2027.M33S1

2027L022G1ES1

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination
Sample 1

Chemistry

Ordinary Level

2 hours 30 minutes

300 marks

Examination Number

Date of Birth For example, 3rd February 2005 is entered as 03 02 05

Centre Stamp

Instructions

There are seven questions on this paper. Each question carries 50 marks.

Answer **Question 1** and any **five other** questions.

Write your Examination Number and your Day, Month and Year of Birth in the boxes on the front cover.

Write your answers in blue or black pen. You may use pencil in graphs and diagrams only.

This examination booklet will be scanned and your work will be presented to an examiner on screen. All of your work should be presented in the answer areas, or on the given graphs, or diagrams. Anything that you write outside of these areas may not be seen by the examiner.

Write all answers into this booklet. There is space for extra work at the back of the booklet. If you need to use it, label any extra work clearly with the question number and part.

The superintendent will give you a copy of the *Formulae and Tables* booklet. You must return it at the end of the examination. You are not allowed to bring your own copy into the examination.

Data from the *Formulae and Tables* booklet, including atomic numbers and relative atomic masses, should be used wherever necessary.

You may lose marks if your solutions do not include relevant supporting work.

You may lose marks if the appropriate units of measurement are not included, where relevant.

You may lose marks if your answers are not given in their simplest form, where relevant.

Diagrams are generally not drawn to scale.

Write the make and model of your calculator(s) here:

Question 1

(a) A student is given 250 cm^3 of a colourless liquid. The liquid contains 1.0 g of sodium hydroxide (NaOH) dissolved in water.

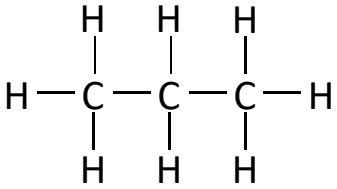
(i) Outline how the student could make the solution more concentrated.

(ii) What is a saturated solution?

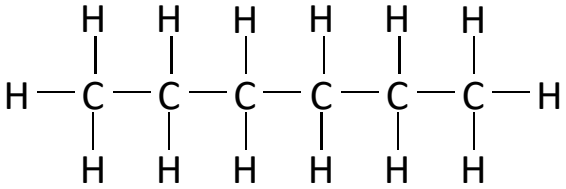
(iii) Calculate the number of moles of NaOH in 1.0 g.

(iv) Calculate the concentration of the solution in moles per litre.

(b) The boiling point of alkanes can be affected by their molecular structures.

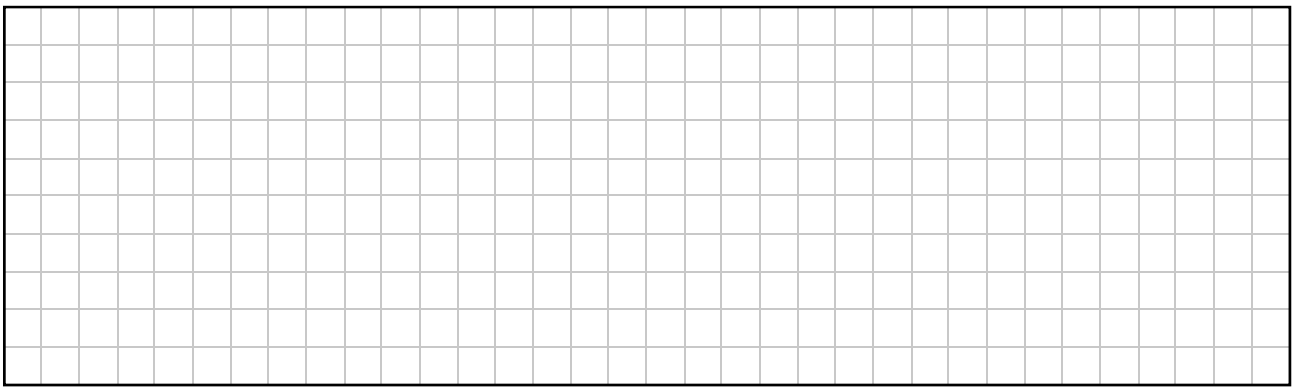


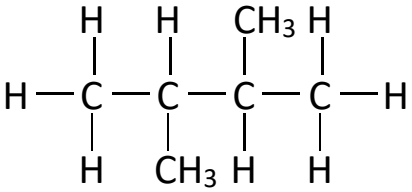
propane



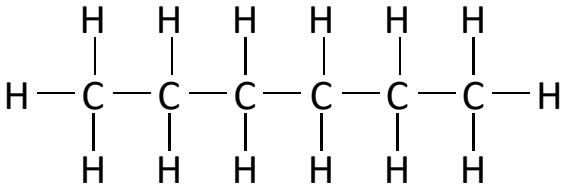
hexane

(i) Which of the above compounds (propane or hexane) has a higher boiling point? Justify your answer.



