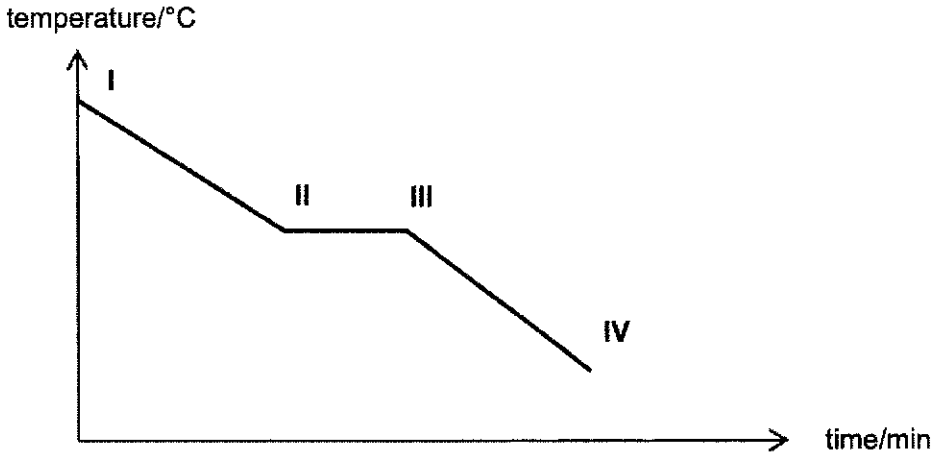
1 A sample of nitrogen dioxide gas is cooled. The temperature is measured every minute and represented in the graph below.



Which row describes the arrangement and movement of particles in the region **III** to **IV**?

	arrangement	movement
A	closely packed and orderly	vibrate about fixed positions
B	closely packed and disorderly	moving rapidly
C	closely packed and disorderly	sliding over one another
D	mixture of particles closely packed in orderly and disorderly arrangement	some particles are vibrating about fixed positions while others slide over one another

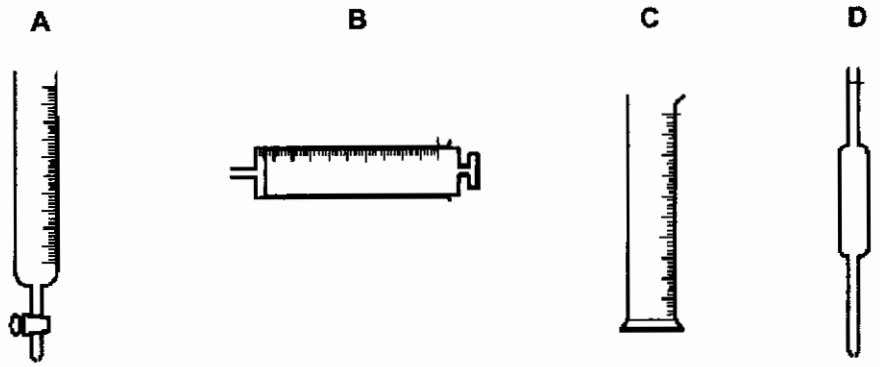
2 The table gives data about four substances.

substance	melting point / °C	boiling point / °C
tannium	50	90
changon	70	600
karenium	−30	−12
chinium	−15	101

At what temperature would there be exactly two substances in liquid state?

A −20 °C **B** 0 °C **C** 16 °C **D** 60 °C

3 **A** to **D** are pieces of apparatus.

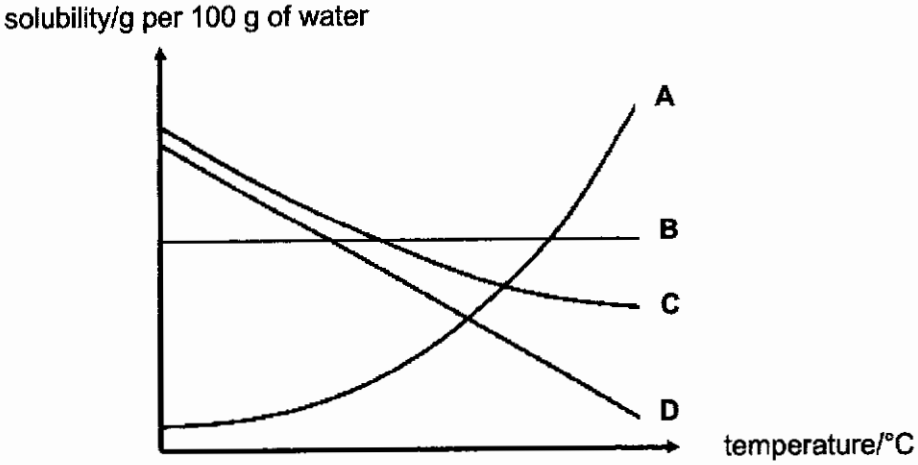


Which row describes the correct apparatus for the measurement made?

	measurement made
A	30.50 cm^3 of acid added to an alkali in a titration
B	1 cm^3 of acid added to calcium carbonate in a rate-determining experiment
C	40 cm^3 of gas evolved in a rate-determining experiment
D	12.0 cm^3 of alkali for use in a titration

4 The solubility curves of four different substances **A** to **D** in water are shown below.

The solubility of a substance refers to the mass of substance that can dissolve completely in 100 g of water at different temperature.



Which substance is the **most** suitable to be collected by crystallisation, from cooling its hot saturated aqueous solution?

5 When separating a mixture of sodium carbonate and magnesium oxide, why is it important to stir the mixture thoroughly in water before filtration?

A to ensure a good separation of the mixture

B to ensure that all the sodium carbonate dissolves

C to ensure that all the magnesium oxide dissolves

D to increase the rate of reaction between the two substances

6 When crude oil is fractionally distilled, which compounds leave from the bottom of the fractionating column?

A the compounds that are the most flammable

B the compounds that are the least viscous

C the compounds with the highest relative molecular mass

D the compounds with the lowest boiling points

7 A sample of a white crystalline solid is heated in the absence of oxygen. It melts sharply at 120 °C but on further heating, smoky fumes and a black solid were observed.

What can be concluded about the white crystalline solid?

A It is a compound that decomposed to form simpler substances.

B It is a mixture known as hydrated salt.

C It is a pure substance that undergoes combustion to form two products only.

D It is an element that decomposed to form simpler substances.

8 In March 2011, an earthquake in Japan caused the release of radioactive isotopes from the Fukushima Daiichi nuclear power plant.

One of these radioactive isotopes is $^{131}_{53}I$, which has been linked to an increased risk of thyroid cancer.

Which statement about $^{131}_{53}I$ is correct?

A This isotope has a nucleon number of 78.

B The number of electrons in one atom of this isotope is 53.

C The number of neutrons in one atom of this isotope is 131.

D $^{131}_{52}Te$ is an isotope of $^{131}_{53}I$.

9 Which statement about the F^-, Na^+ and Ne is correct?

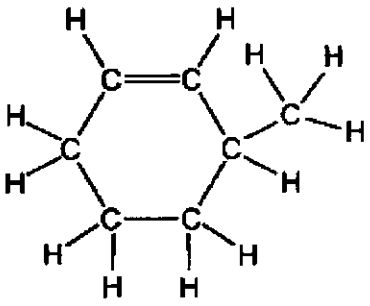
A They all contain the same number of protons.

B They all contain the same number of electrons.

C They all contain more electrons than protons.

D They all contain more neutrons than protons.

10 The diagram shows a molecule of a hydrocarbon.



What is the total number of electrons involved in bonding?

A 10 **B** 20 **C** 30 **D** 40

11 Which statement explains the electrical conductivity of copper?

A Free moving electrons and positive ions in copper can carry charge.

