O

GAN ENG SENG SCHOOL

Preliminary Examination 2024

CANDIDATE NAME			
CLASS		**INDEX NUMBER**	

CHEMISTRY

Paper 1 Multiple Choice

6092/01

9 September 2024

1 hour

Additional Materials: OTAS

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and index number on the OTAS. Shade your index number on the OTAS.

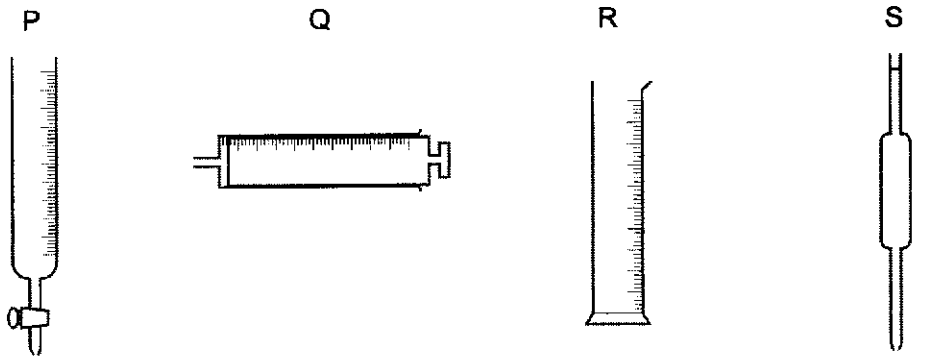
There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice **in soft pencil** on the separate Answer Sheet.

Read the instructions on the OTAS 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 **18**.
The use of an approved scientific calculator is expected, where appropriate.

Total Marks
40

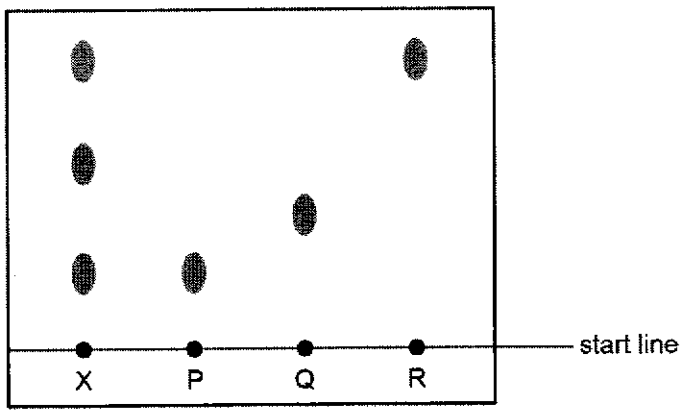
1 P, Q, R and S are pieces of apparatus.



Which row describes the correct apparatus for the measurement made?

	apparatus	measurement made
A	P	the volume of acid added to alkali in a titration
B	Q	0.24 dm^3 of hydrogen gas produced when magnesium reacts with an acid
C	R	75 cm^3 of a gas given off in a rate-determining experiment
D	S	20 cm^3 of alkali for use in a titration

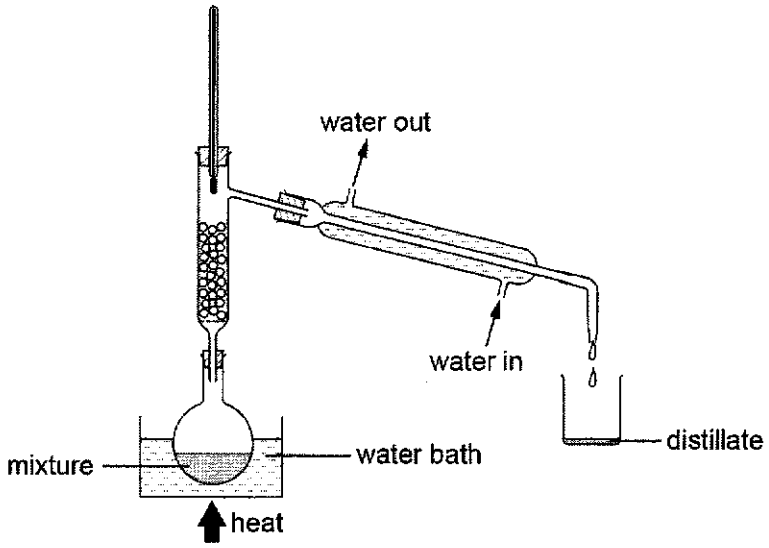
2 X is a mixture of colourless compounds. The diagram shows a chromatogram of X and of three pure compounds, P, Q and R.



Which statement is **not** correct?

A X could contain P and R.
B Q has a greater R_f value than R.
C P and R have different solubilities in the solvent.
D A locating agent was used to develop the chromatogram of X.

3 Which substance can be distilled using the apparatus below?

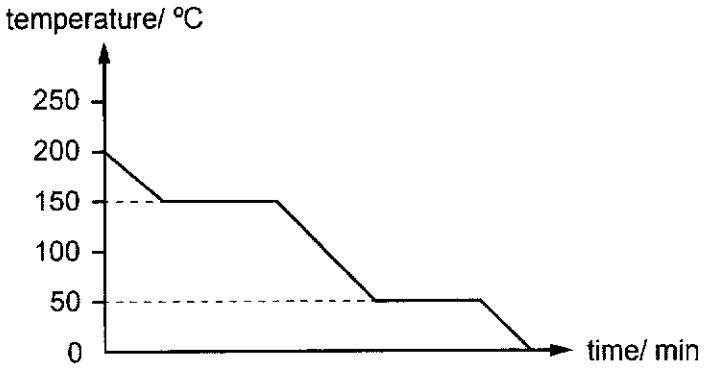


	melting point/ °C	boiling point/ °C
A	–138	0
B	–123	50
C	0	108
D	41	182

4 Which row about a change of state is correct?

	change of state	energy change	process
A	solid → liquid	heat given out	melting
B	gas → liquid	heat taken in	evaporation
C	solid → gas	heat taken in	sublimation
D	liquid → solid	heat given out	condensing

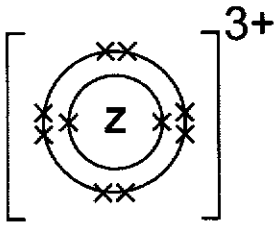
5 The cooling curve for substance **X** is shown below.



At which temperature does both solid and liquid exist?

A 0 °C
B 50 °C
C 150 °C
D 200 °C

6 The ion of an element **Z** is shown below.



In which group and period does element **Z** belong to in the Periodic Table?

	group	period
A	13	2
B	13	3
C	15	2
D	15	3

7 Which row includes an element, a compound and a mixture?

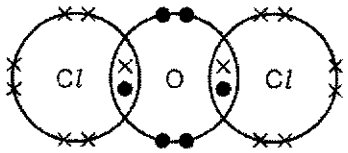
A sea water, tap water, pure water
B sodium chloride, chlorine, pure water
C sea water, sodium chloride, chlorine
D sodium chloride, sea water, pure water

8 Which row correctly classifies how graphite, aluminium and molten sodium chloride conduct electricity?

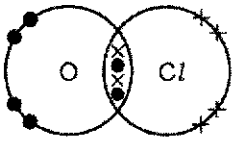
	using mobile ions and electrons	using mobile electrons only	using mobile ions only
A	molten sodium chloride	graphite	aluminium
B	molten sodium chloride	aluminium, graphite	none of the above
C	aluminium	graphite	molten sodium chloride
D	none of the above	aluminium, graphite	molten sodium chloride

9 Which dot and cross diagram for a compound of oxygen and chlorine is correct?

A



B



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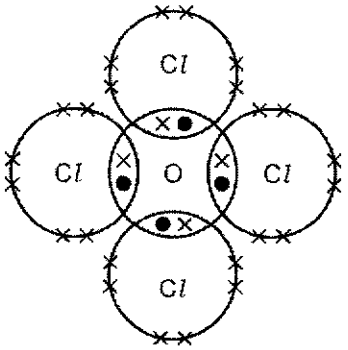
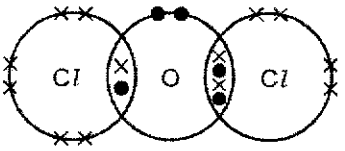


D



10 Which statement about the structure and properties of silicon(IV) oxide is **not** correct?

A It has a giant covalent structure similar to that of diamond.
B There are strong covalent bonds between silicon and oxygen atoms.
C Each silicon atom is bonded to four neighbouring oxygen atoms.
D It has a high melting point due to the strong attractive force between molecules.

11 What is the number of molecules in 500 cm^3 of oxygen gas at room temperature and pressure?

A 1.25×10^{22}
B 1.34×10^{22}
C 3.0×10^{22}
D 3.0×10^{26}

12 The percentage by mass of magnesium in chlorophyll-a (M_r = 893) is 2.69%.

How many magnesium atoms are there in one molecule of chlorophyll-a?

A 1
B 2
C 24
D 100

13 Saline solution is a solution of sodium chloride dissolved in water. It is commonly used in hospitals for cleaning wounds and treating dehydration.

A 0.9% saline solution has 0.9 g of sodium chloride for every 100 cm^3 of solution.

What is the concentration of the 0.9% saline solution in mol/dm^3?

A 0.00154 mol/dm^3
B 0.0154 mol/dm^3
C 0.154 mol/dm^3
D 1.54 mol/dm^3

14 A mixture containing 8.0 g of hydrogen gas with 8.0 g of oxygen gas is ignited.

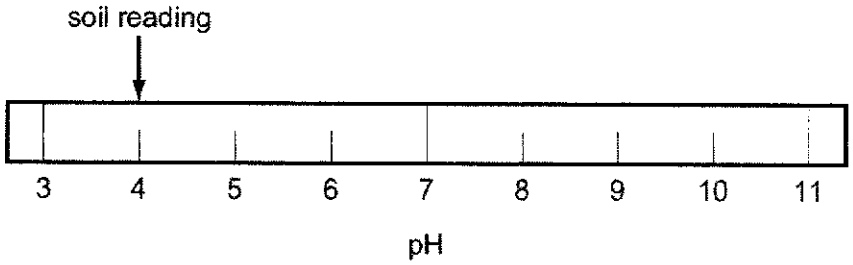
The reaction is represented by the following chemical equation.

$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$$

What is the mass of water formed?

