ORCHID PARK SECONDARY SCHOOL

End-of-Year Examination 2022

CANDIDATE NAME

CLASS V 8 INDEX NUMBER

CHEMISTRY **6092/01**

Paper 1 **10 October 2022**

Secondary 3 Express **1 hour**

Setter: Mr Wong YH **40 Marks**

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil
Do not use staples, paper clips, glue or correction fluid.

There are **forty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
A copy of the Periodic Table is printed on page 19.

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

This document consists of **19** printed pages.

1 Under the same conditions, which gas diffuses at the same rate as nitrogen gas?

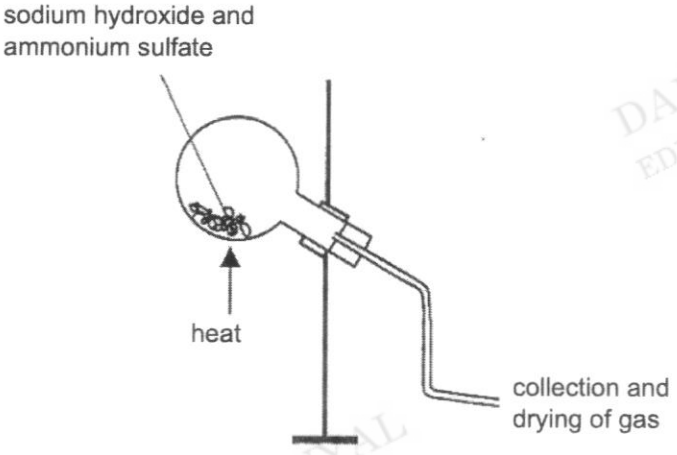
A carbon dioxide gas

B carbon monoxide gas

C methane gas

D oxygen gas

2 Sodium hydroxide and ammonium sulfate is heated together in a setup.



How can the gas produced be collected and dried?

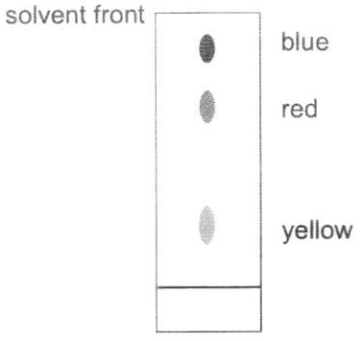
	gas collection	drying agent
A	displacement in water	concentrated sulfuric acid
B	displacement in water	calcium oxide
C	upward delivery	concentrated sulfuric acid
D	upward delivery	calcium oxide

3 An impure substance P melts over a range of −50 °C to −48 °C and boils at 60 °C to 62 °C.

What is the melting and boiling point of pure substance P?

	melting point / °C	boiling point / °C
A	−52	58
B	−52	64
C	−46	58
D	−46	64

4 Paper chromatography was carried out on a sample of dye using water as the solvent. The results are shown on the chromatogram.



Which statement is correct?

A The blue dye has a R_f value close to 1.

B The yellow dye has the highest solubility in water.

C The sample is a pure substance as all of the spots did not overlap.

D The blue dye has the lowest mass hence it travelled the furthest in water.

5 An isotope of uranium ion can be written as $^{235}_{92}U^{3+}$.

Which row indicates the number of sub-atomic particles in the uranium isotope?

	protons	neutrons	electrons
A	92	143	89
B	92	146	89
C	92	143	92
D	89	146	92

6 The table shows four elements, W, X, Y and Z and their number of electrons.

element	W	X	Y	Z
atomic number	2	4	7	8

Which two elements will react to form an ionic compound?

A W and X

B W and Y

C W and Z

D X and Z

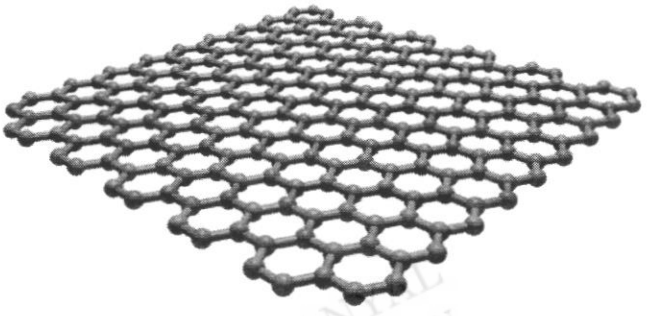
[Turn over

7 Element Y forms a carbonate with chemical formula YCO_3.
Element Z forms a compound with hydrogen with the chemical formula HZ, that has a boiling point of −85 °C.

What is the type of bonding and the chemical formula of the compound formed between Y and Z?

	bonding	chemical formula
A	covalent	YZ
B	covalent	YZ_2
C	ionic	YZ
D	ionic	YZ_2

8 Graphene is a form of carbon and has a two-dimensional structure.



Which statement about the properties of graphene is true?

A It is soluble in water.

B It has a low melting point.

C It has a simple molecular structure.

D It can conduct electricity in the solid state.

9 The table shows the electrical conductivity of some substances.

What row shows the correct electrical conductivity and the structure?

	electrical conductivity		structure
	solid state	molten state	
A	yes	yes	giant molecular structure
B	no	yes	giant ionic structure
C	yes	no	simple molecular structure
D	no	no	giant metallic structure

10 In which molecule are all the valence electrons involved in bonding?

A CO

B CH_4

C HF

D NH_3

11 Which substance has the greatest number of atoms?

A 0.5 mole of sulfuric acid

B 1 mole of carbon dioxide

C 1 mole of ice

D 1.5 moles of oxygen

12 The equations show the reactions involved in the formation of nitric acid HNO_3, starting from nitrogen.

Step 1 $N_2 + O_2 \rightarrow 2NO$

Step 2 $2NO + O_2 \rightarrow 2NO_2$

Step 3 $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$

How many moles of nitrogen is needed to form 0.1 mole of nitric acid?

A 0.025 mole

B 0.05 mole

C 0.1 mole

D 0.2 moles

13 What is the mass of hydrated copper(II) sulfate crystals, $CuSO_4.5H_2O$, to be dissolve in 200 cm^3 of water to form 0.1 mol/dm^3 copper(II) sulfate solution?

A 2.5 g

B 3.2 g

C 3.56 g

D 5 g

14 In an experiment, 90 g of glucose, $C_6H_{12}O_6$, ferments to form 15 g of ethanol, C_2H_5OH.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

What is the percentage yield of ethanol?

A 17 %

B 33 %

C 51 %

D 65 %

15 20 cm of methane burns in 20 cm^3 of oxygen to form carbon dioxide and water.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

What is the total volume of gases remaining at room temperature after the reaction?

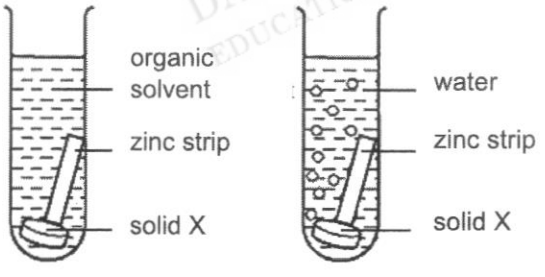
A 10 cm^3

B 20 cm^3

C 30 cm^3

D 40 cm^3

16 Two experiments were conducted to investigate if solid X is an acid.



test tube 1 test tube 2

Which statement about solid X can be deduced from the experiments?

