2027.M34S1

2027L022A1ES1

Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate Examination
Sample 1

Chemistry

Higher 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

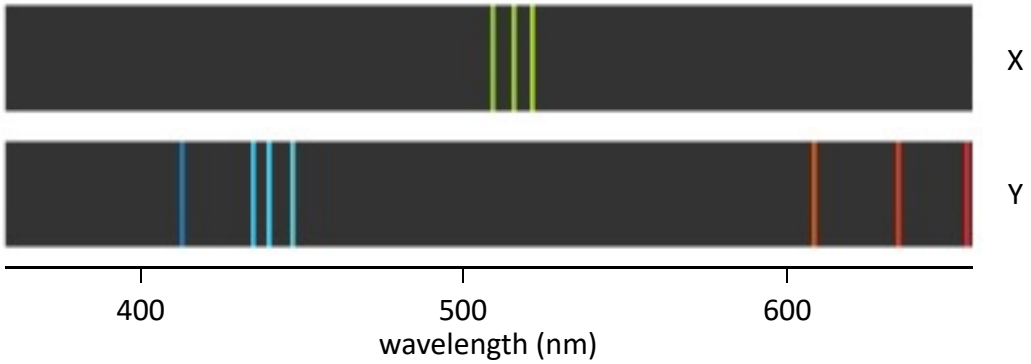
(a) The line emission spectra for elements can be modelled using the formula $E_m - E_n = hf$.

(i) State the physical quantity represented by E_m.

(ii) State the physical quantity represented by E_n.

(iii) State the physical quantity represented by f.

Examine the line emission spectra below for salts of elements X and Y.



(iv) Identify element X.

(v) Identify element Y.

(b) Hess's law states that the enthalpy change (ΔH) for a chemical reaction is independent of the path taken.

The ΔH values for three gas phase chemical reactions are as follows:

(1) $2OF_2 \rightarrow O_2 + 2F_2$ $\Delta H = -49.1$ kJ mol^{-1}

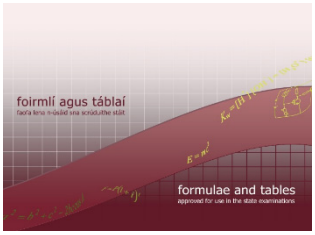
(2) $2ClF + O_2 \rightarrow Cl_2O + OF_2$ $\Delta H = 205.6$ kJ mol^{-1}

(3) $2ClF_3 + 2O_2 \rightarrow Cl_2O + 3OF_2$ $\Delta H = 533.4$ kJ mol^{-1}

Using the data, calculate ΔH for the following chemical reaction:

$$ClF + F_2 \rightarrow ClF_3$$

(c) Examine the first ionisation energies of the elements on page 80 of the *Formulae and Tables* booklet.



(i) What is meant by the first ionisation energy of an element?

First ionisation energies generally increase from left to right across a period (row) of the periodic table. There are, however, exceptions to this general trend.

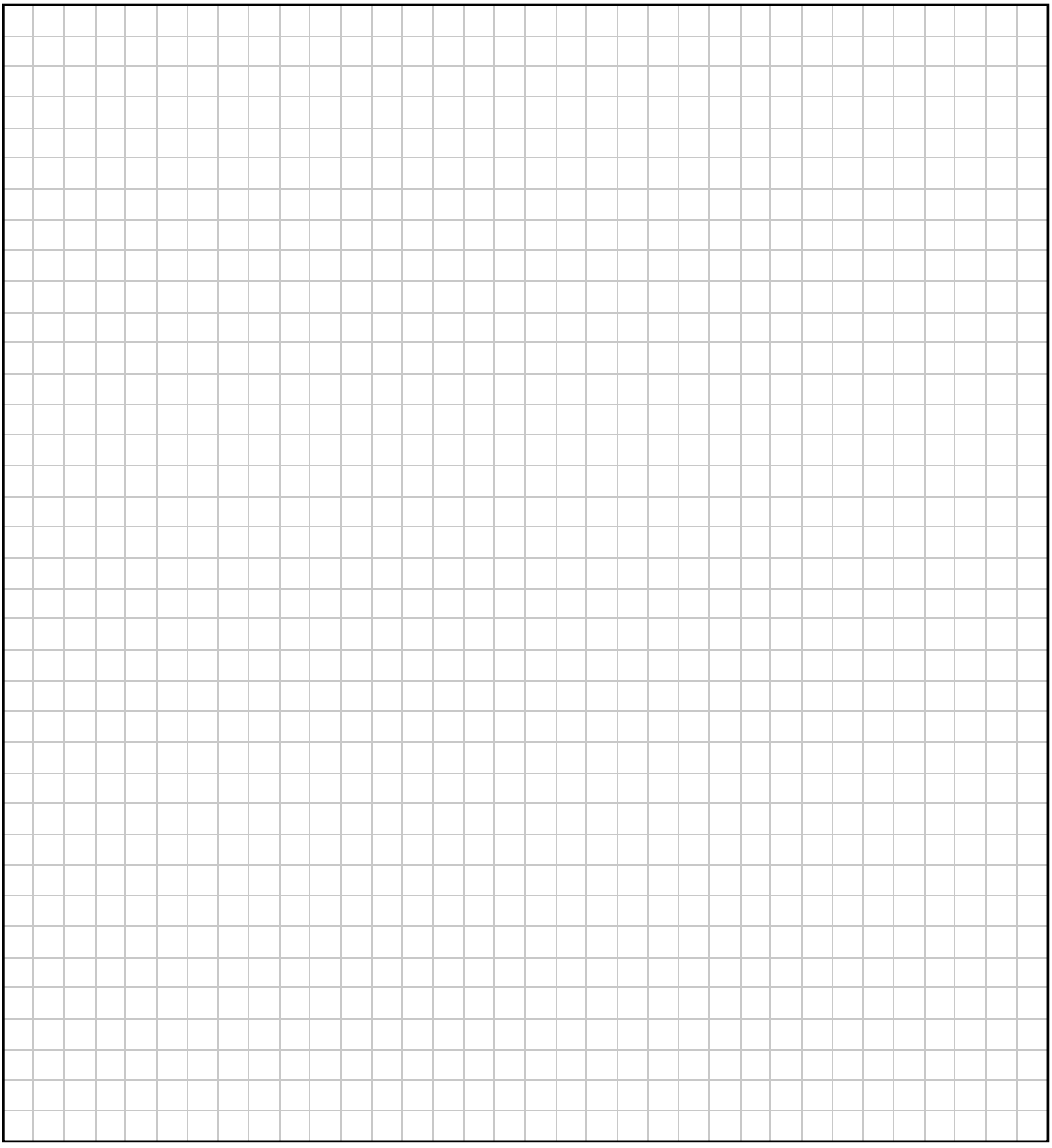
(ii) Identify and explain the exceptions in the second period of the periodic table, i.e. Li to Ne.