A 9.0 g
B 16.0 g
C 18.0 g
D 36.0 g

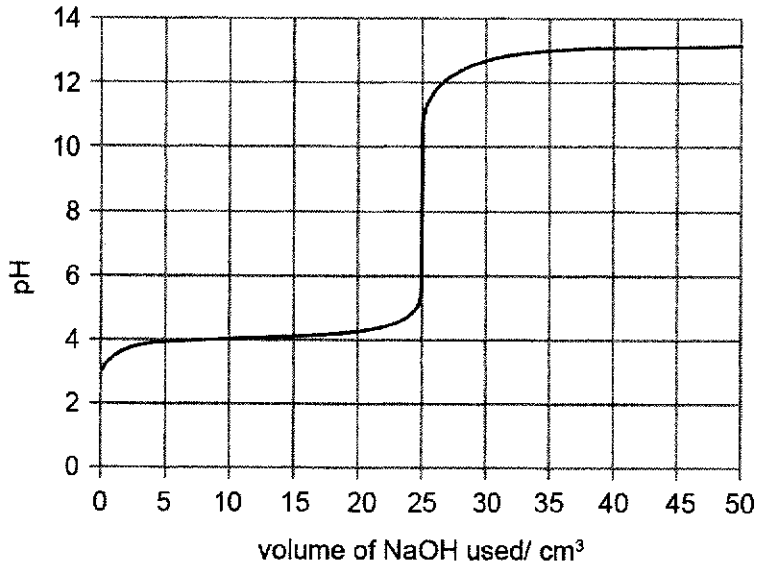
15 The diagram shows the results of a pH test on a sample of garden soil.



What could be added to the soil to change its pH to 7?

A calcium oxide
B sodium oxide
C sodium chloride
D ammonium nitrate

16 The graph shows how pH changes as 0.1 mol/dm^3 of dilute sodium hydroxide is gradually added to 0.1 mol/dm^3 of ethanoic acid.



Which indicator is most suitable to be used in the titration to identify the end-point of neutralisation?

	indicator	colour change	pH at which colour change occurs
A	crystal violet	yellow → violet	0.0 – 2.0
B	methyl orange	red → yellow	3.1 – 4.4
C	phenolphthalein	colourless → pink	8.3 – 10.0
D	indigo carmine	blue → yellow	11.4 – 13.0

17 Copper(II) sulfate is made by reacting excess insoluble solid M and solution N.

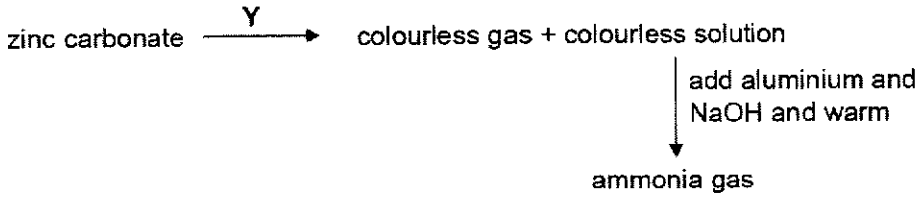
Which row identifies M and N and the method used to extract crystals of copper(II) sulfate from the mixture?

	M	N	method
A	copper	sodium sulfate	filter the mixture to obtain the residue
B	copper	sulfuric acid	filter the mixture and evaporate filtrate until crystals form
C	copper(II) oxide	sulfuric acid	filter the mixture to obtain the residue
D	copper(II) carbonate	sulfuric acid	filter the mixture and evaporate filtrate until crystals form

18 Which of the following pairs of gases changes the colour of damp red litmus paper?

A ammonia and chlorine
B ammonia and carbon dioxide
C chlorine and hydrogen
D chlorine and sulfur dioxide

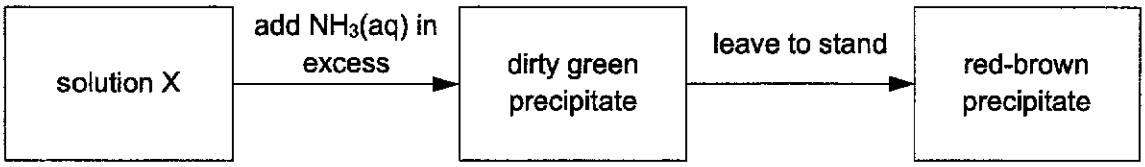
19 The diagram shows a reaction scheme.



What is Y?

A dilute nitric acid
B dilute hydrochloric acid
C aqueous sodium nitrate
D aqueous ammonia

20 The flowchart below shows the reactions of solution X.



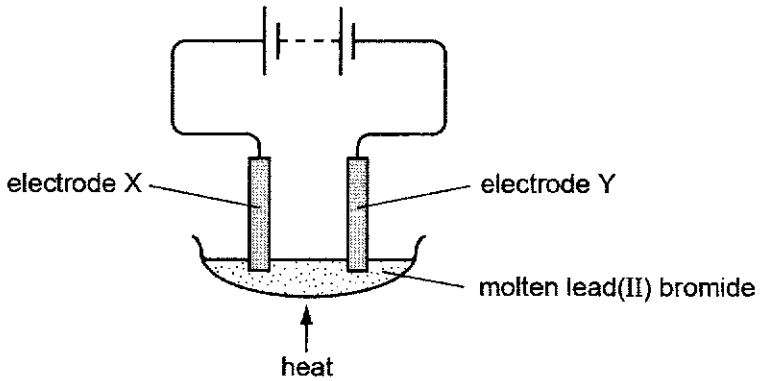
Which row is correct?

	formula of dirty green precipitate	reaction that resulted in red-brown precipitate
A	$Fe(OH)_2$	reduction
B	$Fe(NH_4)_2$	reduction
C	$Fe(OH)_2$	oxidation
D	$Fe(NH_4)_2$	oxidation

21 In which reaction is the underlined substance acting as a reducing agent?

A $\underline{2\,CuO} + C \rightarrow CO_2 + 2\,Cu$
B $Fe_2O_3 + \underline{3\,CO} \rightarrow 2\,Fe + 3\,CO_2$
C $2\,Mg + \underline{O_2} \rightarrow 2\,MgO$
D $\underline{MnO_2} + 4\,HCl \rightarrow MnCl_2 + 2\,H_2O + Cl_2$

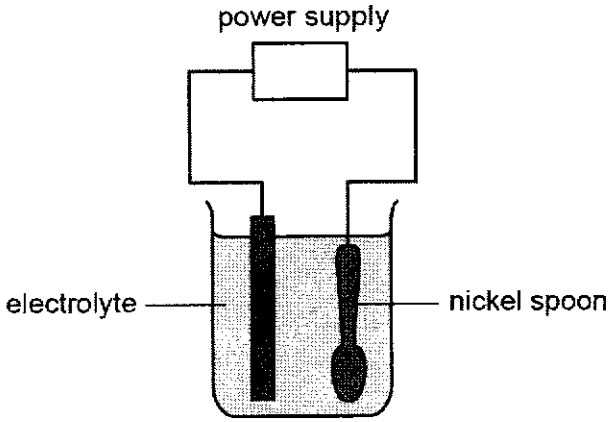
22 The diagram shows the electrolysis of molten lead(II) bromide.



What is seen at each electrode?

	electrode X	electrode Y
A	brown gas	grey metal
B	colourless gas	grey metal
C	grey metal	colourless gas
D	grey metal	brown gas

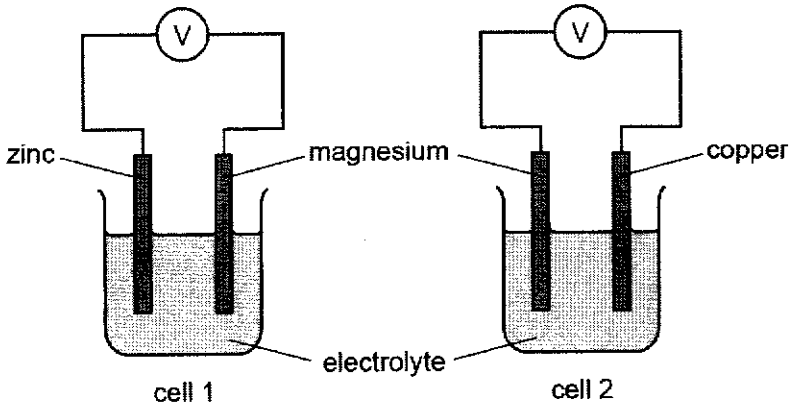
23 The diagram shows an experiment to electroplate a nickel spoon with silver.



Which row correctly describes the positive electrode, the negative electrode and the electrolyte?

	positive electrode	negative electrode	electrolyte
A	nickel spoon	pure nickel	silver nitrate solution
B	nickel spoon	pure silver	nickel nitrate solution
C	pure nickel	nickel spoon	silver nitrate solution
D	pure silver	nickel spoon	silver nitrate solution

24 The electrical energy, or voltage, of two simple cells is measured.



Which statement correctly describes the results of the experiment?

A The voltage of cell 1 is greater than cell 2.
B The electrolyte gradually turns blue in cell 2.
C Electrons flow from zinc to magnesium in cell 1.
D Magnesium loses electrons and undergoes oxidation in both cells.

25 Sodium and rubidium are elements in Group 1 of the Periodic Table.

Which statement is correct?

A Sodium atoms have more electrons than rubidium atoms.
B Sodium has a lower density than rubidium.
C Sodium has a lower melting point than rubidium.
D Sodium is more reactive than rubidium.

26 Elements X and Y are in Group 17 of the Periodic Table.
X is a liquid at room temperature. Y is a solid at room temperature.

Which statements are correct?

1 Atoms of Y have more protons than atoms of X.
2 Molecules of Y have more atoms than molecules of X.
3 Y displaces X from aqueous solutions of X^- ions.

A 1 only
B 2 only
C 3 only
D 1, 2 and 3

27 The statements refer to a number of elements in the Periodic Table.

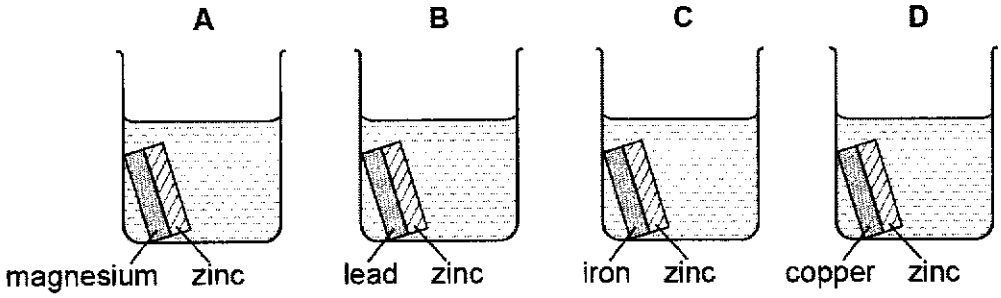
1 The elements form coloured compounds.
2 The elements have variable oxidation states.

For which pair of elements is each statement correct?

