Paya Lebar Methodist Girls' School (Secondary)
Preliminary Examination 2020
Secondary 4 Express

CANDIDATE NAME		CLASS		CLASS INDEX NO	

CENTRE NUMBER	S					INDEX NO				

CHEMISTRY 6092/02

Paper 2 **25 August 2020**

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name 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, highlighters, 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.

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 2.

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

For Examiner's Use		
Section A		
Section B		
7		
8		
9	E/O	
Total		

The Periodic Table of Elements

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		**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 –		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.).

Section A

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

The total mark for this section is 50.

A1 Bromate(V) ions, BrO_3^-, react with bromide ions, Br^-, in acidic solution to form bromine.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

(a) (i) Explain why the acidity of the reaction mixture decreases as the reaction proceeds. [1]

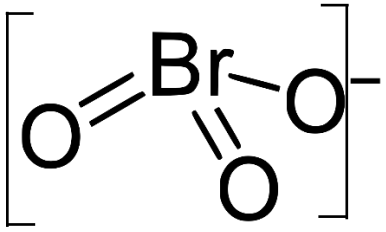
(ii) Describe the colour change you will observe as the reaction proceeds. [1]

(iii) Use ideas about collisions between particles to explain the effect of increasing the temperature of the mixture on the rate of the reaction. [2]

(b) The above reaction is a *disproportionation* reaction. *Disproportionation* is a reaction in which the same element is both oxidized and reduced. Explain, in terms of oxidation state, why the above reaction is a *disproportionation* reaction. [3]

[Turn Over

(c) The bromate(V) ion, BrO_3^- contains covalent bonds between oxygen and bromine atoms as shown below. All the oxygen atoms in the ion have a stable octet electron arrangement because the ion also has an overall negative charge.



Draw a 'dot-and-cross' diagram to show the arrangement of outer shell electrons in a bromate (V) ion. [3]

[Total: 10]

A2 Iodine reacts with chlorine to form iodine(I) chloride, IC*l*.

$$I_2 + Cl_2 \rightarrow 2ICl$$

(a) Sodium reacts with iodine(I) chloride to form two sodium compounds only.
Construct the balanced chemical equation for the reaction between sodium and iodine(I) chloride. [1]

.....

(b) Would the boiling point of iodine(I) chloride be higher or lower than chlorine gas? Explain your answer in terms of bonding. [2]

.....

.....

.....

(c) Give the chemical formula of a particle that has the same electronic configuration as an iodide ion, I^-. [1]

.....

(d) I_2 and Cl_2 are bubbled separately into solutions of Na**X** and Na**Y** where **X** and **Y** are two different halogens. The table below shows the observations of the reactions.

Key: √ =reaction x = no reaction

	I_2	**Cl_2**
Na**X**	x	√
Na**Y**	x	x

(i) Determine the order of reactivity of the four halogens, iodine, chlorine, **X** and **Y**, starting with the most reactive. [1]

.....

(ii) Identify the halogens **X** and **Y**. [2]

X is .....

Y is .....

[Total: 7]

[Turn Over

A3 Chlorate(I) ions undergo the following reaction under aqueous conditions to form hydrazine, N_2H_4.

$$2NH_3 + ClO^- \rightarrow N_2H_4 + Cl^- + H_2O$$

A series of experiments was carried out using different concentrations of ClO^- and NH_3. The table shows the results obtained.

Experiment	$[ClO^-]$ /mol dm^{-3}	$[NH_3]$ /mol dm^{-3}	initial rate /mol dm^{-3} s^{-1}
1	0.200	0.100	0.256
2	0.400	0.200	2.05
3	0.400	0.400	8.20
4	0.400	0.100	0.512

(a) Use the information in the table to describe how increasing the concentration of each of these reactants affects the initial rate of reaction. [4]

$[ClO^-]$ ions .....

.....

.....

.....

$[NH_3]$ .....

.....

.....

.....

