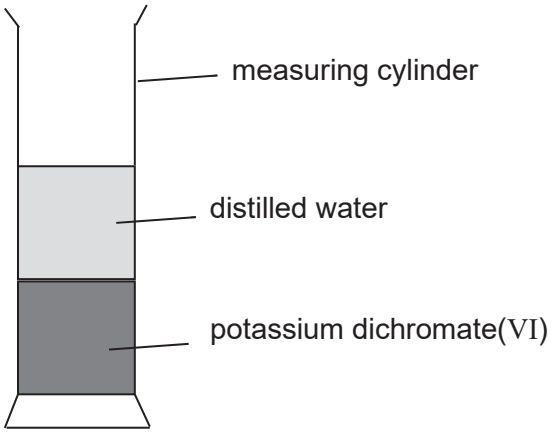
1 Potassium dichromate(VI) contains potassium ions (colourless) and dichromate(VI) ions (orange). An experiment was set up as shown below.

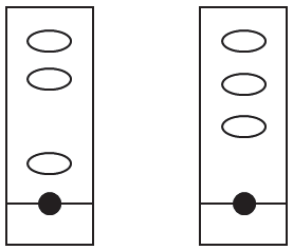


After a few days, a uniformly orange solution was obtained in the measuring cylinder.

The phenomenon was caused by the movement of _____.

A dichromate(VI) ions only.
B dichromate(VI) ions and water molecules only.
C potassium ions and dichromate(VI) ions only.
D potassium ions, dichromate(VI) ions and water molecules.

2 Two students were investigating the type of pigments found in flower petals. After obtaining a solution from the petals, the separation of the pigments was performed using chromatography. The chromatograms obtained are shown below.

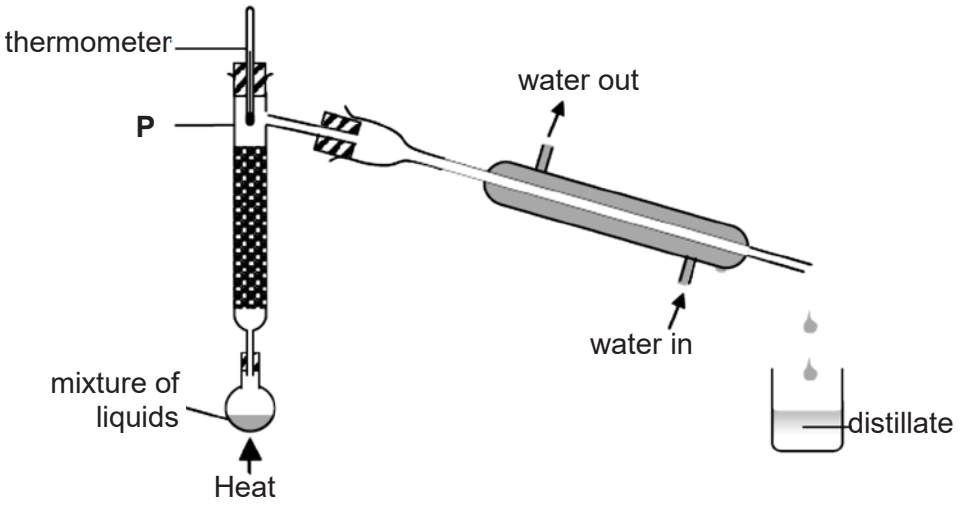


If both students used flowers from the same plant, why were the chromatograms different?

A One student did not use enough solvent.
B The solvent travelled up the paper at different speeds.
C The two students used different solvents.
D The solvent in one of the separation did not reach the top of the paper.

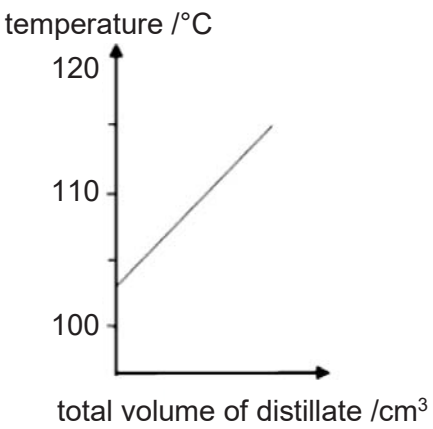
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3 The diagram below shows the apparatus used to separate a mixture of two liquids with boiling points 102.5°C and 115°C.

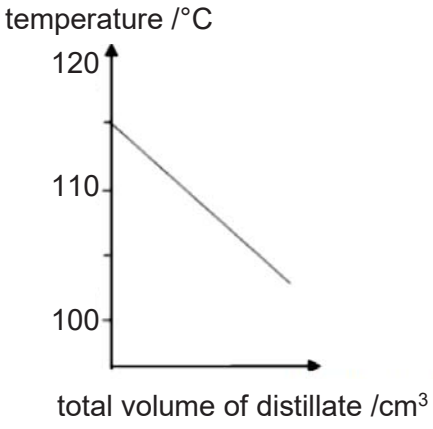


Which graph would be obtained if the temperature at point **P** was plotted against the total volume of distillate produced?

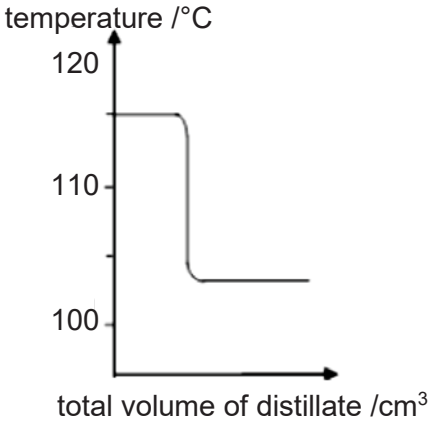
A



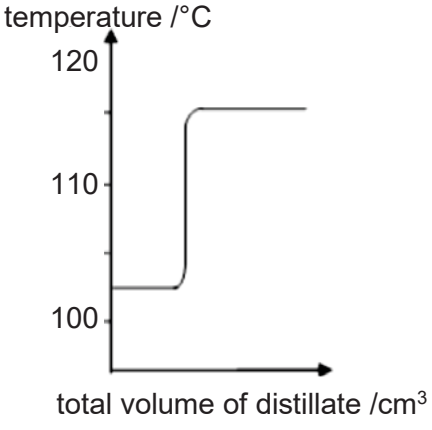
B



C



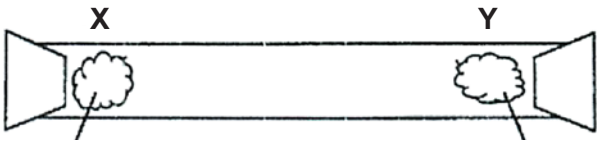
D



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4 The apparatus below was set up with two cotton wool plugs soaked in concentrated aqueous ammonia and concentrated aqueous hydrochloric acid respectively.

These plugs were secured at opposite ends of a long glass tube as shown. After some time, a white solid formed within the tube.



concentrated aqueous ammonia on cotton wool

concentrated aqueous hydrochloric acid on cotton wool

The experiment was then repeated by placing the tube vertically, where the cotton wool soaked in concentrated aqueous hydrochloric acid is at the top.

Which of the following is true of the repeated experiment?

A The white solid forms even closer to **X** compared to the first experiment but at the same rate.
B The white solid forms even closer to **Y** compared to the first experiment but at the same rate.
C The white solid forms even closer to **X** and at a much faster rate compared to the first experiment.
D The white solid forms even closer to **Y** and at a much faster rate compared to the first experiment.

5 Which of the following list of substances contains an element, a compound and a mixture?

A crude oil, stainless steel, graphite
B diamond, ethanol, dry air
C petrol, neon, oxygen
D methane, carbon dioxide, air

6 An ion $\mathbf{X}^{3-}$ has a mass number of **m** and **n** electrons.

What does the nucleus of an atom of **X** contain?

	number of protons	number of neutrons
A	**n** - 3	**m** – **n**
B	**n** – 3	**m** – (**n** -3)
C	**n** + 3	**m** – (**n** – 3)
D	**n** + 3	**m** – (**n** + 3)

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7 An element **Z** exists in three isotopic forms as shown below.

isotope	^{86}Z	^{87}Z	^{88}Z
isotopic abundance (%)	10	**p**	**q**

If the relative atomic mass of element **Z** is 87.7, what is the value of **p**?

A 10
B 20
C 70
D 80

8 Hydrogen can form both H^+ and H^- ions.

Which statement about these two ions is correct?

A H^+ ion has 1 more proton than a H^- ion.
B H^+ ion has 2 more protons than a H^- ion.
C H^- ion has 1 more electron than a H^+ ion.
D H^- ion has 2 more electrons than a H^+ ion.

9 Which substance consists of both ionic and covalent bonds in their structures?

A ethanol
B magnesium chloride
C potassium nitrate
D ethyl ethanoate

10 When dry ice is left at room temperature, it sublimes.

Which of the following statements correctly describes this process?