B Free moving electrons in copper can carry charge.

C Free moving electrons, positive and negative ions in copper can carry charge.

D Free moving positive ions in copper can carry charge.

12 Silicon carbide has a similar structure to diamond. Boron nitride has a similar structure to graphite. However, boron nitride does not contain any delocalised electrons. Bronze is an alloy of copper and tin.

Which statement is true?

A All three substances are covalently bonded.

B All three substances have high melting point.

C Bronze and silicon carbide conduct electricity.

D Silicon carbide can be used as a lubricant, while boron nitride can be used as a drill tip for cutting.

[Turn over

13 12 g of impure magnesium oxide was added to excess dilute nitric acid to form magnesium nitrate and water, as shown in the equation below.

$$MgO + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2O$$

Given that 23 g of magnesium nitrate was obtained in the experiment, what is the percentage purity of magnesium oxide?

A 47.8% **B** 51.8% **C** 52.2% **D** 58.0%

14 What is the number of ions in 319.5 g of aluminium nitrate, $Al(NO_3)_3$?
[Relative formula mass of $Al(NO_3)_3$ is 213]

A 6.0×10^{23} **B** 9.0×10^{23} **C** 1.8×10^{24} **D** 3.6×10^{24}

15 Which method(s) is/are suitable to distinguish 1.00 mol/dm^3 of aqueous hydrochloric acid from 1.00 mol/dm^3 of aqueous ethanoic acid?

I	using a pH meter
II	determining the volume of 1.00 mol/dm^3 of sodium hydroxide solution used to neutralise 25.0 cm^3 of the acids separately
III	measuring the total volume of hydrogen gas formed when excess magnesium is added to the same volume of acids separately

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

16 An alloy of copper and zinc is added to an excess of dilute hydrochloric acid.

The resulting mixture is then filtered.

Which row shows the correct observations?

	filtrate	residue
A	blue solution	grey
B	blue solution	none
C	colourless solution	none
D	colourless solution	pink

17 Which ions are present in aqueous chromium(III) nitrate?

A chromium(III) ions and nitrate ions only
B chromium(III) ions, nitrate ions and hydrogen ions
C chromium(III) ions, nitrate ions and hydroxide ions
D chromium(III) ions, nitrate ions, hydrogen ions and hydroxide ions

18 Which pair of compounds could be used in the preparation of lead(II) sulfate?

A lead(II) carbonate and sodium sulfate
B lead(II) chloride and ammonium sulfate
C lead(II) chloride and barium sulfate
D lead(II) nitrate and sodium sulfate

19 Which mixture of gases would **not** change the colour of a damp blue litmus paper when they are tested separately?

A carbon dioxide and ammonia
B chlorine and nitrogen
C hydrogen and ammonia
D nitrogen and hydrogen chloride

20 An aqueous solution of a compound, T, undergoes the following the reactions.

reaction	result
add aqueous sodium hydroxide	green precipitate
add acidified aqueous silver nitrate	yellow precipitate

What is T?

A iron(II) bromide
B iron(III) chloride
C iron(II) iodide
D iron(III) nitrate

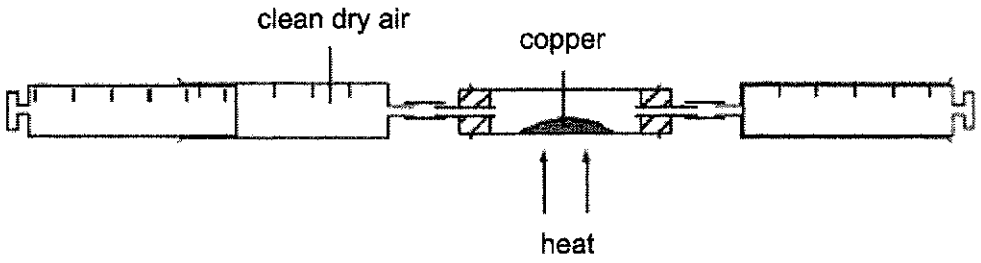
21 Which pair of gases are involved in the formation of acid rain?

A CO and CO_2
B CH_4 and NO_2
C NO and CO_2
D SO_2 and NO_2

22 Which pairs of substances are used to remove sulfur dioxide from flue gases?

A $CaCO_3$ and CaSO
B $CaCO_3$ and CaO
C $CaSO_3$ and CaO
D $CaSO_3$ and $CaSO_4$

23 A sample of clean, dry air is passed over hot copper until all the oxygen in the air reacts with the copper.



The volume of air decreases by 84 cm^3.

What is the initial volume of the sample of air?

A 60 cm^3 **B** 100 cm^3 **C** 150 cm^3 **D** 400 cm^3

24 When potassium manganate(VII) is added slowly to a sample of iron(II) sulfate solution, it turns from purple to colourless. The iron(II) sulfate solution turns from green to light brown.

Which of the following can be concluded from the observation?

	role of potassium manganate(VII)	reaction that iron(II) sulfate has undergone
A	oxidising agent	oxidation
B	oxidising agent	reduction
C	reducing agent	oxidation
D	reducing agent	reduction

25 Which statement describes the changes in the elements from left to right across a period in the Periodic Table?

A The ability to conduct electricity decreases.
B The elements change from non-metals to metals.
C The number of electrons in an atom decreases.
D The number of neutrons in an atom decreases.

[Turn over

26 Four different metals, zinc, silver, magnesium and copper powders were added separately in excess to yellow iron(III) sulfate solution in four beakers.

How many beaker(s) of solution will remain yellow after a few days?

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

27 A newly discovered alkali metal, Q, has an atomic number greater than 37.

Which property is typical of Q?

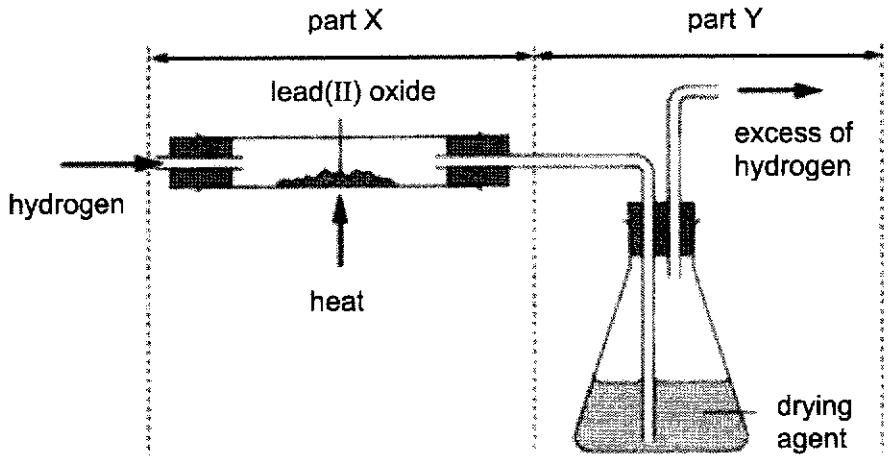
A Q floats on water.

B Q has a higher melting point than sodium.

C Q reacts with water more vigorously than potassium with water.

D Q reacts with chlorine gas to form a yellow crystalline solid.

28 Lead(II) oxide is reduced in the experimental set-up below.



How do the masses of part X and Y of the apparatus change at the end of the reaction?

	part X	part Y
A	increase	increase
B	increase	decrease
C	decrease	increase
D	decrease	decrease

[Turn over

29 One mole of solid carbonates of copper, calcium, lead and magnesium undergo thermal decomposition respectively.

Which metal carbonate will release the greatest volume of carbon dioxide after one minute at room condition?