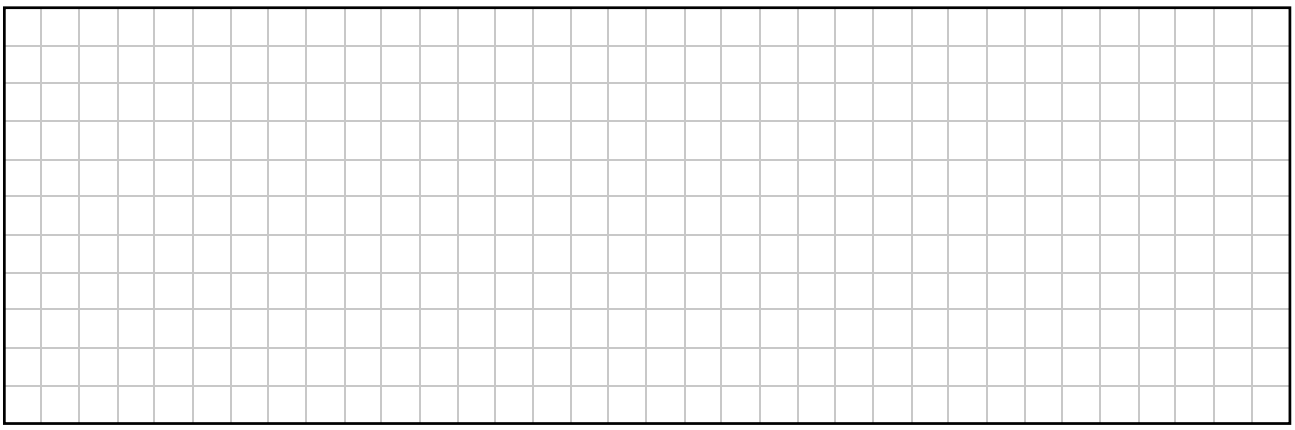


2,3-dimethylbutane



hexane

(ii) Which of the above compounds (2,3-dimethylbutane or hexane) has a higher boiling point? Justify your answer.



(c) Matter exists in three states: solid, liquid and gas.

(i) In the table below, identify the state of matter described.

description	solid/liquid/gas
particles vibrate around a fixed position	
completely fills the container in which it is held	

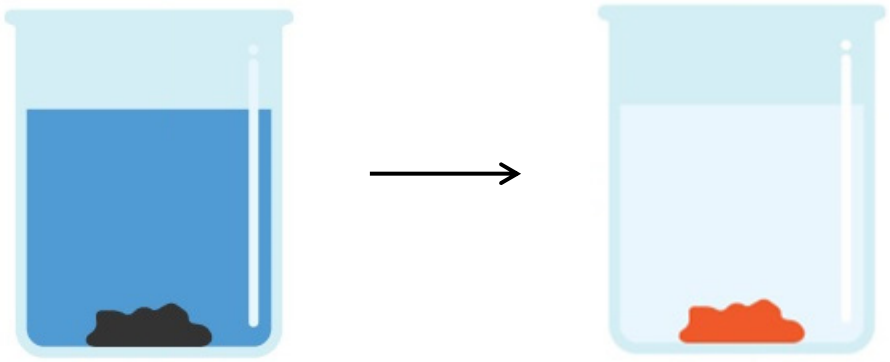
Diffusion can take place in a liquid or a gas.

(ii) Explain what is meant by diffusion.

The ideal gas equation is $PV = nRT$.

(iii) What physical quantity is represented by the letter T?

(d) A student wishes to investigate the reactivity of different metals. She puts some powdered magnesium metal into a beaker containing a pale blue solution of copper sulfate. She observes that when she stirs the mixture, the solution becomes colourless and solid copper metal appears on the bottom of the beaker.



The reaction may be described by the following balanced chemical equation:

$$Mg + CuSO_4 \rightarrow MgSO_4 + Cu$$

On a chemistry website, the student learns that this reaction is called a displacement reaction.

Magnesium displaces copper from solution because magnesium is higher than copper on the electrochemical series.

Part of this series is shown in the table on the right.

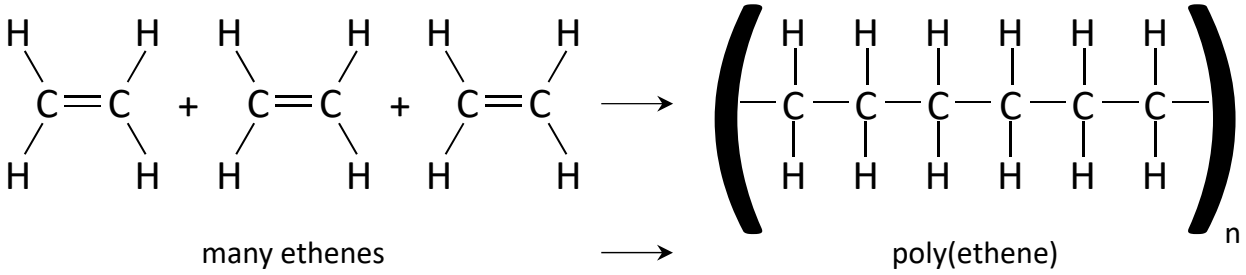
electrochemical series
lithium (Li)
calcium (Ca)
magnesium (Mg)
zinc (Zn)
lead (Pb)
copper (Cu)
silver (Ag)
gold (Au)

(i) During this reaction, is magnesium oxidised or reduced? Justify your answer.

(ii) From the table, identify a metal (other than magnesium) that will react with copper sulfate in a similar way.

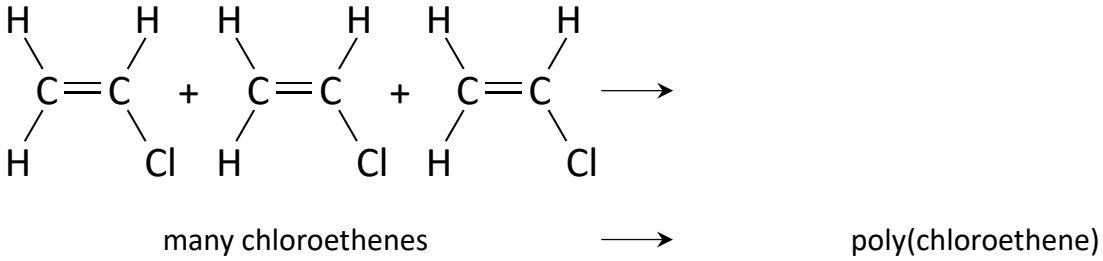
(iii) From the table, identify a metal that will <u>not</u> react with copper sulfate in this way.

(e) Poly(ethene), also known as polythene, is formed from ethene during an addition polymerisation reaction, as shown below for three repeating units of poly(ethene).



Poly(chloroethene), also known as polyvinyl chloride (PVC), is formed from chloroethene during an addition polymerisation reaction.

(i) Complete the reaction below to show the structure of three repeating units of poly(chloroethene).



(ii) State one everyday use of poly(ethene) or poly(chloroethene).