A Energy is absorbed to overcome the ionic bonds between the ions.
B Energy is absorbed to overcome the covalent bonds between the atoms.
C Energy is absorbed to overcome the van der Waals forces between the atoms.
D Energy is absorbed to overcome the van der Waals forces between the molecules.

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11 In the lattice structure of ionic compounds, coordination number is the number of nearest neighbouring ions of the opposite charge. For instance, in sodium chloride, each sodium ions is surrounded by 6 chloride ions and each chloride ion is surrounded by six sodium ions. Hence, coordination number of sodium ions and chloride ions is 6.

The table below shows the ions present and the coordination number of the ions in some ionic compounds.

compound	ions present		coordination number of		formula
	cation	anion	cation	anion	
sodium chloride	Na^+	Cl^-	6	6	NaCl
titanium(IV) oxide	Ti^{4+}	O^{2-}	6	3	TiO_2
P	**Q**	**R**	4	8	?

What is the formula of compound **P**?

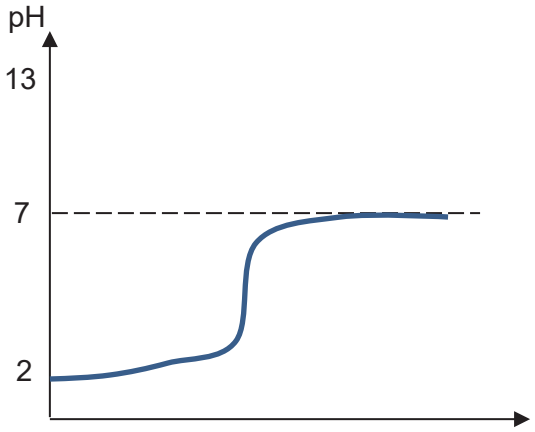
A $\mathbf{QR_2}$
B $\mathbf{Q_2R}$
C $\mathbf{QR_4}$
D $\mathbf{Q_4R}$

12 Which of the following equations suggests that the underlined oxide has amphoteric properties?

A $\underline{K_2O} + H_2O \rightarrow 2\ KOH$
B $\underline{P_2O_5} + 6\ NaOH \rightarrow 2\ Na_3PO_4 + 3\ H_2O$
C $\underline{Cl_2O} + 2\ LiOH \rightarrow 2\ LiClO + H_2O$
D $\underline{Ga_2O_3} + 2\ KOH \rightarrow 2\ KGaO_2 + H_2O$

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13 An excess of substance **J** was added bit by bit, with stirring, to aqueous solution **M**. The changes in the pH of the mixture are shown in the graph below.



What could substance **J** and solution **M** be?

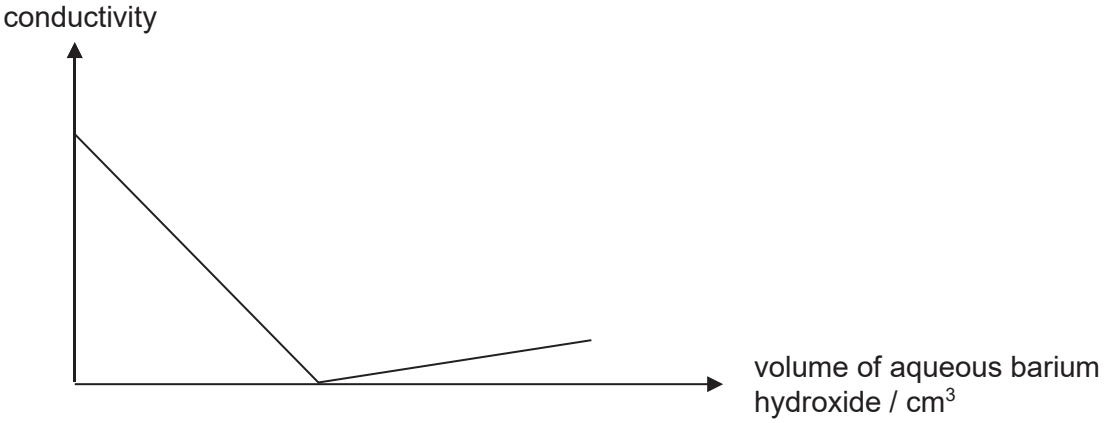
	substance **J**	solution **M**
A	aqueous ammonia	sulfuric acid
B	magnesium oxide	nitric acid
C	potassium oxide	hydrochloric acid
D	zinc oxide	ethanoic acid

14 Which pair of reagents is most suitable in preparing the following salts?

	salt	reagents
A	copper(II) chloride	copper + hydrochloric acid
B	iron(II) sulfate	iron(II) chloride + sulfuric acid
C	lead(II) chloride	lead(II) nitrate + ammonium chloride
D	potassium nitrate	potassium + nitric acid

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15 The diagram below shows the change in electrical conductivity when aqueous barium hydroxide is added to a fixed volume of substance **X**.



Which of the following is a possible identity for substance **X**?

A aqueous zinc sulfate
B aqueous iron(III) nitrate
C aqueous sodium hydroxide
D aqueous copper(II) chloride

16 Which of the following does **not** represent 0.25 mol of nitrogen gas?

A 0.5 mol of atoms
B 3×10^{23} atoms
C 1.5×10^{23} molecules
D 14 g of nitrogen

17 Sodium reacts with water in a violent reaction to give an alkaline solution. A small piece of sodium of mass 0.400 g was added to excess water. When the reaction was complete, the resulting alkaline solution required 35.0 cm^3 of 0.200 mol/dm^3 dilute hydrochloric acid for complete neutralization.

What is the percentage purity of the sodium added?

A 24.8%
B 40.3%
C 60.0%
D 80.5%

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18 When skunks are threatened, they release a foul smell that contains a group of compounds known as thiols.

An example of a thiol is methanethiol, CH_3SH, which burns as follows:

$$CH_3SH + 3\ O_2 \rightarrow CO_2 + SO_2 + 2\ H_2O$$

A sample of 10 cm^3 of methanethiol was burnt in 60 cm^3 of oxygen. What would be the final volume of the resultant mixture of gases when cooled to room temperature and pressure?

A 20 cm^3
B 40 cm^3
C 50 cm^3
D 70 cm^3

19 The atomic radius of some Group I elements of the Periodic Table is given.

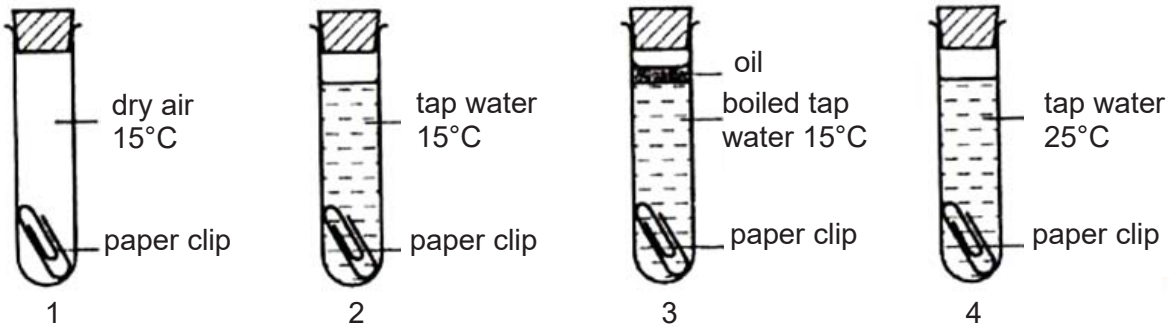
element	atomic radius / pm
K	231
L	152
M	248
N	186

Which of the following shows the correct ascending order of melting point for the elements?

	lowest → highest			
A	**L**	**K**	**N**	**M**
B	**L**	**N**	**K**	**M**
C	**M**	**K**	**L**	**N**
D	**M**	**K**	**N**	**L**

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20 Four experiments on rusting are shown.



Which two experiments can be used to show that air is needed for iron to rust?

A 1 and 3
B 1 and 4
C 2 and 3
D 2 and 4

21 Solid carbonates of three metals **W**, **X** and **Y** are heated.

	result
carbonate of **W**	carbon dioxide given off solid changes colour from green to black
carbonate of **X**	carbon dioxide given off solid does not change colour
carbonate of **Y**	carbon dioxide not given off solid does not change colour

Which of the following statements is/are correct?

I Metal **Y** is a stronger reducing agent than metal **X**.
II Metal **W** can displace metal **Y** from its solution.
III Only the carbonate of **W** gives off carbon dioxide when added to dilute nitric acid.