A calcium carbonate

B copper(II) carbonate

C lead(II) carbonate

D magnesium carbonate

30 Which statement about the extraction of iron in a blast furnace is correct?

A Haematite, containing mainly iron(II) oxide, is reduced.

B Limestone is used as a catalyst.

C Slag is formed due to a reaction between an acidic oxide and a basic oxide.

D The main impurity in the iron formed is slag.

31 Which product is formed at the anode when molten aluminum oxide is electrolysed?

A aluminium ions

B aluminum atom

C oxide ions

D oxygen gas

32 A student sets up three chemical cells, each containing two of the metals, X, Y and Z, immersed in an electrolyte.

The table below shows the voltage and the positive terminal of each chemical cell.

chemical cell	metals used	voltage/V	positive terminal
1	Z and Y	+1.60	Y
2	X and Y	+1.10	X
3	X and Z	+2.70	X

What is the correct order of reactivity for these three metals?

	most reactive ⟶		least reactive
A	Y	X	Z
B	Z	Y	X
C	Y	Z	X
D	X	Z	Y

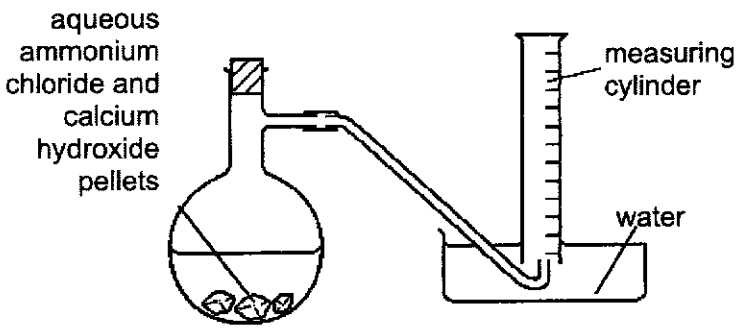
[Turn over

33 A student wants to carry out an experiment to investigate the speed of the reaction between aqueous ammonium chloride and calcium hydroxide pellets.

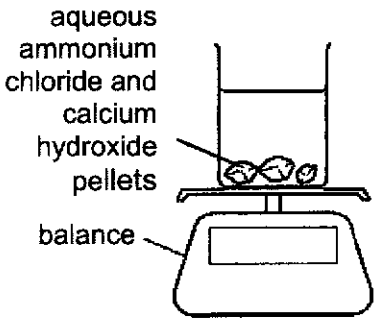
$$Ca(OH)_2 + 2NH_4Cl \rightarrow CaCl_2 + 2NH_3 + 2H_2O$$

Which diagram shows apparatus that is suitable for this experiment?

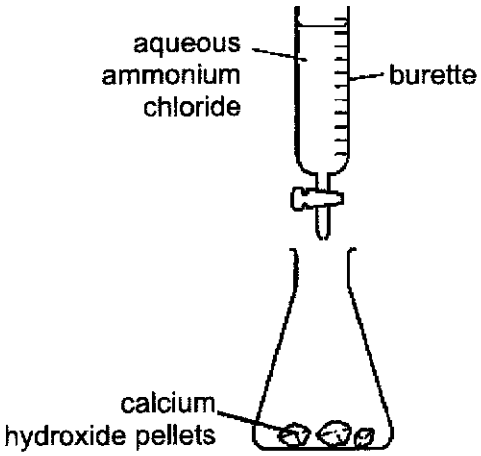
I



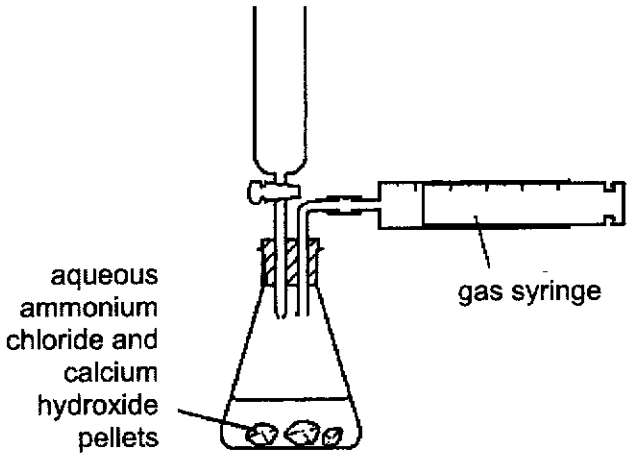
II



III



IV



A I and IV

B II and IV

C I, II and IV

D I, II, III and IV

34 Ammonia is produced by the Haber process.

Which statement is **not** correct?

A A catalyst of iron is used.

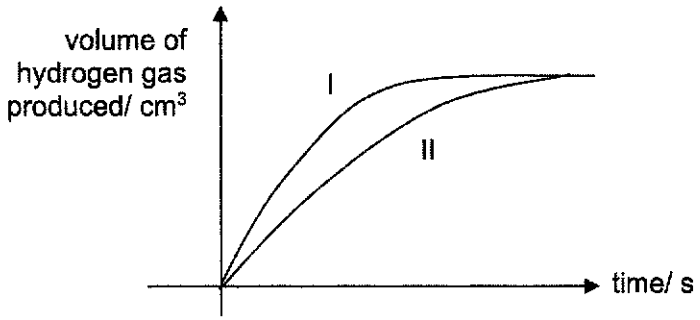
B Each hydrogen molecule reacts with three nitrogen molecules to form two molecules of ammonia.

C Hydrogen for the process can be obtained by cracking of large hydrocarbons.

D The reaction is reversible.

[Turn over

35 In the graph, curve I was obtained when 1 g of granulated zinc was reacted with an excess of 1 mol/dm^3 hydrochloric acid at 50 °C.



Which change would produce curve II?

A lower the concentration of hydrochloric acid to 0.5 mol/dm^3

B increase the temperature

C reduce the pressure of the reacting mixture

D use 1 g of zinc powder

36 Which property shows an increase in the alkane series from butane → propane → ethane → methane?

A boiling point

B flammability

C melting point

D viscosity

37 One mole of a hydrocarbon Q reacted completely with 1 mole of hydrogen gas in the presence of a heated catalyst.

What could be the formula of Q?

A C_2H_6

B C_3H_8

C C_5H_{10}

D C_7H_{16}

38 Ethanol can be manufactured from ethene or from glucose. The table gives statements about the processes involved.

In which row are **both** statements **incorrect**?

	process using ethene	process using glucose
A	conversion to ethanol needs temperature greater than 100 °C	conversion to ethanol also produces carbon dioxide
B	conversion to ethanol uses yeast as catalyst	conversion to ethanol is carried out at 100 °C
C	ethene is obtained by cracking	glucose is obtained from fruits
D	the conversion reaction is carried out with the reagent as gases	the conversion reaction is carried out in aqueous solution

39 Dimethylamine dissolves in water to give an alkaline solution.

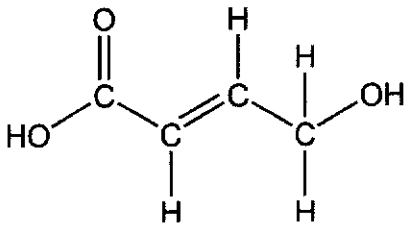
A few drops of Universal Indicator are added to an aqueous solution of dimethylamine.

Which row shows the pH of the solution and the colour of the solution after the indicator has been added?

	pH	colour of solution
A	greater than 7	blue
B	greater than 7	orange
C	less than 7	blue
D	less than 7	orange

40 4-hydroxy-but-2-enoic acid is a drug used in scientific research.

The structure of 4-hydroxy-but-2-enoic acid ($C_4H_6O_3$) is shown below.



