of moles of electrons that flow through the silver electrode per minute is 5.20×10^{-4} mol, calculate the number of oxygen molecules used up per minute.

[2]

(d) Describe a test to identify the presence of oxygen gas.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(e) Suggest why the water sample is stirred constantly during the measurement.

…………………………………………………………………………………………………

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

(f) One of the electrodes needs to be cleaned regularly to remove a white solid which forms during the reaction.

Suggest the identity of the white solid.

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

[Total: 8]

EITHER

B10 The equation below shows the reaction that takes place when solid silver oxide is added to excess aqueous hydrogen peroxide.

$$Ag_2O(s) + H_2O_2(aq) \rightarrow 2Ag(s) + O_2(g) + H_2O(l)$$

(a) State the role of hydrogen peroxide in the equation above.

…….. [1]

(b) State two variables that could be measured to monitor the rate of reaction as shown in the equation above.

Describe briefly how these two variables could be measured in a school laboratory.

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

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

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

(c) **(i)** Use ideas about collisions between particles to explain the effect on the rate of reaction if the experiment was repeated using twice the concentration of aqueous hydrogen peroxide of the same volume.

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

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

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

(ii) A student commented that the volume of oxygen gas produced from the experiment in **(c)(i)** would double.

Do you agree with the student? Explain your answer.

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

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

(d) Calculate the mass of silver oxide required to produce 1.0 dm^3 of oxygen gas.

[2]

(e) A sample of silver oxide was contaminated with traces of lead(II) oxide.

Describe how a pure and dry sample of silver oxide can be obtained from the mixture.

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

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

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

[Total: 10]

OR

B10 Aluminium objects have a thin insoluble oxide layer on their surfaces.

The oxide layer can be removed by adding dilute acid to the aluminium object.

Effervescence of colourless gas was observed after some time.

(a) **(i)** Identify the gas produced.

....[1]

(ii) Explain why the effervescence of gas was observed only after some time.

....

....

....[2]

(b) Aluminium objects that have had the aluminium oxide layer removed may then be anodised to reduce corrosion.

Anodising is an electrolytic process which coats the aluminium anode with a thick protective layer of aluminium oxide using acids as electrolyte.

Explain why dilute hydrochloric acid is used as an electrolyte during anodising instead of concentrated hydrochloric acid.

....

....

....[2]

(c) Ammonium perchlorate, NH_4ClO_4, is commonly used as a solid fuel in rocket boosters.

Aluminium reacts with ammonium perchlorate as shown in the equation.

$$\ldots\ Al + \ldots\ NH_4ClO_4 \rightarrow \ldots\ Al_2O_3 + \ldots\ AlCl_3 + \ldots\ NO + \ldots\ H_2O$$

(i) Balance the equation above. [1]

(ii) Describe how a bottle containing aqueous ammonium perchlorate can be identified from another bottle containing aqueous zinc perchlorate.

....

....

....[2]

(iii) A student wrote the following steps in the preparation of ammonium perchlorate.

1. Add excess ammonium carbonate to dilute perchloric acid.
2. Filter the mixture.
3. Heat the filtrate until saturated and allow it to cool.

Do you agree with the student? Explain your answer.

………………………………………………………………………………………..

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

(iv) Identify another reactant that can be added to dilute perchloric acid to make ammonium perchlorate.

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

[Total: 10]

End of Paper

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.).