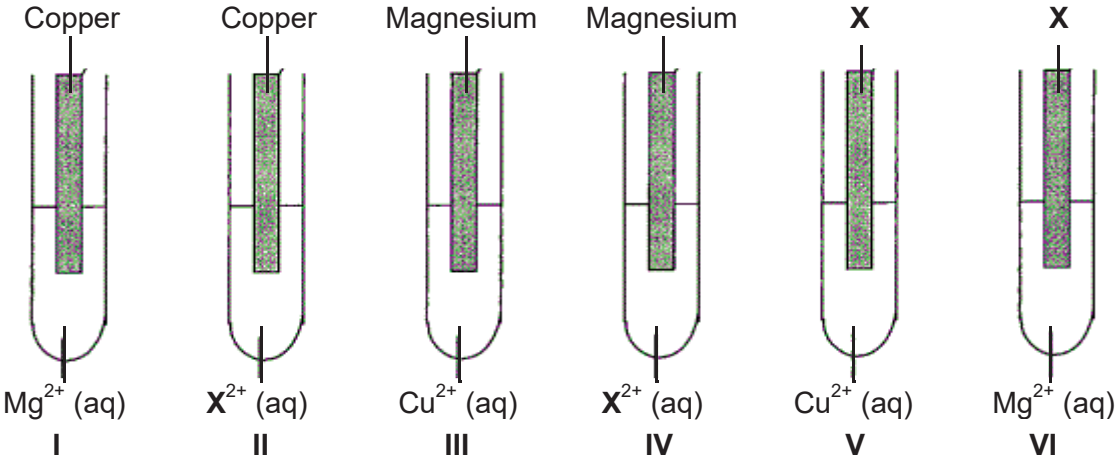
A **I** only
B **I** and **III**
C **II** and **III**
D **I**, **II**, and **III**

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22 **X** is an unknown metal.

A student did the following experiments to compare the reactivity of magnesium, copper and metal **X**.

Six tubes were arranged as shown in the diagrams below. Each tube contained a piece of metal half immersed in an aqueous solution containing ions of one of the other two metals.



The following observations were made:

- There was a deposit seen in only three tubes including tube **V**.
- There was no deposit in tube **VI**.

Besides tube **V**, which two other tubes contain a deposit?

A **I** and **II**

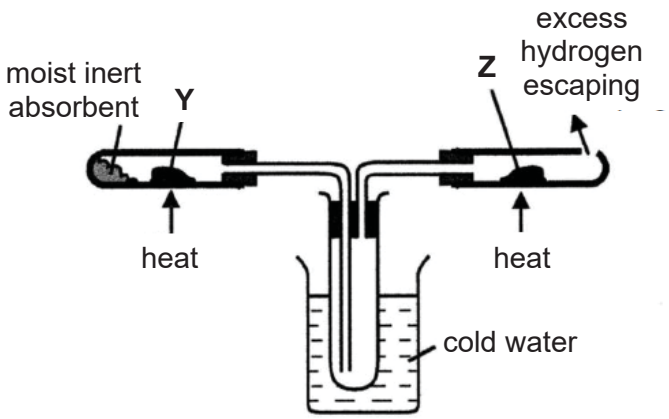
B **II** and **III**

C **II** and **IV**

D **III** and **IV**

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23 The diagram shows an apparatus used to demonstrate the reduction of a metallic oxide **Z** by hydrogen, which is produced by the action of steam on metal **Y**.



Which of the following could be **Y** and **Z**?

	Y	**Z**
A	copper	iron(II) oxide
B	iron	copper(II) oxide
C	lead	lead(II) oxide
D	magnesium	zinc oxide

24 Nitric acid, HNO_3, is a strong oxidizing agent.

Which of the following **cannot** be a product of nitric acid in its reaction with other substances?

A N_2
B NO
C NO_2
D N_2O_5

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25 The equations below show the properties of sulfur dioxide.

$SO_2 + Cl_2 \rightarrow SO_2Cl_2$
$SO_2 + 2\ H_2S \rightarrow 3\ S + 2\ H_2O$

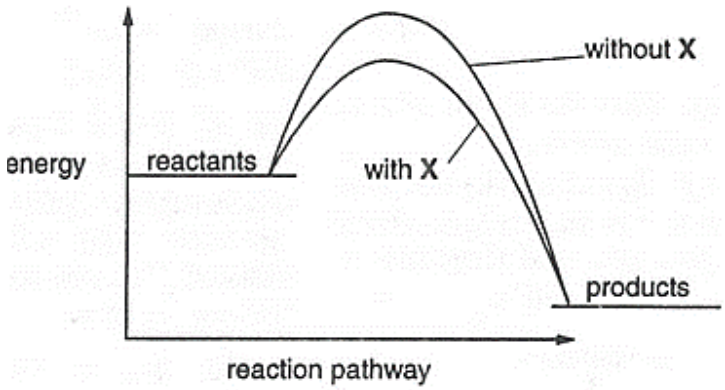
In two different experiments, sulfur dioxide was bubbled into acidified aqueous potassium manganate(VII) and aqueous potassium iodide. Which of the following correctly describes the observations seen in these experiments?

	acidified aqueous potassium manganate(VII)	aqueous potassium iodide
A	colourless to purple	remains brown
B	purple to colourless	remains colourless
C	purple to colourless	colourless to brown
D	colourless to purple	brown to colourless

26 Which of the following chemicals can be used to distinguish between aqueous calcium chloride and lead(II) nitrate?

A ammonium sulfate
B iron(II) sulfate
C sodium hydroxide
D potassium carbonate

27 The energy profile diagram of a reaction, where **X** is a catalyst, is shown.



Which of the following statements is correct?

A The addition of **X** increases the yield of the products.
B As the reaction proceeds, the amount of **X** present decreases.
C The enthalpy change of the reaction is decreased by the addition of **X**.
D Less heat is absorbed in bond breaking than is released in bond forming.

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28 Which of the following reactions is an exothermic reaction?

A photosynthesis
B boiling of water
C condensation of steam
D thermal decomposition of metal carbonates

29 Methane and sulfur dioxide are gases which affect the atmosphere and the environment.

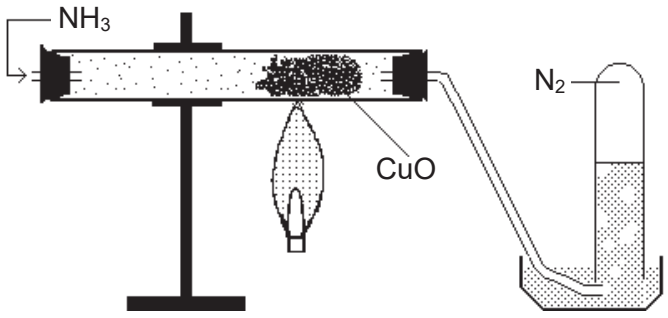
In what way do these gases affect the environment?

	methane	sulfur dioxide
A	depletion of the ozone layer	acid rain
B	global warming	photochemical smog
C	photochemical smog	global warming
D	global warming	acid rain

30 During the Haber process, ammonia that is produced is separated from the reaction mixture by _____.

A cooling the mixture
B dissolving the other two gases
C passing the gaseous mixture through fused calcium oxide
D filtering out the other two gases by passing through cotton wool

31 The diagram below shows an experiment involving ammonia.

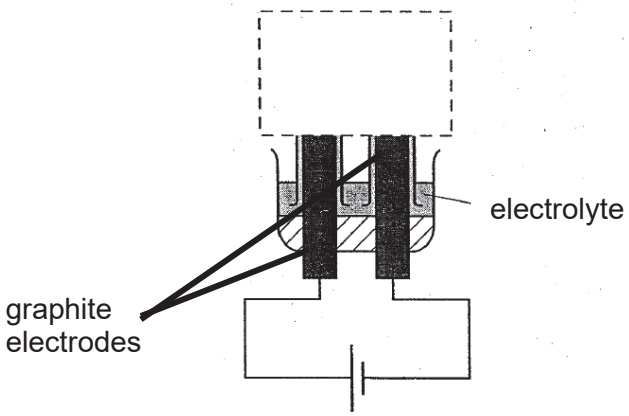


In this experiment, copper(II) oxide functions as _____.

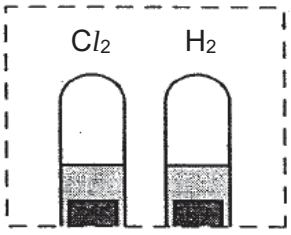
A a basic oxide
B a catalyst
C a reducing agent
D an oxidising agent

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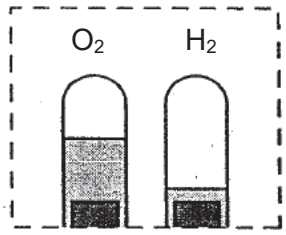
32 The diagram below is an incomplete diagram of an electrolysis experiment.