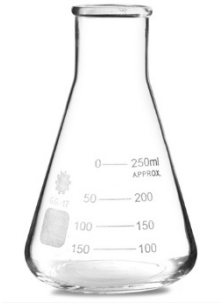
(iii) Why is it desirable that we recycle polymers such as these?

Question 2

Milk of Magnesia is a liquid medicine used to treat stomach indigestion. It contains magnesium hydroxide ($Mg(OH)_2$), a strong base. It works by neutralising excess hydrochloric acid (HCl), a strong acid found in the stomach.

A student investigated the concentration of a solution of $Mg(OH)_2$. The student carried out a series of titrations between $Mg(OH)_2$ and 0.15 M HCl in a school laboratory.

The photographs below show some of the pieces of apparatus used by the student.



A

B

C

(i) In the table below, name the three pieces of apparatus labelled A, B and C.

label	name
A	
B	
C	

(ii) Describe the procedure for washing and filling the piece of apparatus labelled B.

$Mg(OH)_2$ is considered a strong base.

(iii) Why is $Mg(OH)_2$ considered a strong base?

(iv) Which of the compounds listed below is classified as a weak base?
Place a tick (✓) in the correct box.

vinegar (CH_3COOH) ☐

sodium carbonate (Na_2CO_3) ☐

hydrogen chloride (HCl) ☐

Before using the 0.15 M HCl in the titration, the student wanted to check its pH.

(v) How could the student check the pH of the HCl?

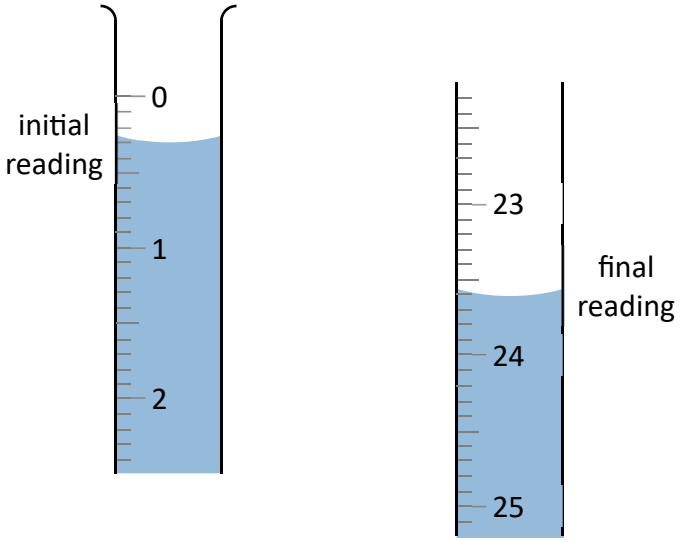
(vi) Explain what is meant by the pH of a solution.

For each titration, the student noted the endpoint, i.e. the minimum volume of HCl added to neutralise the $Mg(OH)_2$.

(vii) How did the student know when the endpoint had been reached, i.e. when neutralisation had occurred?

The student first carried out an approximate titration and then carried out two accurate titrations.

For the approximate titration, the student read the volume of HCl using the piece of apparatus labelled C. The initial reading and final reading are shown in the diagram below.



(viii) From the diagram, write the initial reading.

(ix) From the diagram, write the final reading.

(x) Using your initial and final readings, calculate the volume of HCl added.

The volumes of HCl added for the two accurate titrations were 22.7 cm^3 and 22.8 cm^3.

(xi) Calculate the average volume of HCl added in the accurate titrations.

The reaction between magnesium hydroxide and hydrochloric acid is described by the following balanced chemical equation:

$$Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$$

The student titrated the 0.15 M HCl against 25.0 cm^3 of $Mg(OH)_2$.

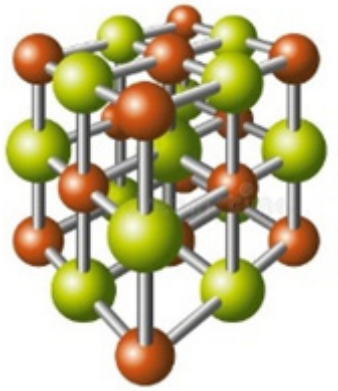
(xii) Calculate the concentration of the $Mg(OH)_2$ solution.

Question 3

(a) The diagram shows a small part of a crystal of sodium chloride (NaCl).

The crystal is made up of sodium ions (Na^+) and chloride ions (Cl^-) which are attracted to each other.

(i) What is an ion?



(ii) Complete the table below to show the number of electrons, and the arrangement of electrons, for a chlorine atom and a chloride ion.
The table is partially completed.

atom/ion	number of electrons	arrangement of electrons
chlorine atom (Cl)	17	
chloride ion (Cl^-)		

(iii) Use a ✓ or **×** in each row to identify the physical properties of an ionic compound such as NaCl.

property	✓ or ×
high melting point	
conducts electricity when dissolved in water	
conducts electricity when solid	

(iv) Explain what is meant by electronegativity.

(v) Is the type of bonding in a molecule of hydrogen chloride (HCl) considered to be ionic, polar covalent or pure covalent? Justify your answer.
(Note that the electronegativity values of the elements may be found on page 81 of the *Formulae and Tables* booklet.)

The type of bonding in a molecule of fluorine (F_2) is considered to be pure covalent.

A Lewis diagram shows the bonding between atoms in a molecule, as well as the lone pairs of electrons that may exist in the molecule.

(vi) Draw a Lewis diagram to show the bonding in F_2.

(b) In a school laboratory a group of students conducted flame tests to identify the presence of specific metals in three unknown compounds.

The students used the following method:

step 1 soak wooden splints in water

step 2 dip a damp wooden splint into a sample of an unknown compound

step 3 hold the wooden splint above the flame of a Bunsen burner

The students' method did not work very well.

(i) Suggest one improvement which the students could have made to step 3 of their method so that a brightly coloured flame would be observed.