Which statement is **not** likely to be true for 4-hydroxy-but-2-enoic acid?

A It can undergo addition polymersation.

B It reacts with potassium manganate(VII) .

C It reacts with calcium carbonate to produce carbon dioxide gas.

D It can polymerise to produce a polyamide without the addition of other reagent.

END OF PAPER

[Turn over

Section A

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

1 **(a)** Use the list of substances to answer the questions.

aluminium chloride

ammonium chloride

copper(II) chloride

hydrogen chloride

iron(III) chloride

magnesium chloride

silver chloride

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

(i) Which **two** substances contain a cation with a 3+ charge?

..... [1]

(ii) Which substance is insoluble in water?

..... [1]

(iii) Which substance turns Universal Indicator red when dissolved in water?

..... [1]

(iv) Which substance is a coloured solid at room temperature and pressure?

..... [1]

(v) Which substance contains three different elements chemically combined together?

..... [1]

[Turn over

(b) Describe how you would carry out a chemical test to differentiate aluminium chloride from zinc chloride. Include your expected observations.

.....

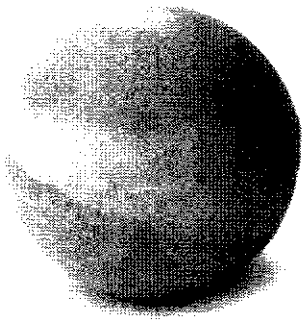
.....

..... [3]

[Total: 8]

2 **(a)** Bath bombs are a mixture of dry ingredients that are packed tightly into various shapes and sizes. They can be used in bathtubs and are commonly infused with a blend of essential oils.

The label shows some common ingredients found in many different bath bombs.



ingredients: sodium hydrogencarbonate, citric acid, titanium dioxide, tin oxide, benzyl alcohol

Suggest why bath bomb will produce effervescence when dropped into water.

.....

.....

..... [2]

(b) Describe how you can identify the gas liberated.

test: .....

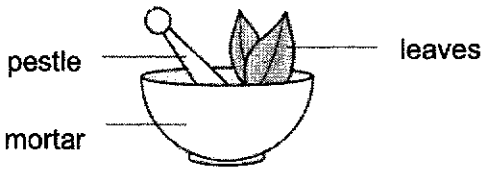
observation: ..... [1]

[Total: 3]

[Turn over

3 **(a)** Leaves of plants contain a number of different coloured pigments.

Three students want to extract and analyse some of these coloured pigments. The leaves are chopped up and grinded using a mortar and pestle and then mixed with ethanol.



The pigments are separated using paper chromatography.

(i) Fig. 3.1 shows the students' experimental set-ups. Two students made mistakes in their experimental set-ups.

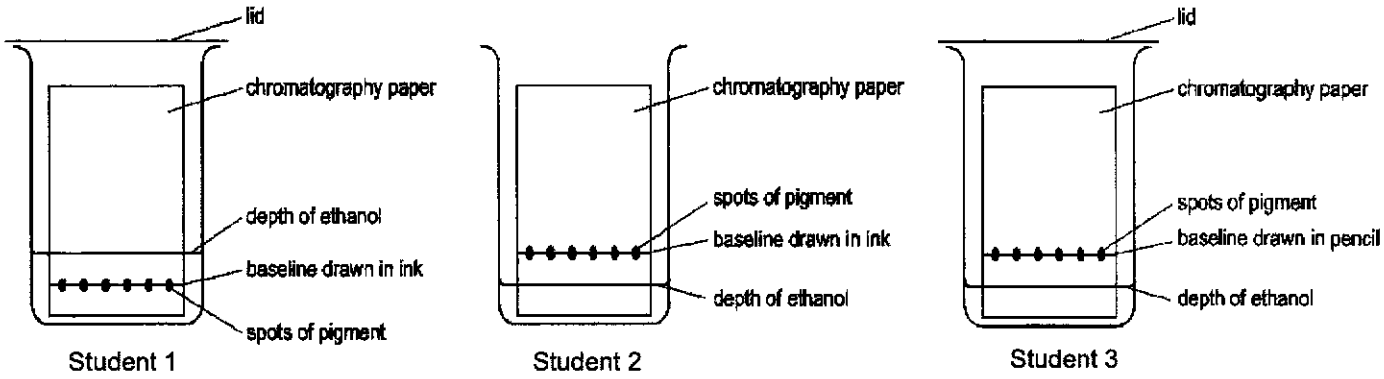


Fig. 3.1

State **two** mistakes made by **different students** shown in Fig. 3.1.
Include in your answer the student who made the respective mistake.

mistake 1: .....

.....

mistake 2: .....

..... [2]

(b) Three different coloured pigments were observed on the chromatogram and analysed after being separated using paper chromatography.

Complete Table 3.2 to show the distance travelled by the other two pigments.

Table 3.2

coloured pigments	R_f value	distance travelled (cm)
light blue	0.2	
dark pink	0.4	1.00
dark blue	0.6	

[1]

[Total: 3]

[Turn over

4 **(a)** The reaction of zinc with nickel(II) nitrate solution is a redox reaction.

The equation for the reaction is shown.

$$Zn(s) + Ni(NO_3)_2(aq) \rightarrow Zn(NO_3)_2(aq) + Ni(s)$$

(i) Use oxidation state to explain why this is a redox reaction.

.....

.....

.....

..... [2]

(ii) Write an ionic equation, with state symbols, for this reaction.

..... [1]

(b) **(i)** Draw a labelled diagram to show how a rectangular block made of nickel is electroplated with silver. Your diagram should include labels and identity the anode, cathode and electrolyte.

[2]

(ii) Write the half equations for the reaction that happens at each electrode. Include state symbols.

anode: .....

cathode: ..... [2]

[Total: 7]

[Turn over

5 Down the Group, the hydroxides of Group II vary in their solubilities in water as shown in Table 5.1.

Table 5.1

Group II hydroxide	solubility in mol/dm^3
$Mg(OH)_2$	0.000160
$Ca(OH)_2$	0.0250
$Ba(OH)_2$	0.410

(a) A student made the following statement:

The pH of aqueous solutions of Group II hydroxides increases down the Group.

Explain using the information in Table 5.1, why the statement is true.

.....

..... [1]

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

..... [1]

(c) Fig. 5.2 shows a list of period 3 oxides.

Na_2O MgO Al_2O_3 SiO_2 P_2O_5 SO_2 Cl_2O

Fig. 5.2

(i) Identify the oxides in Fig. 5.2 that can react with $Ba(OH)_2$.
Explain your answer.

.....

..... [2]

(ii) Explain, in terms of structure and bonding, why MgO exists as a solid at room temperature and pressure.

.....

.....

.....

..... [2]

[Turn over

(iii) Draw a 'dot-and-cross' diagram to show the bonding in MgO.
Show outer electrons only.

[2]

(iv) Explain why SiO_2 has a higher melting point than SO_2.

.....

.....

.....

..... [2]

(v) An oxide of phosphorus contains 43.7% by mass of phosphorous.

Show that the empirical formula for this oxide is P_2O_5.
[*Ar*: O, 16; P, 31]

[2]

(d) Chlorine exists as two isotopes, chlorine-35 and chlorine-37.

In a sample of 100 chlorine atoms, there are 76 atoms of chlorine-35 and 24 atoms of chlorine-37.

Find the relative atomic mass of this chlorine sample.

[2]

[Total: 14]

[Turn over

6 Fractional distillation and cracking are important processes in the conversion of petroleum into useful substances.

Fractional distillation separates petroleum into fractions such as paraffin and naphtha.

(a) State one use for the paraffin fraction.

..... [1]

(b) The naphtha fraction is used as chemical feedstock.