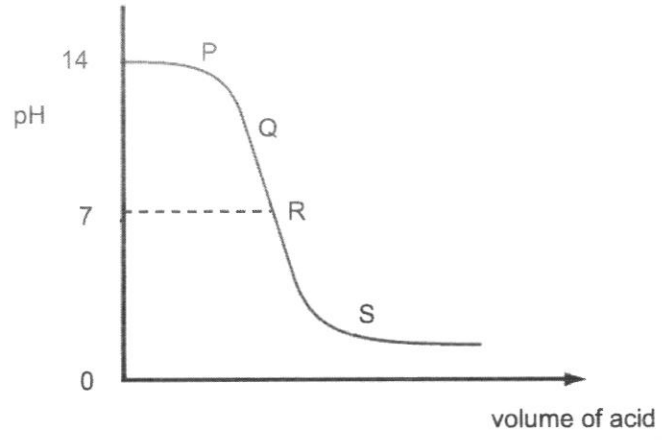
A Solid X is a strong acid

B Solid X is a monobasic acid.

C Solid X display acidic properties only in water.

D Solid X is not an acid as it did not react with zinc in test tube 1.

17 The graph shows the change in pH as an acid is added to an alkali.

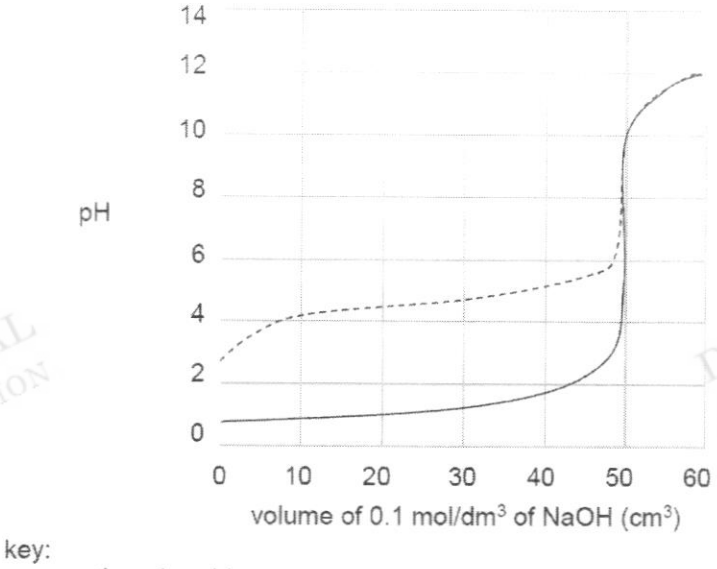


Which letters represents the points where both alkali and salt are present?

A R only
B P and Q only
C Q and R only
D P, Q, and R

18 0.1 mol/dm^3 aqueous sodium hydroxide is added to separate test tubes containing 50.0 cm^3 solutions of 0.1 mol/dm^3 of hydrochloric acid and 0.1 mol/dm^3 ethanoic acid.

The graphs show the changes in pH in the reactions.



key:
- - - - ethanoic acid
—— hydrocholoric acid

Which statement about the reactions are true?

A A strong acid has a higher initial pH.

B The salts formed in both reactions are alkaline.

C The same number of moles of products are formed in both reactions.

D A strong acid reacts with sodium hydroxide completely, but a weak acid only reacts with sodium hydroxide partially.

19 A complex salt consists of ammonium ions, iron ions and sulfate ions has the chemical formula $(NH_4)_2Fe(SO_4)_2$.

In an experiment, a sample of the complex salt was dissolved in deionsed water and separated into two portions.

In the first portion, a few drops of aqueous barium nitrate were added.
In the second portion, aqueous sodium hydroxide was added drop wise till excess to the mixture and heated until there is no further change.

Which observation would **not** be made?

A A white precipitate is formed.

B A dirty green precipitate is formed.

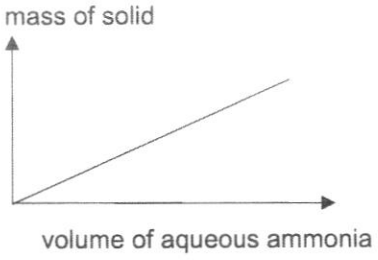
C A reddish brown precipitate is formed.

D Effervescence of a colourless and pungent gas.

20 Sample A consists of a mixture of aqueous copper(II) sulfate and aqueous zinc chloride. Aqueous ammonia was added to sample A dropwise till excess.

Which graph best represents the change in the mass of solid present in the mixture?

A



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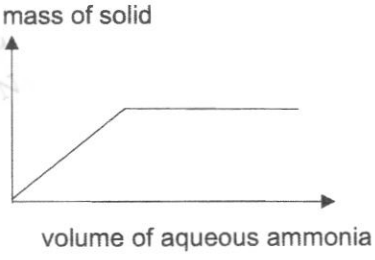

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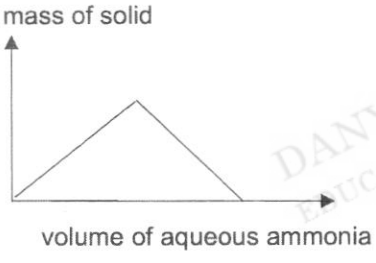

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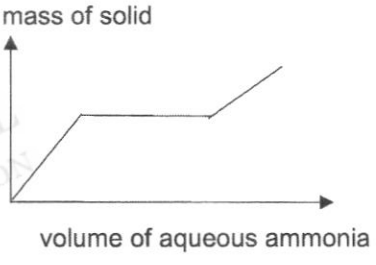


21 Which pair of reagents would be most suitable to safely prepare a pure sample of silver chloride?

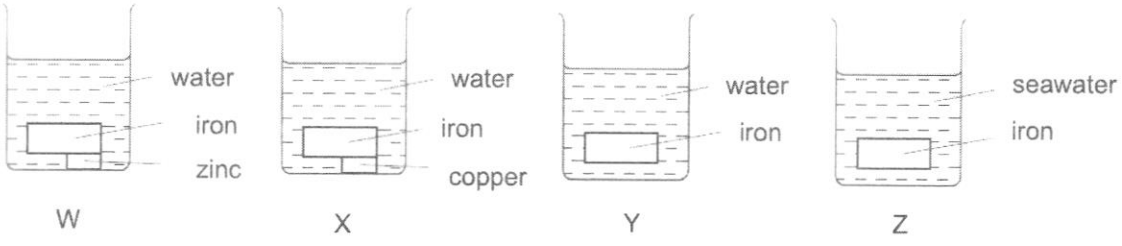
A silver and dilute hydrochloric acid

B silver oxide and dilute hydrochloric acid

C silver carbonate and dilute hydrochloric acid

D aqueous silver nitrate and dilute hydrochloric acid

22 Four pieces of iron are placed separately in water.



In which setup will the iron rust the slowest?

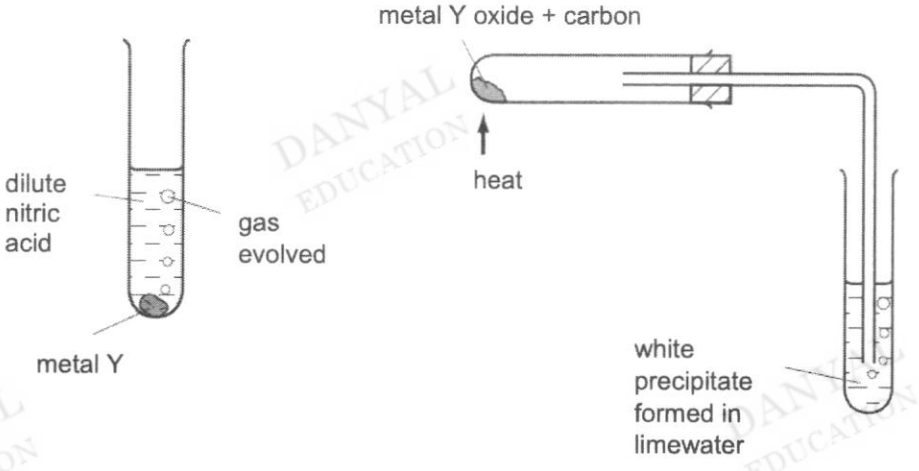
A setup W

B setup X

C setup Y

D setup Z

23 The diagrams show two experiments to investigate the reactivity of metal Y.



What can metal Y be?