(d) Propanone (CH_3COCH_3) is the smallest ketone. It is an important solvent in industries, laboratories and homes. It mixes easily with both polar solvents like water and non-polar solvents like benzene.

Draw a diagram to explain why propanone mixes easily with water.

Your diagram should show:

- one molecule of propanone and one molecule of water,
- displacements of charge (or dipoles) in each molecule,
- intermolecular forces between specific parts of the molecules.



(e) A student carried out an experiment to investigate the percentage of elemental iron in tablets containing iron compounds.

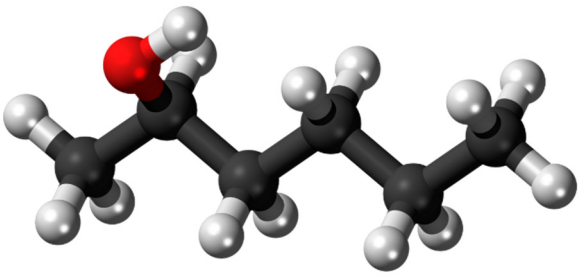
The student was given five of the tablets.

Describe how the student could use the tablets to make up an exact volume of a solution of iron(II). Your answer should identify all relevant chemicals and apparatus and describe how they were used.

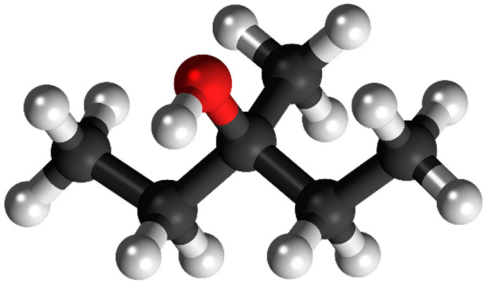
Question 2

(a) The diagrams below show 3D models of two alcohols with the molecular formula $C_6H_{14}O$.

The condensed structural formula for compound A is $CH_3CH(OH)CH_2CH_2CH_2CH_3$.



A



B

(i) State the IUPAC name for compound A.

(ii) Is compound A a primary, secondary or tertiary alcohol? Justify your answer.

(iii) State the IUPAC name for compound B.

(iv) Is compound B a primary, secondary or tertiary alcohol? Justify your answer.

(v) Write the condensed structural formula for compound B.

One advantage of using 3D models such as these is that the shape of the molecule can be better understood. For example, from the diagrams of compounds A and B it is clear that the bond angle at the oxygen atom is less than 180°.

(vi) Explain why the bond angle at the oxygen atom in compounds such as alcohols and water is less than 180°.

(b) Another alcohol, methanol, reacts with ethanoic acid under reflux conditions to produce an ester.

(i) State the IUPAC name for the ester produced.

(ii) Draw the molecular structure of the ester produced, including all atoms and bonds.

(iii) Identify the other product of this chemical reaction.

(iv) State one advantage of using reflux conditions during the production of an ester.

(c) Soaps may be produced using long chain esters such as triglycerides, which are natural oils or fats.

(i) Identify the other reactant needed to produce soap from long chain esters.

(ii) A soap is an example of a surfactant. Describe how soaps work as surfactants.

(iii) Other than soap, state one other use or application of surfactants.

Question 3

(a) Magnesium chloride is an inorganic compound with the chemical formula $MgCl_2$.
It is classified as an ionic compound.

(i) By reference to data on page 81 of the *Formulae and Tables* booklet, explain why magnesium chloride is classified as an ionic compound.

(ii) Write the arrangement of electrons in energy levels and sublevels for the Cl^- ion.
Explain why this is a stable electronic configuration.

(iii) Explain why magnesium chloride is highly soluble in water.

(b) One aspect of electrochemistry is electrolysis. This is where an electric current is used to drive a redox reaction. When an electric current is passed through molten magnesium chloride, it can undergo electrolysis to produce magnesium metal, as described by the following balanced chemical equation:

$$MgCl_2 \rightarrow Mg + Cl_2$$

(i) Is magnesium metal produced at the anode or the cathode during this reaction? Justify your answer.

Another aspect of electrochemistry is the use of redox reactions to produce an electric current. This is called a galvanic cell.

(ii) Explain the operation of a simple galvanic cell. Your explanation should identify which chemical species is oxidised and which is reduced.

(c) Magnesium chloride may be produced by the neutralisation reaction between solid magnesium hydroxide and hydrochloric acid, as described by the following balanced chemical equation:

$$Mg(OH)_{2(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$$

22.0 g of magnesium hydroxide reacts completely with 1.8 M hydrochloric acid to produce magnesium chloride and water.

(i) Calculate the mass of magnesium in 22.0 g of magnesium hydroxide.

(ii) Calculate the minimum volume of 1.8 M hydrochloric acid needed to completely neutralise 22.0 g of magnesium hydroxide.

(iii) Calculate the concentration, in moles per litre, of the solution of magnesium chloride produced when the volume of 1.8 M hydrochloric acid that you calculated in part **(ii)** is added to the 22.0 g of magnesium hydroxide.
(You may assume that water has a density of 1.0 g cm^{-3}.)

Question 4

(a) Hydrogen peroxide (H_2O_2) decomposes to produce water and oxygen according to the following balanced chemical equation:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

A student measured the volume of oxygen gas produced when a catalyst was introduced to a sample of hydrogen peroxide solution.

The data gathered are plotted on the graph on the next page.

