**Q1.** A sample of hydrated nickel sulfate ($NiSO_4.xH_2O$) with a mass of 2.287 g was heated to remove all water of crystallisation. The solid remaining had a mass of 1.344 g.

(a) Calculate the value of the integer $x$.
Show your working.

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**(4)**

(b) Suggest how a student doing this experiment could check that all the water had been removed.

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**(2)**
**(Total 6 marks)**

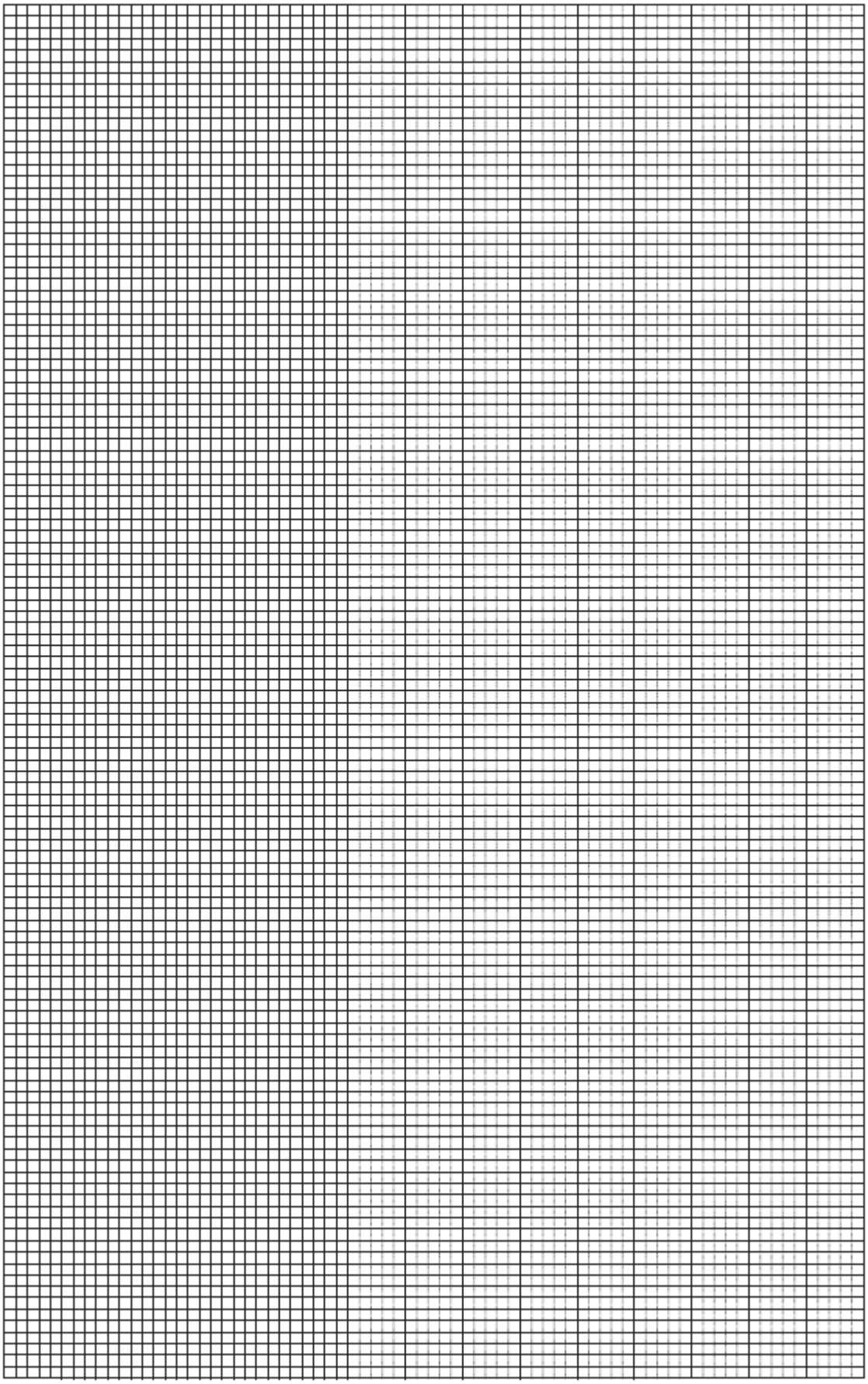
**Q2.** When boric acid ($H_3BO_3$) is applied as a coating on wood, it acts as a fire retardant by decreasing the rate of combustion.