A copper

B magnesium

C sodium

D zinc

24 In an experiment to find the order of reactivity of some metals, three metals P, Q and R were placed into four separate sulfate solutions containing the aqueous metal ions.

The results are shown in the table where a tick indicates

metal	aqueous metal ions			
	P^{2+}	Q^{3+}	R^{2+}	S^{2+}
P	X	X	X	✓
Q	✓	X	✓	✓
R	✓	X	X	✓
S	X	X	X	X

✓ = reaction observed
X = no reaction observed

What is the order of reactivity of the metals?

	lease reactive ⟶			most reactive
A	Q	R	P	S
B	Q	P	R	S
C	S	R	P	Q
D	S	P	R	Q

25 The extraction of iron from haematite involves a few reactions.

1 $C + O_2 \rightarrow CO_2$

2 $CO + O_2 \rightarrow 2CO$

3 $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

4 $CaCO_3 \rightarrow CaO + CO_2$

5 $CaO + SiO_2 \rightarrow CaSiO_3$

How many of the reactions are redox reactions?

A 2

B 3

C 4

D 5

26 Which pair of reagents, when reacted together, do not produce a gas?

A ammonium sulfate and potassium hydroxide with heating

B aqueous copper(II) sulfate and zinc

C potassium and water

D silver oxide and hydrogen with heating

27 Which is true for all metals?

A They react with acids

B They have a high density.

C They have high melting points.

D They have delocalised electrons.

28 Which property of Group VII elements decreases moving down the group?

A melting point

B number of valence electrons

C oxidising power

D size of the atom

29 Metal M is soft and can be cut easily with a knife.

Which property of metal M is true?

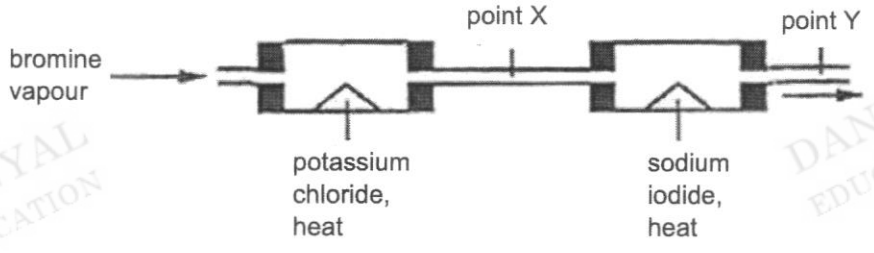
A It reacts with air to form an acidic oxide.

B The metal hydroxide can be used as a test for cations.

C It reacts with chlorine to form an insoluble metal chloride.

D It reacts with water violently to form a solution that turns Universal Indicator red.

30 Bromine vapour is passed over a sample of potassium chloride and sodium iodide.



What is the correct colour seen at point X and Y?

	colour at point X	colour at point Y
A	reddish-brown	purplish black
B	reddish-brown	reddish-brown
C	yellowish green	yellowish green
D	yellowish green	purplish black

31 Chrysotile is a type of asbestos which is used in buildings for its flame-retarding and insulating properties. It has the formula $Mg_3Si_2O_5(OH)_4$.

What is the oxidation state of silicon in this chrysotile?

A +1

B +2

C +3

D +4

32 In which equation(s) is manganese being reduced?

1 $2Mn(OH)_2 + H_2O_2 \rightarrow Mn_2O_3 + 3H_2O$

2 $MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$

3 $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$

A 1 and 2 only

B 1 and j3 only

C 2 and 3 only

D 1, 2 and 3

33 A colourless gas is passed into each of the different solutions.
The results for each solution are shown in the table.

solution	result
potassium iodide	colourless solution turns brown
acidified potassium manganate(VII)	purple solution remains purple

What is the property of the colourless gas?

A an oxidising agent

B a reducing agent

C both oxidising and reducing agent

D neither oxidising or reducing agent

34 Calcium carbonate reacts with dilute nitric acid.

Which change will increase the rate of reaction by increasing the movement of the particles?

A by adding a catalyst

B by increasing the concentration of the acid

C by carrying out the reaction at a higher temperature

D by increasing the surface area by using powdered calcium carbonate

[Turn over

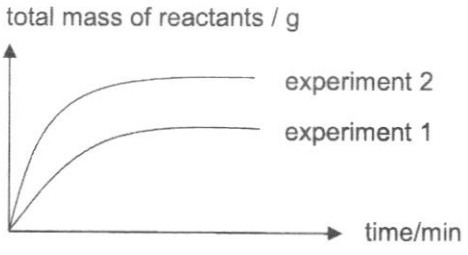
35 In experiment 1, 500 cm^3 of 1 mol/dm^3 dilute hydrochloric acid is reacted with excess magnesium

In experiment 2, 300 cm^3 of 1.5 mol/dm^3 dilute hydrochloric acid is reacted with excess magnesium

The volume of hydrogen given off is plotted against time.

Which graph is correct?

A



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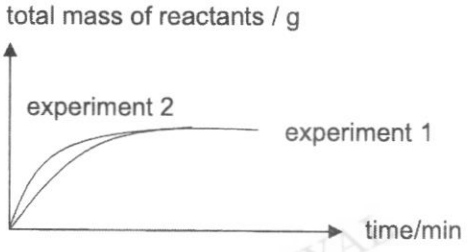

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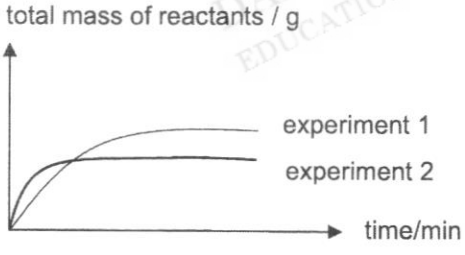

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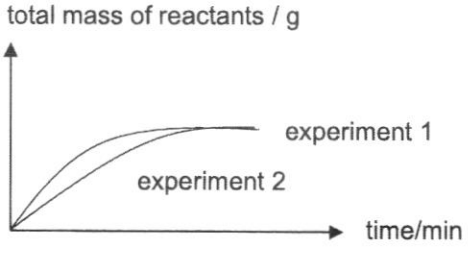
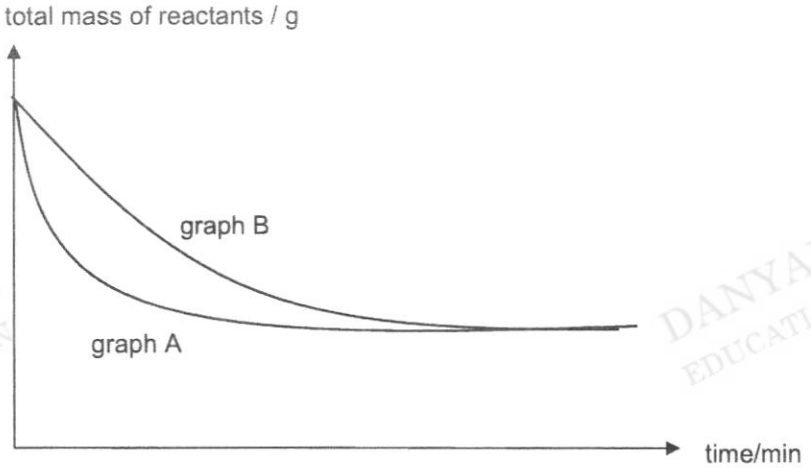


36 A student conducted an experiment using hydrochloric acid and excess magnesium powder in an open conical flask. As the reaction proceeded, he measured the total mass of the reaction mixture over time and plotted graph A.

