

Empirical + Molecular Formula

Question Paper 1

Level	A Level
Subject	Chemistry
Exam Board	AQA
Module	3.1 Physical Chemistry
Topic	3.1.2 Amount of Substance
Sub-Topic	3.1.2.4 Empirical + Molecular Formula
Booklet	Question Paper 1

Time Allowed: 49 minutes

Score: /44

Percentage: /100

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

Q1. A sample of hydrated nickel sulfate ($\text{NiSO}_4 \cdot x\text{H}_2\text{O}$) 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)

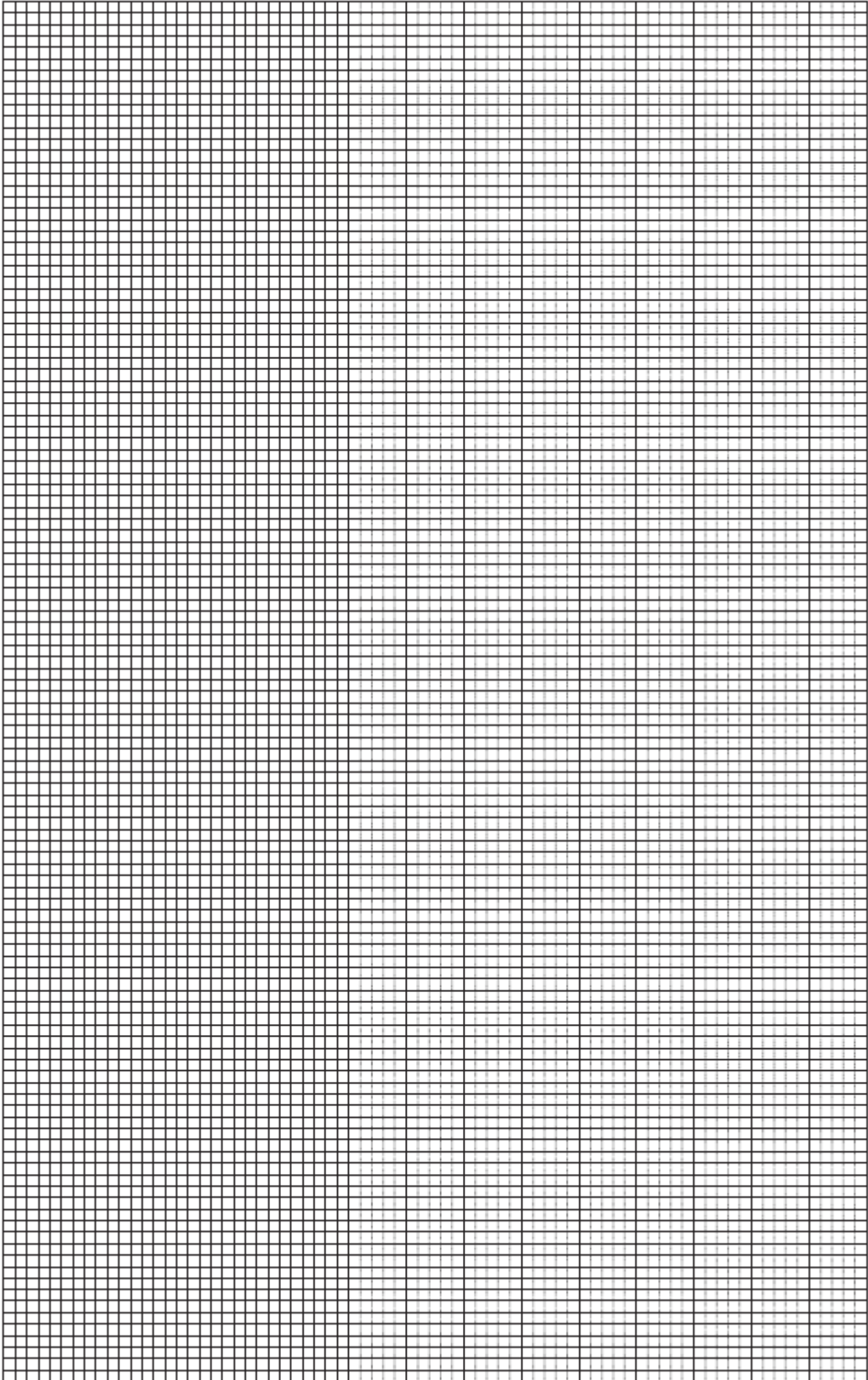
Q2. When boric acid (H_3BO_3) is applied as a coating on wood, it acts as a fire retardant by decreasing the rate of combustion.

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.



- (i) A 7.26 g sample of calcium phosphate reacted completely when added to an excess of aqueous nitric acid to form 38.0 cm³ 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 $\text{Ca}(\text{H}_2\text{PO}_4)_x$, 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.

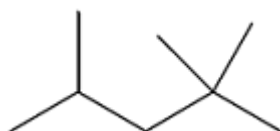
Calculate the empirical formula and hence the value of x .
Show your working.

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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.

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(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.

$M_r = \dots\dots\dots$

(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)