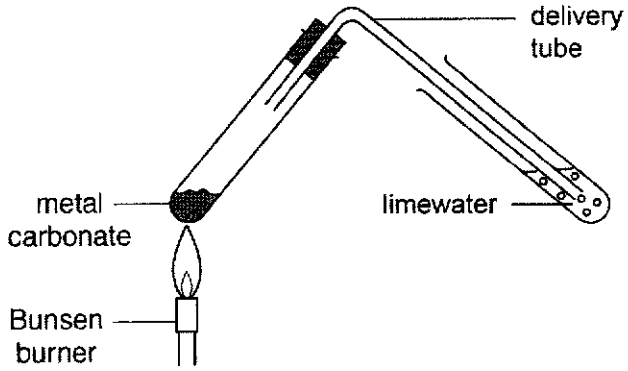
	form coloured compounds	have variable oxidation states
A	Co, Mg	Fe, Al
B	Fe, V	Co, Mn
C	Co, Mn	Mg, Al
D	Mg, Al	Fe, V

28 Each beaker contains two strips of metal fastened together and immersed in hydrochloric acid. All the strips are of the same size.

After 5 minutes, which beaker contains the least amount of zinc ions?



29 Three metal carbonates were each heated as shown below.

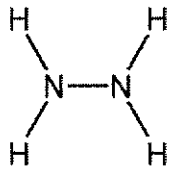


On mild heating of the carbonate of **Y**, a white precipitate formed in the limewater. Heating more strongly gave the same observation for the carbonate of **X** but not for the carbonate of **Z**.

What could **X**, **Y** and **Z** be?

	X	Y	Z
A	Zn	Cu	Na
B	Zn	Na	Cu
C	Na	Zn	Cu
D	Na	Cu	Zn

30 The compound hydrazine is used as a rocket fuel. It has the structural formula shown.



One of the reactions of hydrazine is shown.

$$N_2H_4(g) \rightarrow N_2(g) + 2\ H_2(g)$$

	H–H	N–H	N–N	N≡N
bond energy in kJ / mol	436	390	160	945

What is the enthalpy change for this reaction?

A –339 kJ/mol
B –97 kJ/mol
C +97 kJ/mol
D +339 kJ/mol

31 When a hydrogen–oxygen fuel cell is in operation, a different reaction happens at each electrode.

at the hydrogen electrode: $H_2(g) \rightarrow 2\ H^+(aq) + 2\ e^-$
at the oxygen electrode: $O_2(g) + 2\ H_2O(l) + 4\ e^- \rightarrow 4\ OH^-(aq)$

The electrons that are lost at the hydrogen electrode travel through the external circuit to the oxygen electrode, where they are gained by the oxygen and water.

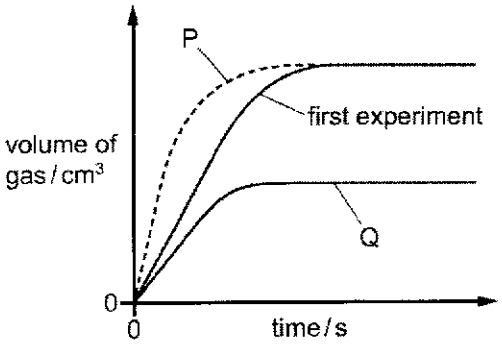
A hydrogen–oxygen fuel cell is operated for a period of time and 4 mol of oxygen molecules are consumed.

Which mass of hydrogen is consumed?

A 2.0 g
B 4.0 g
C 8.0 g
D 16.0 g

32 25 cm^3 of 1.0 mol/dm^3 hydrochloric acid reacts with excess of a solid to produce a gas.

The graph labelled first experiment shows the volume of gas produced over time.
Graphs P and Q show the volume of gas produced under different conditions.

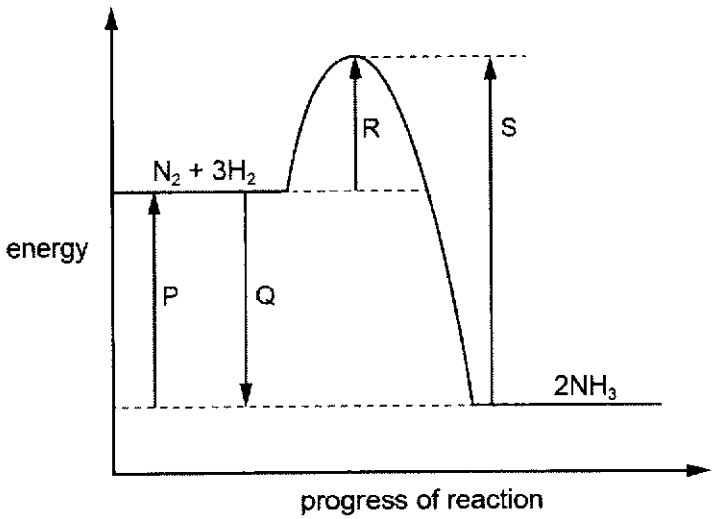


Which changes in conditions produce graphs P and Q, if all other conditions are kept the same?

A P uses a catalyst and Q has a lower temperature.
B P uses 25 cm^3 of more concentrated acid and Q uses smaller pieces of solid.
C P uses a higher temperature and Q uses 25 cm^3 of 0.5 mol/dm^3 hydrochloric acid.
D P uses smaller pieces of solid and Q uses larger pieces of solid.

33 The equation and the energy profile diagram for the reversible reaction in the Haber process are shown.

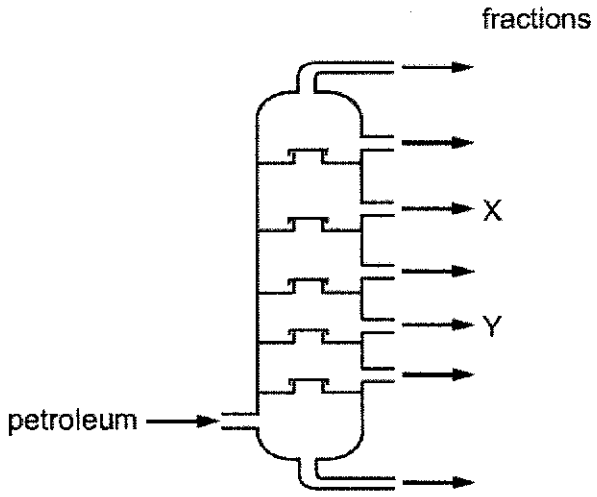
$$N_2 + 3\,H_2 \rightleftharpoons 2\,NH_3$$



Which statement about the arrows P, Q, R and S is correct?

A P represents the enthalpy change for the forward reaction.
B Q represents the enthalpy change for both the forward and reverse reaction.
C R represents the activation energy for both the forward and reverse reaction.
D S represents the activation energy for the reverse reaction.

34 Petroleum (crude oil) is separated into useful fractions by fractional distillation. The positions at which fractions X and Y are collected from the fractionating column are shown.

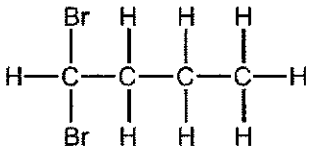


Which statement is correct?

A The temperature increases up the column.
B X condenses at a lower temperature than Y.
C X has a higher boiling point than Y.
D X has longer chain molecules than Y.

35 When butene reacts with bromine in an addition reaction, which compound could be made?

1



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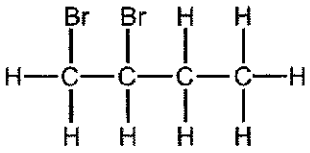

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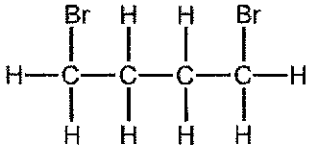
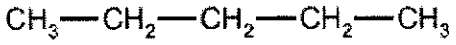
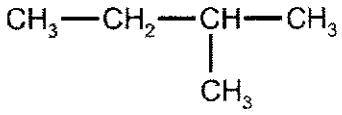


A 1 only
B 2 only
C 2 and 3 only
D 1, 2 and 3

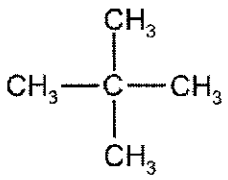
36 Which structure is **not** an isomer of the structure shown?



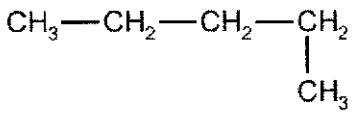
A



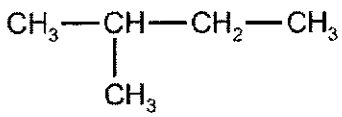
B



C



D



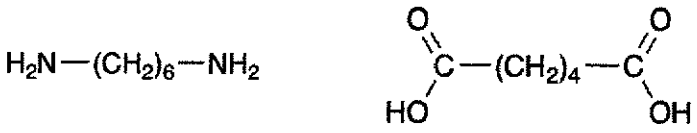
37 In which chemical reaction does the named product formed have a lower molecular mass than the reactant?

A the formation of an ester from ethanol
B the formation of ethanoic acid from ethanol
C the formation of ethanol from ethene
D the formation of ethanol from glucose

38 Which bond in a molecule of propanoic acid is broken when it reacts with magnesium?

A C–H bond
B C–O bond
C C–C bond
D O–H bond

39 Molecule **1** and molecule **2** react together to make a condensation polymer.



1
(M_r = 116)

2
(M_r = 146)

What is the relative molecular mass of the repeating unit of the polymer formed from molecules **1** and **2**?

A 224
B 226
C 244
D 262

40 Catalytic converters in car exhausts change polluting gases into non-polluting gases.

Which statement(s) about oxides of nitrogen and car engines is/are correct?

1 The nitrogen in oxides of nitrogen comes from compounds in petrol.
2 The oxygen in oxides of nitrogen comes from the air in the car engine.
3 Catalytic converters convert oxides of nitrogen into nitrogen and other gases.

A 2 only
B 3 only
C 1 and 2
D 2 and 3

End of paper

The Periodic Table of Elements

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

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

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

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}

GAN ENG SENG SCHOOL

Preliminary Examination 2024

CANDIDATE NAME	
CLASS	
INDEX NUMBER	

CHEMISTRY

Paper 2

6092/02

21 August 2024

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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 an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

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

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page **23**.

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

For Examiner's Use	
Section A	**70**
Section B Q9 Q10 **Circle where appropriate*	**10**
Total	**80**

This document consists of **23** printed pages.

Section A

Answer **all** questions.

1 The equations below show reactions involving elements **A** to **E**.

Element **A**: $2\ \mathbf{A} + 2\ H_2O \rightarrow 2\ \mathbf{A}OH + H_2$

Element **B**: $\mathbf{B}O_2 + 2\ NaOH \rightarrow Na_2\mathbf{B}O_3 + H_2O$

Element **C**: $\mathbf{C}_2 + 2\ Br^- \rightarrow 2\ \mathbf{C}^- + Br_2$

Element **D**: $\mathbf{D} + Cu^{2+} \rightarrow \mathbf{D}^{2+} + Cu$

Element **E**: $\mathbf{E}_2O_3 + 6\ H^+ \rightarrow 2\ \mathbf{E}^{3+} + 3\ H_2O$

Each letter represents an element found in **Period 3** of the Periodic Table (sodium to argon). The letters do not represent the actual symbols of the elements.