The experiment was repeated and graph B was obtained.



Which change could result in graph B?

A adding a catalyst

B increasing the concentration of the acid

C changing to magnesium ribbon

D increasing the temperature

37 In which process is energy released?

A melting of ice

B photosynthesis

C electrolysis of dilute sulfuric acid

D reaction of magnesium and dilute nitric acid

38 The equation for the combustion of hydrogen is shown.

$$2H_2 + O_2 \rightarrow 2H_2O$$

bond	bond energy in kJ/mol
H – H	436
O – H	463
O – O	142
O = O	498

What is the enthalpy change of this reaction?

A +88 kJ/mol

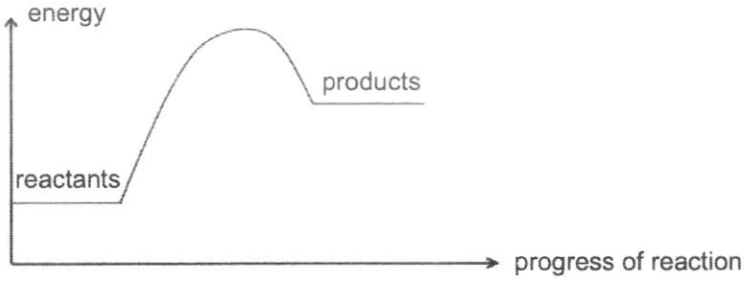
B +444 kJ/mol

C –482 kJ/mol

D –788 kJ/mol

39 Which is the correct energy profile diagram that shows a reaction that would proceed most rapidly?

A



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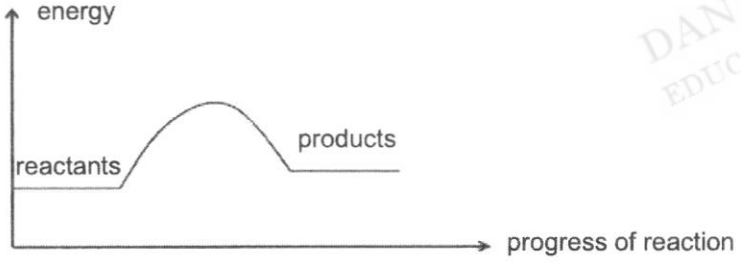

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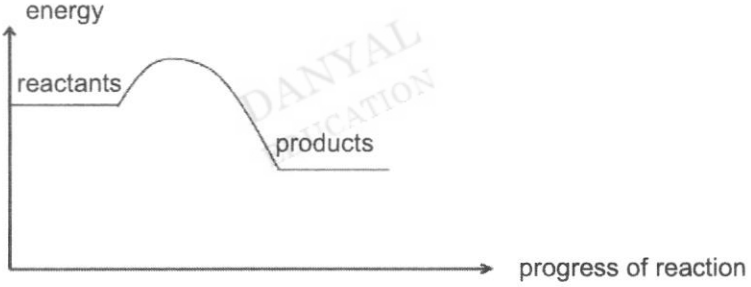

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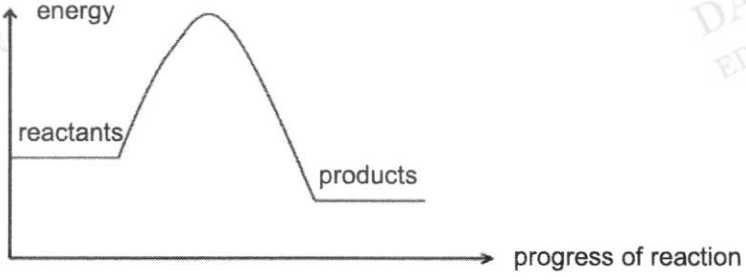
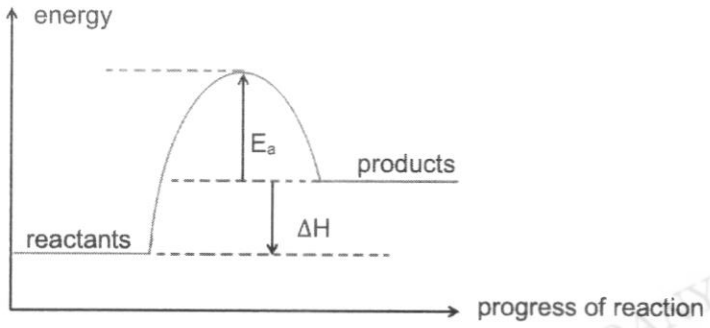


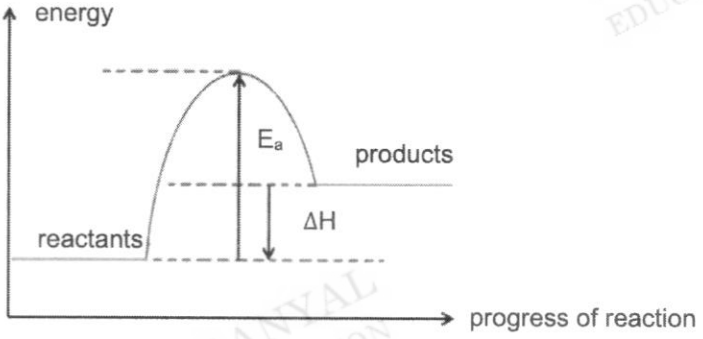
40 The energy profile diagram shows the energy changes that occur as a reaction takes place.

Which energy profile diagram is correct for an endothermic reaction?

A



B



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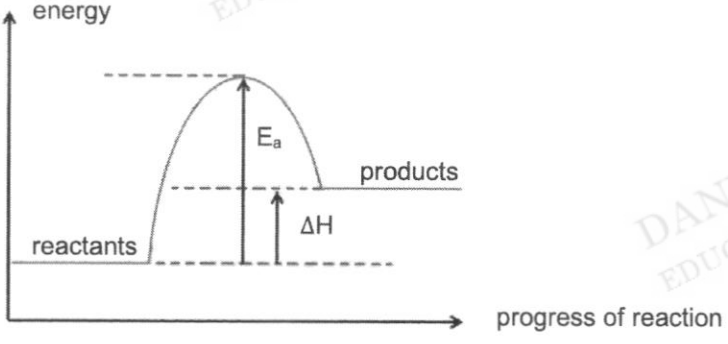

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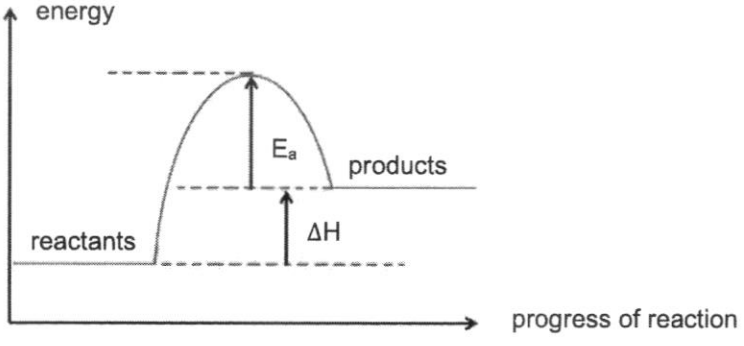

--- End of Paper ---

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.)