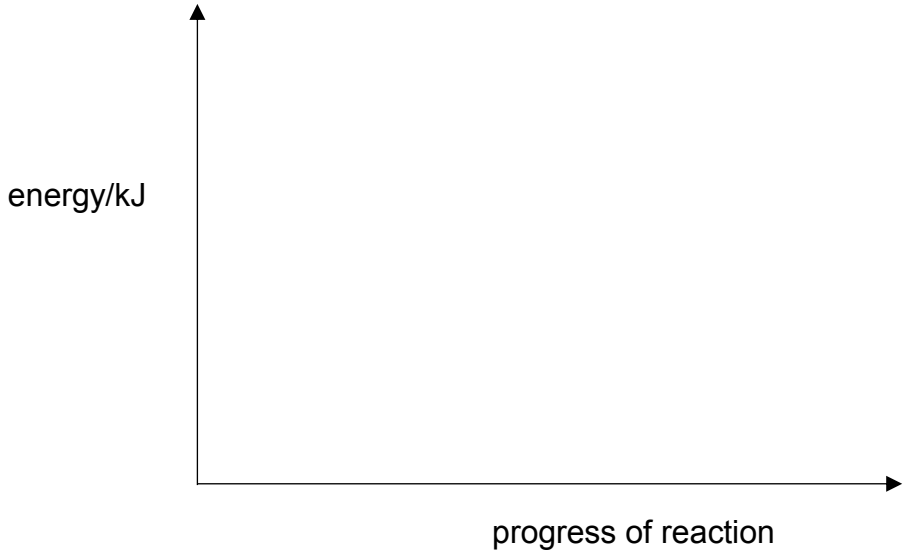
(b) The compound, hydrazine, N_2H_4 can also be produced by reacting nitrogen with hydrogen as shown below.

$$N_2 + 2H_2 \rightarrow N_2H_4$$

(i) Use the bond energies given below to calculate the enthalpy change for the above reaction in **(b).** [3]

Bond	**Bond energy /kJ mol^{-1}**
N ≡ N	945
H – H	432
N – N	160
N – H	391

(ii) Hence, draw the energy profile diagram for the reaction in **(b).** Indicate the E_a and ΔH on the diagram. [2]



[Total: 9]

[Turn Over

A4 Iron is a relatively reactive metal that can form several compounds. **Table 4** shows some of these iron compounds.

Compound	Colour	Oxidation state
FeS_2	Shiny gold solid	
$Fe_2(SO_4)_3$	Grey powder	+3
$FeCl_3.6H_2O$	Orange yellow crystals	

Table 4

(a) Fill in the missing oxidation states in **Table 4** above. [2]

(b) Where would you place iron in the Periodic Table? Explain your choice with the help of the information in **Table 4**. [2]

(c) Iron (III) oxide, Fe_2O_3, the main compound found in haematite undergoes the reaction shown below.

$$Fe_2O_3(s) + 3\ H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + 3\ H_2O\ (l)$$

(i) Based on the reaction above, describe and explain the nature of iron (III) oxide. [1]

(ii) Describe how crystals of iron (III) sulfate can be obtained from the products in the reaction above. [2]

(d) Iron can be extracted from iron (III) oxide by two different methods.

In the first method, using the Thermite reaction, powdered aluminium is added and the mixture is ignited.

In the second method, using the Blast furnace, coke and limestone are added and the mixture is heated.

(i) Give one similarity and one difference between the two methods of extraction of iron from iron (III) oxide. Do not give different starting materials as a difference.

[3]

Similarity:

.....

.....

.....

Difference:

.....

.....

.....

[Total: 10]

[Turn Over

A5 Phosgene is the chemical compound with the formula $COCl_2$**.** This colourless gas was used as a chemical weapon during the World Wars.
Isotopically labelled phosgene gas, $^{13}COCl_2(g)$ was prepared in a laboratory by reacting 48 cm^3 of $^{13}CO(g)$ and some $Cl_2(g)$ in a cylinder at 25^0C.

$$^{13}CO(g) + Cl_2(g) \rightarrow {}^{13}COCl_2(g)$$

(a) Calculate the **mass** of $^{13}COCl_2(g)$ produced. [2]

(b) Explain the term *isotopes*. [1]

(c) Besides phosgene, carbon can form other harmful compounds known as CFCs. CFCs contain carbon, fluorine and chlorine. CFCs are now banned in most countries because they lead to the depletion of the ozone layer. There are various types of CFCs. One of the CFC, known as Freon has 10.7% ^{13}C, 31.1% F and 58.2% Cl by mass.