A student carries out the experiment above and obtains two different results **I** and **II** as shown below.



result **I**



result **II**

Which of the following correctly identifies the electrolyte used in the experiment to obtain results **I** and **II**?

	electrolyte used to obtain result **I**	electrolyte used to obtain result **II**
A	dilute hydrochloric acid	dilute sodium chloride
B	concentrated hydrochloric acid	dilute nitric acid
C	concentrated sodium chloride	concentrated hydrochloric acid
D	dilute sodium chloride	dilute nitric acid

33 In an electrolysis experiment, the same amount of charge deposited 32 g of copper and 13 g of chromium.

What is the charge of the chromium ion?

A +1
B +2
C +3
D +4

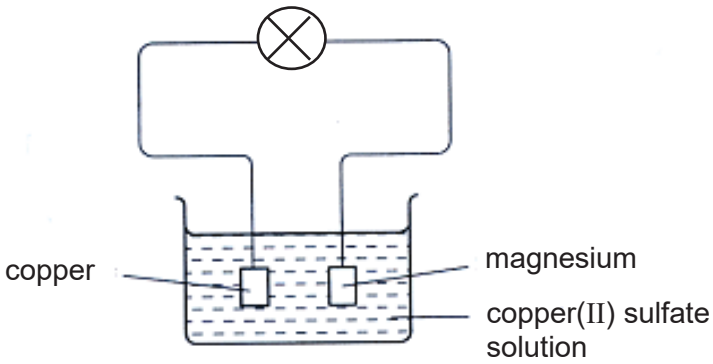
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34 When electroplating an orchid with gold, a coating of carbon particles is painted onto the orchid first.

Why is this coating applied?

A It allows the orchid to act as the negative electrode.
B It provides a rough surface for the gold plating to stick to.
C It allows the gold to form a tough alloy on the orchid's surface.
D It pre`vents the pigments on the orchid from dissolving into the electrolyte.

35 Consider the simple cell below.



What would be observed in the simple cell after the bulb has been lighted for some time?

A Oxygen gas was produced at the copper electrode.
B The solution of copper(II) sulfate turned dark blue.
C Oxygen gas was produced at the magnesium electrode.
D The copper electrode was coated with a layer of pink solid.

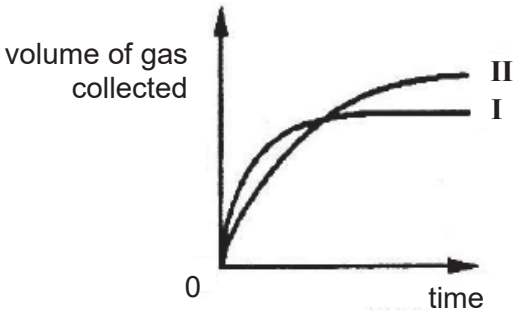
36 A sawmill is a facility where logs are cut into lumber. Sawmills with a large amount of sawdust face a greater danger of explosions with a naked flame than sawmills with a large amount of wood shavings.

What is the most likely reason for this?

A Sawdust is more flammable than wood shavings.
B Sawdust has a larger surface area than wood shavings.
C Wood in powdered form acts as a catalyst for combustion.
D Sawmills produce methane which combine with the sawdust to form an explosive mixture.

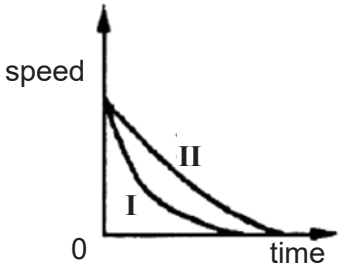
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37 In two separate experiments, a substance was decomposed and the gas evolved was collected. The graph below shows the total volume of gas collected against time for each experiment.

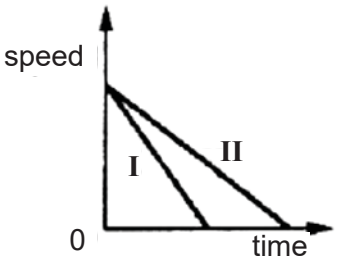


Which of the following graphs shows how the speed of the reaction varied with time in each experiment?

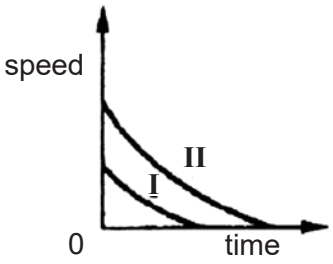
A



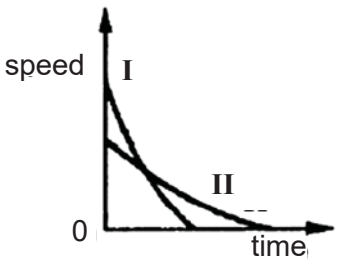
B



C



D



38 Useful fractions are obtained by the fractional distillation of petroleum.

Which of the following petroleum fractions is correctly matched with its use?

	fraction	use
A	bitumen	fuel in cars
B	kerosene	fuel for cars
C	naphtha	petrochemical feedstock

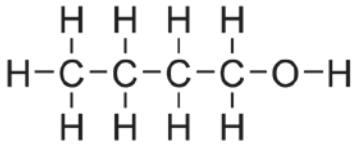
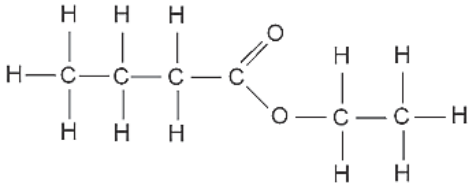
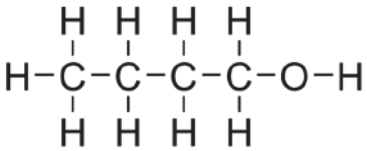
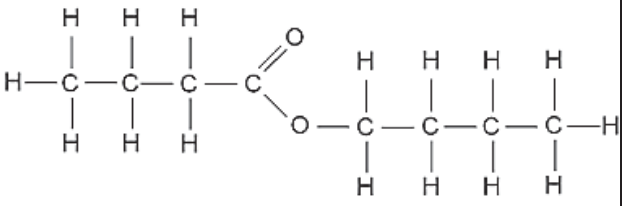
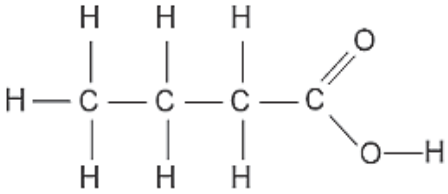
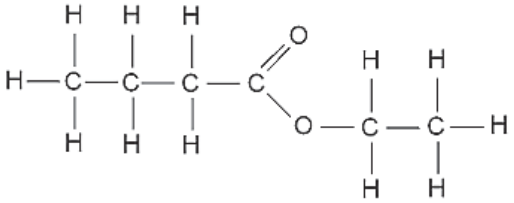
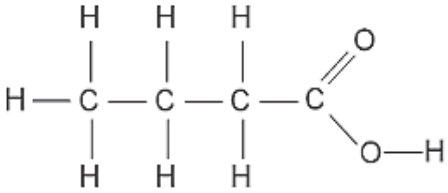
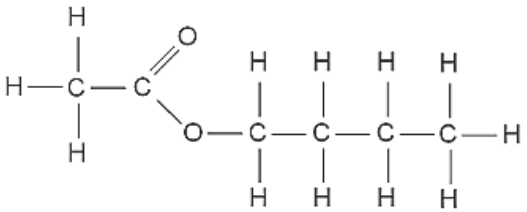
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D	diesel	fuel for aircraft engines

39 The following shows some descriptions about different organic compounds **P** – **T**.

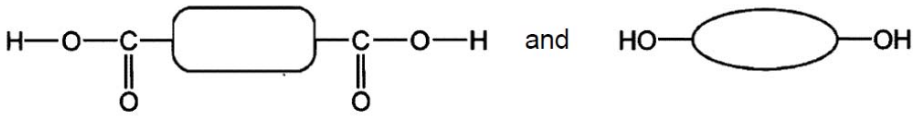
I **P** (C_4H_8) can undergo hydration to form **Q**
II **Q** can be oxidised to form **R**.
III **R** and magnesium react together to form bubbles of gas.
IV **S** is formed from the fermentation of sugar.
V **R** and **S** react together to form a sweet smelling product **T**.

Which of the following correct shows the full structural formula of **R** and **T**?

	R	**T**
A		
B		
C		
D		

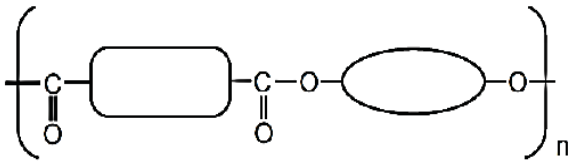
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40 Terylene is made by the condensation polymerisation of the two monomers shown.

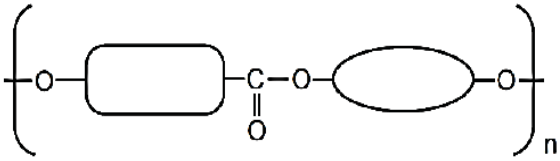


Which diagram represents the structure of the polymer formed?