Thermal decomposition of boric acid takes place in two stages.

In an experiment a sample of boric acid was heated in a crucible at 170 °C. The results of this experiment are given in the table.

| Time of heating / minutes | Mass of crucible and contents / g |
|---|---|
| 0 | 35.85 |
| 5 | 35.10 |
| 10 | 34.41 |
| 15 | 34.00 |
| 20 | 33.70 |
| 25 | 33.56 |
| 30 | 33.50 |
| 35 | 33.50 |

Plot a graph of the results from the table above to show the mass of the crucible and boric acid (*y*-axis) against time of heating on the grid.



**(Total 4 marks)**

**Q3.**(a) Calcium phosphate reacts with aqueous nitric acid to produce phosphoric acid and calcium nitrate as shown in the equation.

$$Ca_3(PO_4)_2 + 6HNO_3 \longrightarrow 2H_3PO_4 + 3Ca(NO_3)_2$$

(i) A 7.26 g sample of calcium phosphate reacted completely when added to an excess of aqueous nitric acid to form 38.0 $cm^3$ of solution.

Calculate the concentration, in mol $dm^{-3}$, of phosphoric acid in this solution.
Give your answer to 3 significant figures.

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**(5)**

(ii) Calculate the percentage atom economy for the formation of calcium nitrate in this reaction.
Give your answer to 1 decimal place.

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**(2)**

(b) Write an equation to show the reaction between calcium hydroxide and phosphoric

acid to produce calcium phosphate and water.

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**(1)**

(c) Calcium dihydrogenphosphate can be represented by the formula $Ca(H_2PO_4)_x$ where $x$ is an integer.
A 9.76 g sample of calcium dihydrogenphosphate contains 0.17 g of hydrogen, 2.59 g of phosphorus and 5.33 g of oxygen.

Calculate the empirical formula and hence the value of $x$.
Show your working.

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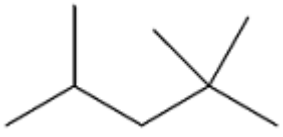
**(4)**
**(Total 12 marks)**

**Q4.** Isooctane ($C_8H_{18}$) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isooctane is shown below.



(a) Give the IUPAC name for isooctane.

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**(1)**

(b) Deduce the number of peaks in the $^{13}C$ NMR spectrum of isooctane.

5 ⬭

6 ⬭

7 ⬭

8 ⬭

**(1)**

(c) Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

.....

**(1)**

(d) How do the products of the reaction in part (c) show that the reaction is an example of thermal cracking?

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**(1)**

(e) Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

Number of monochloro isomers .....

Structure

**(2)**

(f) An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the **skeletal formula** of this monochloro compound.

**(1)**

(g) A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes $^{35}Cl$ and $^{37}Cl$ in the ratio 1.5 : 1.0
Calculate the $M_r$ of this monochlorooctane.

$M_r$ = .....

**(2)**

(h) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds.
One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass.
Calculate the molecular formula of this compound.

Molecular formula = .....

**(3)**
**(Total 12 marks)**

**Q5.** Glucose can decompose in the presence of microorganisms to form a range of products. One of these is a carboxylic acid ($M_r$ = 88.0) containing 40.9% carbon and 4.5% hydrogen by mass.

(a) Deduce the empirical and molecular formulas of the carboxylic acid formed.

Empirical formula = ..... Molecular formula = .....

**(4)**

(b) Ethanol is formed by the fermentation of glucose.
A student carried out this fermentation reaction in a beaker using an aqueous solution of glucose at a temperature of 25 °C in the presence of yeast.

Write an equation for the reaction occurring during fermentation.

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**(1)**

(c) In industry, this fermentation reaction is carried out at 35 °C rather than 25 °C.

Suggest **one** advantage and **one** disadvantage for industry of carrying out the fermentation at this higher temperature.

Advantage .....

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Disadvantage .....

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**(2)**

(d) The method used by the student in part (b) would result in the ethanol being

contaminated by ethanoic acid.

How does this contamination occur?

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**(1)**

(e) Give **two** differences between the infrared spectrum of a carboxylic acid and that of an alcohol other than in their fingerprint regions.
Use **Table A** on the Data Sheet.

Difference 1 .....

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Difference 2 .....

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**(2)**
**(Total 10 marks)**