(a) Identify elements **A** to **E**.

A .....

B .....

C .....

D .....

E ..... [5]

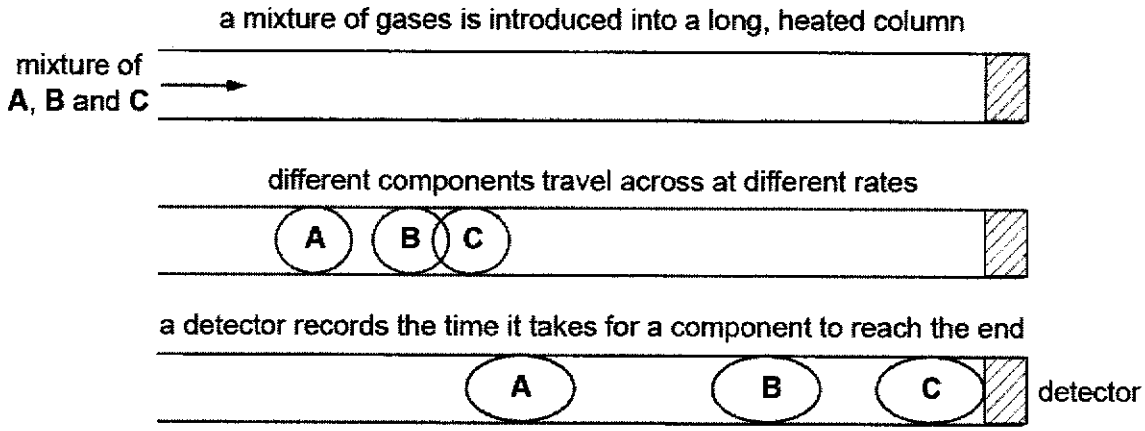
(b) Classify each element as having undergone oxidation, reduction or neither. Put a tick (✓) in each row.

element	undergone oxidation	undergone reduction	neither oxidised nor reduced
A			
B			
C			
D			
E			

[3]

[Total: 8]

2 Gas chromatography can be used to separate a mixture of gases as shown below.



The retention time is the time it takes each component to travel through the column.

(a) The gases entering the column must be dry to avoid interference from water molecules.

Suggest how the gases may be dried.

..... [1]

(b) Vegetable oils can be changed into bio-diesel for use in diesel engines.

Gas chromatography is used to identify the methyl esters in a sample of bio-diesel.

The table shows the retention time for three methyl esters.

methyl ester	M_r	retention time / min
lauric	214	1.6
palmitic	270	3.1
stearic	298	3.9

One factor affecting retention time is the rate of diffusion.

(i) The data in the table suggests a correlation between the relative molecular mass and the retention time.

Describe this correlation.

.....

..... [1]

(ii) The experiment is repeated with the column at a higher temperature.

Suggest and explain how this will affect the retention times.

.....

.....

.....

.....

.....

..... [3]

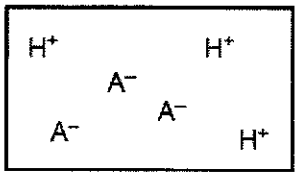
(c) Unlike gas chromatography, paper chromatography compares R_f values instead of retention times.

Besides temperature, state one factor that affects R_f values.

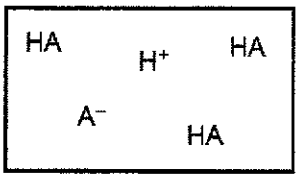
..... [1]

[Total: 6]

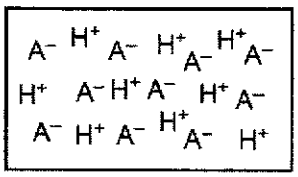
3 The diagrams show four different types of acid solutions.
The acid molecule is represented as HA. The ions formed in solution are represented as H^+ and A^-.



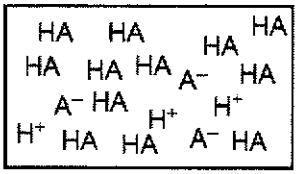
1



2



3



4

(a) State which diagram represents a dilute solution of a weak acid. Explain your answer.

.....

.....

.....

..... [3]

(b) Explain why sulfuric acid is not represented by the diagrams above.

.....

..... [2]

(c) Equal volumes of ethanoic acid and hydrochloric acid of the same concentration was allowed to react completely with magnesium.

State, with a reason, whether the volume of hydrogen gas produced will differ.

..... [1]

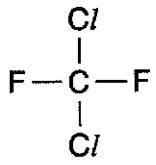
(d) An unknown bottle is suspected to contain dilute sulfuric acid.
Outline a chemical test that can be used to confirm this.

.....

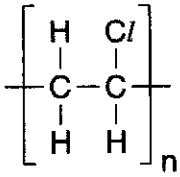
..... [2]

[Total: 8]

4 Two chlorine-containing organic molecules shown below are known to cause harm to the environment.



dichlorodifluoromethane (CFC-12)



polyvinyl chloride (PVC)

(a) In the presence of sunlight, CFC-12 decomposes into chlorine atoms, which deplete the ozone layer by causing the breakdown of ozone in a two-step reaction.

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

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

(i) Explain why the depletion of the ozone layer would be undesirable to humans.

.....

.....

..... [2]

(ii) Use the equations to write an overall equation for the reaction.

..... [2]

(iii) Explain how the equations show that chlorine atoms act as a catalyst for the breakdown of ozone.

..... [1]

(iv) Chlorine exists as two stable isotopes, with chlorine-35 (^{35}Cl) reacting faster with ozone than chlorine-37 (^{37}Cl). Studying the ^{37}Cl to ^{35}Cl ratio helps scientists model the rate of ozone depletion more accurately.

Complete Table 4.1 to show the number of subatomic particles in each isotope of chlorine.

Table 4.1

isotope	^{35}Cl	^{37}Cl
number of electrons		
number of neutrons		
number of protons		

[2]

(b) (i) Draw the structure of the monomer used to make polyvinyl chloride (PVC).

[1]

(ii) Describe one pollution problem caused by non-biodegradable plastics such as polyvinyl chloride (PVC).

.....

.....

..... [1]

(iii) The best way of disposing of plastic waste is recycling to form new plastics. State an advantage of recycling plastics made from petroleum.

.....

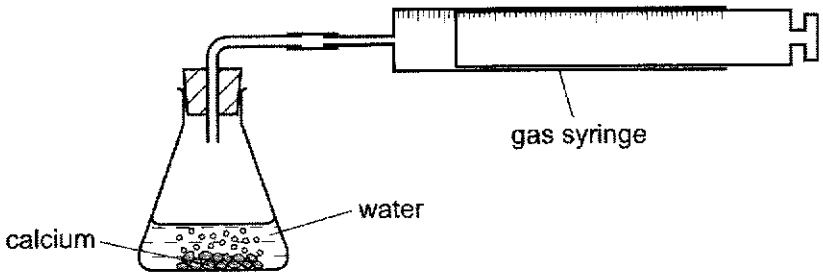
..... [1]

[Total: 10]

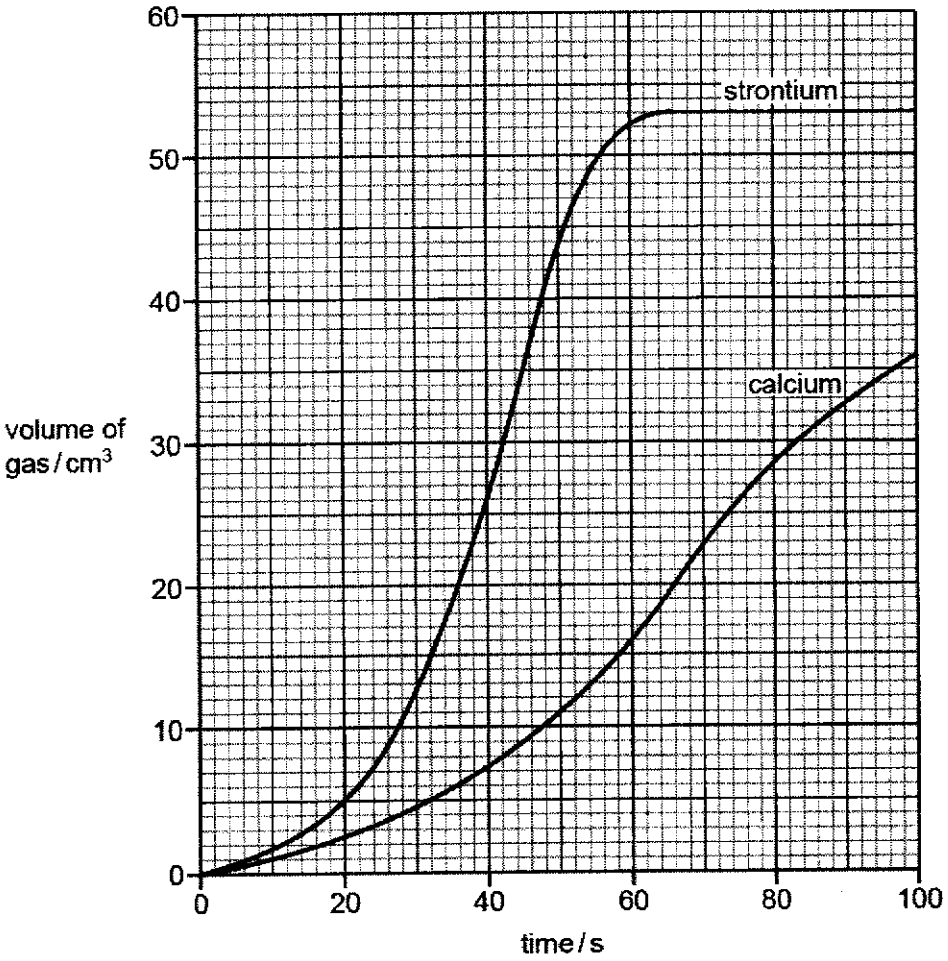
5 The reaction between metals and water can be studied using the apparatus shown.

A fixed mass of calcium was allowed to react completely with water.

The volume of gas given off was recorded at fixed time intervals during the reaction.



The experiment was repeated using strontium but keeping all the conditions the same.
The graph obtained from the results is shown below.



(a) Explain how the graph shows that strontium is more reactive than calcium.

.....

..... [1]

(i) Calculate the average rate of reaction, in cm^3/s, for the reaction between strontium and water.

average rate of reaction = ... cm^3/s [1]

(ii) Explain how the graph shows that the reaction between calcium and water was **not** complete at 100 seconds after the reaction started.

.....