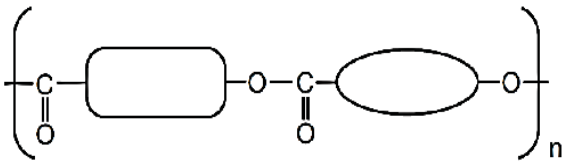
A



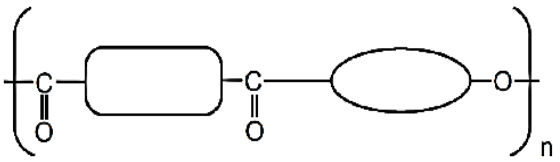
B



C



D



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COVER PAGE

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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.).

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Section A [50 marks]

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

A1 Choose from the following substances to answer the questions below.

CF_3Cl	O_3	Ni	NaCl
Mg	CO	Al_2O_3	Cu

Each substance can be used once, more than once or not at all.

(a) State the substance which

(i) is responsible for ozone depletion.

……..[1]

(ii) dissolves in rainwater and speeds up rusting.

……..[1]

(iii) must be used in order to convert naptha to ethene.

……..[1]

(iv) reacts with aqueous iron(II) chloride and causes the solution to decolourise.

……..[1]

(b) Is the reaction in **(a)(iv)** a redox reaction? Explain your answer in terms of electron gain or loss.

……

……

……..[2]

[Total: 6]

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A2 An oxyacid is an acid that contains an oxygen atom bonded to a hydrogen atom and at least one other element. Sulfuric acid (H_2SO_4), phosphoric acid (H_3PO_4) and nitric acid (HNO_3) are all oxyacids.

Chlorine forms several types of oxyacids. The table below shows some properties of oxyacids of chlorine that have the same concentration.

name of acid	chemical formula	reaction with magnesium	oxidation state of chlorine
perchloric acid	$HClO_4$	very vigorous	+7
hypochlorous acid	$HOCl$	only a few bubbles seen	
chloric acid	$HClO_3$	vigorous	
chlorous acid	$HClO_2$	reacts readily	+3

(a) Complete the table by filling in the oxidation state of chlorine. [1]

(b) **(i)** Arrange, in ascending order, the strength of these acids.

……..

……[1]

(ii) Hence, deduce the trend in the strength of the acid with reference to the information in the table.

……..

……[1]

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(c) Carboxylic acids are also a type of oxyacid.

In another experiment, a solution containing 0.172 g of an unknown carboxylic acid, $C_xH_yCO_2H$, is titrated with 0.100 mol/dm^3 aqueous sodium hydroxide. The volume of sodium hydroxide solution needed to exactly neutralize the acid is 23.20 cm^3.

$$C_xH_yCO_2H + NaOH \rightarrow C_xH_yCO_2Na + H_2O$$

Calculate the relative formula mass of the carboxylic acid and suggest its identity.

relative formula mass: ……..

identity: …… [3]

[Total: 6]

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A3 Ammonia is manufactured on a large scale by the Haber Process. **Fig. 3** below shows the effect of pressure on the amount of ammonia in the equilibrium mixture at five different temperatures.

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

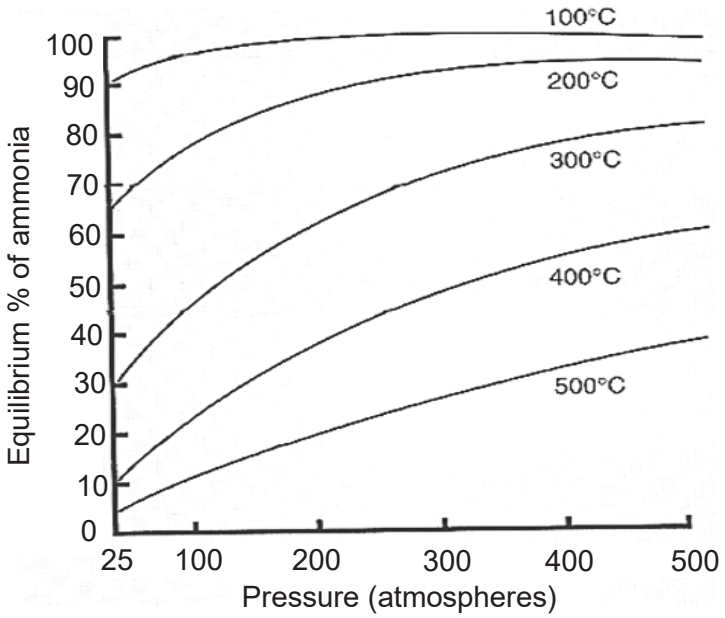


Fig. 3

(a) Using data from **Fig. 3**, describe the effect of pressure on the percentage of ammonia at equilibrium.

……

……

……

……..[2]

(b) State the actual conditions used in industry for the manufacture of ammonia in the Haber Process.

……..[1]

(c) **(i)** Based on the information in **Fig. 3**, state the temperature of the reaction that would give 80% ammonia at equilibrium when the pressure is at 100 atm.

……..[1]

(ii) By comparing the temperature in **(c)(i)** with the actual temperature stated in **(b)**, explain why the temperature in **(c)(i)** is not used in practice.

……

……[1]

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(d) Ammonia is used to make ammonium nitrate fertilisers.
To ensure that crops grow well at a suitable pH, farmers add fertilisers and slaked lime to the soil.

Explain why slaked lime and ammonium nitrate fertilisers should not be added together.

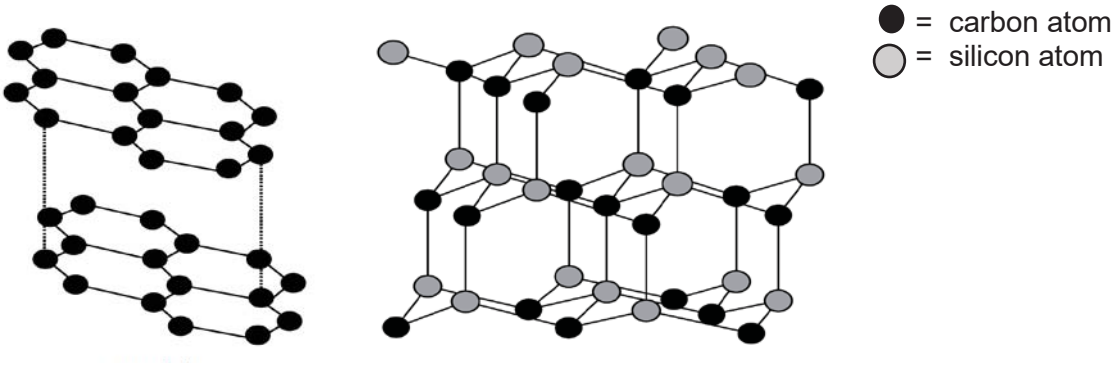
……

……

……..[2]

[Total: 7]

A4 The structure of graphite and silicon carbide are shown in **Fig. 4**.



graphite silicon carbide

Fig. 4

With reference to the bonding present in the substances,

(a) state and explain which substance is able to conduct electricity.

……

……

……

……..[3]

(b) state and explain which substance is more suitable to be used as drill bits.

……

……

……

……

……..[3]

[Total: 6]

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A5 An electrical circuit is set up as shown. **A** and **B** are the poles of the battery. Electrodes **P** and **Q** are both made of platinum. 0.2025 g of silver metal was deposited on electrode **P**.

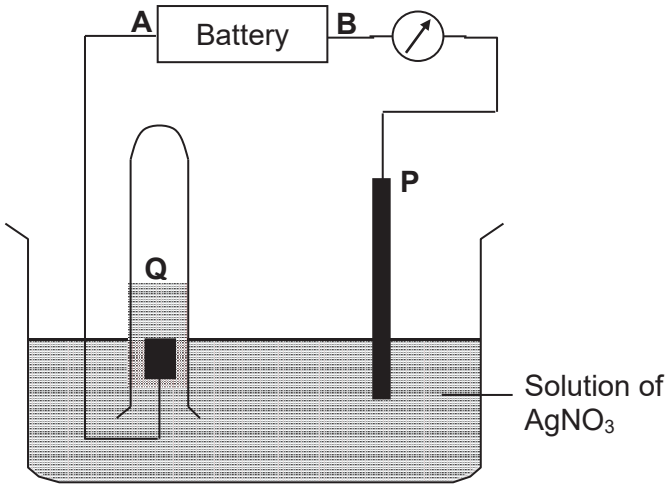


Fig. 5

(a) **(i)** State whether electrode **Q** is the positive or negative electrode.

……..[1]

(ii) Write an ionic equation for the reaction occurring at electrode **Q**.

……..[1]

(iii) Calculate the volume of gas collected, at room temperature and pressure, in the tube.

volume of gas collected: …… [3]

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(b) If the experiment was repeated using molten zinc chloride as the electrolyte, describe and explain the observations seen in the set-up.