(i) Determine the empirical formula of Freon. [2]

(ii) The chlorine atoms from the CFC cause the breakdown of ozone in a two step reaction.

$Cl + O_3 \rightarrow ClO + O_2$
$ClO + O_3 \rightarrow 2O_2 + Cl$

Use the equations to write an overall equation for the reaction. [1]

(iii) Explain how the equations in **(ii)** show that chlorine atoms act as a catalyst for the breakdown of ozone. [1]

(iv) Describe one harmful effect of the depletion of the ozone layer. [1]

[Total: 8]

[Turn Over

A6 The hydroxides of Group II vary in their solubilities in water.

Hydroxide	Solubility / mol dm^{-3}
$Mg(OH)_2$	1.6×10^{-4}
$Ca(OH)_2$	2.5×10^{-2}
$Ba(OH)_2$	4.1×10^{-1}

(a) Suggest a value for the solubility of strontium hydroxide, $Sr(OH)_2$. [1]

.....

(b) A student made the following statement:

> The pH of the aqueous solutions of Group II hydroxides increases down the group

To what extent do you agree or disagree with the statement above?
Explain your answer. [2]

.....

.....

.....

(c) $Ca(OH)_2$ is used to neutralize acidic soil, **making the soil neutral**. Based on the information in the table, is $Mg(OH)_2$ or $Ba(OH)_2$ a better choice to neutralise acidic soil? Explain your answer. [1]

.....

.....

(d) Use the list of Period 3 oxides below to answer the following question.

Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_2	Cl_2O

Which of the above oxide(s) will react with aqueous $Ba(OH)_2$? Explain your answer. [2]

.....

.....

.....

.....

[Total: 6]

Section B

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

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

B7 A strong acid is completely ionised while a weak acid is partially ionised when dissolved in water. The general equation below shows the reaction for a monobasic weak acid in water, where **HA** represents the acid molecule and $\mathbf{A^-}$ represents the anion of the acid.

$$\mathbf{HA} \rightleftharpoons \mathbf{H^+ + A^-}$$

The **HA** molecules, $\mathbf{H^+}$ and $\mathbf{A^-}$ ions are in equilibrium in water. Weak acids have different degree of ionisation. The further the equilibrium lies to the left, the lower the degree of ionisation, the weaker the acid.

The measure of the position of the equilibrium or degree of ionisation can be determined by the **acid dissociation constant, K_a**. The lower the value of the K_a, the more the equilibrium lies to the left, the weaker the acid.

K_a can be expressed as

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

Key:
$[H^+]$ = concentration of H^+ ions
$[A^-]$ = concentration of A^- ions
[HA] = concentration of HA molecules

Carbonic acid, H_2CO_3, a weak dibasic acid ionises in two steps as shown below.

Step	Equation	K_a/ mol dm^{-3}
1	$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$	4.3×10^{-7}
2	$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$	5.6×10^{-11}

(a) (i) Which is a weaker acid, H_2CO_3 or HCO_3^-? [1]

.....

[Turn Over

(ii) Why is HCO_3^- considered an acid? [1]

.....

.....

(iii) Write an expression for the acid dissociation constant, $\mathbf{K_a}$ for step 1. [1]

(iv) Deduce the concentration of H^+ ions, $[H^+]$ of a solution which contains both H_2CO_3 and HCO_3^- in equal concentrations, using the $\mathbf{K_a}$ expression in step 1. [1]

(v) Write a balanced chemical equation for the complete ionisation of H_2CO_3. [1]

.....

(b) In a school laboratory, a student titrated 25.0 cm^3 of 0.100 mol dm^{-3} carbonic acid, H_2CO_3, with 0.0625 mol dm^{-3} barium hydroxide, $Ba(OH)_2$.