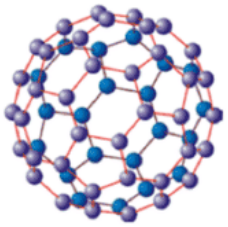
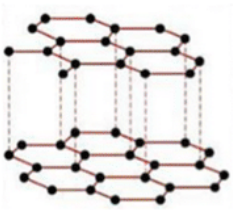
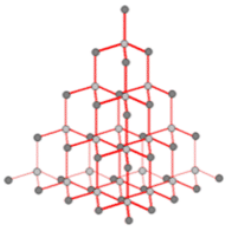
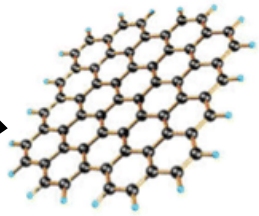
The table below shows some of the results of flame tests on compounds P, Q and R.

(ii) Complete the table to identify the metal present in compounds P and R, and the flame colour due to the presence of barium in compound Q.

compound	flame colour	metal
P	yellow-orange	
Q		barium/Ba
R	crimson	

(c) Carbon exists in allotropes, which are different physical forms of the same element.

(i) In the table below, use arrows to match the name of each allotrope with its structure. One arrow is already drawn.

name of allotrope	structure
diamond	
graphene	
graphite	
fullerene	

(ii) State one use of any one named allotrope of carbon.

Question 4

(a) The text below has been adapted from an article published in *The Irish Times* on 23 March 2024. Read the article and answer the questions that follow.

Ecological tragedy in Clare heralds imminent water crisis

On 5 May 2023, 14 dead fish were removed from the lower Ballymacraven river, outside Ennistymon. Initial inspection of the dead fish showed that their gills (the organ they use to breathe underwater) were clogged with gloopy clumps of rust-coloured residue. Samples of gill tissue were sent away to a laboratory for analysis. The results were clear – the thick ketchup-like material was from a chemical sludge containing iron(III) sulfate ($Fe_2(SO_4)_3$), a coagulant used in water treatment plants to remove impurities.

The water source for the Ennistymon water treatment plant is a 250-acre lake in the Burren called Lickeen, a few kilometres away. Ireland depends heavily on surface waters, such as rivers and lakes, for drinking water. The challenge with using water from lakes and rivers is purification – the bits of soil, sand, clay and organic matter must be removed before the water is chlorinated and sent out as drinking water.

Iron(III) sulfate solves this problem by binding to the material in the water so that it can be removed. What's left behind is sludge. This sludge was released into the waterways and caused fish in the Ballymacraven river to die.

(i) What is the chemical symbol for iron?

(ii) What term is used to describe the addition of coagulants (such as iron(III) sulfate or aluminium sulfate) to water to cause suspended particles to clump together?

(iii) Name one step in the treatment of water that should take place *before* the addition of coagulants like iron(III) sulfate.

(iv) Name one step in the treatment of water that should take place *after* the addition of coagulants like iron(III) sulfate.

(v) Which reagent is used to test for the presence of sulfate ions in water?
Place a tick (✓) in the correct box.

sodium chloride (NaCl)	☐
silver nitrate ($AgNO_3$)	☐
barium chloride ($BaCl_2$)	☐
sodium carbonate (Na_2CO_3)	☐

Another source of water pollution is the run-off from agricultural effluent and fertilisers.
This can cause eutrophication in the water.

(vi) Explain what is meant by eutrophication.

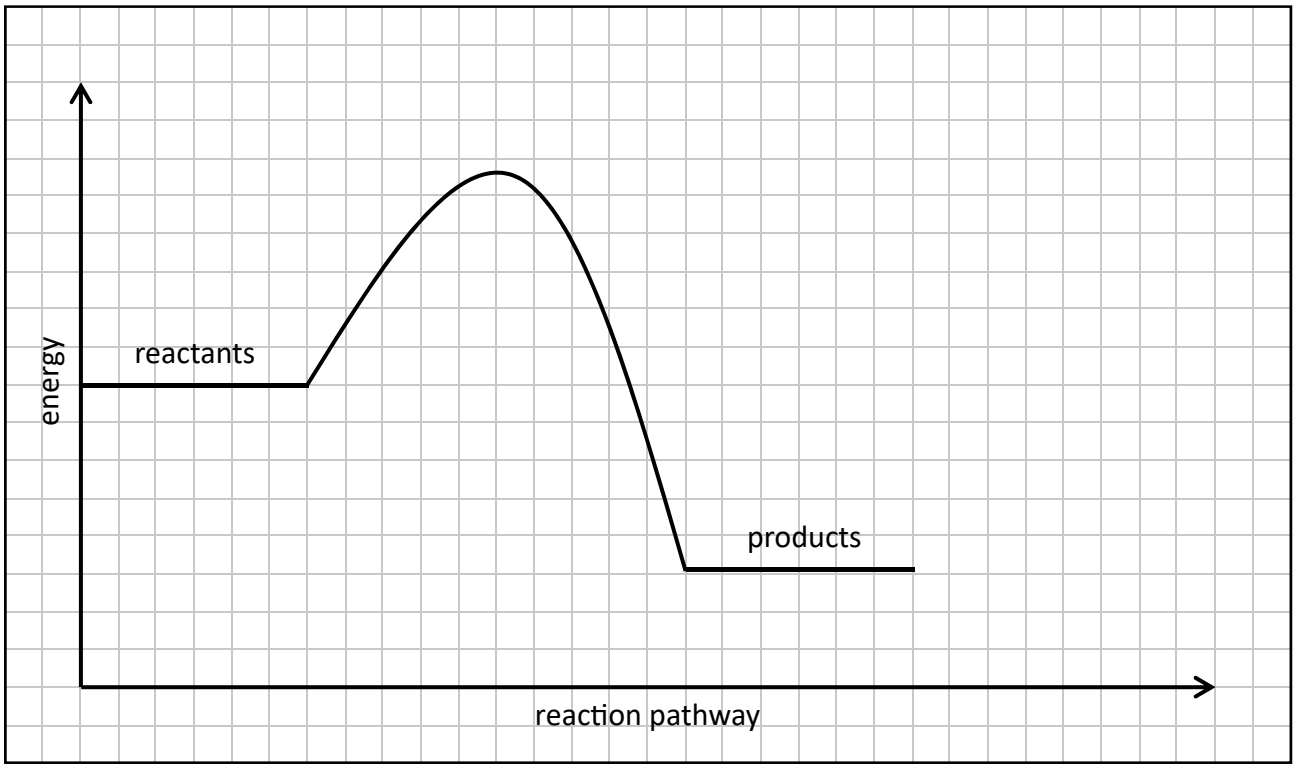
A mass analysis of a certain fertiliser compound shows that it contains 60% oxygen (O), 35% nitrogen (N) and 5% hydrogen (H).