……

……

……

……

……[3]

[Total: 8]

A6 The Periodic Table shows trends down each group and across each period.

(a) Which trends are only true down a group, across a period, true for both or not true for both?

Put a tick(✓) in the appropriate box for each trend. [2]

trend	only true down a group	only true across a period	true for both	not true for both
The mass number increases.				
The atomic radius decreases.				
The melting point increases.				
The character of the oxides changes from basic to amphoteric to acidic.				

(b) Chlorine gas was bubbled into a solution of potassium iodide.

(i) Describe the expected observation of this reaction.

……[1]

(ii) With reference to the atomic radii of relevant elements, explain why the reaction in **(b)(i)** occurs.

……

……

……

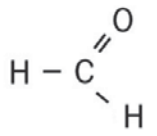
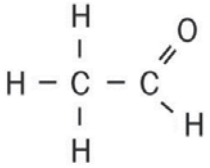
……

……[3]

[Total: 6]

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A7 The table shows some information about the homologous series of organic compounds called aldehydes.

name	condensed formula	full structural formula
methanal	HCHO	
ethanal	CH_3CHO	
propanal		

(a) **(i)** Complete the table to show the name, condensed formula and structural formula of propanal. [1]

(ii) With reference to the structural formula, explain how you can deduce that these molecules are from the same homologous series.

……

……[1]

(b) Suggest and explain the trend in the boiling points of the aldehydes down the series.

……

……

……

……[3]

[Total: 5]

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A8 Acrylamide is an organic compound that is classified as a hazardous substance as it is a potential carcinogen and is easily absorbed by the skin. It is used to manufacture polymers that are highly water absorbent and are used as thickeners. Acrylamide has the following structure.

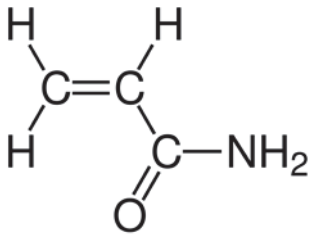


Fig. 8

(a) Draw the structure of the polymer formed from acrylamide, showing three repeating units. [1]

(b) Name the polymer drawn in **(a)**.

……[1]

(c) Describe one difference and one similarity between acrylamide and its polymer.

……

……

……

……[2]

(d) The polymer from acrylamide is *non-biodegradable*.
Explain the term '*non-biodegradable*' and describe a problem caused by the disposal of non-biodegradable polymers.

……

……

……

……[2]

[Total: 6]

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Section B [30 marks]

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

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

B9 Heat waves and carbon emissions

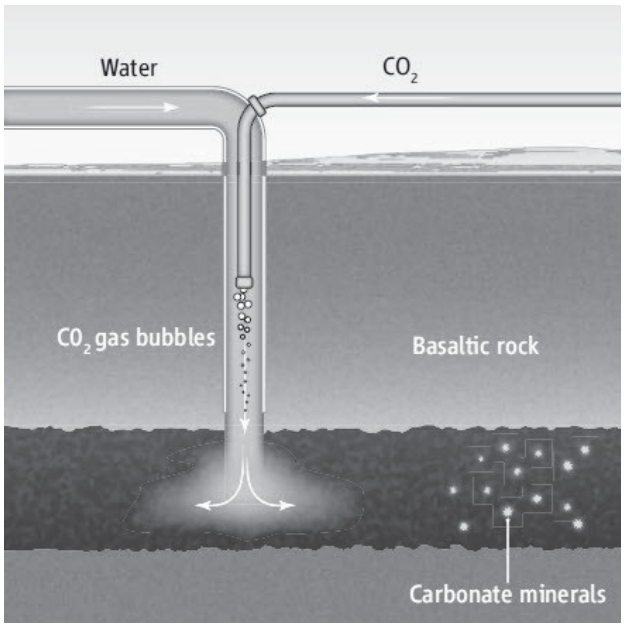
The recent spell of heat waves that are sweeping across Europe and the United States have led to an increase in global awareness about the need to control carbon emissions. Extreme heat refers to temperatures that are exceptionally high relative to typical local conditions or reach levels that may be harmful to human health or infrastructure. When extreme daytime temperatures persist over a prolonged period (usually at least two days), it is often referred to as a heat wave.

In order to control carbon emissions, scientists have found ways to 'lock away' carbon dioxide. The article below was adapted from The Straits Times dated June 11, 2016.

Scientists say they may have found a radical breakthrough to tackling climate change – by pumping heat-trapping carbon dioxide gas into the ground and turning it into stone.

The research, called the *CarbFix* project and led by Columbia University, was published in American journal *Science* on Thursday (June 9).

The approach involves dissolving carbon dioxide gas with water and pumping the resulting mixture – essentially soda water – down into certain kinds of rocks. Soda water then accelerates the release of metal ions from the rocks, such as calcium and magnesium, which react with the soda water to form minerals such as calcite ($CaCO_3$) and magnesite ($MgCO_3$). Acidic ions also produced in this reaction, which then further promotes the release of metal ions from the rocks, hence speeding up the reaction of soda water with metal ions. By turning the carbon dioxide gas into calcite and magnesite, scientists can then lock it away permanently.



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One key to the approach is to find the right kind of rocks. Volcanic rocks called basalts are excellent for the process, because basalts are rich in calcium and magnesium.

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

Fig. 9

(a) Explain how high levels of carbon emissions cause heat waves.

……

……

……

……[2]

(b) **(i)** 'Soda water' mentioned in the article is weak carbonic acid (H_2CO_3). Explain what is meant by the term weak acid.

……

……[1]

(ii) Write an equation for the formation of magnesite.

……[1]

(c) Other than calcite, name another mineral that also contains calcium carbonate.

……[1]

(d) Suggest a reason why

(i) the conversion of carbon dioxide gas into calcite happened relatively quickly around volcanic areas in Iceland.

……

……[1]

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

……

……[1]

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(e) Other than the process described above, describe two other natural process that traps and stores carbon dioxide in the atmosphere.

……

……

……

……[2]

(f) As vehicles are a major source of air pollution, governments have introduced regulations to ensure that all vehicles install catalytic converters.

Describe briefly how catalytic converters work and explain why they are not useful in lowering carbon emissions.

……

……

……

……

……[3]

[Total: 12]

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B10 A growing concern for the environment has promoted a shift towards the use of cleaner sources of energy such as hydrogen fuel. Currently, the dominant technology for the production of hydrogen is through steam reforming of hydrocarbons.

Steam-methane reforming is a method used for producing hydrogen from natural gas. In the process, methane reacts with steam to produce carbon monoxide and hydrogen.

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

The carbon monoxide produced is transferred into another reaction vessel, where it is further reacted with more steam to produce more hydrogen in the water-gas shift reaction.

$$CO\ (g) + H_2O\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$$

(a) The bond energies of various bonds are shown in the table.

bond	bond energy (kJ/mol)
C–O	358
C≡O	1080
O–H	464
H–H	436

Given that the enthalpy change of the steam-methane reforming reaction is +200 kJ/mol, calculate the bond energy of the C–H bond.

bond energy: …..…….[2]

(b) Explain, in terms of bond breaking and bond forming, whether the reaction above is endothermic or exothermic.

……

……

……...[2]

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(c) Both reactions described above are *reversible* reactions.

Explain the term '*reversible* reaction'.

……

……...[1]

(d) If 1 kg of methane and 1.6 kg of steam are used in the steam-methane reforming reaction, what is the maximum mass of hydrogen that can be produced from 1 kg of methane?

mass of hydrogen: ……. [3]

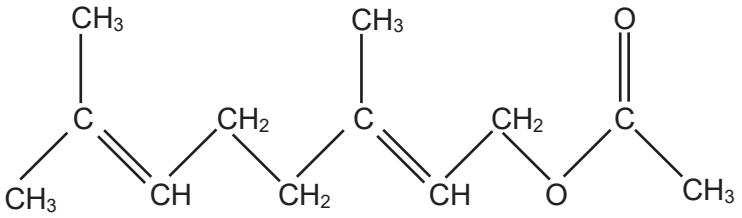
[Total: 8]

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EITHER

B11 Perfumes usually contain three groups of components called the top note, middle note and end note.

(a) The top note compounds vapourise most readily. An example of a top note compound is geranyl acetate. The structure of geranyl acetate is shown below.



(i) Explain why geranyl acetate is suitable to be used as a top note for perfumes.

……

……

……[2]

(ii) Draw the full structural formula of the carboxylic acid and alcohol used to synthesize geranyl acetate.

carboxylic acid

alcohol

(iii) State the name of the carboxylic acid drawn in **(a)(ii)**.