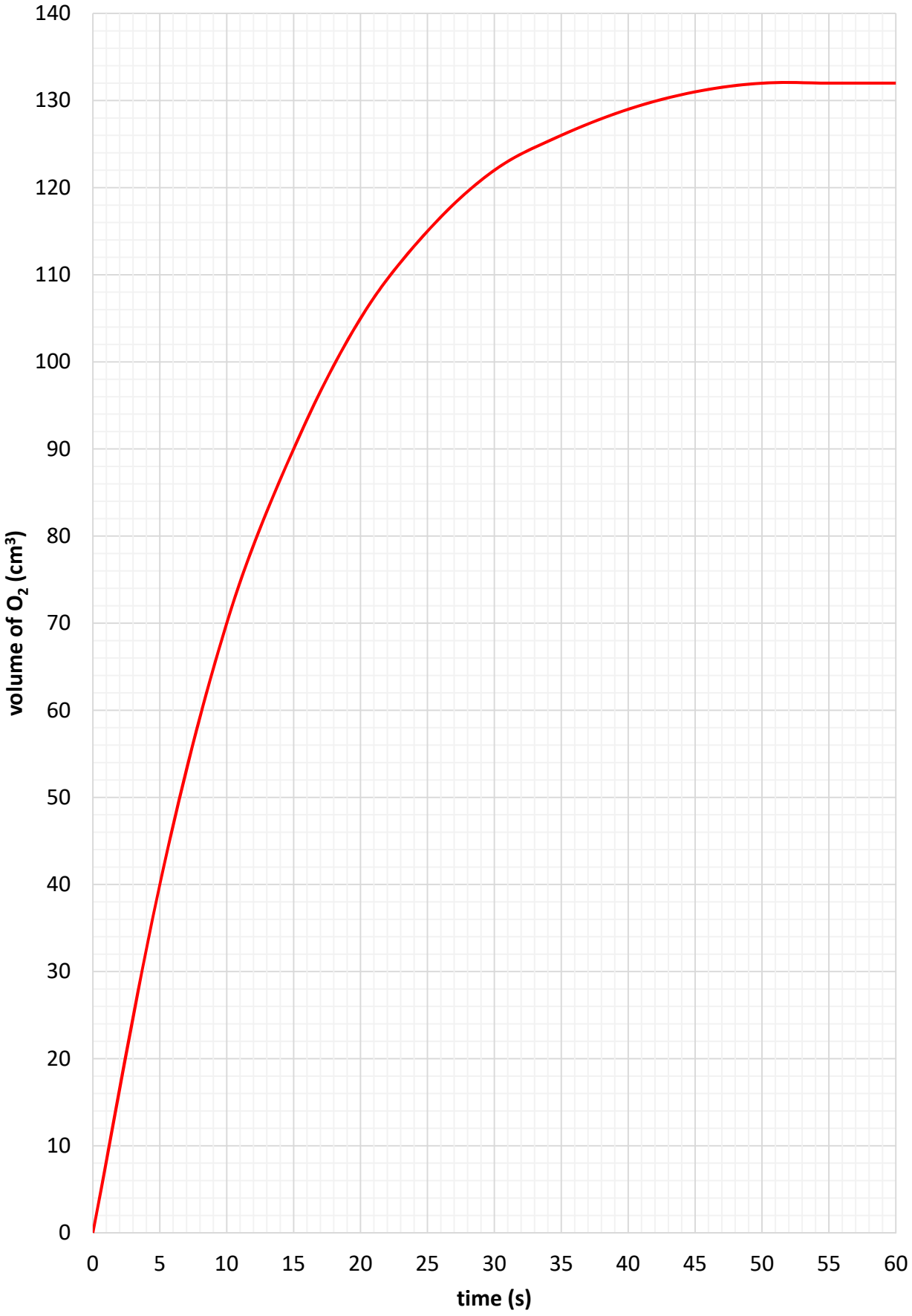
(i) Calculate the average rate of reaction over the first 20 s.

(ii) Calculate the instantaneous rate of reaction at 20 s.

(iii) Explain why the rate of this reaction decreases over time.

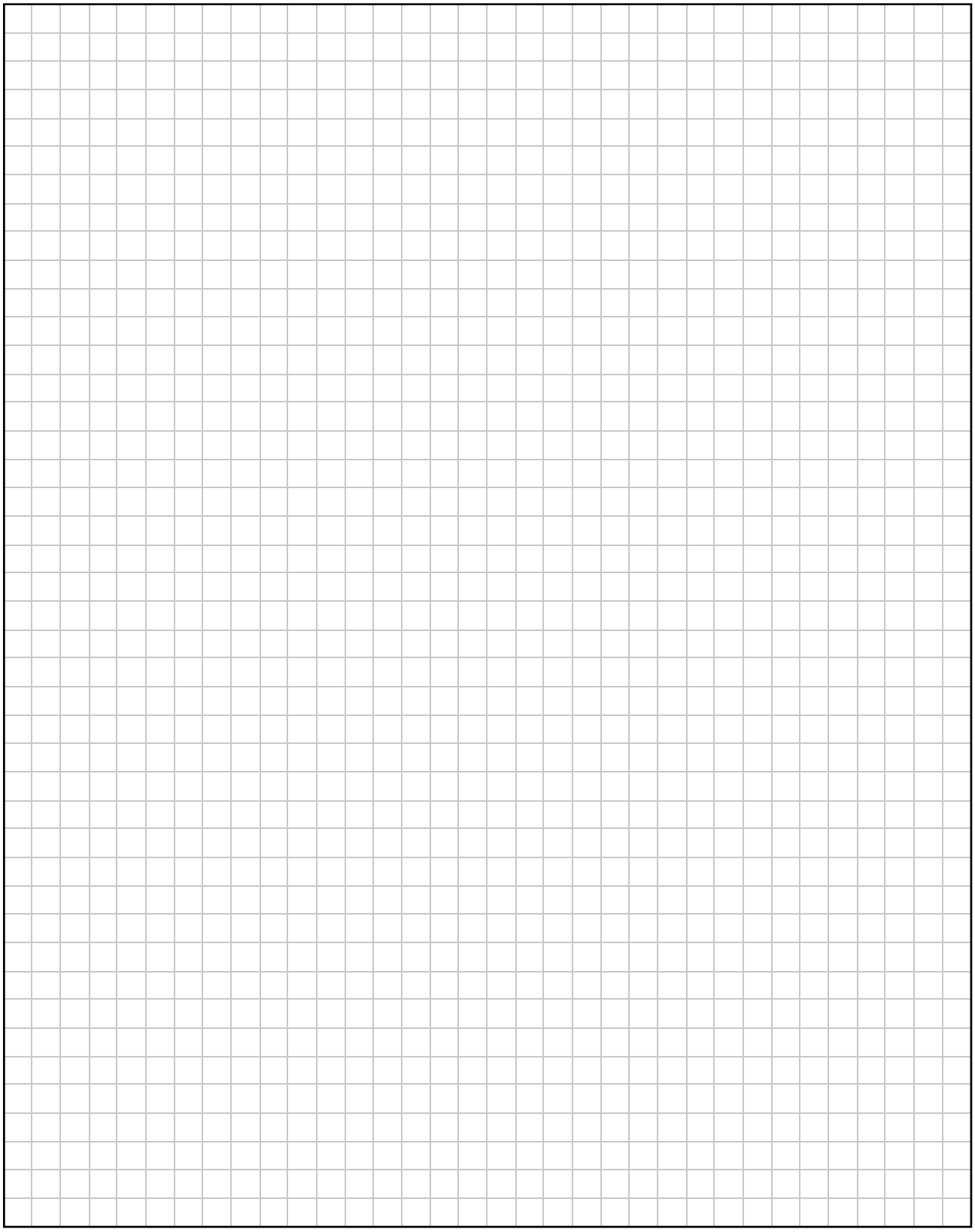
(iv) On the graph, show how the data would change if a more effective catalyst had been used.