(vii) Calculate the empirical formula of this compound.

(b) Some chemical reactions release energy. These are called exothermic reactions.

(i) Does the temperature increase or decrease when an exothermic reaction takes place?

The energy profile diagram shown below is for an exothermic reaction.



(ii) What evidence in the diagram shows that this is an exothermic reaction?

The overall energy change (ΔH) for a chemical reaction can be modelled as the sum of all the energies involved in breaking bonds and making new bonds.

(iii) Does breaking a bond release energy or does it require energy?

(iv) Draw a labelled diagram showing the chemicals that a student might use and how the student might arrange the apparatus in an experiment to determine Δ*H* for a neutralisation reaction.

(v) Would the student expect the temperature to increase, decrease or stay the same during this neutralisation experiment?

Question 5

(a) The table below identifies four organic compounds.

compound A	compound B	compound C	compound D
propan-1-ol	propan-2-ol	butanal	butanone

Compounds A and B are structural isomers.

(i) Name one property which structural isomers have in common.

(ii) Draw the molecular structure of compound A showing all of the atoms and bonds.

(iii) Draw the molecular structure of compound B showing all of the atoms and bonds.

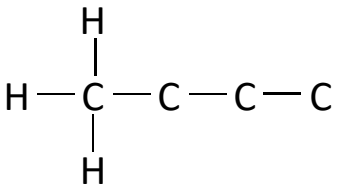
Compound A is a primary alcohol.

(iv) Is compound B a primary alcohol, a secondary alcohol or a tertiary alcohol?

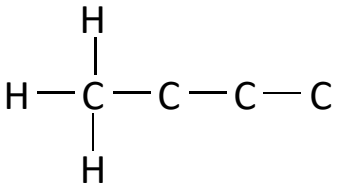
Compounds C and D are also structural isomers.

Compound C is an aldehyde and compound D is a ketone.

(v) Complete the molecular structure below for compound C.



(vi) Complete the molecular structure below for compound D.



(vii) Describe a test to distinguish between compounds C and D.
Your answer should identify all chemicals used and observations made.

(b) When hydrogen gas (colourless) and iodine gas (dark purple) are mixed together, they react to produce hydrogen iodide gas (colourless) in an equilibrium reaction.

The balanced chemical equation for this reaction is:

$$H_2 + I_2 \rightleftharpoons 2HI$$

The equilibrium mixture contains hydrogen (H_2), iodine (I_2) and hydrogen iodide (HI). The mixture has a pale purple colour.

(i) Write an expression for the equilibrium constant (K_c) for this reaction.

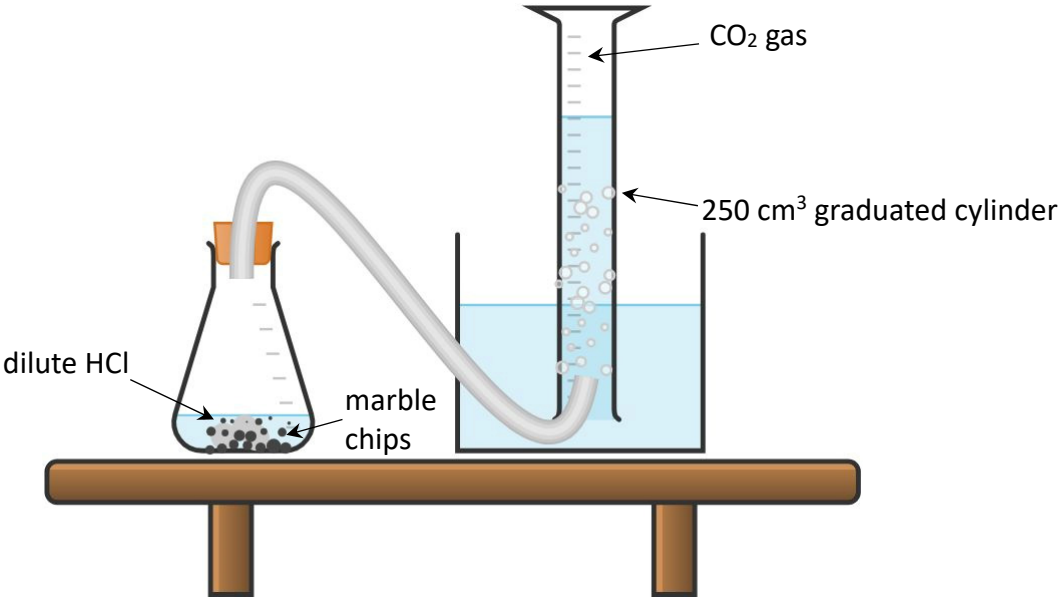
(ii) Complete the following statement of Le Châtelier's principle:

When a stress is applied to a system at equilibrium, the position of equilibrium shifts to _____ the stress.

(iii) Use Le Châtelier's principle to predict the change in the position of the equilibrium when the concentration of hydrogen is increased. Justify your answer.