One of the hydrocarbons in naphtha is a straight chain alkane with the molecular formula of $C_{10}H_{22}$.
When one molecule of $C_{10}H_{22}$ is cracked, three possible products are propane, butene and unsaturated compound, **Y**.

(i) Identify **Y**.

..... [1]

(ii) Butene is an alkene.

Draw the full structural formulae of **two** isomers of butene.

[2]

(iii) A student has a sample of propane and a sample of butene.

State a reagent and describe the observations which could be used to distinguish between the samples.

reagent	observation for propane	observation for butene

[2]

[Turn over

(c) Octane, C_8H_{18}, is a main component present in motorcar fuel. When burnt in excess oxygen, carbon dioxide and water are produced.

The enthalpy change for the burning of octane is –5500 kJ/ mol.

(i) Write an equation for the complete combustion of octane, C_8H_{18}.

..... [1]

(ii) Explain in terms of bond making and bond breaking, why the enthalpy change for the burning of 1 mole of octane, has a negative sign.

.....

.....

..... [2]

[Total: 9]

[Turn over

7 Esters are organic compounds that have a sweet, fruity aroma and are widely used in food industry and perfumery,

Table 7.1 shows the name, structural formula, relative molecular mass and boiling point of four esters.

Table 7.1

name	structural formula	relative molecular mass	boiling point/°C
methyl ethanoate	CH_3COOCH_3	74	57
ethyl ethanoate	$CH_3COOCH_2CH_3$	88	77
propyl ethanoate	$CH_3COOCH_2CH_2CH_3$	102	102
butyl ethanoate	$CH_3COOCH_2CH_2CH_2CH_3$	116	126

(a) Use the information in Table 7.1 to give **two** pieces of evidence that suggest that the esters are in a homologous series.

.....

.....

..... [2]

(b) Which ester has the **greatest** rate of diffusion at room temperature and pressure? Use the information in Table 7.1 to explain your reasoning.

.....

..... [2]

(c) Complete the table to show the full structural formulae and the names of the carboxylic acid and alcohol used to make propyl ethanoate.

carboxylic acid	alcohol
name:	name: .....

[2]

[Total: 6]

[Turn over

Section B

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

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

8 Properties of Hydrogen Halides

The hydrogen halides make up one of the most important classes of inorganic compounds containing Group VII elements. High purity hydrogen halides are formed when hydrogen and halogens are chemically combined.

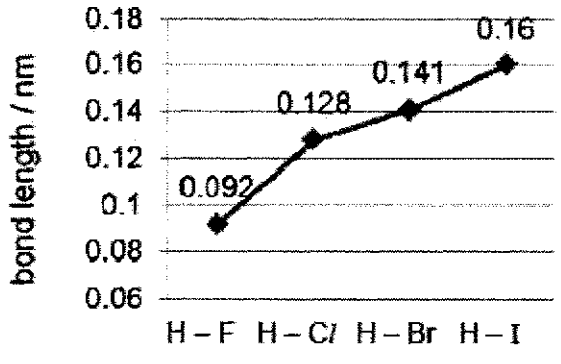
Table 8.1 shows the observations when hydrogen combined directly with different halogens.

Table 8.1

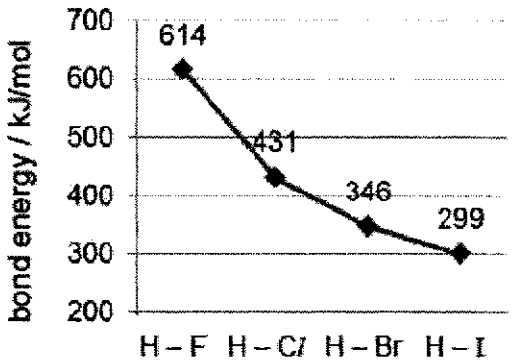
reaction	observation
$H_2 + F_2 \rightarrow 2HF$	Reacts explosively even in the dark at -200°C
$H_2 + Cl_2 \rightarrow 2HCl$	Reacts explosively in sunlight but takes place slowly in the dark
$H_2 + Br_2 \rightarrow 2HBr$	
$H_2 + I_2 \rightleftharpoons 2HI$	Reacts very slowly in sunlight even on heating with platinum

Graphs 1 and 2 show how bond length and bond energy vary for the different hydrogen halides.

Bond length refers to the average distance between the nuclei of two bonded atoms in a molecule. Bond energy is a measure of the bond strength in a chemical bond. It is the energy required to break one mole of molecules into their individual atoms.



Graph 1



Graph 2

[Turn over

Strength of Acids

The acid dissociation constant, K_a, is a quantitative measure of the strength of an acid in solution. The larger the K_a value, the more dissociation of the acid molecules in solution and thus the stronger the acid.

Hydrogen halides are extremely soluble in water, forming acidic solutions with its respective K_a, as shown in Table 8.2.

Table 8.2

	acidic solution	chemical formula	acid dissociation constant, K_a
hydrogen halides	hydrofluoric acid	HF	6.8×10^{-4}
	hydrochloric acid	HC*l*	1.0×10^{6}
	hydrobromic acid	HBr	1.0×10^{9}
	hydroiodic acid	HI	3.0×10^{9}

(a) **(i)** With reference to Table 8.1, predict the observation for the reaction of bromine with hydrogen gas.

.....

..... [1]

(ii) Suggest the function of platinum in the reaction of iodine with hydrogen gas.

..... [1]

(b) Describe the relationship between the bond length and bond energy of the hydrogen halides.

.....

..... [2]

[Turn over

(c) **(i)** With reference to Table 8.2, determine the strongest acid. Explain your reasoning.

.....

.....

.....

..... [2]

(ii) Describe and explain the relationship between the bond energy of the hydrogen halides in Graph 2 and the strength of acid in Table 8.2.

.....

.....

.....

..... [2]

(d) **(i)** With reference to Graph 2, determine the bond energy of H-Br.

..... [1]

(ii) The equation for the formation of HBr is as shown.

$$H_2 + Br_2 \rightarrow 2HBr$$

Given that the bond energy of the Br – Br bond is 193 kJ/mol and the bond energy of the H – H bond is 432 kJ/mol, calculate the enthalpy change of this reaction.

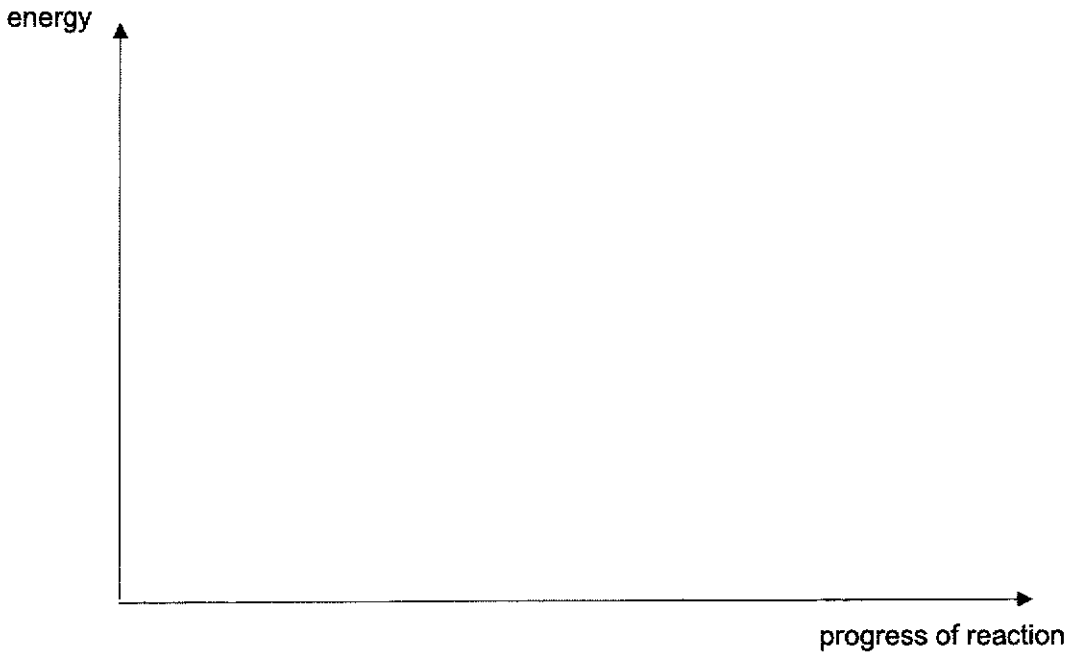
[2]

[Turn over

(iii) Draw an energy profile diagram for the formation of HBr.