(v) Describe how the catalyst could be made more effective.


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
volume of O_2 (cm^3)
0
5
10
15
20
25
30
35
40
45
50
55
60
time (s)

(b) Another student measured out 150 cm^3 of a different solution of H_2O_2, which had a concentration of 5% w/v.

Calculate the volume of oxygen gas produced when this sample of H_2O_2 decomposed completely at standard temperature and pressure.



(c) H_2O_2 can be used in forensic science to detect blood at a crime scene. The H_2O_2 reacts with the iron (Fe^{2+}) ions in blood in a redox reaction.

(i) State the oxidation number of oxygen in H_2O_2.

(ii) Hence or otherwise, balance the following chemical equation:

$$H_2O_2 + Fe^{2+} + H^+ \rightarrow Fe^{3+} + H_2O$$

Question 5

(a) Uisce Éireann treats and monitors the water supply in Ireland to ensure we have sufficient safe water for our homes and businesses.

The water treatment process typically starts with screening, flocculation and sedimentation.

(i) Explain what is meant by flocculation and explain why it is carried out during water treatment.

Drinking water is regularly tested in line with EU legislation. Many contaminants are tested for, including bacteria, organic molecules and metal ions. Discussions are taking place at EU level about also testing for microplastics, which are seen as a contaminant of emerging concern.

(ii) Describe how microplastics could come to be in our water supply.

Another step in the water treatment process is UV treatment.

(iii) Explain what is meant by UV treatment and explain why it is carried out during water treatment.

(iv) Explain the advantage of using UV treatment instead of chlorination to treat water.

(b) Uisce Éireann provides over 1.5 billion litres of water each day. An industry of this size has a high energy demand and thus a significant carbon footprint. In order to reduce carbon emissions, solar panels have been installed at some water treatment plants, such as the one in Thurles, pictured here.

(i) Describe how the use of solar panels can help reduce carbon emissions.

(ii) Other than the use of solar panels, suggest one way of reducing carbon emissions from the water treatment industry, without affecting the quality of the water.

(c) The chlorination of water results in the formation of hypochlorous acid (HOCl). HOCl is a weak and unstable acid that partially dissociates, forming an equilibrium with the hypochlorite anion (ClO^-), as described by the following balanced chemical equation:

$$HOCl \rightleftharpoons H^+ + ClO^-$$

(i) Explain what is meant by the term 'chemical equilibrium'.

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

At a pH of 7.53 and a temperature of 25 °C, HOCl and ClO^- have equal equilibrium concentrations.

(iii) Calculate the value of K_c.

(iv) State Le Châtelier's principle.

(v) Sodium hypochlorite (NaOCl) was added to the equilibrium mixture.
Will the pH increase, decrease or stay the same?
Explain your answer with reference to Le Châtelier's principle.

Question 6

(a) Arrhenius, Brønsted and Lowry are notable scientists who each helped to develop and modify our understanding of acids and bases.

(i) Distinguish between an acid and a base.

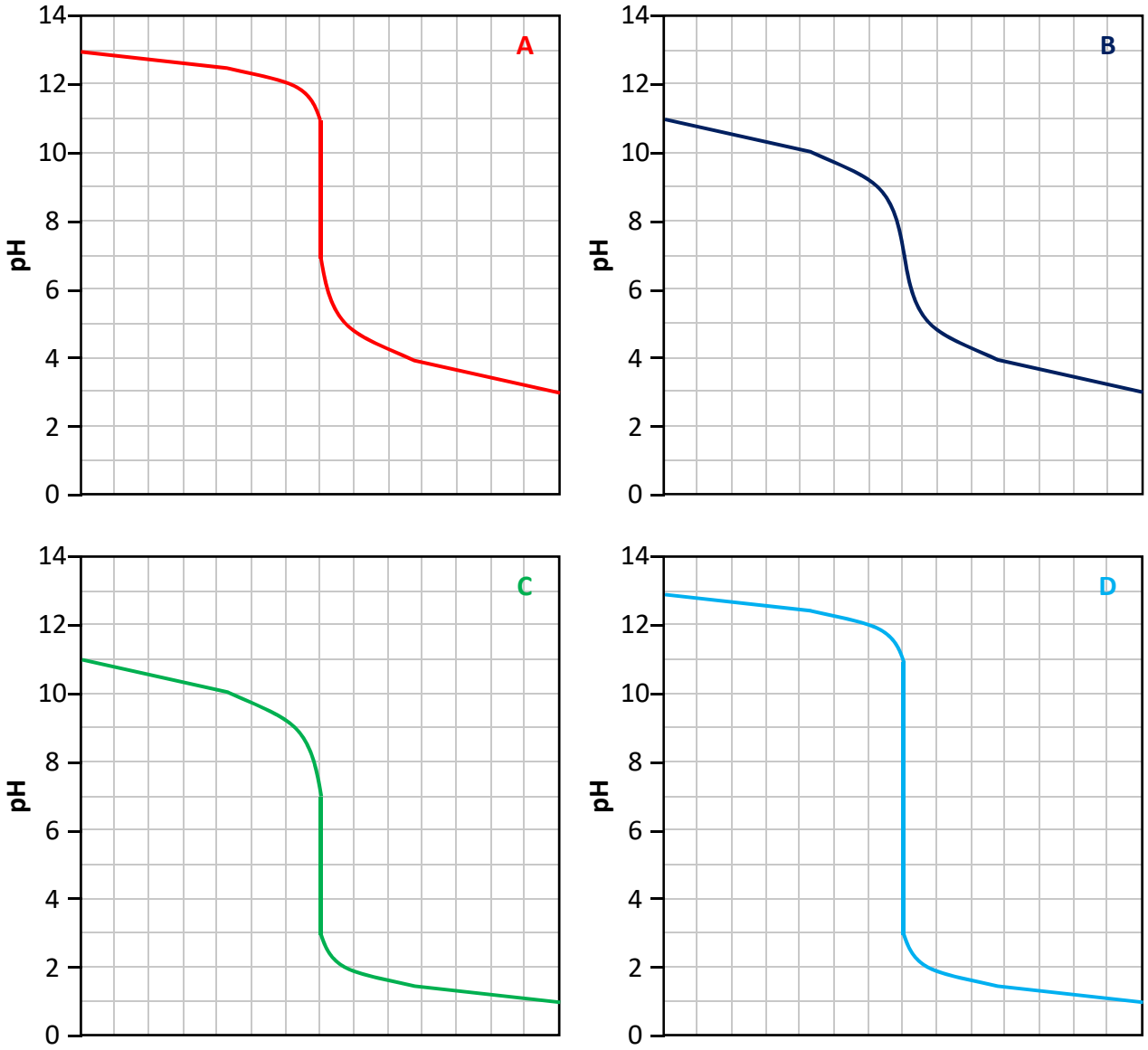
(ii) Distinguish between a strong acid and a weak acid.