ORCHID PARK SECONDARY SCHOOL
End-of-Year Examination 2022

CANDIDATE NAME

CLASS V 8 INDEX NUMBER

CHEMISTRY **6092/02**

Paper 2 **5 October 2022**

Secondary 3 **1 hour 45 minutes**

Setter: Mr Wong YH **80 Marks**

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your register number and name on the all the work you hand in.
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Write in dark blue or black pen.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

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

Section B
Answer all **three** questions. The last question is in the form of 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.
A copy of the Periodic Table is provided on Page 20.

Section A

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

A1 The table shows the properties of particles **A**, **B**, **C**, **D**, **E**, **F** and **G**.
Use the letters to answer the questions.

particle	no. of protons	no. of electrons	nucleon number
A	10	10	20
B	19	18	39
C	12	12	24
D	8	8	16
E	7	7	14
F	19	19	39
G	8	10	18

(a) Which particle is a cation?

..... [1]

(b) Which two particles are isotopes?

..... [1]

(c) Which particle can react with oxygen to form a neutral oxide?

..... [1]

(d) Which particle is in Group 0?

..... [1]

(e) Which particle is present in rust?

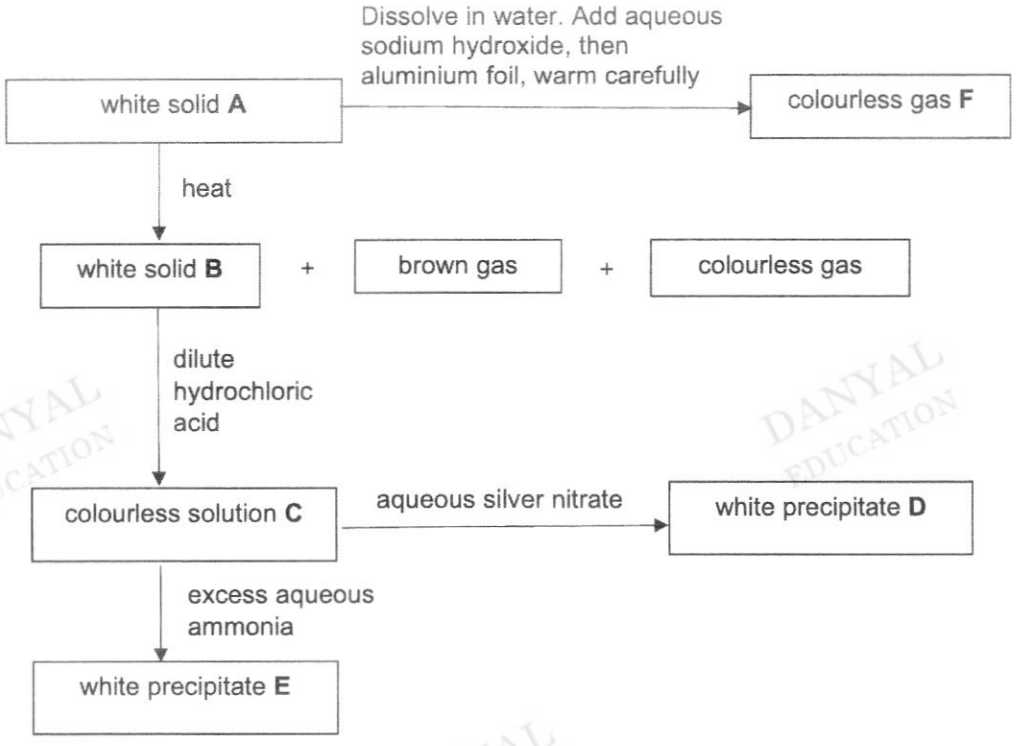
..... [1]

A2 State the most efficient separation techniques to obtain the desired compounds from its mixtures.

	mixture	desired compound	most efficient method
(a)	silver chloride and water	silver chloride	
(b)	iron(II) sulfate and water	iron(II) sulfate	
(c)	ammonium chloride and sodium chloride	sodium chloride	

[3]

A3 Study the reactions in the diagram.



(a) Write the chemical formula of the following substances.

substance	chemical formula
A	
B	
C	
F	

[4]

(b) Write a balanced chemical equation for the formation of substance **D**.

..... [1]

(c) Write an ionic equation for the formation of substance **E**.

..... [1]

A4 The table shows some properties of the oxides formed from the unknown elements **W**, **X**, **Y** and **Z**.

element	chemical formula of oxide	chemical property	melting point	period in Periodic Table
W	W_2O	basic oxide	high	period 2
X	X_2O	neutral oxide	low	period 1
Y	Y_2O_3	amphoteric oxide	high	period 3
Z	ZO_2	acidic oxide	High	period 3

(a) Deduce and name the unknown elements **W**, **X**, **Y** and **Z**.

element	name
W	
X	
Y	
Z	

[2]

(b) By using the actual identity of the elements, draw the 'dot and cross' diagram of

(i) X_2O

[1]

(ii) Y_2O_3

[2]

(c) By using the actual identity of the elements, explain

(i) the low melting point of X_2O,

.....

.....

.....

.....

..... [2]

(ii) the high melting point of ZO_2.

.....

.....

.....

.....

..... [2]

A5 Chromium is a transition metal found in period 4 of the Periodic Table with the chemical symbol Cr.

Iron(II) chromite ore has the chemical formula $FeCr_2O_4$ and is insoluble in water. It can be heated with sodium carbonate in the presence of oxygen to produce carbon dioxide and a solid mixture of sodium chromate salt and iron(III) oxide.

$$4FeCr_2O_4\,(s) + 8Na_2CO_3\,(s) + 7O_2\,(g) \rightarrow 8CO_2\,(g) + 8Na_2CrO_4\,(s) + 2Fe_2O_3\,(s)$$

In a reaction, 5.3 grams of sodium carbonate reacted with 1080 cm^3 of oxygen and excess iron(II) chromite ore.

(a) Find the limiting reactant.

[3]

(b) The sample of sodium chromate salt obtained is contaminated with the excess iron(II) chromite ore and iron(III) oxide.

Briefly describe how a pure and dry sample of sodium chromate can be obtained from the mixture.

.....

.....

.....

.....

.....

..... [3]

(c) Complete the table.

oxidation state of chromium in $FeCr_2O_4$	
oxidation state of chromium in Na_2CrO_4	
Is $FeCr_2O_4$ oxidised or reduced	

[2]

A6 Hydrogen peroxide decomposes into oxygen gas and water.

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

In an experiment, 50.0 cm^3 of an unknown concentration of aqueous hydrogen peroxide, H_2O_2, was placed in a conical flask together with one spatula of manganese(IV) oxide powder. It was observed that the conical flask felt hot during the reaction.

The gas produced was collected and recorded every 30 seconds and the results were recorded in a table.

Time / s	30	60	90	120	150	180
Volume of gas / cm^3	180	280	350	400	420	420

(a) Calculate the unknown concentration of the aqueous hydrogen peroxide.

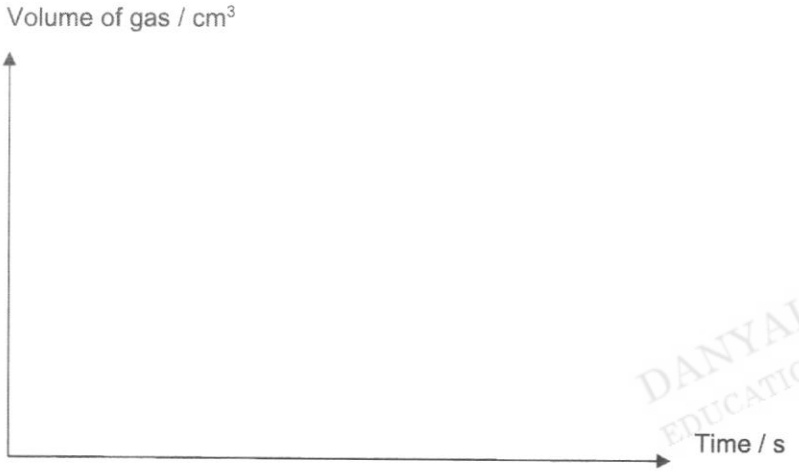
[3]

(b) Draw an energy profile diagram to represent the decomposition of hydrogen peroxide.