Your diagram should include:

- the **formulae of the reactants and products**,
- labels to show the **enthalpy change of reaction** and **activation energy.**



[2]

[Total: 13]

[Turn over

9 Table 9.1 shows some information about Earth and some other planets.

The predicted surface temperature of each planet takes into account a number of factors including its distance from the Sun. The prediction does not take into account the absorption of heat energy by the atmosphere.

Table 9.1

	Earth	Venus	Mercury
distance from Sun/millions of km	150	108	58
predicted surface temperature/°C	-18	-41	163
actual surface temperature/°C	15	462	167
composition of atmosphere	78% N_2 21% O_2 0.04% CO_2	97% CO_2 (plus other gases)	none

(a) Use the information in Table 9.1, explain the difference between the actual surface temperature and predicted surface temperature of each planet.

.....

.....

.....

..... [2]

(b) In Table 9.1, the term 'other gases' includes sulfur dioxide (SO_2).

(i) Suggest a possible source for the sulfur dioxide in the atmosphere of Venus.

..... [1]

(ii) Rainwater never reaches the surface of Venus.

Use the information in Table 9.1 to suggest why.

.....

..... [1]

[Turn over

(c) Scientists think that the early atmosphere on Earth was similar to the atmosphere on Venus today.

After plant life appeared, the atmosphere on Earth changed.

(i) Explain why plant life changed the percentages of oxygen and carbon dioxide on Earth.

.....

.....

.....

..... [2]

(ii) Explain, in terms of processes involved, why the percentage of carbon dioxide on Earth is now increasing rapidly.

.....

..... [1]

[Total: 7]

[Turn over

EITHER

10 Carbon dioxide and hydrogen gas can be converted to methanol industrially. The following equations show the two main reactions that occur in the reactor.

Reaction 1: $CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O$

Reaction 2: $CO_2 + H_2 \rightleftharpoons CO + H_2O$

Fig. 10.1 shows the simplified diagram for the production of methanol.

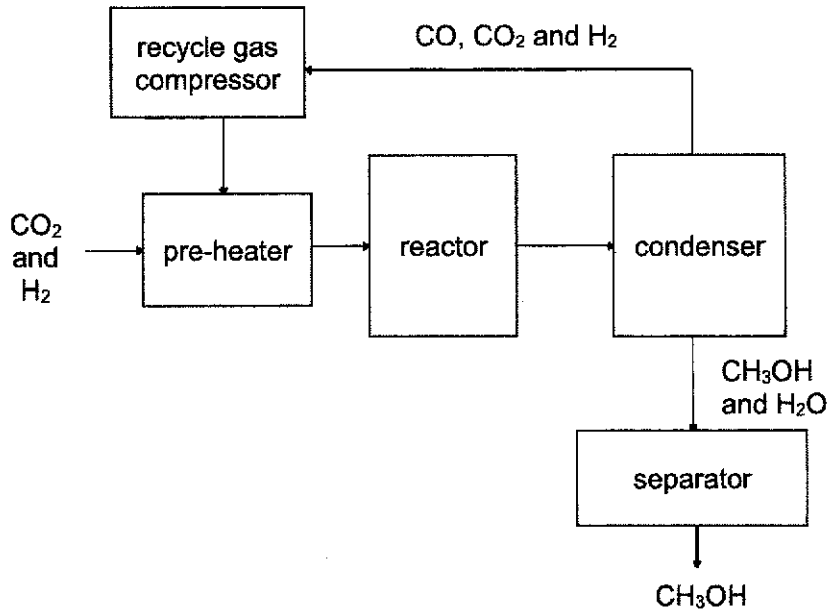


Fig. 10.1

(a) Explain why it is **not** possible to obtain 100% yield of methanol for this reaction.

.....

[1]

(b) Name the separation technique that is used to separate methanol from water.

.....

[1]

(c) A mixture of palladium and copper acts as the catalyst in the reactor.

Explain why the cost of palladium would **not** contribute significantly to the monthly production cost of methanol.

.....

.....

[1]

[Turn over

(d) Explain, in terms of collisions between (reacting) particles, how each of the following increases the **rate of reaction** in the production of methanol.

(i) pre-heating the gases

.....

.....

.....

..... [2]

(ii) compressing the gases

.....

.....

.....

..... [2]

(e) Ethanol, C_2H_5OH, is in the same homologous series as methanol.
It can be made on an industrial scale by reacting ethene, C_2H_4, with steam in a reactor.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH\ (g)$$

A volume of 1000 dm^3 of ethene is measured at room temperature and pressure.
The ethene is mixed with steam and enters the reactor.
The yield of ethanol form the reaction is 10%.
Calculate the **mass** of ethanol formed at room temperature and pressure.
(One mole of gas occupies 24 dm^3 at room temperature and pressure.)

[3]

[Total: 10]

[Turn over

OR

10 An experiment was carried out to investigate the reaction between a solution of metal nitrate, $\mathbf{X}(NO_3)_2$ and aqueous potassium iodide.

Using a measuring cylinder, 40 cm^3 of aqueous potassium iodide was poured into five different conical flasks. The solution of metal nitrate was then added to each conical flask using another measuring cylinder. The precipitate formed, $\mathbf{X}I_2$, was filtered, dried and weighed.

The results are recorded in Table 10.2.

Table 10.2

volume of 0.100 mol/dm^3 KI/cm^3	40	40	40	40	40
volume of 0.100 mol/dm^3 $\mathbf{X}(NO_3)_2$ added/cm^3	10	15	20	25	30
mass of $\mathbf{X}I_2$ formed/g	0.461	0.692	0.922	0.922	0.922

(a) Write an ionic equation, with state symbols, for this reaction.

..... [1]

(b) Calculate the number of moles in 40 cm^3 of KI solution.

[1]

(c) **(i)** Given that the number of moles of 0.922 g of $\mathbf{X}I_2$ is 0.002 mol., calculate the relative atomic mass of **X**.

[2]

(ii) Hence, identify metal **X**.

..... [1]

[Turn over

(d) Predict the mass of $\mathbf{X}I_2$ formed if 35 cm^3 of $\mathbf{X}(NO_3)_2$ is added to 40 cm^3 of KI.
Explain your answer.

.....

..... [2]

(e) Suggest **one** improvement that could be made to the experiment to obtain a more accurate result.

..... [1]

(f) Describe **two** observations in the reaction between metal **X** and aqueous copper(II) sulfate.

.....