A student carried out a number of acid-base titrations. She used a pH meter to measure how the pH of the solutions changed during each titration. She generated the pH curves shown on the next page.

(iii) Fill in the table to match the pH curves to the different types of reaction.

type of reaction	pH curve (A, B, C or D)
strong acid – strong base	
strong acid – weak base	
weak acid – strong base	
weak acid – weak base	

(iv) Explain why it is difficult to carry out an accurate weak acid – weak base titration.



(v) Explain why the student used a pH meter rather than universal indicator to measure the pH.

(vi) Name one variable which the student should have kept constant to make sure that she could make a fair comparison between the titrations.

(b) A different student carried out a titration using a weak acid (HA) and a standard solution of a base (XOH). The reaction is described by the following balanced chemical equation:

$$HA + XOH \rightarrow XA + H_2O$$

(i) Explain the importance of using a standard solution in a titration.

The XOH solution had a concentration 0.08 M. At the start of the titration, the student transferred a 20.0 cm^3 portion of the base into a conical flask.

(ii) Calculate the number of moles of XOH in the conical flask.

The student carried out a number of accurate titrations. The average value for the endpoint was found to be 11.4 cm^3 of HA.

(iii) Name the piece of equipment the student used to measure this volume of HA.

(iv) How many moles of HA did the student add?

(v) Calculate the concentration of HA.

The acid dissociation constant (K_a) for HA is 1.74×10^{-9}.

(vi) Calculate the pH of HA.

Question 7

(a) But-2-ene is the name given to two different hydrocarbon compounds that have the molecular formula C_4H_8. But-2-ene exists as two geometric isomers, *cis*-but-2-ene and *trans*-but-2-ene, which have similar physical and chemical properties.

(i) Identify one significant industrial use of hydrocarbon compounds.

(ii) Draw the molecular structure of *cis*-but-2-ene, including all atoms and bonds.

As part of a research investigation on hydrocarbons, a student learned that *cis*-but-2-ene and *trans*-but-2-ene have similar heats of combustion. However, the student also learned that the conversion between these two geometric isomers has a high activation energy, approximately 262 kJ mol^{-1}.

(iii) Explain why *cis*-but-2-ene and *trans*-but-2-ene have similar heats of combustion.

(iv) Write a balanced chemical equation for the complete combustion of but-2-ene, or any compound with the molecular formula C_4H_8.

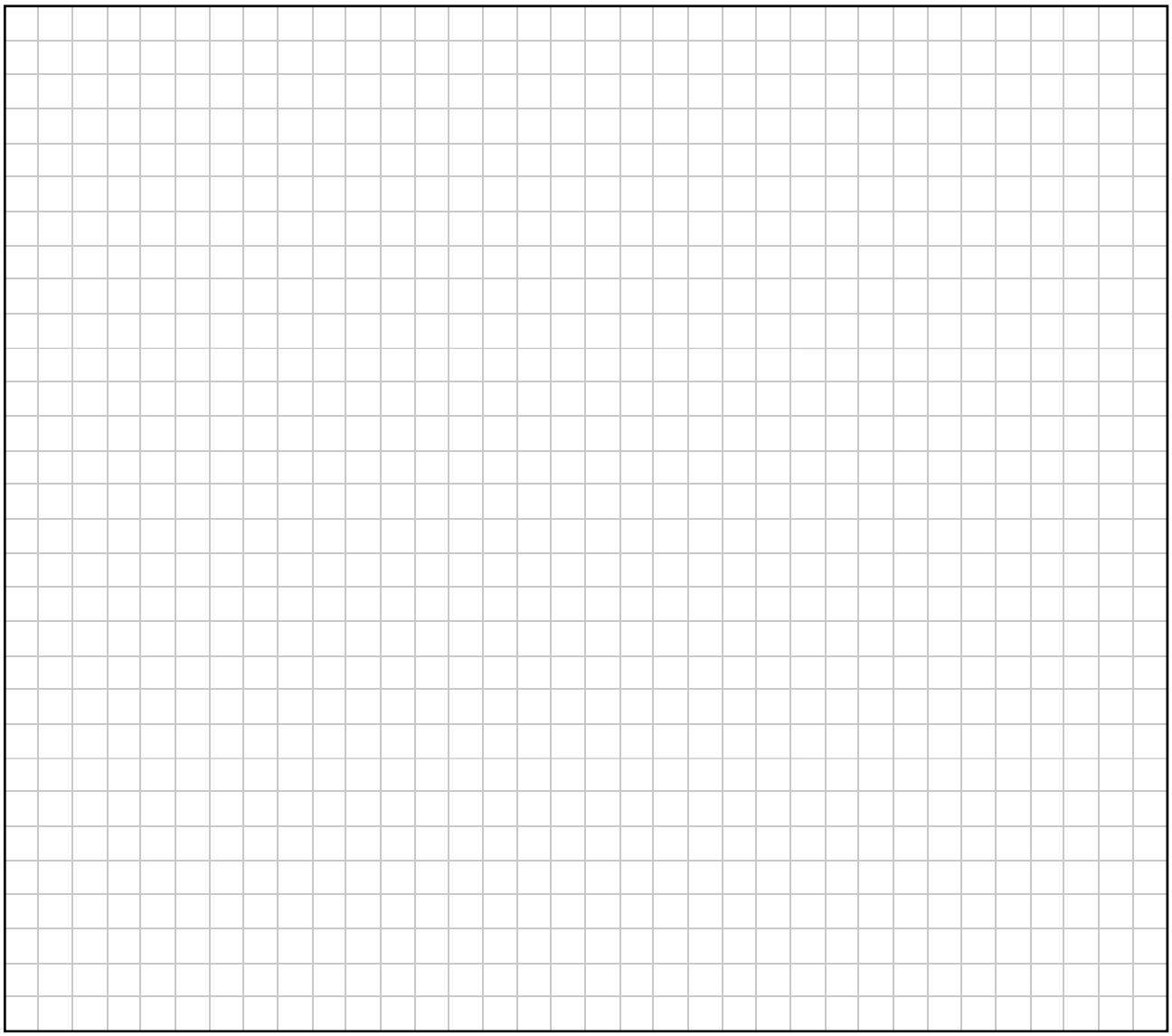
(v) Explain why the conversion between *cis*-but-2-ene and *trans*-but-2-ene has a high activation energy.