(i) Write the balanced chemical equation for the reaction between carbonic acid and barium hydroxide, including state symbols. [2]

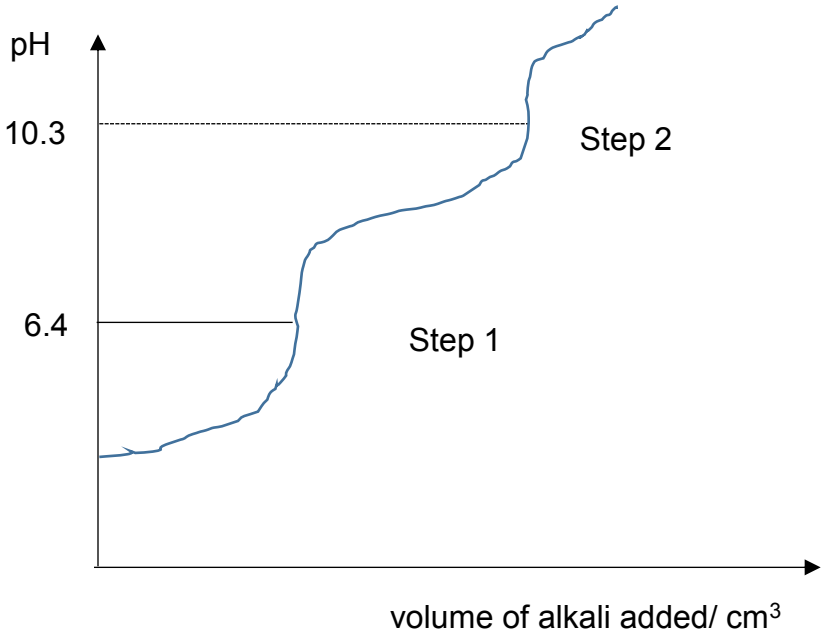
.....

(ii) Describe what you will observe in the conical flask as the titration proceeds. [1]

.....

(iii) Calculate the volume of $Ba(OH)_2$ needed to completely react with the H_2CO_3. [2]

(c) The pH curve for the titration between H_2CO_3 and $Ba(OH)_2$ in **(b)** is shown below.



[Turn Over

The pH range at which various indicators change colour is shown in the table below.

Indicator	pH range for colour change
Thymolphthalein	9.3 – 10.5
Phenolphthalein	8.3 – 10.5
Bromothymol blue	6.0 – 7.6
Creseol red	7.2 – 8.8
Methyl orange	3.1 – 4.4

(i) Name a suitable indicator to track the end-point for Step 2. [1]

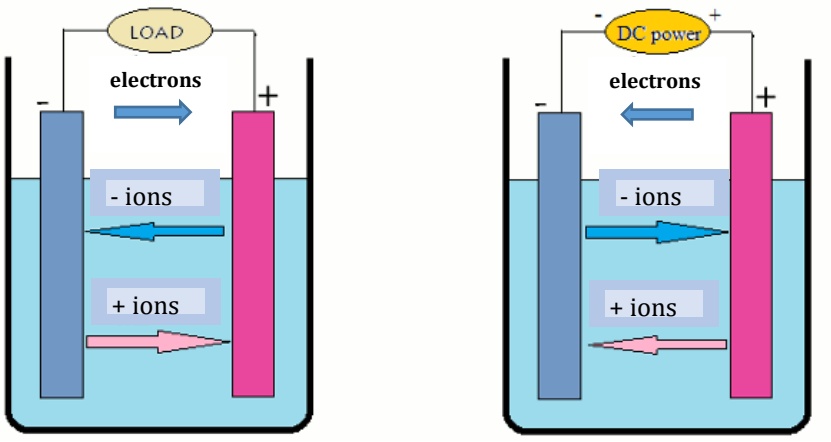
(ii) Jean used bromothylmol blue for the titration but could not get the correct volume of $Ba(OH)_2$ required for the complete neutralisation of H_2CO_3. Explain why this is so. [2]

(iii) Suggest what Jean can do to estimate the correct volume of $Ba(OH)_2$ required for complete neutralisation of H_2CO_3, using bromothymol blue as indicator. [1]

[Total: 14]

B8 Lithium-ion battery is a common rechargeable battery. The Li^+ ions move in different directions during discharging and charging.