..... [2]

[Total: 10]

END OF PAPER

Marking Scheme for 4E Prelim 2021

P1 [40 marks]

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

[Turn over

P2 – to minus 1m from overall for any missing units

Section A [50 marks]

1 **(ai)** aluminium chloride and iron(III) chloride **[1]**

(aii) silver chloride [1]

(aiii) hydrogen chloride **[1]**

(aiv) copper(II) chloride / iron(III) chloride **[1]**
if students write both correct answers – to still award [1]

(av) ammonium chloride [1]

(b) test: add excess aqueous ammonia until no further change [1]
reject – add ammonia / add aqueous ammonia / add aqueous sodium hydroxide

observation for aluminium chloride:
white ppt. observed, insoluble in excess **[1]**

observation for zinc chloride:
white ppt. observed, soluble in excess giving a colourless solution **[1]**
reject – white ppt. observed, soluble in excess

2 **(a)** Citric acid dissolves / ionises / dissociates in water to produce H^+ ions **[1]** and react with sodium hydrogencarbonate to produce carbon dioxide/ a gas. **[1]**

(b) test: bubble the gas into limewater
observation: odourless and colourless gas forms white ppt. in limewater
[1] for both test & observation

to only award ecf [1] if correct test & observation of stated gas given, based on students' answer in (a)

3 **(a)** mistake: In student 1's set-up, the baseline is in / under the ethanol. **[1]**
mistake: in student 2's set-up, the baseline is drawn in ink. / there is no lid. **[1]**

(b)

coloured pigements	R_f value	distance travelled (cm)
light blue	0.2	0.50 / 0.5
dark pink	0.4	1.00
dark blue	0.6	1.50 / 1.5

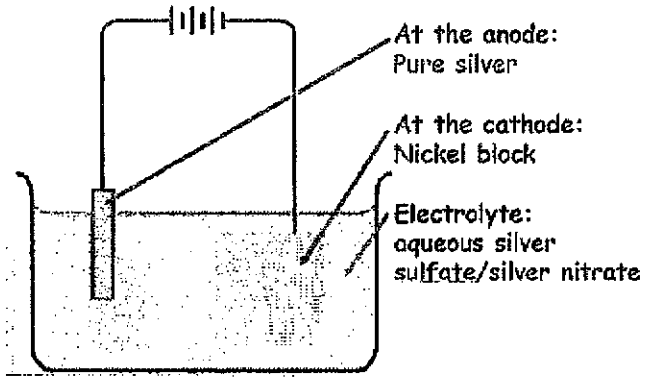
[1]

[Turn over

4 **(ai)** Zn is oxidised as the oxidation state of Zn increases from 0 to +2 in $Zn(NO_3)_2$. [1]
$Ni(NO_3)_2$ is reduced as the oxidation state of Ni decreases from +2 in $Ni(NO_3)_2$ to 0 in Ni. [1]
reject – correct explanation without stating the substance oxidised & reduced

(aii) $Zn(s) + Ni^{2+}(aq) \rightarrow Zn^{2+}(aq) + Ni(s)$ [1]
reject – without state symbols

(bi) Electroplating a nickel rectangular block with silver



[1] - diagram
[1] – labelling of anode as pure silver, cathode as nickel block and electrolyte as aqueous silver salt

(bii) anode: $Ag(s) \rightarrow Ag^+(aq) + e^-$ **[1]**
cathode: $Ag^+(aq) + e^- \rightarrow Ag(s)$ **[1]**
reject – without state symbols

5 **(a)** As solubility of Group II hydroxides increases down the Group, (from 0.000160 mol/dm^3 for $Mg(OH)_2$ to 0.410 mol/dm^3 for $Ba(OH)_2$), the concentration of OH^- increases / more OH^- present,. **[1]**

(b) Accept any value between 0.0250 to 0.410 mol/dm^3 **[1]**

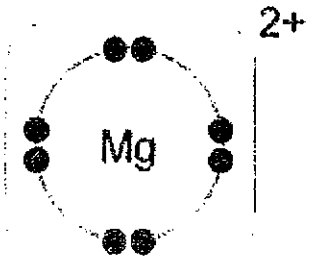
(ci) Al_2O_3, SiO_2, P_2O_5, SO_2 and Cl_2O [1]

Al_2O_3 is an amphoteric oxide, SiO_2, P_2O_5, SO_2 and Cl_2O are acidic oxides will react with $Ba(OH)_2$, which is basic in nature. **[1]**

(cii) It is a solid at r.t.p. since it has a high melting point. **[1]**

A lot of energy is required to overcome the strong electrostatic forces of attraction between the oppositely charged ions (Mg^{2+} and O^{2-}) in its giant ionic lattice structure. [1]

(ciii)



[1] [1]

[Turn over

(civ) SiO_2 - More heat energy is required to break the extensive, strong covalent bonds between (the Si and O) atoms in its giant three-dimensional molecular structure. [1]

SO_2 – Lesser heat energy is required to overcome the weak Van der Waals forces / intermolecular forces of attraction between the SO_2 molecules in its simple molecular structure. [1]

Hence SiO_2 has a higher melting point than SO_2.

(cv)

element	P	O	
% by mass	43.7	56.3	
A_r	31	16	
no of mol	43.7 ÷ 31 = 1.4096	56.3 ÷ 16 = 3.5187	[1]
divide by the smallest no of mol	1.4096 ÷ 1.4096 = 1	3.5187 ÷ 1.4096 = 2.496	
mol ratio	2	5	[1]

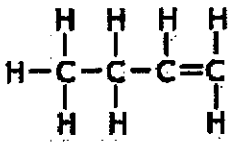
Hence the empirical formula of this oxide is P_2O_5.

(d) relative atomic mass = [76(35) + 24(37)] / 100 **[1]**
= 35.5 (to 3 s.f.) **[1]**
reject – if final ans is not evaluated to 3 s.f.

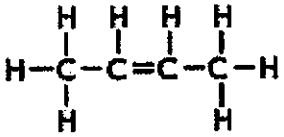
6 (a) Fuel for aircraft /jet engine / used in candles / wax paper / polishes / cosmetics / electrical insulators [1]

(bi) Propene/C_3H_6 [1]

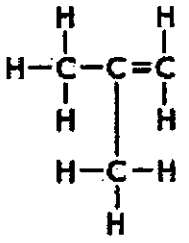
(bii)



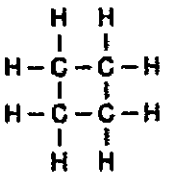
1-butene



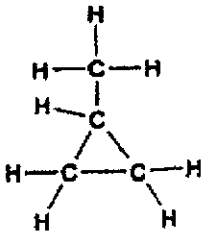
2-butene



2-methypropene



cyclobutane



methycyclopropane

[1] each for any 2 isomers – no need to name the isomers

[Turn over

(biii)

reagent	observation for propane	observation for butene
add aqueous bromine/bromine solution [1]	aqueous bromine/bromine solution remains reddish-brown	aqueous bromine/bromine solution decolourises/change from reddish-brown to colourless

[1] – correct reagent
[1] – correct observation for both propane and butane

(ci) $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ **[1]**

(cii) Energy absorbed to break the bonds in C_8H_{18} (or C-H, C-C bonds) and O_2 (or O=O bonds) + energy released when form bonds in CO_2 (or C=O bonds) and H_2O (or O-H bonds). **[1]**

Energy absorbed is less than energy released/energy released is more than energy absorbed. **[1]**

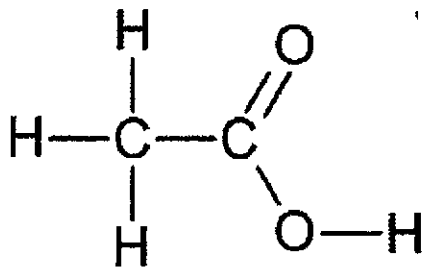
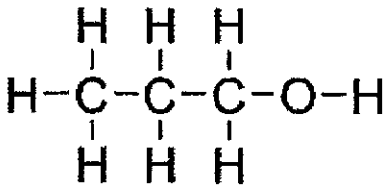
7 (a) 1. same functional group –COO–
2. successive members differs by $–CH_2–$
3. same general formula, $CH_3COOC_nH_{2n+1}$
4. boiling point increases with the (relative) molecular mass of compound