In addition to *cis*-but-2-ene and *trans*-but-2-ene, there are a number of other isomers with the molecular formula C_4H_8. One such isomer is but-1-ene.

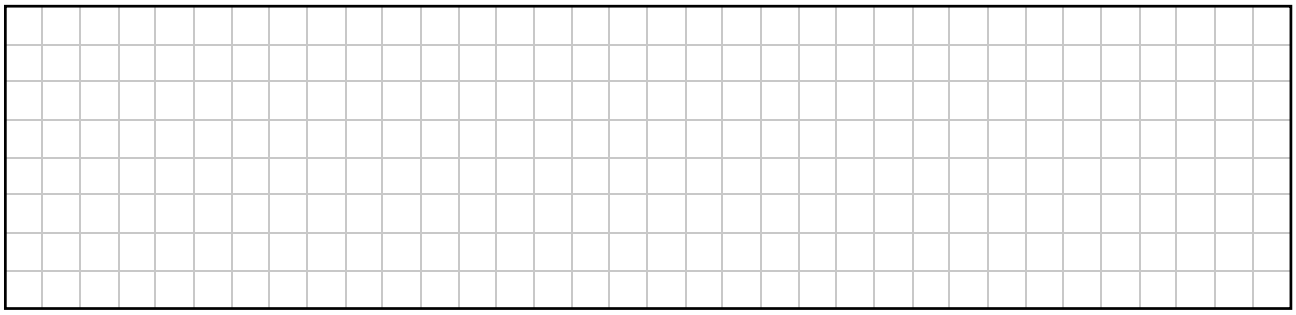
(vi) Explain why but-1-ene does not exhibit geometric isomerism.

(b) As part of your studies in Chemistry, you should have conducted an experiment to dehydrate ethanol so as to prepare and collect a sample of the hydrocarbon compound ethene (C_2H_4) in your school laboratory.

(i) Draw a labelled diagram of the arrangement of apparatus and chemicals you used during the laboratory preparation and collection of ethene.



(ii) When ethene is bubbled through a dilute pink-purple solution of acidified potassium permanganate ($KMnO_4$), the solution becomes colourless. Explain why this happens.

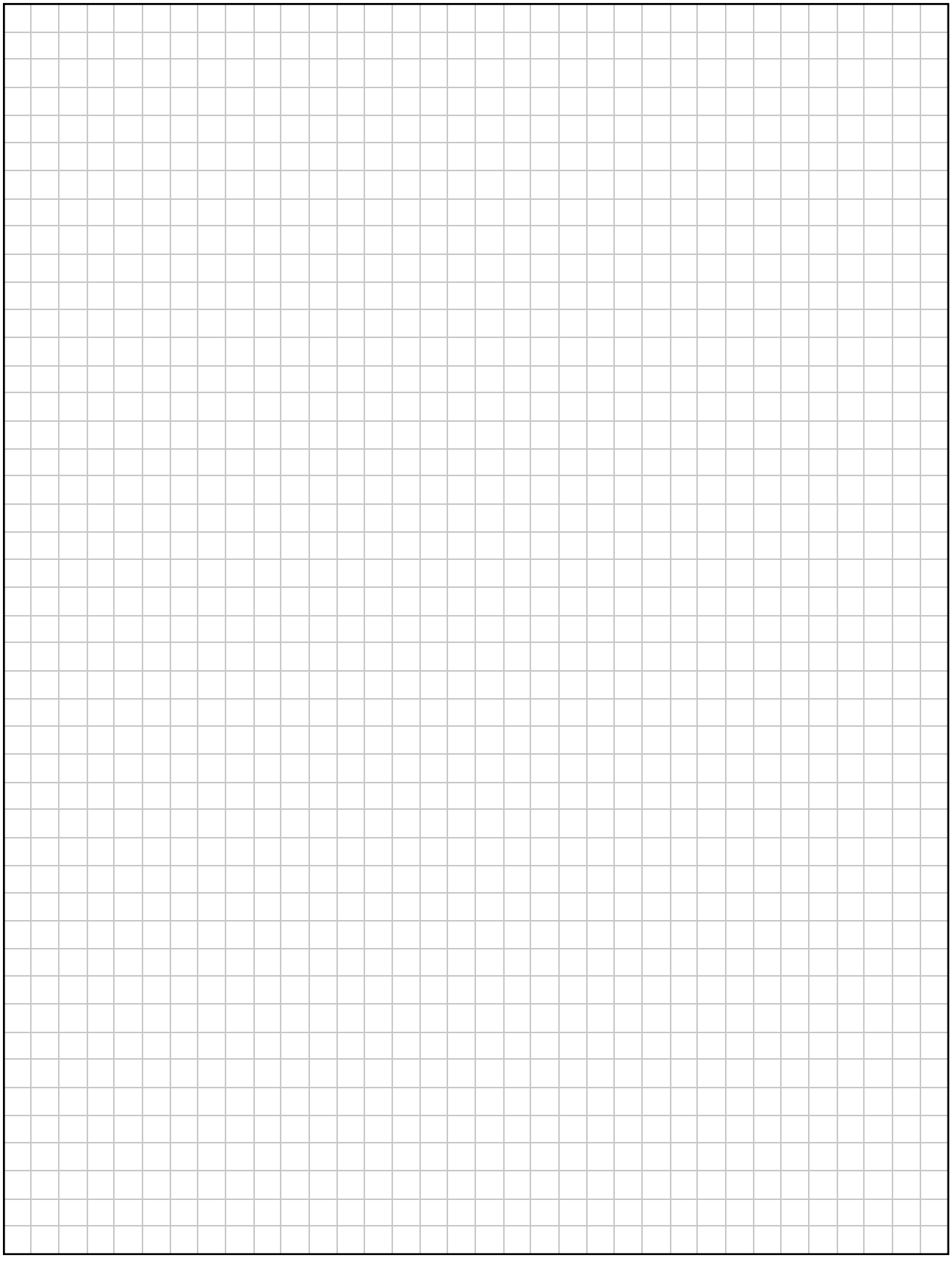


(iii) Describe the reaction mechanism for the ionic addition of chlorine (Cl_2) to ethene.
Your answer should include a drawing of the structure of any intermediate(s) formed and should show the movement of electrons during the reaction.