..... [1]

(b) The solution formed at the end of the reaction between strontium and water was tested with Universal Indicator. The indicator turned purple.

Explain this observation with the aid of a chemical equation.

.....

.....

..... [3]

(c) The electrolysis of a molten electrolyte is one method of extracting a metal from its ore. Other methods are the electrolysis of an aqueous solution and the reduction of the oxide by carbon.

Explain why these last two methods cannot be used to extract strontium from strontium oxide.

electrolysis of an aqueous solution .....

.....

reduction of the oxide by carbon .....

..... [2]

[Total: 8]

6 Ammonia is manufactured by the Haber Process.
The equation for the reaction is shown.

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

The economics of this process require that as much ammonia as possible is made as quickly as possible.

The percentage yield of ammonia varies with conditions.

pressure / atm	100	200	300	400
% ammonia at 300 °C	45	65	72	78
% ammonia at 500 °C	9	18	25	31

(a) Describe how hydrogen is obtained for the Haber process.

..... [1]

(b) Use the electronic structure of nitrogen to explain why the formula of ammonia is NH_3 not NH_4.

.....

.....

..... [2]

(c) Describe the effect of changing temperature on the percentage yield of ammonia.

..... [1]

(d) **(i)** Explain, in terms of particles, what happens to the rate of this reaction when the pressure is increased.

.....

.....

.....

.....

.....

..... [3]

(ii) State one other advantage of using a high pressure.

..... [1]

(iii) The conditions actually used are 200 atmospheres, 450 °C and finely divided iron catalyst.

Suggest one reason why a pressure higher than 200 atmospheres is not used in the Haber process.

.....

..... [1]

(e) State what happens to the unreacted nitrogen and hydrogen.

..... [1]

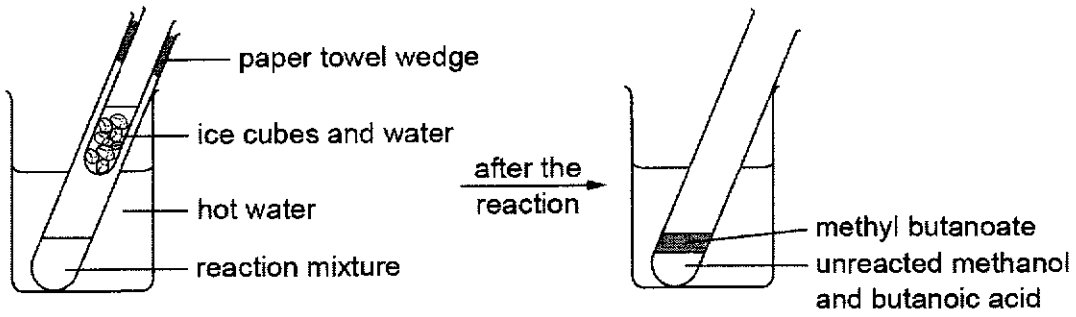
[Total: 10]

7 Chemists use esterification reactions to create various pleasant-smelling esters, which are essential components of many artificial and natural flavours.

One such ester, methyl butanoate, is a key contributor to the characteristic aroma of raspberries. It is made by reacting methanol with butanoic acid.

$$\underset{(M_r = 32)}{\text{methanol}} + \underset{(M_r = 88)}{\text{butanoic acid}} \rightleftharpoons \underset{(M_r = 102)}{\text{methyl butanoate}} + \underset{(M_r = 18)}{\text{water}}$$

The diagram of the experiment is shown below.



(a) Draw the full structural formula of methyl butanoate.

[1]

(b) Suggest the purpose of the test-tube containing ice cubes and water in the set-up.

.....

..... [1]

(c) Based on the information above, explain why an ester can be separated from the mixture using a separating funnel.

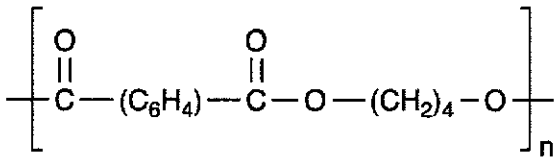
..... [1]

(d) In an experiment, 2.0 g of methanol was reacted with excess butanoic acid to produce methyl butanoate. However, only 1.0 g of methyl butanoate was isolated after purification.

Calculate the percentage yield of the reaction.

percentage yield = ... % [3]

(e) Polyethylene terephthalate is a polyester used in fibres for clothing, containers for liquids and food.



polyethylene terephthalate (PET)

Outline **one** similarity and **one** difference in the formation of methyl butanoate and polyethylene terephthalate from their respective reactant molecules.

.....

.....

.....

..... [2]

[Total: 8]

8 How carbon dioxide affects the oceans

The oceans act as a carbon sink, absorbing much of the CO_2 produced from burning fossil fuels. When CO_2 dissolves in water, carbonic acid, H_2CO_3 is formed.

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

H_2CO_3 dissociates in water to form bicarbonate ions, HCO_3^- and hydrogen ions, H^+. When atmospheric CO_2 levels increase, more CO_2 to dissolves into ocean waters, decreasing the pH of the oceans.

$$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$$

The ocean naturally contains carbonate ions, CO_3^{2-}, which shell-making marine organisms use to build their calcium carbonate shells. However, when the pH of the ocean decreases, the excess H^+ ions consume the CO_3^{2-} ions available to these organisms.

$$CO_3^{2-}(aq) + H^+(aq) \rightleftharpoons HCO_3^-(aq)$$

A Bjerrum plot (Fig 8.1) shows the percentage of each carbon-containing species at different pH.

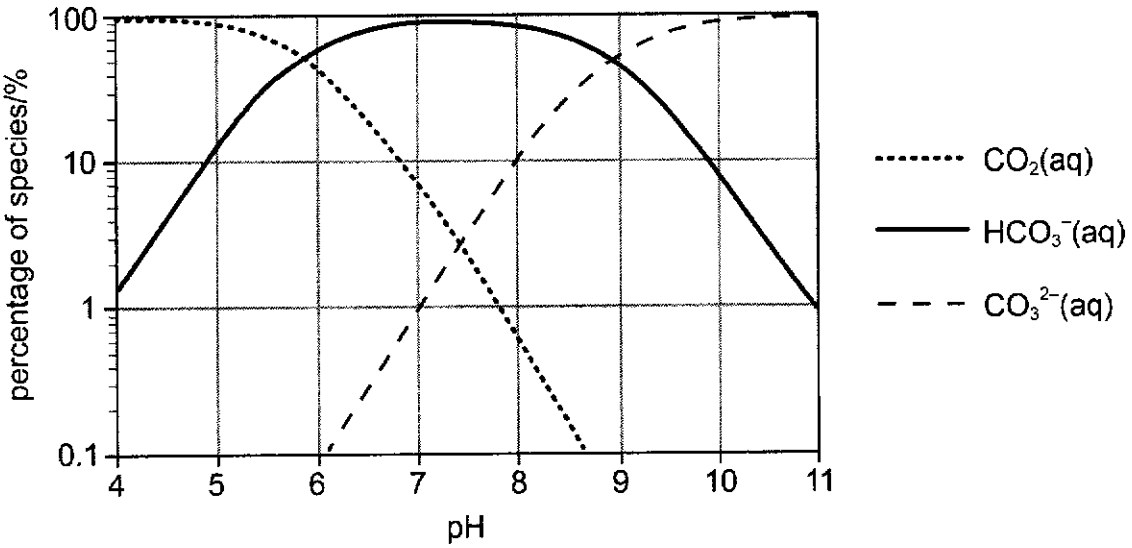


Fig. 8.1: Bjerrum plot

The uptake of CO_2 by seawater has led to the average ocean surface pH falling from 8.2 to 8.1 in the last 200 years. While this change may seem small, it represents an approximate increase of 30% in acidity. Besides far-reaching implications for marine creatures, there is a limit to the capacity of the oceans to absorb CO_2, unless the CO_2 is simultaneously removed.

Removing CO_2 from oceans

Singapore produces over 50 million tonnes of CO_2 annually. Scientists are exploring the use of electrolytic processes to remove CO_2 from the oceans to expand the ocean's capacity to absorb more CO_2. By 2025, the world's largest ocean-based CO_2 removal plant, dubbed the Equatic-1, will be built in Singapore. The facility can remove 10 tonnes of CO_2 per day from

seawater and the atmosphere. This will bring Singapore closer towards the target of achieving net zero emissions by 2050.

A scheme of the process used by Equatic-1 is shown in Fig. 8.2.

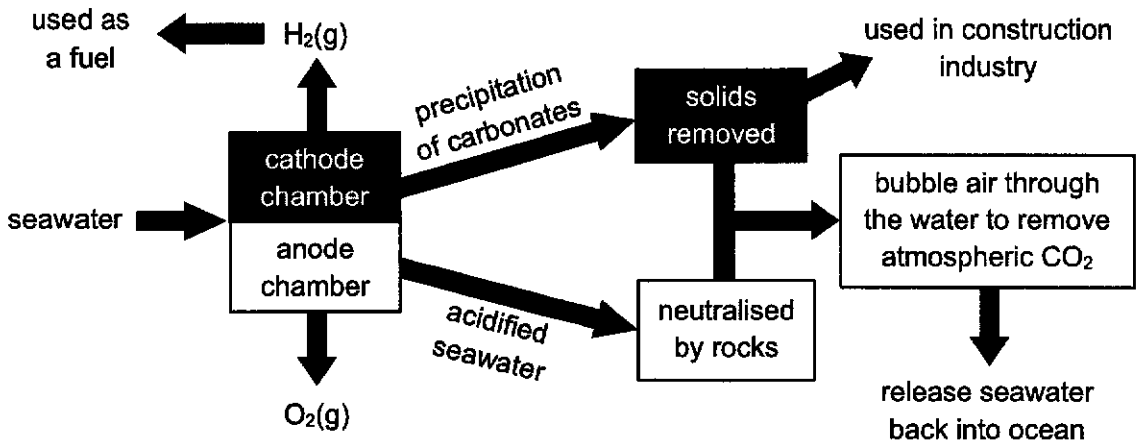


Fig. 8.2

Seawater from the adjacent PUB desalination plants enters the cathode and anode chambers where water is electrolysed and decomposed into oxygen and hydrogen.

In the cathode chamber, the water flows through a porous electrode. The electrode surface is continuously scraped with a blade that dislodges accumulated solids and re-exposes the mesh surface. These metal carbonates could potentially be used in the construction industry for land restoration, cement, or concrete.

The concentration of ions in seawater is shown in Table 8.3.