[2]

(c) **(i)** Sketch the graph of 'volume of gas' collected vs 'time'.

Label this graph as Expt 1.



[1]

(ii) Draw on the diagram above, the graph you would expect if the concentration of hydrogen peroxide was changed to 0.8 mol/dm^3 instead.

Label this graph as Expt 2.

[1]

(d) What is the purpose of adding manganese(IV) oxide powder?

Explain using ideas of colliding particles.

.....

.....

.....

.....

..... [2]

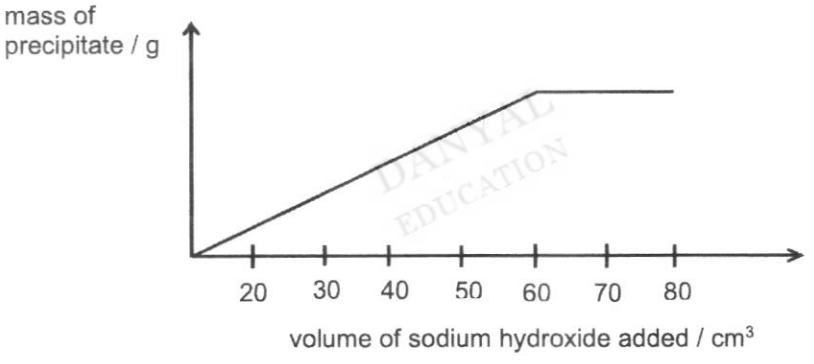
A7 An unknown transition metal **M** is found in period 4 of the Periodic Table.

Metal **M** reacts with chlorine gas to form a metal chloride. An experiment was carried out to determine the unknown metal **M** by using precipitation reaction.

The following mixtures were prepared in 7 different test tubes using 0.2 mol/dm^3 of aqueous metal chloride and 0.1 mol/dm^3 of aqueous sodium hydroxide.

test tube	volume of 0.2 mol/dm^3 metal chloride (cm^3)	volume of 0.1 mol/dm^3 sodium hydroxide (cm^3)
1	10	20
2	10	30
3	10	40
4	10	50
5	10	60
6	10	70
7	10	80

After the reaction, the mass of the precipitate formed in each of the test tubes were measured and the results are plotted in the graph below.



(a) State **one** property of metal **M** which are usually not found in other non-transition metals.

..... [1]

(b) **(i)** What is the volume of aqueous sodium hydroxide that resulted in the complete reaction of the 10 cm^3 of aqueous metal chloride?

..... [1]

(ii) Hence, calculate the number of moles of aqueous sodium hydroxide that reacted completely with 10 cm^3 of aqueous metal chloride.

[1]

(c) Calculate the number of moles of metal chloride used in each of the tests.

[1]

(d) Hence, using your answer in part **(b) (ii)** and part **(c)**, deduce the mole ratio of sodium hydroxide to the metal chloride in the reaction.

[1]

(e) Balance the following three equations.

Equation 1 ..... NaOH + ... **M**C*l* → ..... NaC*l* + ... **M**OH

Equation 2 ..... NaOH + ... **M**C*l*$_2$ → ..... NaC*l* + ... **M**(OH)$_2$

Equation 3 ..... NaOH + ... **M**C*l*$_3$ → ..... NaC*l* + ... **M**(OH)$_3$

[2]

(f) Using your answer in part **(d)** and **(e)**, deduce and circle the correct chemical formula of the metal chloride.

MC*l* **M**C*l*$_2$ **M**C*l*$_3$ [1]

(g) Given that the metal chloride solution contains 0.325 g of the metal chloride, determine the unknown metal **M**.

[2]

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.

B8 Salts

A salt is a compound formed when the hydrogen ion in an acid is replaced by a metallic ion or an ammonium ion. Common acids used in the laboratory are dilute hydrochloric acid, dilute sulfuric acid and dilute nitric acid.

Some other less common acids are hydroiodic acid, perchloric acid and boric acid.

(I) Hydroiodic acid dissociates in water to form hydrogen ions and iodide ions.

$$HI(aq) \rightarrow H^+(aq) + I^-(aq)$$

- all iodide compounds are soluble, except for silver iodide and lead(II) iodide

(II) Perchloric acid dissociates in water to form hydrogen ions and perchlorate ions.

$$HClO_4(aq) \rightarrow H^+(aq) + ClO_4^-(aq)$$

- all perchlorate compounds are soluble

(III) Boric acid dissociates in water to form hydrogen ions and borate ions.

$$H_3BO_4(aq) \rightarrow 3H^+(aq) + BO_4^{3-}(aq)$$

- all borate compounds are insoluble except for sodium borate, potassium borate and ammonium borate

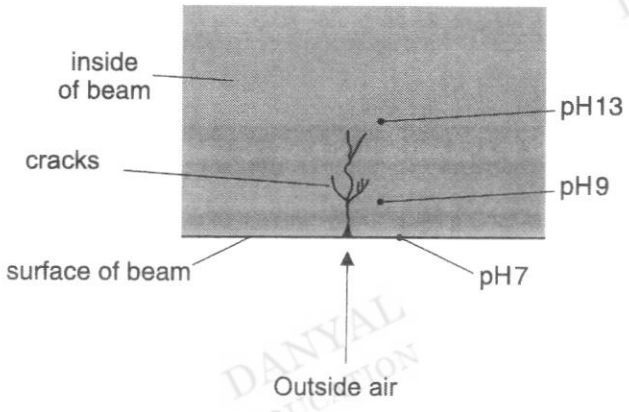
Applications of salts in buildings

(a) Crushed calcium carbonate is first heated strongly. During this process, one of the products formed is calcium oxide, which is slightly soluble in water.

Cement is a mixture of calcium oxide, clay and other substances. Cement is usually used with sand to form concrete.

When set or hardened, concrete is slightly porous. If there are cracks in the concrete beam, rainwater can soak through the concrete, and a small amount of the solid calcium oxide can dissolve in the rainwater to form aqueous calcium hydroxide. Carbon dioxide in the air can also diffuse into the cracks and creates a difference in pH inside the beam.

The diagram shows the variation in pH in the cross-section of a concrete beam after raining.



(b) In highly polluted cities with high sulfur dioxide pollution, the sulfur dioxide can react with rainwater and oxygen to form sulfuric acid, resulting in acid rain. The acid rain will result in historic monuments made of concrete to be damaged over time when the rainwater seeps through the micro cracks in these structures.

To protect the monuments, a thin coating of aqueous barium hydroxide solution is applied over the surface of the concrete monuments. When acid rain falls, a chemical reaction will occur that will better prevent the concrete monument to be corroded by acid rain over time.

The table shows the solubility of some compounds at 25 °C

substance	$CaSO_4$	$BaSO_4$
solubility (in mol/dm^3)	0.045	0.0000094

(a) Complete the table to identify two reactants that can be used to react to obtain a pure and dry sample the following salts.

	name of salt	reactant 1	reactant 2
(i)	copper(II) iodide		
(ii)	sodium perchlorate		
(iii)	silver borate		

[3]

(b) What is the name of the chemical reaction to obtain calcium oxide by heating crushed calcium carbonate strongly?

..... [1]

(c) Write a balanced chemical equation with state symbols for the reaction between rainwater and calcium oxide.