(iv) State the IUPAC name for the compound produced by the ionic addition of chlorine to ethene.

Page for extra work.

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



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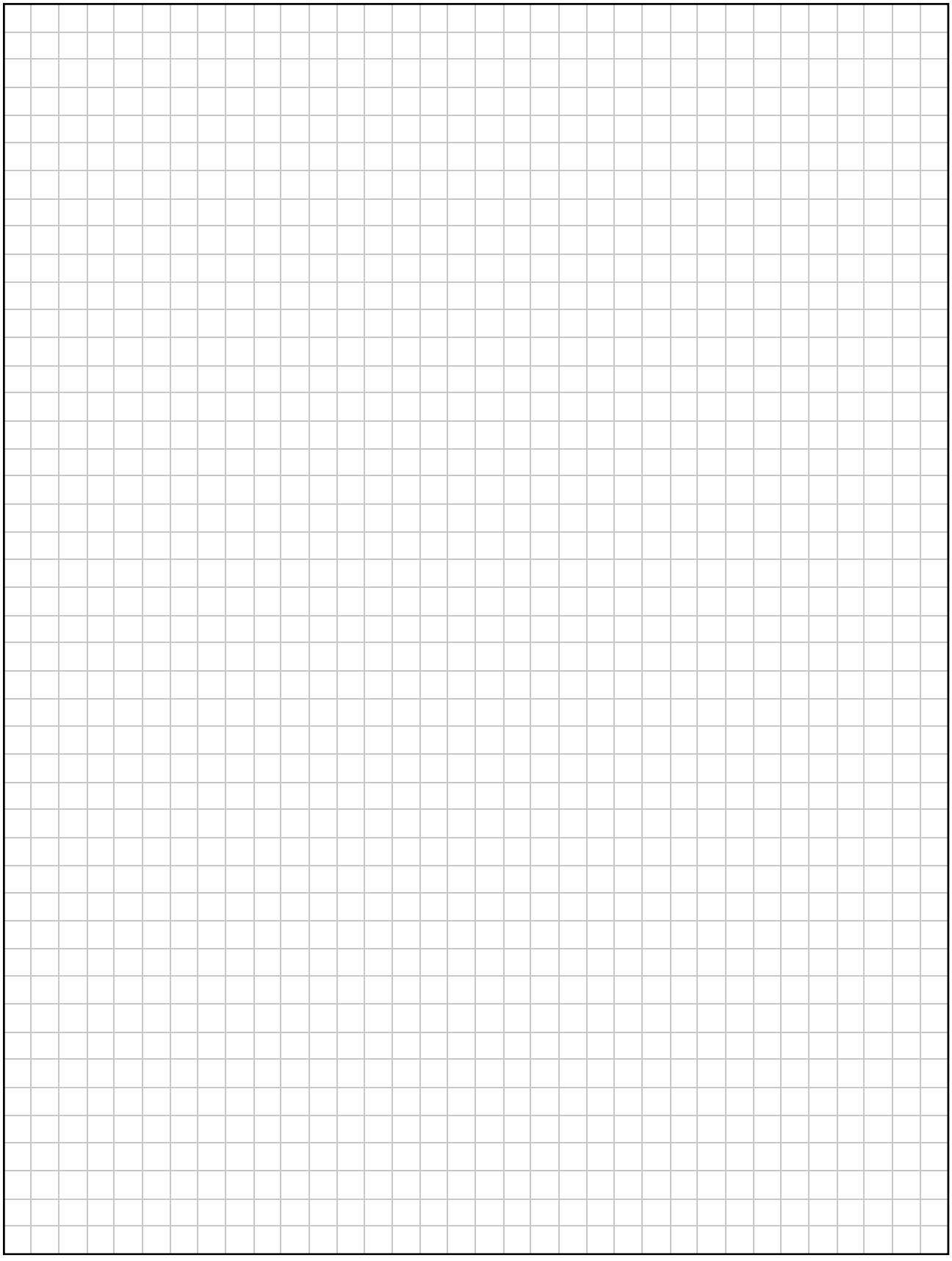