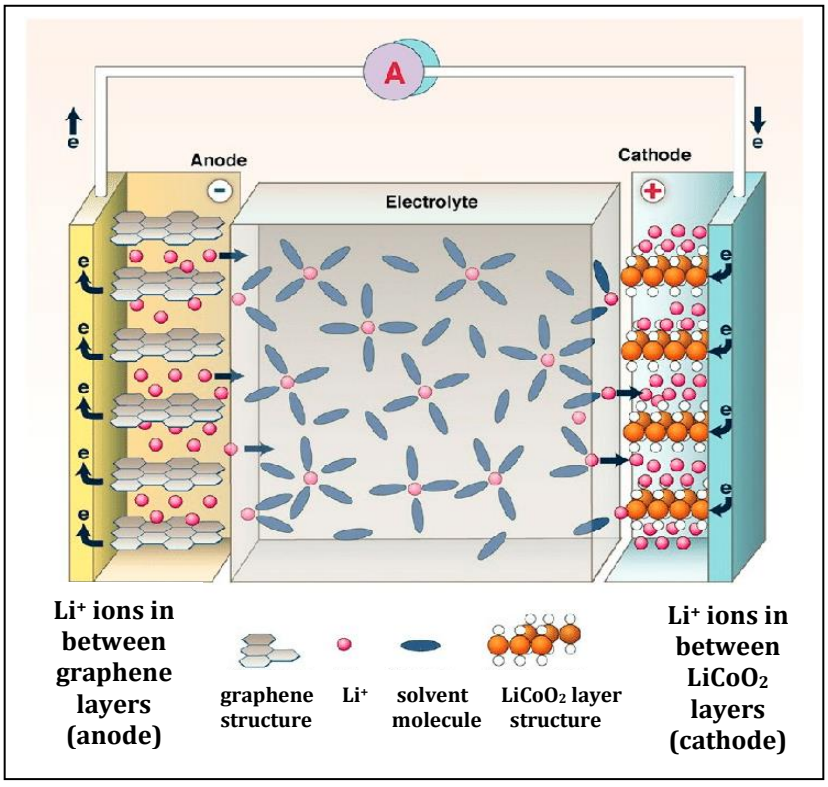
The **simplified** schematic diagrams below show the movement of ions and electrons during discharging and charging of the rechargeable lithium-ion battery.



Discharging **Charging**

Source: http://large.stanford.edu/courses/2010/ph240/nie1/

The **detailed** diagram below shows how a rechargeable lithium-ion battery works.



Source: Lennon, Alison & Jiang, Yu & Hall, Charles & Lau, Derwin & Song, Ning & Burr, Patrick & Grey, Clare & Griffith, Kent. (2019). High-rate lithium ion energy storage to facilitate increased penetration of photovoltaic systems in electricity grids. MRS Energy & Sustainability. 6. 10.1557/mre.2019.4.

[Turn Over

(a) Is the **detailed** diagram showing discharging or charging? Explain your answer. [1]

(b) The anode is made of graphene, an allotrope of carbon. Explain why graphene is suitable as an anode. [2]

(c) Recently, there has been many reports of rechargeable lithium-ion batteries exploding during charging. Dr Balaya makes this comment, "Every time a cell warms up, you are evaporating the liquid electrolyte into gas. The local pressure builds up and it leads to an explosion."

Source: CNA, 7 Feb 2018

Explain, in terms of kinetic particle theory why the pressure builds up when the electrolyte changes from the liquid to gaseous state. [3]

[Total: 6]

EITHER

B9 The results of an experiment involving the electrolysis of aqueous copper (II) sulfate using copper electrodes are shown below.