Table 8.3: Concentration of ions in seawater

cation	concentration (mg/dm^3)
Na^+	10600
Mg^{2+}	1260
Ca^{2+}	400
K^+	380

anion	concentration (mg/dm^3)
Cl^-	19000
SO_4^{2-}	2650
HCO_3^-	140
Br^-	65

The anode is covered with an oxygen evolution selective coating to ensure that oxygen gas is produced. As the mixture exiting the anode chamber is acidic, the natural alkalinity and composition of seawater is restored by dissolving alkaline rocks such as $Mg_2SiO_4(s)$ (forsterite) and $CaAl_2Si_2O_8(s)$ (anorthite) before releasing the seawater back into the ocean.

(a) Based on information in Fig. 8.1, arrange, in increasing order, the percentage of $CO_2(aq)$, $HCO_3^-(aq)$ and $CO_3^{2-}(aq)$ in naturally-occurring seawater.

..... [1]

(b) Explain, with the aid of a half equation, why the pH increases at the cathode chamber during electrolysis.

.....

.....

..... [2]

(c) Explain, using information in Fig. 8.1 and Table 8.3, why the increase in pH at the cathode would result in the precipitation of metal carbonates. You should identify the metal carbonates in your answer.

.....

.....

..... [2]

(d) Deduce, using information from Table 8.3, the gas that would be produced in significant quantity in the anode chamber without the oxygen evolution selective coating. Explain your reasoning.

.....

.....

..... [2]

(e) A silicate is a polyatomic anion consisting of silicon and oxygen, with the general formula $[SiO_{(4-x)}^{(4-2x)-}]_n$ where n is a whole number and $0 \leq x < 2$.

Show, using values of n and x, that forsterite and anorthite are silicates.

.....

.....

..... [2]

(f) Discuss whether the Equatic-1 facility in Singapore would better manage the carbon cycle to result in human lifestyles becoming more environmentally sustainable.

.....

.....

.....

.....

.....

..... [3]

[Total: 12]

Section B

Answer **one** question from this section.

9 Calcium nitrate, $Ca(NO_3)_2$, and ammonium nitrate, NH_4NO_3, are ionic compounds which are used to make fertilisers.

Fig. 9.1 shows how the ions are arranged in a solid, ionic compound.

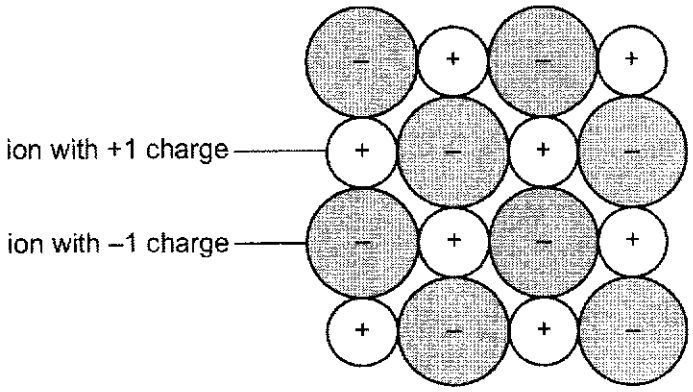


Fig. 9.1

(a) Give two reasons why Fig. 9.1 is a better representation for the ions in solid ammonium nitrate, NH_4NO_3, than the ions in solid calcium nitrate, $Ca(NO_3)_2$.

.....

.....

.....

..... [2]

(b) In Fig. 9.1 the ions are shown far larger than they actually are.

Suggest one other reason why Fig. 9.1 does not accurately represent a solid ionic compound.

.....

..... [1]

The overall energy changes that happen when solid fertilisers dissolve in water are related to bond breaking and bond forming processes.

Fig. 9.2 shows the process of a solid ionic compound dissolving in water.

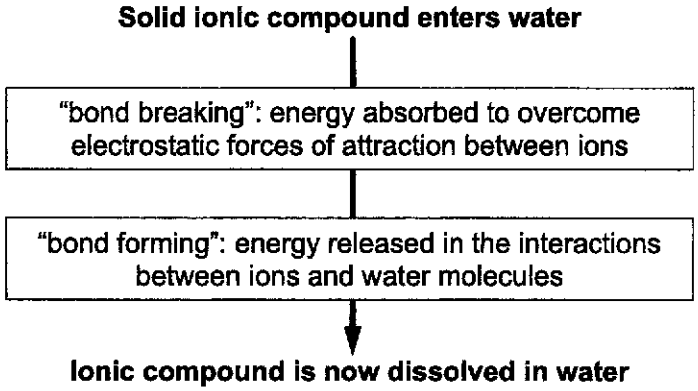


Fig. 9.2

Fig. 9.3 shows the overall energy changes when solid calcium nitrate and solid ammonium nitrate dissolve in water.

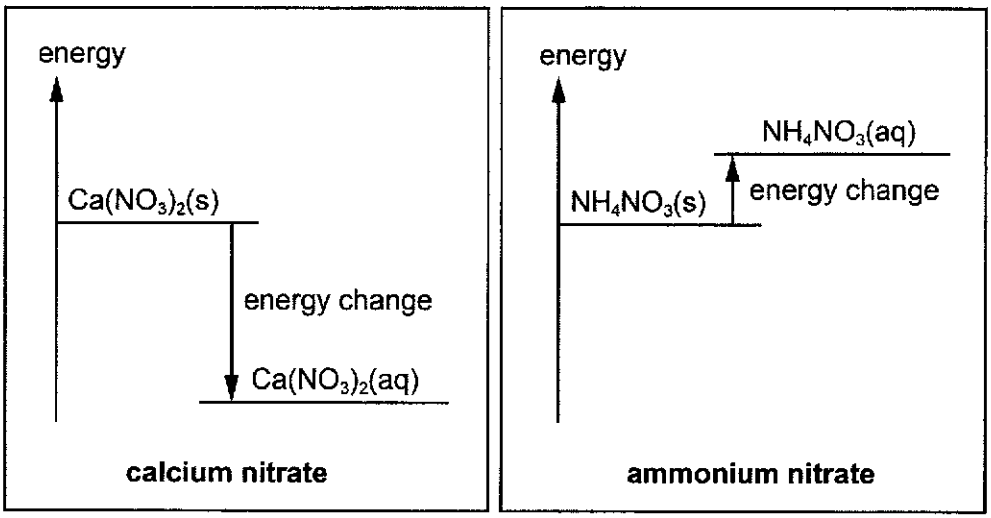


Fig. 9.3

(c) Using Fig. 9.2 and Fig. 9.3, describe and explain the differences in the overall energy changes when calcium nitrate and ammonium nitrate dissolve in water.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(d) **(i)** Describe the steps required to prepare a solution of calcium nitrate, starting with powdered calcium carbonate.

.....

.....

..... [2]

(ii) Ammonium nitrate can be prepared by the method of titration.

Suggest a suitable pair of reagents that react to produce ammonium nitrate.

..... [1]

[Total: 10]

10 The table shows information about some alkanes.

alkane	molecular formula	melting point / °C	physical state at 25 °C
methane	CH_4	–182	gas
propane	C_3H_8	–190	gas
butane	C_4H_{10}	–138	gas
octane	C_8H_{18}	–57	liquid
pentacontane	$C_{50}H_{102}$	93	solid

(a) **(i)** State the empirical formula of pentacontane.

..... [1]

(ii) The empirical formulae of methane and propane are the same as their molecular formulae.

Explain why.

.....

..... [1]

(b) Explain, in terms of structure and bonding, why the melting points of the alkanes are generally low.

.....

.....

..... [2]

(c) A textbook has this description of a homologous series.

> *A homologous series contains compounds with similar structures, the same general formula and similar chemical properties. The compounds show a trend in physical properties down the series.*

Use your own knowledge and the information in the table to explain how the alkanes match this description of a homologous series.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(d) Petrol companies 'crack' larger molecules like pentacontane to make smaller molecules such as octane.

Explain why 'cracking' makes the business more profitable and better for the environment.

.....

.....

.....

..... [2]

[Total: 10]

End of paper

The Periodic Table of Elements

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

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

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

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}

GESS Sec 4 Chemistry (6092) Preliminary Exams 2024
Suggested Solutions

PAPER 1

Question Number	*Key*	*Question Number*	*Key*
1	**A**	21	**B**
2	**B**	22	**A**
3	**B**	23	**D**
4	**C**	24	**D**
5	**B**	25	**B**
6	**B**	26	**A**
7	**C**	27	**B**
8	**D**	28	**A**
9	**A**	29	**A**
10	**D**	30	**B**
11	**A**	31	**D**
12	**A**	32	**C**
13	**C**	33	**D**
14	**A**	34	**B**
15	**A**	35	**B**
16	**C**	36	**C**
17	**D**	37	**D**
18	**A**	38	**D**
19	**A**	39	**B**
20	**C**	40	**D**

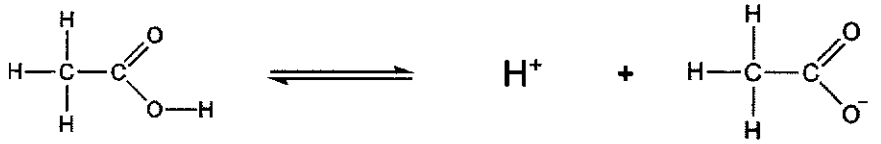
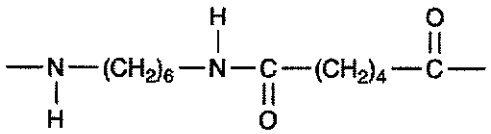
Question	Answer	Explanation
1	**A**	Option A is correct as the burette can measure variable volumes of a liquid in a titration. Option B is incorrect because the 0.24 dm^3 is equivalent to 240 cm^3 which exceeds the capacity of the gas syringe. Option D is incorrect as a pipette can only measure a fixed volume of a liquid depending on its size, in this case 25.0 cm^3.
2	**B**	Q has a lower R_f value than R as it travelled a shorter distance from the start line.
3	**B**	The mixture is heated using a water bath, hence any substance with a boiling point above 100 °C (i.e. **C** & **D**) cannot be distilled. Substance **A** is a gas at room temperature.
4	**C**	The transition from (s) → (*l*) → (g) is endothermic as energy is absorbed to overcome forces of attraction between the particles.
5	**B**	A mixture of solid and liquid exists at the melting point/freezing point, which occurs at 50 °C.
6	**B**	Since the ion has a charge of 3+, it means that Z would have lost 3 electrons, and is therefore in Group 13. Since the ion has 2 electron shells, Z must have had three electron shells in total and is hence in Period 3.
7	**C**	Sea water is a mixture; sodium chloride is a compound and chlorine is an element.
8	**D**	In graphite, each carbon atom is only bonded to three other carbon atoms, leaving one electron per carbon atom not involved in bonding. The electrons which are not involved in bonding are delocalised, acting as mobile charged carriers. Metals such as aluminium have a sea of delocalised electrons which act as mobile charged carriers. Ionic compounds conduct electricity due to the presence of mobile ions.
9	**A**	The electronic structure of oxygen is 2,6. It needs 2 more electrons to have a fully-filled valence shell. Each oxygen atom forms 2 covalent bonds. The electronic structure of chlorine is 2,8,7. It needs 1 more electron to have a fully-filled valence shell. Each chlorine atom forms 1 covalent bond. This results in a structure with the formula Cl_2O.
10	**D**	Both silicon and carbon are in Group 14, hence SiO_2 and diamond both have a giant covalent structure where the atoms around Si and C are in a tetrahedral arrangement, i.e. each Si and C atom forms 4 covalent bonds. For giant covalent structures, there are no intermolecular forces of attraction as all the atoms are joined via covalent bonds. Melting requires breaking these covalent bonds.
11	**A**	nO_2 = 500/24000 = 0.020833 mol 1 mol contains 6.02×10^{23} molecules. Hence, number of molecules = $0.020833 \times 6.02 \times 10^{23} = 1.254 \times 10^{22}$