Question 6

A student used the apparatus shown below to investigate the rate of the reaction between marble chips ($CaCO_3$) and dilute hydrochloric acid (HCl) at room temperature. The marble chips were mixed with the hydrochloric acid in the conical flask, and the total volume of carbon dioxide (CO_2) produced was measured every minute for 7 minutes.



(i) Explain what is meant by the rate of a chemical reaction.

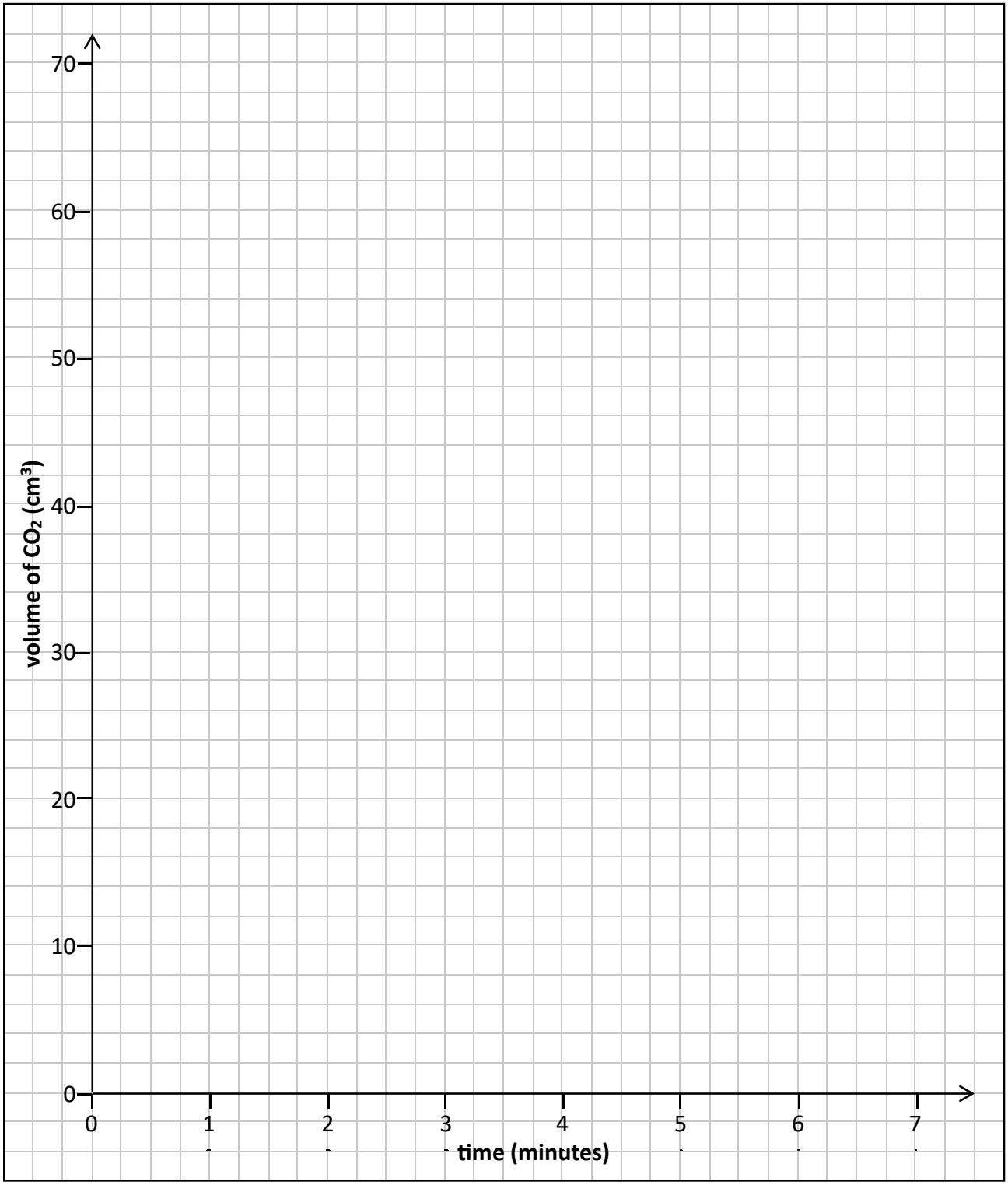
One way of measuring how much gas is produced in a reaction is by using a basin of water and a graduated cylinder to collect the gas, as in the diagram above.

(ii) Describe another way of measuring how much gas is produced in a reaction.

The student recorded the following data for the volume of CO_2 produced over 7 minutes.

time (minutes)	0	1	2	3	4	5	6	7
volume of CO_2 (cm^3)	0	22	38	50	57	61	62	62

(iii) Plot a graph of the volume of CO_2 produced against time.



(iv) Use your graph to determine the volume of CO_2 produced in the first 90 seconds.

(v) Use your graph to determine the time taken for 40 cm^3 of CO_2 to be produced.

(vi) Calculate the average rate of reaction over the first 2 minutes.

The student measured the volume of gas for 7 minutes.

(vii) Explain why the student did not need to measure the volume of gas for longer than this.

The student repeated the investigation using a more concentrated solution of HCl.

The rate of the reaction increased.

(viii) How would the student have known that the rate of the reaction had increased?

(ix) Explain why the rate of the reaction increased when more concentrated HCl was used.

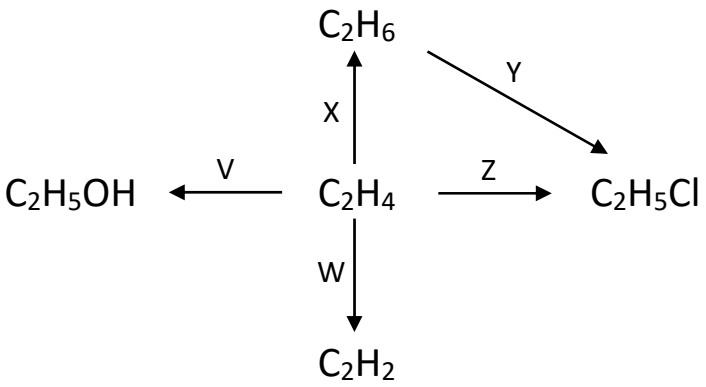
The student suggests other ways of increasing the rate of the reaction.