Experiment	Temperature of electrolyte /^{0}C	Current used / amps	Duration of electrolysis / s	Mass of copper formed at the cathode / g
1	20	1.0	1000	0.329
2	20	2.0	1000	0.658
3	20	2.0	2000	1.320
4	25	2.0	2000	1.320
5	30	1.0	1000	0.329

(a) Use the information in the table to describe how each of the variables affects the mass of copper formed at the cathode. [3]

Temperature .....

.....

Current .....

.....

Duration .....

.....

(b) Write the half - equations taking place at the anode and cathode for the electrolysis of copper (II) sulfate solution using copper electrodes. [2]

Anode: .....

Cathode: .....

[Turn Over

(c) Two students, Ariel and Brian make two statements about the electrolysis of copper (II) sulfate solution using copper electrodes.

Ariel: We need to replace the copper anode after some time as it is used up.
Brian: We need to replenish the copper (II) sulfate solution electrolyte as it is used up.

Who do you agree with? Justify your choice with explanation. [2]

(d) In another experiment, a concentrated solution of copper (II) chloride is electrolysed using inert electrodes.

(i) State the products formed at each electrode. [1]

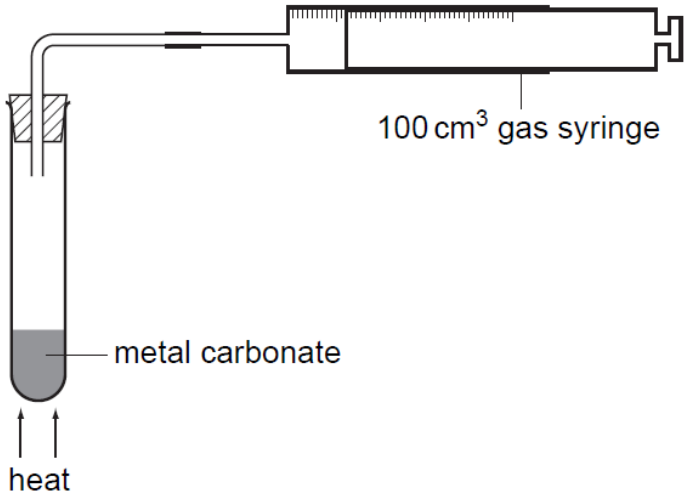
Anode: _____ Cathode: _____

(ii) Describe a chemical test to determine the presence of chloride ions in the electrolyte. [2]

[Total: 10]

OR

B9 **(a)** A student investigates the decomposition of five different metal carbonates.
The diagram shows the apparatus the student uses.



The student heats a 0.010 mol sample of each carbonate using the blue flame of the same Bunsen burner. She measures the time it takes for 100 cm^3 of gas to be collected in the gas syringe. The table shows her results.

Carbonate	Time taken to collect 100 cm^3 of gas / s
metal **U** carbonate	25
metal **V** carbonate	100
metal **X** carbonate	300
metal **Y** carbonate	no gas produced after 1000 seconds
metal **Z** carbonate	50

The student used calcium carbonate, copper (II) carbonate, magnesium carbonate, sodium carbonate and zinc carbonate.

(i) Complete the table to show the identity of each metal **U**, **V**, **X**, **Y** and **Z**. [2]

Metal	Name of metal
U	
V	
X	
Y	
Z	

[Turn Over

(ii) Explain how you used the student's results to identify each metal in **(i).** [2]

(b) The nitrates of metallic elements also decompose when heated.
Calcium nitrate decomposes to form calcium oxide, nitrogen dioxide and oxygen.

$$2Ca(NO_3)_2\,(s) \rightarrow 2CaO\,(s) + 4NO_2\,(g) + O_2\,(g) \quad \Delta H = +230\ kJ$$

15 g of calcium nitrate was heated. Assume that all the calcium nitrate decomposed,

(i) calculate the enthalpy change. [2]

(ii) calculate the total volume of gaseous products obtained at room temperature and pressure. [2]

(c) Explain the enthalpy change, in terms of the energy changes taking place in both bond making and bond breaking during the decomposition of calcium nitrate. [2]

[Total: 10]

END OF PAPER