<table>
<tr><td>12</td><td>A</td><td>The sum of the relative molecular masses of Mg atoms in a molecule of chlorophyll-a is $\frac{2.69}{100} \times 893 = 24.02$. Since the A_r of a Mg atom is 24, there is only one Mg atom.</td></tr>
<tr><td>13</td><td>C</td><td>concentration of saline in g/dm^3 = $\frac{0.9}{\frac{100}{1000}} = 9$ g/dm^3
concentration of saline in mol/dm^3 = $\frac{9}{23+35.5} = 0.1538$ mol/dm^3</td></tr>
<tr><td>14</td><td>A</td><td>$nH_2 = \frac{8}{2} = 4$ mol
$nO_2 = \frac{8}{32} = 0.25$ mol (limiting reactant)
nH_2O formed = 0.5 mol
mass of $H_2O = 0.5 \times 18 = 9$ g</td></tr>
<tr><td>15</td><td>A</td><td>Quicklime (CaO) or slaked lime ($Ca(OH)_2$) are both used by farmers to neutralise the excess acids in the soil, raising the pH.</td></tr>
<tr><td>16</td><td>C</td><td>The pH at which the indicator changes colour must fall within the region of drastic pH change in the titration graph. This is where the 'step' occurs, in this case it spans the range of around pH 5 to 11.</td></tr>
<tr><td>17</td><td>D</td><td>Copper is an unreactive metal, hence it does not react with acids.
To prepare copper(II) sulfate, we add excess copper(II) oxide, copper(II) carbonate or copper(II) hydroxide to ensure all the acid is reacted. We then filter the mixture to remove the excess solid, collect the filtrate and carry out crystallisation on the filtrate.</td></tr>
<tr><td>18</td><td>A</td><td>Ammonia turns moist red litmus paper blue, while chlorine bleaches both blue and red litmus papers.</td></tr>
<tr><td>19</td><td>A</td><td>Y must be an acid since a gas is produced when reacted with a carbonate. Y also contains nitrate ions as ammonia gas is given off when the solution is warmed with aluminium and sodium hydroxide.</td></tr>
<tr><td>20</td><td>C</td><td>In the chapter of Acids and Bases, we learnt that alkalis dissociate in water to give OH^- ions:
$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$
$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

We also know that most metal hydroxides are insoluble in water. Hence, the green precipitate is $Fe(OH)_2$. The green precipitate slowly turns reddish-brown in air (oxidation).

$4\ Fe(OH)_2(s) + O_2(g) + 2\ H_2O(l) \rightarrow 4\ Fe(OH)_3(s)$</td></tr>
<tr><td>21</td><td>B</td><td>CO acts as a reducing agent as it causes Fe_2O_3 to be reduced to Fe. This is seen in the oxidation state of iron decreasing from +3 in Fe_2O_3 to 0 in Fe.</td></tr>
<tr><td>22</td><td>A</td><td>
<table>
<tr><th></th><th>positive (+) electrode X</th><th>negative (–) electrode Y</th></tr>
<tr><td>Ions attracted</td><td>Br^-</td><td>Pb^{2+}</td></tr>
<tr><td>Half equation</td><td>$2Br^-(l) \rightarrow Br_2(g) + 2e^-$</td><td>$Pb^{2+}(l) + 2e^- \rightarrow Pb(l)$</td></tr>
<tr><td>Nature of reaction</td><td>Oxidation</td><td>Reduction</td></tr>
<tr><td>Anode or cathode?</td><td>Anode</td><td>Cathode</td></tr>
</table>
</td></tr>
</table>

		<table><tr><td>**Observation**</td><td>Effervescence of reddish-brown gas</td><td>Grey/silvery globules of molten lead metal float to the surface</td></tr><tr><td>**Overall reaction**</td><td colspan="2">$PbBr_2(l) \rightarrow Pb(l) + Br_2(g)$</td></tr></table>
23	**D**	In electroplating, the object to be electroplated is always placed at the cathode (negative electrode), so that reduction of cations at the cathode will result in a solid deposit/coating around the object. The anode (positive electrode) is the metal used for electroplating. Oxidation at the anode replenishes the electrolyte with the cations. anode: $Ag(s) \rightarrow Ag^+(aq) + e^-$ cathode: $Ag^+(aq) + e^- \rightarrow Ag(s)$
24	**D**	In a simple cell, the larger the difference in reactivity of the two metal electrodes, the greater the voltage. Hence the voltage of cell 1 < cell 2. In both cells, magnesium is the more reactive metal and hence undergoes oxidation: $Mg(s) \rightarrow Mg^{2+}(aq) + 2\ e^-$. Mg^{2+} ions enter the electrolyte, which does not result in a colour change. Electrons flow from the more reactive metal (magnesium) to the other electrode.
25	**B**	Trends going down Group 1: • Melting and boiling points decrease • Density increases • Reactivity increases
26	**A**	Statement 1 is true. Melting and boiling points increases down the group. Since X is a liquid, it must be Br_2. Y, being a solid, must be below X in the Periodic Table. Statement 2 is false. All Group 17 elements are diatomic, meaning they are diatomic molecules which consist of two atoms covalently bonded. Statement 3 is false. Reactivity decreases down the group. Y is less reactive than X. Hence Y cannot displace X from its solution.
27	**B**	The two properties are characteristic of transition metals. Option B is the only one where all examples are transition metals.
28	**A**	This is a question on sacrificial protection. In the presence of an acid, the more reactive metal is preferentially oxidised: $M(s) + 2\ H^+(aq) \rightarrow M^{2+}(aq) + H_2(g)$ Given that all beakers contain zinc, the beaker where Zn is least likely to be oxidised is where there is a more reactive metal present, i.e. Mg.
29	**A**	The more reactive the metal, the more thermally stable the compound and the harder it is to decompose the carbonate. Z is the most stable carbonate (Na_2CO_3) while Y is the least stable carbonate ($CuCO_3$).
30	**B**	Energy absorbed during bond breaking = 4BE(H–H) + BE(N–N) = 4(390) + 160 = 1720 kJ/mol Energy released during bond forming = BE(N≡N) + 2BE(H–H) = 945 + 2(436) = 1817 kJ/mol

		Enthalpy change = +1720 – 1817 = –97 kJ/mol
31	**D**	nO_2 = 4 mol mole ratio of O_2 : e^- = 1:4 ne^- = 16 mol mole ratio of e^- : H_2 = 2:1 nH_2 = 8 mol Mass of H_2 = 8 × 2 = 16 g
32	**C**	Option A, B and D are incorrect as a lower temperature or different particle size will not change the yield. HC*l* is the limiting reactant. Hence to produce curve Q, a lower number of moles of HC*l* is used.
33	**D**	P represents the enthalpy change for the *backward* reaction. Q represents the enthalpy change for the *forward* reaction. R represents the activation energy for the *forward* reaction.
34	**B**	The temperature at the top of the column is lower. Smaller molecules with lower boiling points condense higher up the column. Hence, X has a lower boiling point range and consists of short chain hydrocarbons than Y.
35	**B**	In an addition reaction, the two bromine atoms are added across the double bond. They must be on <u>adjacent</u> carbon atoms.
36	**C**	Option C is the same molecule as it consists of a continuous chain of 5 carbon atoms.
37	**D**	A: Since the formation of an ester involves condensation of a carboxylic acid with ethanol, he M_r increases. B: The M_r of ethanoic acid is 60 while the M_r of ethanol is 46. C: The M_r of ethanol is 46 while the M_r of ethene is 28. D: The M_r of ethanol is 46 while the M_r of glucose is 180.
38	**D**	When a carboxylic acid dissociates, the O–H bond of the –COOH functional group is broken. The example shown below is for ethanoic acid.  $CH_3COOH(aq)$ ⇌ H^+ + $CH_3COO^-(aq)$ ethanoic acid — hydrogen ion — ethanoate ion
39	**B**	The structure of the repeating unit is:  Subtract the atoms that are lost in the condensation reaction. Therefore, the M_r is 116 + 146 – [1 + 1 + 16 + 1 + 16 + 1]
40	**D**	Under high temperature conditions in the car engine, nitrogen and oxygen in the air react to form oxides of nitrogen. In the catalytic converter, carbon monoxide is oxidised to carbon dioxide, oxides of nitrogen are reduced to nitrogen. 2 NO(g) + 2 CO(g) → N_2(g) + 2 CO_2(g)

PAPER 2

1 **(a)** **A** sodium
B sulfur / silicon
C chlorine
D magnesium
E aluminium [5]

ALLOW symbol of element

(b)

element	undergone oxidation	undergone reduction	neither oxidised nor reduced
A	✓		
B			✓
C		✓	
D	✓		
E			✓

Any 2 correct = 1 m; all 5 correct = 3 m [3]

[Total: 8]

2 **(a)** the gases may be <u>passed through</u> anhydrous/fused calcium chloride / quicklime / <u>bubbled into/passed through</u> concentrated sulfuric acid

Note: Question asks 'how' therefore stating the chemical alone is not sufficient [1]

(b) **(i)** higher M_r, longer retention time / longer time taken for component to travel through the column [1]

(ii) shorter retention time [1]
(kinetic) energy of particles increase [1]
rate of diffusion increases [1] [3]

(c) solubility of solute in solvent / type of solvent / type of solute / type of paper [1]

[Total: 6]

3 **(a)** 2 [1]
weak acid undergoes partial dissociation / presence of undissociated HA [1]
low concentration of H^+ [1] [3]

(b) dibasic [1]
Should be represented as H_2A / H_2SO_4 dissociates to produce 2 H^+ ions for every A^{2-} [1] [2]

(c) No.
same moles of acid / H^+ ions [1] [1]

(d) add dilute nitric acid, then aqueous barium nitrate [1] [2]

white precipitate [1]
Note: not necessary to acidify since the unknown is sulfuric acid which does not contain carbonate ions.