(x) Use a ✓ or **×** in each row to identify which of the suggestions in the table below will increase the rate of the reaction.

suggestion	**✓ or ×**
using a more accurate stopwatch to measure time	
using the same mass of $CaCO_3$ but in powdered form	
placing the conical flask in a mixture of ice and water	
using a smaller graduated cylinder to collect the gas	

Question 7

The reaction scheme below describes reactions involving five different organic compounds.



In three of the five compounds in the reaction scheme, the geometry around *both* of the carbon atoms in the molecule is tetrahedral.

(i) Draw a circle around each of these three compounds in the reaction scheme.

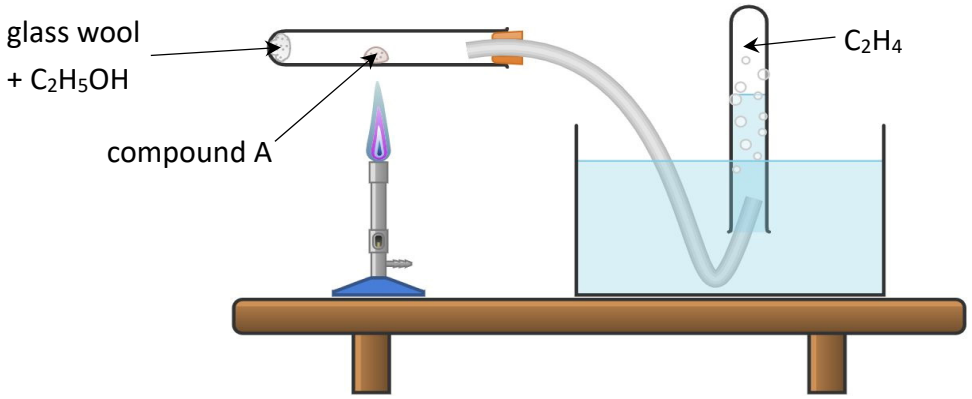
(ii) In the table below, classify each of the reactions (labelled V, W, X, Y and Z) as an addition reaction, a substitution reaction, or an elimination reaction.

reaction	type of reaction (addition, substitution or elimination)
V	
W	
X	
Y	
Z	

(iii) In the table below, state the IUPAC name for each of the compounds in the reaction scheme. The table is partially completed.

compound	IUPAC name
C_2H_6	ethane
C_2H_4	
C_2H_5Cl	
C_2H_2	
C_2H_5OH	

The diagram below shows how a student could prepare C_2H_4 in the school laboratory.



(iv) Identify compound A, which is a white solid.

The student discarded the first few test tubes of gas collected.

(v) Explain why the student discarded the first few test tubes of gas collected.

C_2H_4 is classified as an unsaturated hydrocarbon.

(vi) What is a hydrocarbon?

(vii) Describe how a student would test to confirm that C_2H_4 was unsaturated.
Your answer should identify all chemicals used and observations made.

C_2H_4 undergoes complete combustion in excess oxygen to produce carbon dioxide and water, as described by the following balanced chemical equation:

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

Some CO_2 was produced when 0.25 moles of C_2H_4 underwent complete combustion.

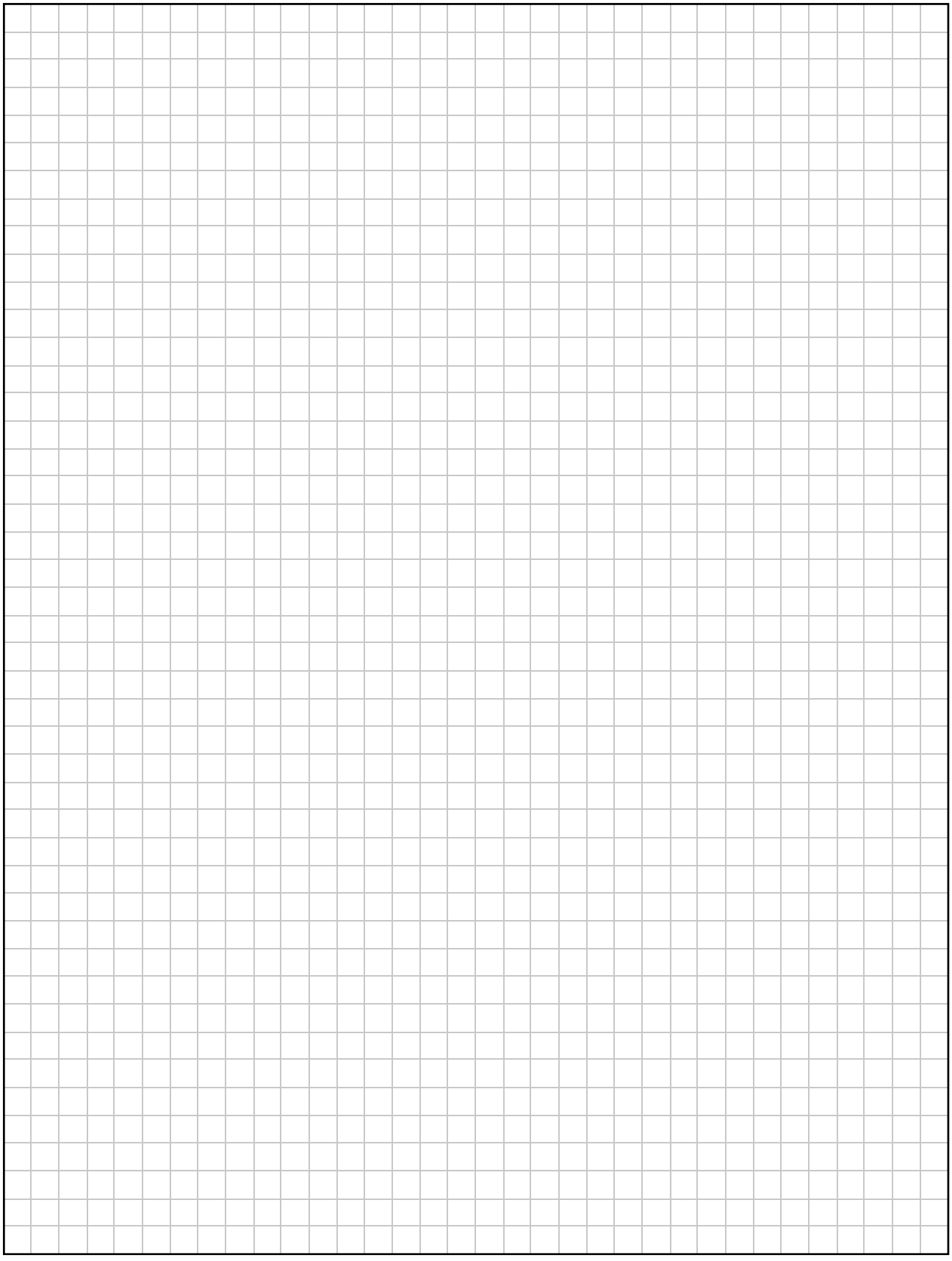
(viii) How many moles of CO_2 were produced?