..... [1]

(d) If there are cracks in the concrete beam, carbon dioxide in the air can diffuse in.

Using a balanced chemical equation, explain why the pH is much higher on the inside of the beam.

.....

.....

.....

.....

.....

..... [3]

(e) Write a balanced chemical equation for the formation of sulfuric acid from sulfur dioxide.

..... [1]

[Turn over

(f) With the aid of a suitable ionic equation, explain how the barium hydroxide solution will help to better prevent the concrete monument from being corroded by the acid rain.

.....

.....

.....

.....

.....

..... [3]

B9 The table shows the results when small pieces of different metals were added to the chloride solutions containing different metal ions.

metals / solutions	chromium	nickel	iron	cobalt	zinc
chromium(II) chloride	–	no visible change	no visible change	no visible change	solution turns colourless
nickel(II) chloride	solution turns blue	–	solution turns yellow	solution turns red	solution turns colourless
iron(III) chloride	solution turns blue	no visible change	–	no visible change	solution turns colourless
cobalt(II) chloride	solution turns blue	no visible change	solution turns yellow	–	solution turns colourless
zinc chloride	no visible change	no visible change	no visible change	no visible change	–

(a) What is the order of reactivity of the five metals?

Most reactive .....

.....

.....

.....

Least reactive .....

[2]

(b) Complete the table to show the colours of the metal chloride solutions.

metal chloride	colour of solution
chromium(II) chloride	
cobalt(II) chloride	

[2]

(c) From the results of the experiment, suggest what method would be used to extract chromium form its ores.

..... [1]

(d) Using structure and bonding, explain the electrical conductivity of cobalt and cobalt(II) chloride.

.....

.....

.....

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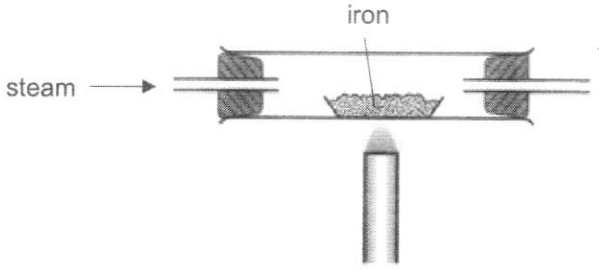
.....

.....

..... [3]

Either

B10 Steam is passed over a sample of iron powder and heated. A gas is formed and the silver powder turns black. When the black solid is left to stand in air, the black solid slowly turns reddish brown.



(a) Explain the colour changes observed.

.....

.....

.....

..... [2]

(b) State the gas formed in the reaction and how the gas can be identified.

.....

..... [1]

(c) Write a balanced chemical equation with state symbols for the reaction between steam and iron to form the black solid.

..... [1]

(d) State and explain the observations if the reaction is repeated using copper powder instead.

.....

..... [1]

(e) The hulls of the ships are usually made of iron.

Explain why zinc sheets are usually added to the iron hulls of the ships.

.....

.....

.....

..... [2]

(f) An iron compound contains 23.5 % sulfur and 35.3 % oxygen.

Find the empirical formula of the compound.

[3]

OR

B10 Hydrogen is used as a fuel in some space rockets. It is also a green fuel as only water is produced when hydrogen is combusted.

$$2H_2\,(g) + O_2(g) \rightarrow 2H_2O(l) \quad \Delta H = -484\ kJ/mol$$

(a) Explain why the reaction is exothermic.

.....

..... [1]

(b) Calculate the energy change when 1 kg of hydrogen is being combusted.

[3]

(c) Using Kinetic Particle Theory, explain why liquid hydrogen is usually carried by the space rockets instead of hydrogen gas.

.....

..... [1]

(d) Hydrogen can be produced from the electrolysis of water.

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g) \quad \Delta H = +484\ kJ/mol$$

A student commented that although the electrolysis of water to form hydrogen gas requires electrical energy, the same amount of energy is given out when hydrogen gas is combusted, hence it does not require any net energy to produce and use hydrogen gas a fuel.

Do you agree with the student?

Explain why.

.....

.....

..... [1]

(e) **(i)** Hydrogen and sodium are both elements found in the Periodic Table.

State **one** similarity between hydrogen and sodium.

..... [1]

(ii) Sodium reacts with water to form hydrogen gas.

Write a balanced chemical equation with state symbols for the reaction.

..... [1]

(iii) Which substance is reduced in the reaction in part **(ii)**?

Explain your answer using oxidation states.

.....

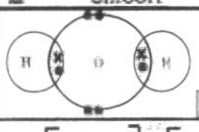
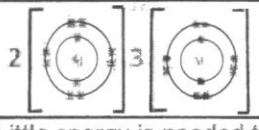
.....

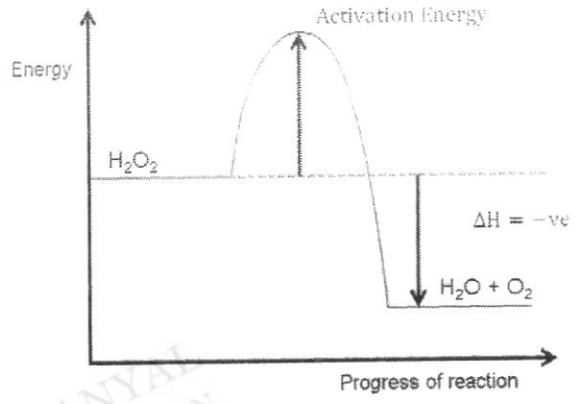
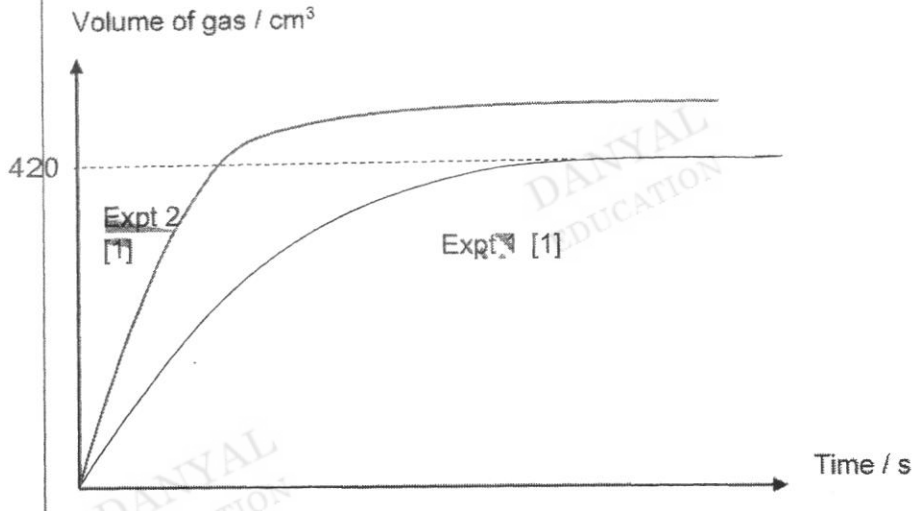
.....