[1] each for any 2 evidences

(b) methyl ethanoate **[1] reject – wrong spelling**

It has the smallest (relative) molecular mass of 74 hence greatest rate of diffusion. **[1]**

(c)

carboxylic acid	**alcohol**
	
name: ethanoic acid **[1] for structure and name**	name: propanol **[1] for structure and name**

Section B [30 marks]

8 **(ai)** Reacts slowly in sunlight and does not react in the dark. **[1]**

(aii) Platinum is added as a catalyst / to speed up the reaction. **[1]**

(b) As the bond length of the hydrogen halide increases, the bond energy decreases. /
As the bond length of the hydrogen halide decreases, the bond energy increases **[2]**
reject – if cause and effect is reversed

(ci) The strongest acid is hydroiodic acid. **[1]**

It has the highest K_a value of 3.0×10^9, hence dissociates the most among the acids listed. **[1]**

(cii) As the bond energy increases, the strength of the acid decreases. **[1]**

This is because more energy is required to break the bonds between the atoms. Hence, it is more difficult to dissociate in water, and hence, strength of acid would decrease. **[1]**

(di) 346 kJ/mol **[1]**

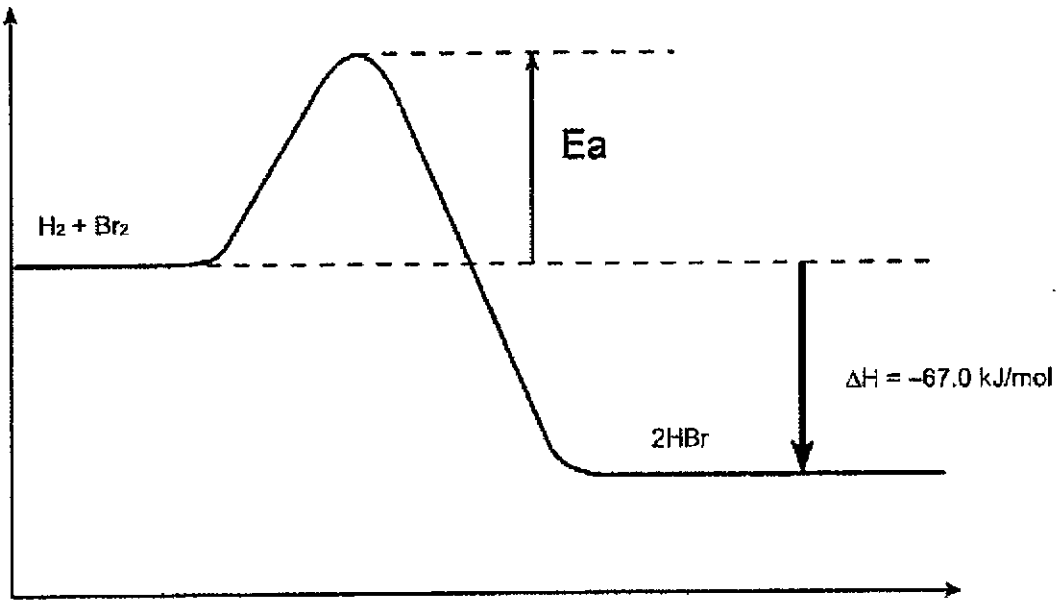
(dii) $H_2 + Br_2 \rightarrow 2HBr$

$\Delta H_{\text{bond breaking}} = 432 + 193$
$= +625$ kJ/mol
$\Delta H_{\text{bond formation}} = 2(-346)$
$= -692$ kJ/mol

[1] for either calculating $\Delta H_{\text{bond breaking}}$ or $\Delta H_{\text{bond formation}}$

$\Delta H_{\text{overall}} = +625 + (-692)$
$= -67.0$ kJ/mol **[1]**

(diii)



correct formula of reactants and products **[1]**

correct label for activation energy – double arrow is accepted too and correct label for enthalpy change **[1]** – **to award ecf if (dii) is an endothermic reaction**

[Turn over

9 (a) The actual surface temperature is closest to the predicted temperature for Mercury since it does not have an atmosphere of gases.

The actual surface temperature of Venus is about 500 °C higher than its predicted temperature, since 97% of its atmosphere is CO_2, a greenhouse gas that traps heat.

The actual surface temperature of Earth is about 33 °C higher than its predicted temperature, since 0.04% of its atmosphere is CO_2, a greenhouse gas that traps heat.

[1] – for correct reason supported with info from the table for any planet.
[2] – for correct reason supported with info from the table for all 3 planets.

(bi) Volcanoes **[1]**

reject – burning of fossil fuels

(bii) At 462 °C, water would have evaporated / boiled to form water vapour / steam since water has a boiling point of 100 °C. **[1]**

(ci) In the presence of sunlight, plants take in carbon dioxide gas and give out oxygen gas to undergo photosynthesis. **[1]**

This thus decreases the percentage of carbon dioxide gas and increases the percentage of oxygen gas on Earth. **[1]**

(cii) Deforestation decreases the number of plants taking in carbon dioxide in the presence of sunlight during photosynthesis, hence increasing the percentage of carbon dioxide gas. / Burning of fossil fuels increases the percentage of carbon dioxide gas. **[1]**

10 E **(a)** As it is a reversible reaction, some reactants will remain. / In reaction 2, some carbon dioxide may be used to react with hydrogen to form carbon monoxide instead. **[1]**

(b) Simple/Fractional distillation **[1]**
reject – wrong spelling

(c) The palladium catalyst will not be used up and hence it does not need to be replaced monthly. **[1]**

(di) When temperature increases, particles gain KE and move faster. **[1]**
Collision between particles becomes more frequent, hence increasing the frequency of effective collisions. **[1]** Speed of reaction thus increases.

(dii) Compressing the gases increases the pressure.
When pressure increases, particles are closer together. **[1]**
Collision between particles becomes more frequent, hence increasing the frequency of effective collisions. **[1]** Speed of reaction thus increases.

[Turn over

(e) no of mol of ethene = 1000 ÷ 24 **[1]**
= 41.667 mol

comparing mol ratio

ethane	:	ethanol
1	:	1
41.667mol	:	41.667mol

actual no of mol of ethanol formed since yield is 10% = 10% x 41.667mol **[1]**
= 4.1667 mol

mass of ethanol formed = 4.1667 x [2(12)+6(1)+16]
= 192 g (to 3 s.f.) **[1]**

10 (a) $X^{2+}(aq) + 2I^-(aq) \rightarrow XI_2(s)$ **[1] – correct ionic equation with state symbols included**

(b) no of mol of KI = 40/1000 x 0.100
= 0.00400 mol **[1] – with working shown clearly**

(ci) Mr of XI_2 = 0.922 / 0.002 **[1]**
= 461
Ar of X = 461 – 2(127)
= 207 **[1]**

(cii) X is lead/Pb **[1]**

(d) 0.922 g **[1]**

Since 35 cm^3 of $X(NO_3)_2$ is added to the same volume of KI in this reaction, KI is the limiting reagent/limiting reactant, **[1]** hence the mass of the precipitate formed remains constant at 0.922 g.

(e) Use a burette to measure out the volume of the solutions **[1]**

(f) Blue solution turns colourless/decolourises **[1]**
Pink/reddish-brown solid/deposit observed **[1]**

[Turn over