**Q1.** Magnesium carbonate, $MgCO_3$, can occur as the anhydrous compound, or as hydrates with 2, 3 or 5 molecules of water of crystallisation. All types of magnesium carbonate can be decomposed to form magnesium oxide, an important starting material for many processes. This decomposition reaction can be used to identify the type of magnesium carbonate present in a mineral.

A chemist was asked to identify the type of magnesium carbonate present in a mineral imported from France. The chemist weighed a clean dry crucible, and transferred 0.25 g of the magnesium carbonate mineral to the crucible. The crucible was then heated for a few minutes. The crucible was then allowed to cool, and the crucible and its contents were reweighed. This process was repeated until the crucible and its contents had reached constant mass. The mass of the crucible and its contents was then recorded.

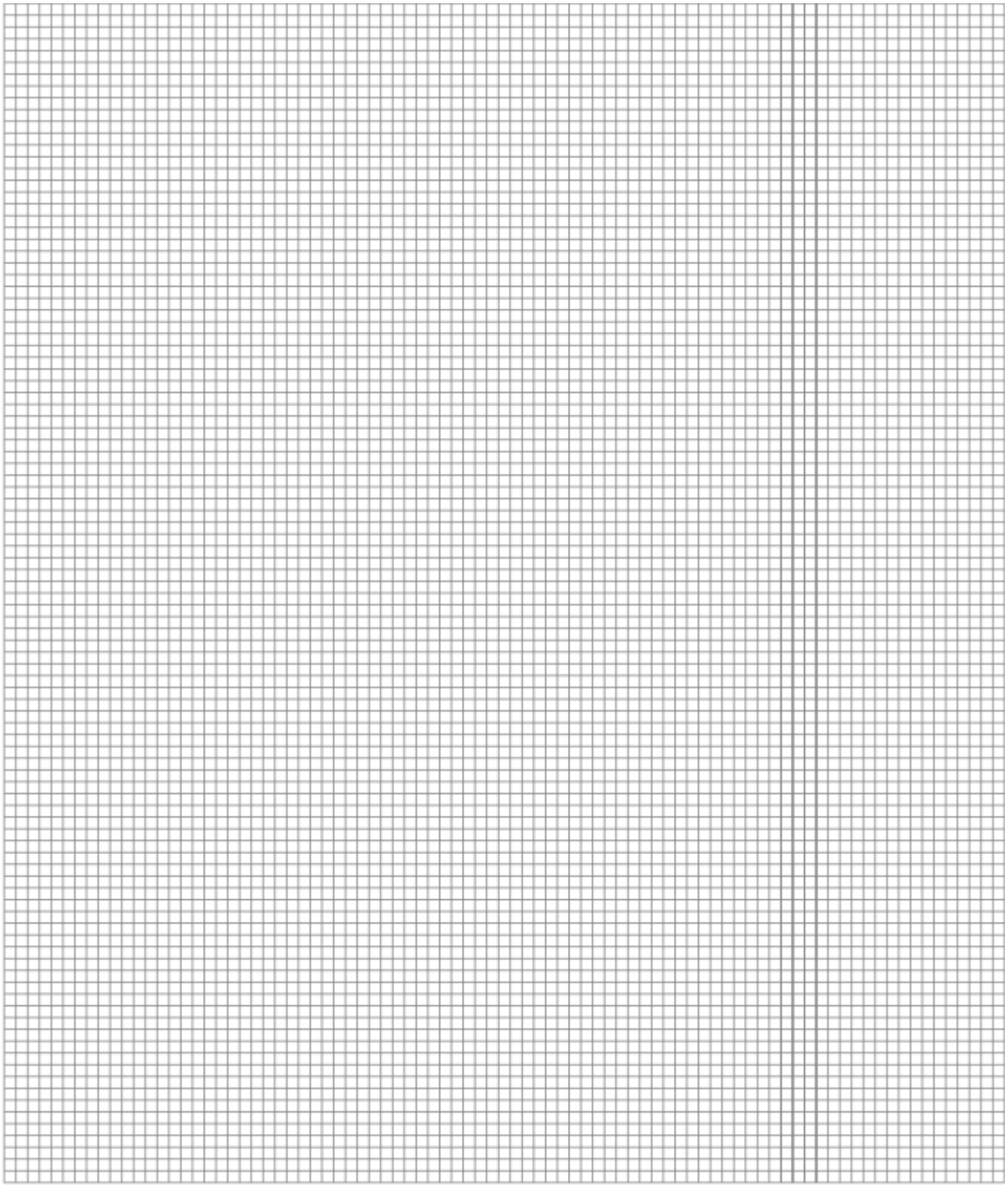
The experiment was repeated using different masses of the magnesium carbonate mineral.