(ix) Calculate the volume of the CO_2 produced, measured at standard temperature and pressure. (Note that one mole of gas has a volume of 22.4 litres at standard temperature and pressure.)

(x) Write the balanced chemical equation for the complete combustion of C_2H_2.

Page for extra work.

Label any extra work clearly with the question number and part.



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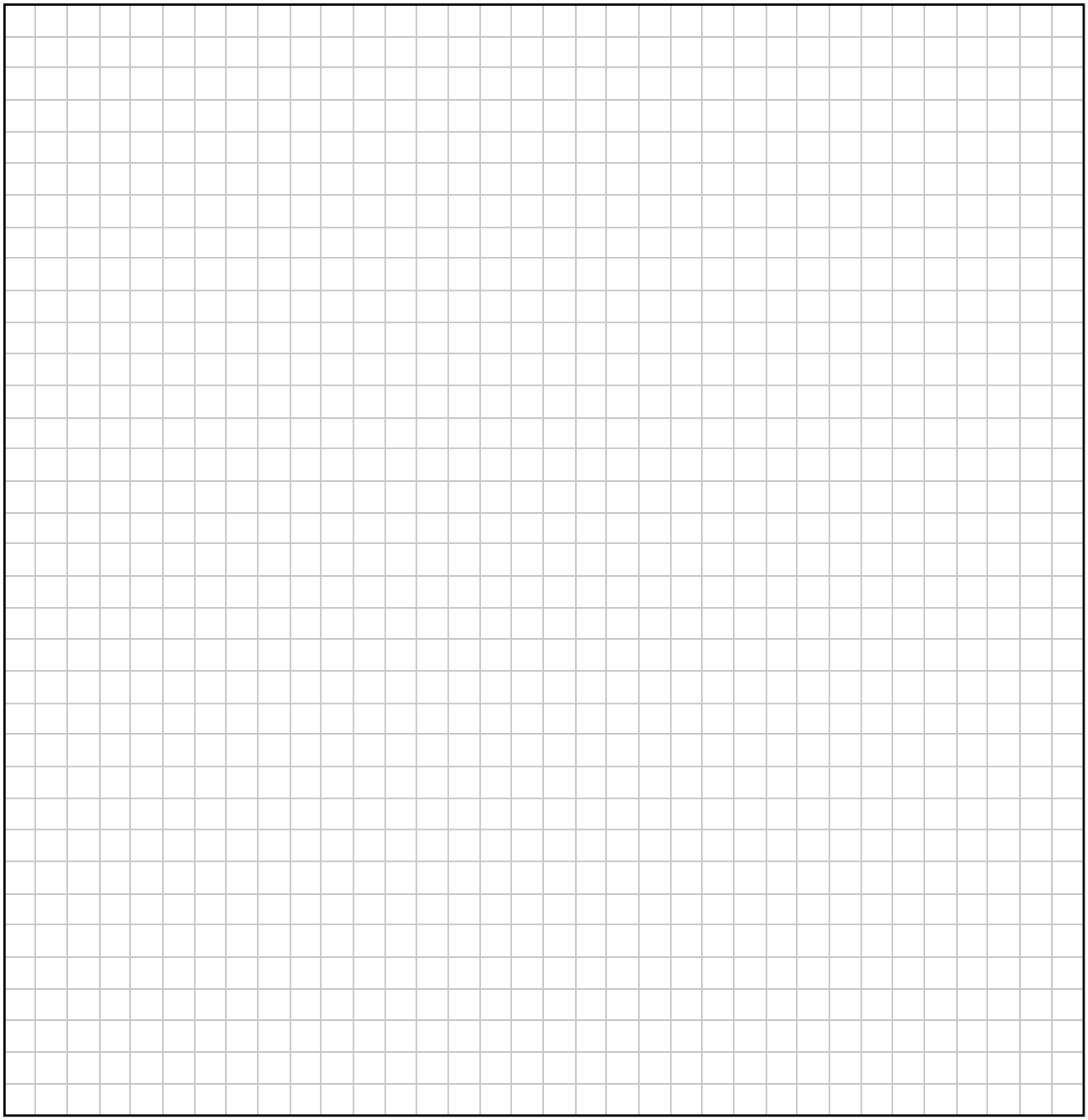

Acknowledgements

Images

Image on page 6:	bbc.co.uk/bitesize
Images on page 8:	indiamart.com; pipette.com; findel-education.co.uk
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Images on page 15:	researchgate.net
Image on page 23:	chemix.org
Image on page 28:	chemix.org

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Leaving Certificate Examination – Ordinary Level

Chemistry

Sample 1

2 hours 30 minutes