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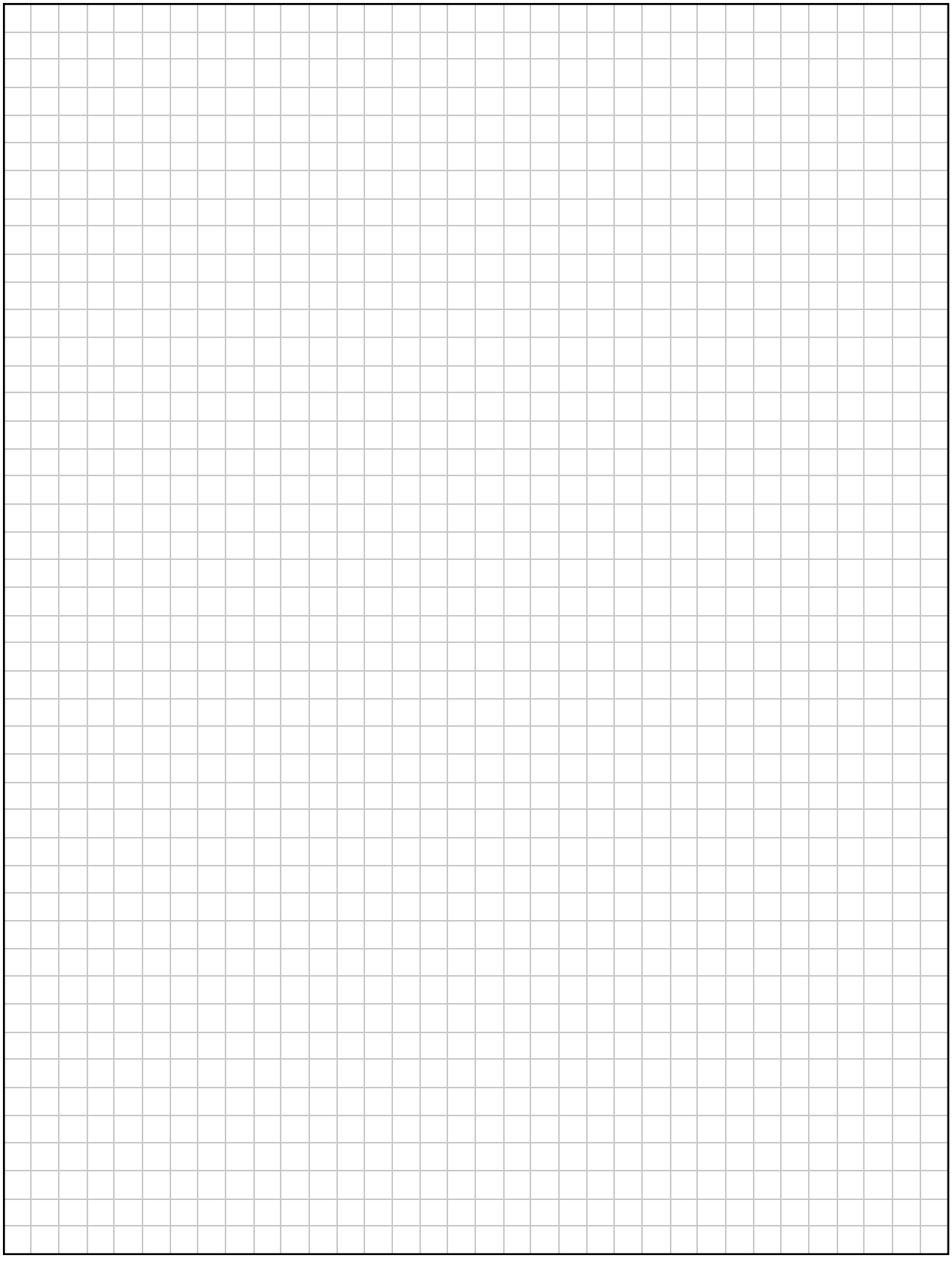

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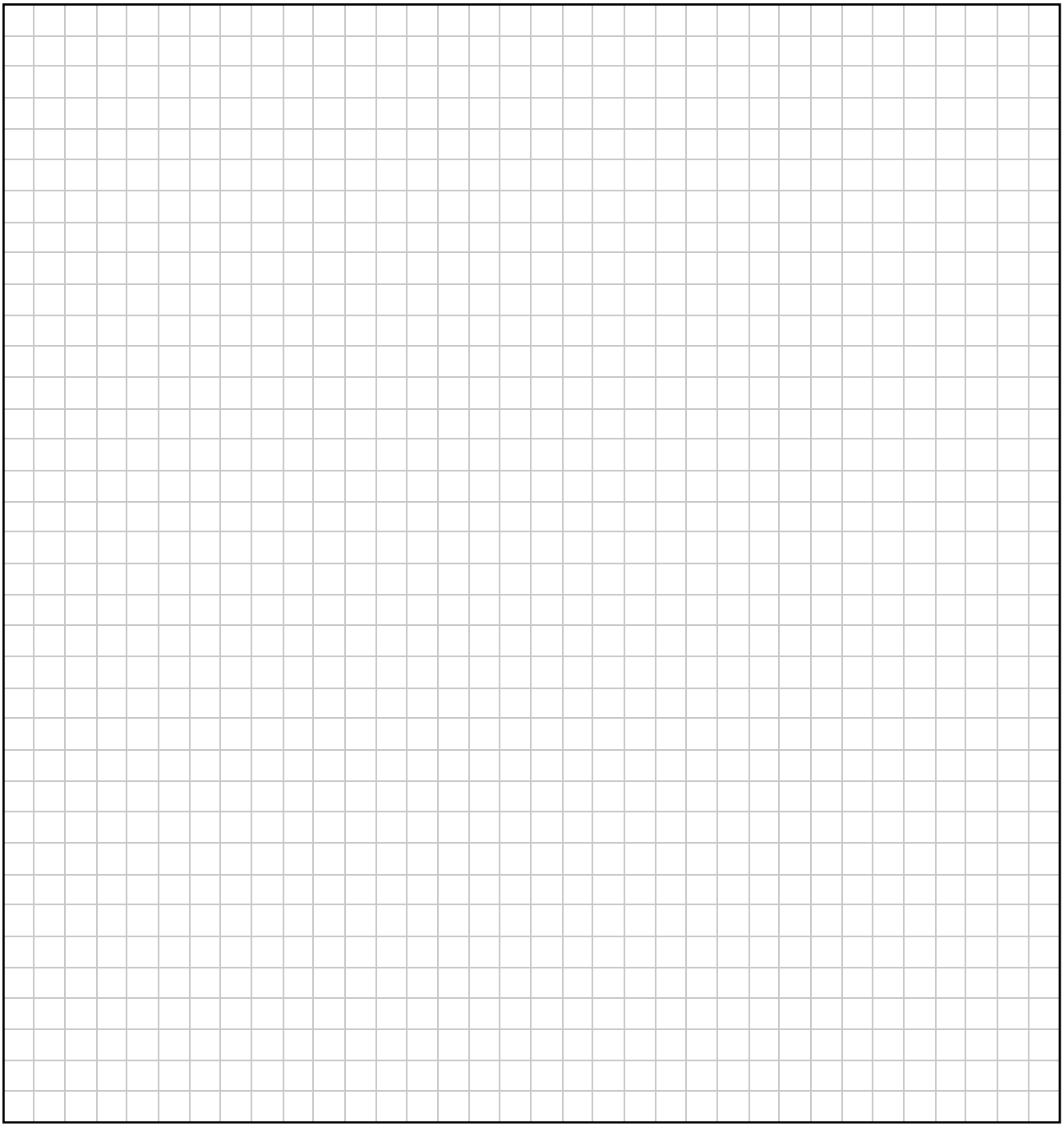

Acknowledgements

Images

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Image on page 7:	healthcastle.com
Images on page 8:	wikipedia.org
Image on page 11:	istockphoto.com
Image on page 21:	water.ie/projects/local-projects

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Leaving Certificate Examination – Higher Level

Chemistry

Sample 1

2 hours 30 minutes