……[1]

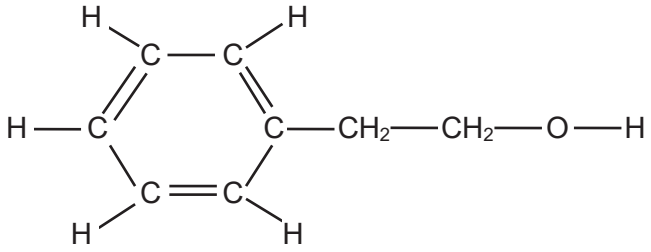
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(iv) Using the following percentage composition data, calculate the empirical formula for geranyl acetate.

element	percentage by mass (%)
carbon	73.47
hydrogen	10.20
oxygen	16.33

empirical formula: …….. [2]

(b) The middle note compounds vapourise less readily. A typical middle note is 2-phenylethanol. The structure of 2-phenylethanol is shown below.



Describe a chemical test which can be carried out to distinguish between the top note (geranyl acetate) and middle note (2-phenylethanol) compounds.

…….....

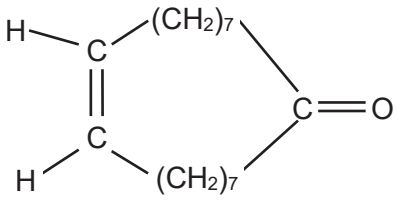
…….....

…….....

……[2]

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(c) The end note of a perfume has a long lasting odour which stays with the user. An example of an end note compound is shown below.



Draw the structure of the compound formed when the end note compound above reacts with steam in the presence of a catalyst. [1]

[Total: 10]

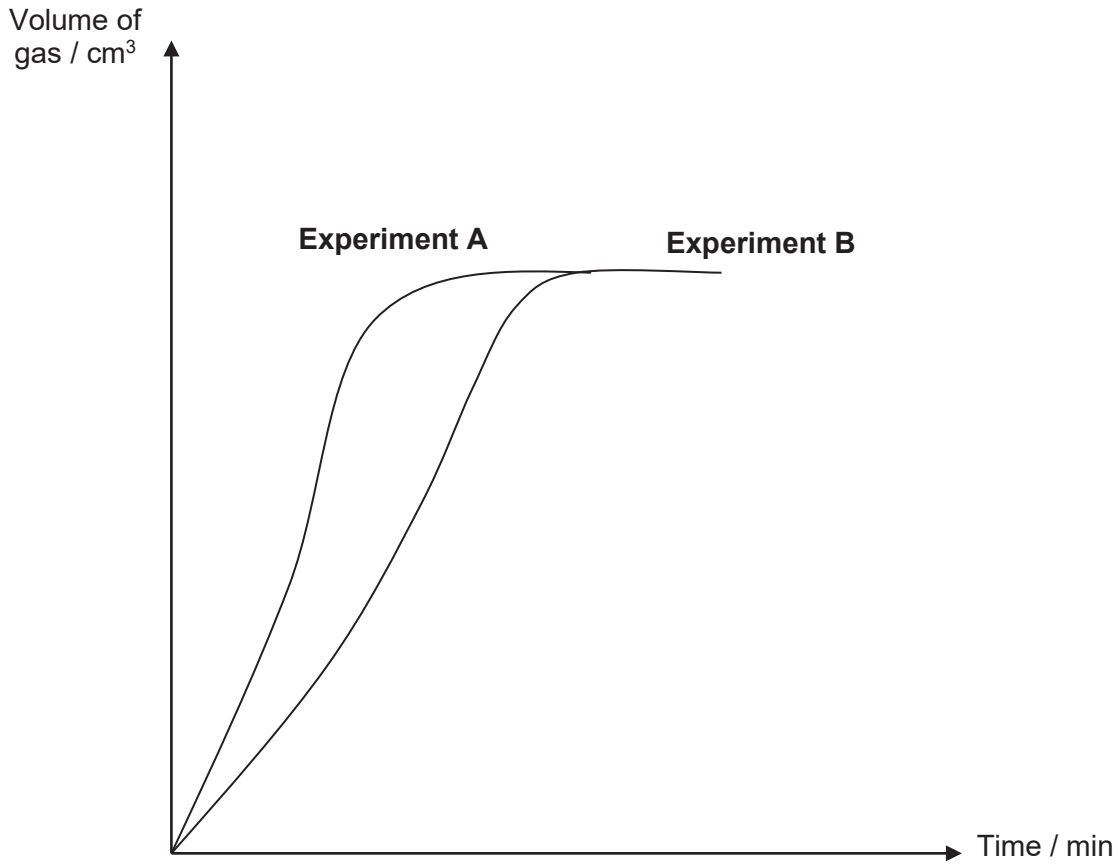
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OR

B11 Lead(II) carbonate reacts with dilute nitric acid as shown by the equation below:

$$PbCO_3(s) + 2\,HNO_3(aq) \rightarrow CO_2(g) + Pb(NO_3)_2(aq) + H_2O(l)$$

Two experiments are carried out using lumps or granules of lead(II) carbonate of the same mass, with other conditions kept the same. The results are shown in the graph below.



(a) With reference to the graph, which experiment, **A** or **B**, was carried out using granules of lead(II) carbonate?
Explain your answer in terms of collisions between particles.

……

……

……

……[3]

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(b) Experiment **A** is repeated using the same mass of calcium carbonate in place of lead(II) carbonate. All other conditions are kept constant.

Will the total volume of gas produced be more, less, or the same, as compared to Experiment **A**? Explain your answer.

……

……

……

……[2]

(c) Experiment **A** is repeated using excess sulfuric acid in place of nitric acid. All other conditions are kept constant.

(i) On the graph above, sketch the results you would expect to obtain. [1]

(ii) Explain the shape of your graph.

……

……

……

……

……

……

……

……

..……[4]

[Total: 10]

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4 Exp 6092 Chemistry Prelim 2019: Answer Scheme

Paper 1

Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans
1	D	**6**	B	**11**	B	**16**	D
2	C	**7**	A	**12**	D	**17**	B
3	D	**8**	D	**13**	B	**18**	C
4	C	**9**	C	**14**	C	**19**	D
5	B	**10**	D	**15**	A	**20**	C

Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans
21	A	**26**	C	**31**	D	**36**	B
22	D	**27**	D	**32**	B	**37**	D
23	B	**28**	C	**33**	D	**38**	C
24	D	**29**	D	**34**	A	**39**	C
25	C	**30**	A	**35**	D	**40**	A

Paper 2

Section A

A1 (a) (i) CF_3Cl

(ii) $NaCl$

(iii) Al_2O_3

(iv) Mg

(b) Mg loses two electrons and is oxidised to form Mg^{2+} [1] while Fe^{2+} gains two electrons and is reduced to Fe. [1] Since oxidation and reduction occurs at the same time, it is a redox reaction.

A2 (a)

chemical formula	oxidation state of chlorine
$HClO_4$	+7
$HOCl$	**+1**
$HClO_3$	**+5**
$HClO_2$	+3

(2 correct answers, 1 mark. No 0.5 mark)

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(b) (i) hypochlorous acid, chlorous acid, chloric acid, perchloric acid

OR HOCl, $HClO_2$, $HClO_3$, $HClO_4$

(ii) The stronger the acid, the higher the number of oxygen atoms in each unit of the acid.

OR The stronger the acid, the higher the oxidation state of chlorine in the acid.

(c) No. of mol of NaOH = 0.1 x 23.2/1000 = 0.00232 mol [0.5]

By mol ratio, NaOH : acid
1 : 1
0.00232 mol : 0.00232 mol [0.5]
Relative formula mass of acid = 0.172 / 0.00232 = 74.138 (to 5 s.f.)
= 74.1 (to 3 s.f.) [1]

Identity of acid = propanoic acid OR $C_2H_5CO_2H$ [1]

A3 (a) The higher the pressure, the larger the percentage of ammonia present at equilibrium. [1]

[1 mark - student quotes data from the graph, stating the percentage of ammonia at different pressures but at the same temperature.]

(b) 450°C, 250 atm, iron catalyst [1]

(c) (i) 200°C

(ii) This temperature is lower than the actual temperature and thus the rate of the reaction to be slower, hence the process of manufacturing ammonia will not be cost-effective.[1]

(d) When ammonium nitrate fertilisers and slaked lime are added together, they react to release ammonia gas [1] which escapes from the soil, thus reducing the amount of nitrogen available in the soil that is needed for plant growth. [1]

A4 (a) Graphite. [1] In graphite, each carbon atom is covalently bonded to three other carbon atoms and has one valence electron that is not used in bonding. [1] These electrons are delocalised and act as charge carriers to enable graphite to conduct electricity. [1]

(b) Silicon carbide. [1] In silicon carbide, each atom is covalently bonded to 4 other atoms to form a repeated network of tetrahedral structures. [1] It takes a large amount of energy to overcome the strong covalent bonds between the atoms, hence it is hard [1] and more suitable to be used as drill bits.