[Total: 8]

4 **(a)** **(i)** ozone blocks UV / destruction leads to more UV radiation [1]
sunburns / skin cancer / premature aging / cataracts [1] [2]

(ii) $2\ O_3 \rightarrow 3\ O_2$ 1 m – formulae, 1 m – balanced [2]

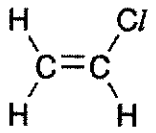
(iii) remains chemically unchanged [1] [1]

(iv) **Table 4.1**

isotope	^{35}Cl	^{37}Cl
number of electrons	17	17
number of neutrons	18	20
number of protons	17	17

Any 3 = 1 m [2]

(b) **(i)**



[1]

(ii)

	Any one from:
Land pollution	filling landfill sites / shortage of landfill sites / visual pollution
Water pollution	gets stuck in animals digestive system / animals get stuck in the plastic / mistake plastic items for food / stops light getting to organisms in sea (must mention an effect on animals)
Air pollution	release poisonous gases when <u>burnt</u> NOT carbon monoxide, sulfur dioxide. If gas named has to be a correct one i.e. HCl

[1]

(iii) conserving crude oil / saving energy / reduce carbon emissions [1]
REJECT: cheaper [1]

[Total: 10]

5 (a) gradient steeper for graph for strontium therefore a greater volume of gas produced per unit time [1] **Note:** steeper graph alone is insufficient to earn full credit as students need to explain what is understood by 'steeper'. [1]

(i) Total volume = 53 cm^3
Time taken for reaction to be complete = 65 s (allow ±1)
Average rate = total volume / total time = 53/65 = **0.815 cm^3/s** (OR 0.828, 0.803) [1] [1]

(ii) the line was still going up / the line was still rising / not horizontal / gradient not zero / gradient still positive
REJECT: not constant [1]

(b) $Sr + 2\ H_2O \rightarrow Sr(OH)_2 + H_2$ [2] 1 m – formulae, 1 m – balanced

strontium hydroxide is an alkali / alkaline / base / contains OH^- [1] [3]

(c) **electrolysis of an aqueous solution:**
Answer must compare reactivity + state what is discharged + what is formed [1]
e.g. hydrogen below strontium in reactivity, H^+ preferentially discharged to form H_2

reduction of the oxide by carbon:
Answer must compare reactivity + state the outcome [1]
e.g. Sr more reactive than carbon therefore carbon cannot reduce strontium oxide/ carbon doesn't displace strontium [1] [2]
[Total: 8]

6 (a) **Any one of**
- cracking of alkanes / hydrocarbon (using heat / catalyst)
  ALLOW: cracking of crude oil
- electrolysis of water (H_2 obtained at cathode)
- steam reforming / reacting alkane with steam using heat / catalyst (not in syllabus) [1]

(b) electronic structure is 2.5 / 5 valence electrons [1]
needs three electrons for fully-filled/complete valence shell [1] (therefore shares three electrons, one to each hydrogen atom) [2]

(c) as temperature increases, yield decreases ORA [1] [1]

(d) (i)
- increases rate of reaction [1]
- molecules closer together / more reacting particles per unit volume [1]
- frequency of effective collisions increases [1] [3]

(ii) **Any one of**
- increases yield of NH_3 / produces higher % of NH_3 [1] [1]

- lower temperature can be used to achieve comparable rate thus saving energy [1]

(iii) **Any one of**

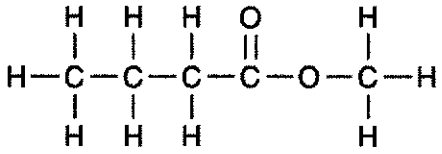
- safety risk / risk of explosion [1]
- high cost, with link to construction / materials to withstand pressure [1]

[1]

(e) recycled / sent over catalyst again [1] ALLOW used again [1]

[Total: 10]

7 **(a)**



[1]

(b) to <u>cool</u> and <u>condense</u> vapours / minimise loss of volatile chemicals during heating
ALLOW: prevent vapours from escaping [1]

(c) immiscible (ALLOW: insoluble / do not mix) [1]

(d)

M1	no. of moles of methanol = 2/32 = **0.0625 mol** [1]
M2	In an esterification reaction, the stoichiometry is 1:1:1:1 actual yield of methyl butanoate (in mol) = **0.009804 mol** theoretical yield of methyl butanoate (in moles) = **0.0625 mol** [1] **OR** actual yield of methyl butanoate (in g) = **1.0 g** theoretical yield of methyl butanoate (in g) = **6.375 g** [1]
M3	percentage yield = $\frac{1.0}{6.375} \times 100\% = 15.686\% \approx$ **15.7% (3 s.f.)** [1] **OR** percentage yield = $\frac{0.009804}{0.0625} \times 100\% \approx$ **15.7% (3 s.f.)** [1]

[3]

(e) **similarity (any one) [1]**

- both involve formation of ester linkage
- both involve loss of water
- both undergo condensation polymerisation between a hydroxyl and carboxyl group (REJECT alcohol and carboxylic acid)
- both require heat / catalyst for formation

difference (any one) [1]

methyl butanoate	polyethylene terephthalate
joining two molecules	joining many molecules (monomers)
between alcohol and carboxylic acid	between diol and dicarboxylic acid
no repeating unit	has repeating units

[2]

loss of one water molecule	loss of many water molecules

[Total: 8]

8 **(a)** At pH 8.2, $CO_2(aq) < CO_3^{2-}(aq) < HCO_3^-(aq)$ (ignore if state symbols are not written) [1]

(b) $2\ H^+(aq) + 2\ e^- \rightarrow H_2(g)$ [1] (ignore if state symbols are not written)

H^+ preferentially discharged (to form H_2) AND $[H^+]$ decreases / $[OH^-]$ increases [1]
ALLOW: 'selectively' in place of 'preferentially'
ALLOW: 'reduced' in place of 'discharged' [2]

(c) When pH increases, concentration of CO_3^{2-} increases / $CO_2(aq)$ and/or HCO_3^- converted to CO_3^{2-} / more CO_3^{2-} formed [1]

Ca^{2+} and Mg^{2+} react with CO_3^{2-} to form $CaCO_3$ and $MgCO_3$ [1]
Allow if expressed in the form of ionic equations. [2]

(d) Cl_2 / chlorine [1]

High concentration of Cl^- relative to other anions AND Cl^- preferentially oxidised / selectively discharged compared to OH^- [1] [2]

(e) In forsterite, the formula of the anion is SiO_4^{4-}. $n = 1$ and $x = 0$

In anorthite, the formula of the anion is $Si_2O_8^{8-}$. $n = 2$ and $x = 0$ [2]

(f)

	Feature of Equatic-1	Impact on environmental sustainability
Positive	H_2 when burnt/used as fuel, water is the only product;	eliminating any further CO_2 emissions / reduce reliance on fossil fuels / relate to competing uses of crude oil / renewable
	CO_2 removed from seawater by precipitation in the form of solid metal carbonates CO_2 removed from environment by bubbling air through (immobilised in the form of dissolved HCO_3^-)	Re-establish levels / reduce carbon content in ocean / counteracts ocean acidification / restore capacity of ocean to take up CO_2 / increase pH of water / reduces the overall rate at which humans are adding CO_2 to the atmosphere
	carbonates used for construction	conserving (finite) resources
Negative	electrolysis is energy intensive	may require fossil fuels / add more CO_2 to the environment / however it is possible to use solar energy
	negligible amount of CO_2 removed compared to annual emissions	One plant is not enough / many plants need to be built to remove enough CO_2 to achieve net zero

[3]

		may not be feasible in terms of construction cost and land use

Any 2 boxes = 1 m (max 3 m)

[Total: 12]

9 (a) Any two

- NH_4^+ (& NO_3^-) ions have single positive and negative charges
- Calcium ion has a +2 charge which is not represented in the diagram
- There is a 1:1 ratio for ammonium nitrate
- There needs to be a 1:2 ratio for calcium nitrate [2]

(b) Any one

- nitrate / polyatomic ions contain multiple atoms
- ions are not spherical
- vibration / movement of ions is not shown
- there are many more ions in a real ionic compound
- only 2D shown but ions in an ionic compound are arranged in 3D [1]

(c)

	Each marking point worth 1 m (max 1 per row)
M1 (magnitude)	• ΔH larger magnitude / value for calcium nitrate / larger difference in energy between reactant and products ORA (BOD: larger energy change)
M2 (ΔH)	• ΔH < 0 / exothermic for $Ca(NO_3)_2$ but ΔH > 0 / endothermic for NH_4NO_3
M3 (explanation for ΔH)	overall exothermic for $Ca(NO_3)_2$ because more energy released than absorbed AND overall endothermic for NH_4NO_3 because more energy because more energy absorbed than released ALLOW heat energy, but NOT heat REJECT: used / required / needed
M4 (explanation for difference in magnitude)	Bigger difference in amount of energy absorbed for bond breaking and amount of energy released in bond forming for $Ca(NO_3)_2$, compared to NH_4NO_3

[4]

(d) (i) add excess $CaCO_3$ to nitric acid [1]
stir until no more effervescence
filter to remove residue / obtain filtrate [1] [2]

(ii) aqueous ammonia / ammonium carbonate + nitric acid [1] [1]

[Total: 10]

10 **(a)** **(i)** $C_{25}H_{51}$ [1] [1]

(ii) The (C and H) <u>atoms</u> are already in the <u>simplest ratio</u> [1]
ALLOW they have odd numbers of carbon atoms / prime numbers of carbon atoms / can't divide by 2
ALLOW formula cannot be simplified / cannot cancel down [1]

(b) simple molecular structure[1]

little energy needed to overcome weak intermolecular forces of attraction [1] [2]

(c)

	Each marking point worth 1 m (max 1 per row)
M1 (similar structure)	• are hydrocarbons / only contain carbon and hydrogen • are saturated/contain all single bonds/do not have any functional groups • covalent bonds / have (weak) intermolecular forces between molecules • each molecule differs from the last by CH_2
M2 (same general formula)	• C_nH_{2n+2}
M3 (similar chemical properties)	• similar (REJECT: same) chemical property / give e.g. undergo combustion/flammable/are generally unreactive/undergo substitution reaction
M4 (trend in physical properties)	• example of physical property which changes down the series (e.g. m.p./b.p. increase, less volatile/more dense/less flammable) • states show a trend in their change from gas (to liquid) to solid

[4]

(d)

	Each marking point worth 1 m (max 1 per row)
M1 (profitability)	• <u>higher demand / meet demand</u> for smaller molecules ALLOW: more valuable *no marks for stating the use of small molecules without idea of matching demand*
M2 (environment)	• <u>reduce waste</u> / fully utilise crude oil by converting excess of large molecules to smaller, more useful ones • <u>reduce pollution</u> as smaller molecules burn more efficiently / cleanly as fuels

[2]

[Total: 10]