..... [2]

--- End of Paper ---

2022 4E Chemistry Paper 2 Marking Scheme

A1a	B [1]
A1b	D and G [1]
A1c	E [1]
A1d	A [1]
A1e	D or G [1]
A2	Filtration [1]
A2b	Crystallisation [1]
A2c	Sublimation [1]
A3a	**A** $Al(NO_3)_3$ [1] **B** Al_2O_3 [1] **C** $AlCl_3$ [1] **F** NH_3 [1]
A3b	$AlCl_3 + AgNO_3 \rightarrow AgCl + Al(NO_3)_3$ [1]
A3c	$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3$ [1]
A4a	**V** lithium [0.5] **W** hydrogen [0.5] **X** aluminium [0.5] **Z** silicon [0.5]
A4bi	 [1]
A4bii	 [1][1]
A4ci	Little energy is needed to overcome [0.5] the weak intermolecular forces of attraction [0.5] between the simple water moecules [0.5] in the simple molecular structure.[0.5]
A4cii	A large amount of energy is required to break [0.5] the strong covalent bonds [0.5] between all the atmos [0.5] in the 3 -dimensional the giant molecular lattice structure. [0.5]
A5a	No. of moles of Na_2CO_3 = $\frac{5.2}{2(23)+12+3(16)} = 0.05\ mol$ [1] No . of moles of O_2 = $\frac{1090}{24000} = 0.045\ mol$ [1] Mole ratio: Na_2CO_3 : O_2 8 : 7 For 0.05 mol , 0.04375 mol needed 0.045 mol present, in excess Na_2CO_3 is limiting reactant [1]
A5b	Add water to the mixture and dissolve the sodium chromate. [0.5] Filter to obtain sodium chromate solution as filtrate [0.5] Heat the filtrate until saturated [0.5] Let it cool and crystallise [0.5] Filter to obtain sodium chromate crystals as residues [0.5] Wash with a little cold deionised water and dry between sheets of filter paper [0.5]
A5c	$FeCr_2O_4$ +3 [1] Na_2CrO_4 +6 [1] $FeCr_2O_4$ is oxidised

A6a	No. of moles of $O_2 = \frac{420}{24000} = 0.0175\ mol$ [1] Mole ratio: O_2 : H_2O_2 1 : 2 0.0175 : 0.035 mol [1] Concentration $= \frac{0.035}{0.05} = 0.7\ mol/dm^3$ [1]
A6b	 Label activation energy correctly [0.5] Label ΔH correctly [0.5] Label axis correctly [0.5] Correct shape [0.5]
A6ci A6cii	
A6d	MnO_2 acts as a catalyst [0.5], and provides an alternative pathway for the reaction with lower activation energy [0.5]. More particles have energy equal or greater than the activation energy [0.5], leading to more frequent effective collisions [0.5] and a higher speed of reaction
A7a	Metal M forms ions with different oxidation states. [1] Metal M forms coloured compound Metal M and its compounds are good catalysts
A7bi	60 cm^3 [1]
A7bii	No. of moles of sodium hydroxide = 0.1 × 0.06 [0.5] = 0.006 mol [0.5]
A7c	No. of moles of metal chloride = 0.2 × 0.01 [0.5] = 0.002 mol [0.5]

A7d	Mole ratio: sodium hydroxide : metal chloride 0.006 : 0.002 3 : 1 [1]
A7e	1) 1 NaOH + 1 MCl → 1 NaCl + 1 MOH 2) 2 NaOH + 1 MCl_2 → 2 NaCl + 1 $M(OH)_2$ 3) 3 NaOH + 1 MCl_3 → 3 NaCl + 1 $M(OH)_3$ [2] Minus 1 mark for each mistake
A7f	Correct chemical formula: MCl MCl_2 MCl_3 [1]
A7g	Molar mass of $MCl_3 = \frac{0.325}{0.002}$ [0.5] = 162.5 [0.5] A_r of M = 162.5 – 3(35.5) = 56 [0.5] M is iron [0.5]
B8a	copper(II) iodide: $CuCO_3$; HI sodium perchlorate: $HClO_4$; NaOH silver borate: $AgNO_3$; Na_3BO_3 K_3BO_3 $(NH_4)_3BO_3$ [0.5] [0.5] Reject Cu [0.5] [0.5] Reject Na [0.5] [0.5] Reject acid reactions due to insoluble coating
B8b	Thermal decomposition [1]
8c	$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$ [1]
8d	$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$ [1] Carbon dioxide is an acidic oxide [0.5] which reacts with calcium hydroxide which is a base [0.5] At the inside of the beam, the concentration of carbon dioxide is lower [0.5] as less carbon dioxide can diffuse in deeply, resulting in less calcium hydroxide reacting [0.5] hence a higher pH as compared to the outside of the beam
8e	$2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4$ [1]
8f	$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ [1] Aqueous barium hydroxide reacts with sulfuric acid to form the (insoluble) barium sulfate [0.5], which has a very low solubility of 0.0000094 mol/dm^3 [0.5]. It is less soluble [0.5] than calcium sulfate[0.5], which is formed when calcium oxide/calcium hydroxide reacts with sulfuric acid. Note: No marks given for neutralisation explanation as only a thin layer of alkali is used.
B9a	Zinc, chromium, iron, cobalt, nickel [1] 1m for zinc most reactive and nickel least reactive 1m for correct order of the other 3 metals

B9b

metal chloride	colour of solution
chromium(II) chloride	blue [1]
cobalt(II) chloride	red [1]

B9c Reduction / heating with carbon [1]

B9d Cobalt has a giant metallic structure. [0.5] The valence electrons in cobalt are delocalised [0.5] and can act as charge carriers to conduct electricity

Cobalt(II) chloride has a giant ionic structure [0.5]. In the solid state, the ions are held in fixed positions by strong electrostatic forces of attraction [0.5]. In molten and aqueous state, the strong electrostatic forces of attraction are overcame [0.5]. The mobile cobalt(II) ions and chloride ions [0.5] can act as charge carriers to conduct electricity

Either

B10a The iron reacts with steam to for iron(II) oxide that is black. [1] The iron(II) oxide is then oxidised by oxygen in the air to form iron(III) oxide which is reddish brown.[1]

B10b Hydrogen[0.5]. The gas will extinguish a lighted splint with a pop sound [0.5]

B10c H_2O (g) + Fe (s) → FeO (s) + H_2 (g) [1]

B10d There is no visible change [0.5] as copper do not react with steam [0.5]

B10e Zinc is more reactive than iron [0.5]. so it will oxidised / react with oxygen in preference of iron [0.5]. It acts as a sacrificial metal [0.5] and prevents the iron hull from rusting [0.5]

B10f

	Fe	S	O
Mass in 100 g	41.2 [0.5]	23.5	35.3
No. of moles	$\frac{41.2}{56} = 0.773571$ [0.5]	$\frac{23.5}{32} = 0.73438$ [0.5]	$\frac{35.3}{16} = 2.20625$ [0.5]
Mole ratio	$\frac{0.773571}{0.73438} = 1.05$	$\frac{0.73438}{0.73438} = 1$	$\frac{2.20625}{0.73438} = 3$
X1	1	1	3

Empirical formula is $FeSO_3$ [1]

OR

B10a More energy is given out during bond forming [0.5] than energy taken in during bond breaking [0.5]

B10b No. of moles of hydrogen = $\frac{1000}{2} = 500\ mol$ [1]

Energy change per 1 mol of hydrogen = $\frac{-484}{2} = -242\ kJ$ [1]

Energy change = $-242 \times 500 = -121000kJ$ [1]

B10c The particles in liquid state are closely packed[0.5], hence resulting in a lower volume [0.5] for the same number of moles of hydrogen gas

B10d No. The energy given out is released to the surrounding [0.5 and cannot be captured.
Other sources of energy such as from combustion of fossil fuels is still needed for the electrolysis of water. [0.5]

B10ei Both have 1 valence electron. [1]

B10eii 2Na(s) + $2H_2O(l)$ → 2NaOH(aq) + H_2(g) [1]

B10eiii H_2O is reduced to form H_2 [0.5], as the oxidation state of hydrogen [0.5] reduces [0.5] from +1 (in H_2O) to 0 in H_2 [0.5]