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A5 (a) (i) Positive electrode [1]

(ii) $4\ OH^-\ (aq) \rightarrow 2\ H_2O\ (l) + O_2\ (g) + 4\ e^-$

(iii) No. of mol of silver = 0.2025 / 108 = 0.001875 mol [1]

At P: $Ag^+\ (aq) + e^- \rightarrow Ag\ (s)$

By mol ratio, Ag : e^-

1 : 1

0.001875 mol : 0.001875 mol [0.5]

$4\ OH^-\ (aq) \rightarrow 2\ H_2O\ (l) + O_2\ (g) + 4\ e^-$

By mol ratio, O_2 : e^-

1 : 4

0.00046875 mol : 0.001875 mol [0.5]

Vol of oxygen gas produced = 0.00046875 x 24 = 0.01125 dm^3

= 0.0113 dm^3 [1]

(b) If molten zinc chloride was used, grey metal deposits will be seen at P and a yellow-green gas will be obtained at Q. [1]

When molten zinc chloride is used, zinc ions are discharged at P to form molten zinc metal [1], chloride ions are discharged at Q to form chlorine gas. [1]

A6 (a)

trend	only true down a group	only true across a period	true for both	not true for both
The mass number increases.	✓			
The atomic radius decreases.		✓		
The melting point increases.				✓
The character of the oxides changes from basic to amphoteric to acidic.		✓		

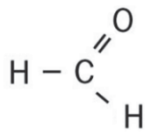
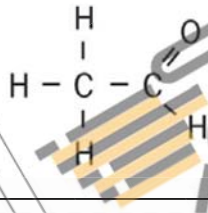
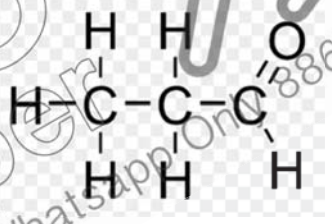
(b) (i) Colourless potassium iodide solution turns brown. [1]

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(ii) The reaction occurs as chlorine is more reactive than iodine, hence chlorine is able to displace iodine from its solution. [1] Chlorine has a smaller atomic radii compared to iodine, and the distance between the positively charged nucleus and the valence electron shell is smaller. [1] Thus when chlorine reacts, its nucleus is able to attract the electrons more strongly [1], and thus chlorine is more reactive than iodine.

A7 (a) (i)

name	condensed formula	full structural formula
methanal	HCHO	
ethanal	CH_3CHO	
propanal	**CH_3CH_2CHO OR C_2H_5CHO [0.5]**	 [0.5]

(ii) They have the same functional group – CHO, hence they belong to the same homologous series. [1]

OR They have the same general formula, $C_{n-1}H_{2n-1}CHO$, hence they belong to the same homologous series. [1]

(b) The boiling points of the aldehydes increases down the series. [1] Going down the series, as the molecules increase in size, there will be stronger intermolecular forces of attraction between the molecules [1], thus more energy is needed to overcome these intermolecular forces [1] and hence the boiling point will increase.

A8 (a)

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(b) polyacrylamide [1]

(c) Both of them have the same empirical formula / contain the amide functional group. [1]

Polyacrylamide has a higher melting and boiling point than acrylamide

OR polyacrylamide has a giant molecular structure while acrylamide has a simple molecular structure. [1]

(Accept any other logical difference and similarity)

(d) 'Non-biodegradable' means that the polymer cannot be broken down by bacteria in the soil. [1]

Disposal of the polymer by burning releases toxic gases such as CO and thus contributes to air pollution.

OR Disposal of the polymer by burying results in the filling up of landfill sites and reduces the amount of land available for other uses such as agriculture and development. [1]

Section B

B9 (a) Carbon dioxide is a greenhouse gas that traps infrared radiation from the earth's surface and prevents it from escaping into space. [1] This thus causes the earth's temperature to rise, and causes heat waves. [1]

(b) (i) Weak acids dissociate partially in water to form hydrogen ions. [1]

(ii) $Mg^{2+} + H_2CO_3 \rightarrow MgCO_3 + 2\,H^+$

(c) Limestone

(d) (i) The higher temperature due to volcanoes around Iceland increases the speed of the reaction. [1]

(ii) The calcite decomposes at high temperatures, hence 100% conversion may not be possible.

OR Carbonic acid is a weak acid, hence lesser amounts of soda water may have reacted and hence the yield is lower. [1]

(e) Plants carry out photosynthesis by taking in carbon dioxide from the atmosphere and converting it into glucose, which is used by plants for energy. [1]

Carbon dioxide dissolves in the oceans, and is subsequently used by plants for photosynthesis or converted into calcium carbonate in the form of shells and skeletons of marine organisms. [1]

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(f) Catalytic converters contain rhodium and platinum catalysts [1] that convert harmful gases such as CO and NO into harmless gases such as N_2 and H_2O. [1]

It does not help to lower carbon emissions, as CO is converted into CO_2, and thus causes an increase in the amount of CO_2 present in the atmosphere. [1]

B10 (a) Let the bond energy for C-H bond be x

Energy absorbed for bond breaking = 4(+x) + 2 (+464)

Energy released for bond forming = -1080 + 3 (-436) = - 2388 kJ/mol

Enthalpy change = Energy absorbed for bond breaking + Energy released for bond forming

+200 = 4(+x) + 2 (+464) + (-2388) [1]

1660 = 4 x

X = 415

Bond energy = 415 kJ/mol [1]

(b) More energy is absorbed to break C-H and O-H bonds and less energy is released to form C≡O and H-H bonds. [1] Thus the reaction is endothermic. [1]

(c) Reversible reactions are reactions where reactants are converted into products, and products are converted back into reactants at the same time. [1]

(d) No. of mol of steam = 1600 / (16 + 1 + 1) = 88.889 mol [0.5]

No. of mol of methane = 1000 / (12 + 1 x 4) = 62.5 mol [0.5]

By mol ratio of the steam-methane reaction,

CH_3 : H_2O
1 : 1
62.5 mol : 62.5 mol (reaction is possible as there is sufficient H_2O)
88.889 mol : 88.889 mol (reaction is not possible as there is insufficient methane)

Hence, as all methane is used up, methane is the limiting reagent. [0.5]

From the seam-methane reaction,

By mol ratio, CH_4 : H_2 : CO
1 : 3 : 1
62.5 mol : 187.5 mol : 62.5 mol [0.5]

From the water-gas shift reaction,

By mol ratio, CO : H_2
1 : 1
62.5 mol : 62.5 mol [0.5]

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Total amount of H_2 formed = 187.5 + 62.5 = 250 mol
Mass of H_2 formed = 250 x (1 + 1) = 500 g [0.5]

EITHER

B11 (a) (i) Geranyl acetate is a covalent compound with a low boiling point. [1] Only a small amount of energy is needed to overcome the weak intermolecular forces between the molecules, [1] thus it evaporates readily and is suitable to be used as a top note for perfumes.

(ii)

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(iii) ethanoic acid [1]

(iv)

	C	H	O
% by mass / %	73.47	10.20	16.33
Mass in 100 g / g	73.47	10.20	16.33
No. of mol / mol	73.47 / 12 = 6.1225	10.20 / 1 = 10.20	16.33 / 16 = 1.0206
Mol ratio	6.1225 / 1.0206 = 5.9989	10.20 / 1.0206 = 9.9941	1.0206 / 1.0206 = 1
	6	10	1

(Calculation of number of mol for all elements – [1])
Empirical formula = $C_6H_{10}O$ [1]

(b) Add the two compounds to 2 separate test tubes containing acidified potassium manganate(VII) and heat. [1]
If the test tube contains the middle note, purple acidified potassium manganate(VII) solution will turn from purple to colourless.

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If the test tube contains the top note, purple acidified potassium manganate(VII) will remain. [1]

(c)

OR

B11 (a) Experiment A. Granules has a smaller particle size compared to lumps, thus it has more surface area exposed for collisions. [1] Hence the reaction that uses granules of lead(II) carbonate will have a higher frequency of effective collisions between reactant particles and thus have a faster rate of reaction. [1] Since the gradient of the graph for experiment A is steeper, it shows that experiment A has a faster rate of reaction, [1] and thus it used granules of lead(II) carbonate.

(b) The total volume of gas produced will be higher. Although the same mass of carbonates are used, the experiment using $CaCO_3$ will have a larger amount of carbonate present compared to $PbCO_3$, as $CaCO_3$ has a smaller molar mass. [1] Thus, more CO_2 will be produced in the reaction that uses $CaCO_3$ [1].

(c) (i) Graph drawn should have the highest loss in mass initially, but quickly remains constant. Volume of gas produced should be small. – [1]

(ii) The rate of reaction is fast initially as sulfuric acid is a dibasic acid and hence the reaction has a twice the number of H+ per unit volume / twice the concentration of H+ compared to experiment A [1] , thus frequency of effective collisions between reactant particles is higher. [1]
The volume of gas produced quickly remains constant as $PbCO_3$ reacts with sulfuric acid to form insoluble $PbSO_4$ [1] which forms a protective layer around the carbonate and prevents further reaction from taking place. [1]

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