For each experiment the chemist recorded the original mass of the mineral and the mass of magnesium oxide left after heating to constant mass. The chemist's results are shown in the table below.

| Experiment | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Mass of mineral / g | 1.60 | 1.17 | 0.74 | 1.31 | 1.80 | 1.34 |
| Mass of magnesium oxide / g | 0.54 | 0.39 | 0.24 | 0.44 | 0.61 | 0.49 |

(a) Plot a graph of the mass of the mineral ($x$-axis) against the mass of magnesium oxide on the grid below.

Draw a straight line of best fit on your graph.



**(4)**

(b) Use the graph to determine the mass of the mineral which would have formed 0.50 g of magnesium oxide.

Mass of the mineral .....

**(1)**

(c) Calculate the amount, in moles, of MgO present in 0.50 g of magnesium oxide.

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**(1)**

(d) Use your answers from part (b) and from part (c) to calculate the $M_r$ of the magnesium carbonate present in the mineral.

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**(1)**

(e) Use your answer from part (d) to confirm that this mineral is $MgCO_3.2H_2O$

(If you could not complete the calculation in part (d), you should assume that the experimental $M_r$ value is 122.0 This is not the correct answer.)

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**(1)**

(f) Explain why it was **not** necessary to use a more precise balance in this experiment.

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**(1)**

(g) Consider your graph and comment on the results obtained by the chemist. Identify any anomalous results.

Comment .....

.....

Anomalous results .....

.....

**(2)**

(h) Explain why it was necessary for the chemist to heat the crucible and its contents to constant mass.

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**(1)**

(i) Suggest **one** reason in each case why

(i) small amounts of the mineral, such as 0.10 g, should **not** be used in this experiment.

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**(1)**

(ii) large amounts of the mineral, such as 50 g, should **not** be used in this experiment.

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**(1)**

(j) Analysis of a different hydrated magnesium carbonate showed that it contained 39.05% by mass of water. Determine the formula of this hydrated magnesium carbonate.

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.....

**(2)**

(k) Magnesium oxide is produced by the thermal decomposition of magnesium

carbonate and by the thermal decomposition of magnesium hydroxide. The equations for the reactions taking place are shown below.

| | | | |
|---|---|---|---|
| Reaction 1 | $MgCO_3$ | → | $MgO + CO_2$ |
| Reaction 2 | $Mg(OH)_2$ | → | $MgO + H_2O$ |

Show that Reaction 2 has the greater atom economy for the production of magnesium oxide.

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**(2)**

(l) Apart from cost, suggest **one** advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

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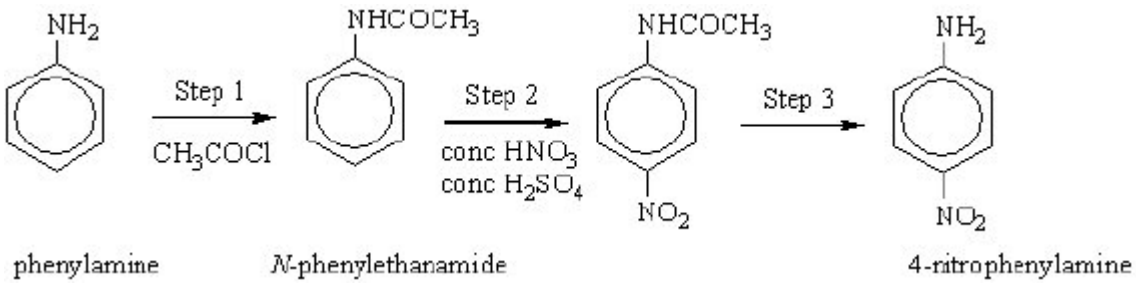
**(1)**

**(Total 19 marks)**

**Q2.** Synthetic dyes can be manufactured starting from compounds such as 4-nitrophenylamine.

A synthesis of 4-nitrophenylamine starting from phenylamine is shown below.




(a) An equation for formation of *N*-phenylethanamide in Step 1 of the synthesis is shown below.

$$2C_6H_5NH_2 + CH_3COCl \rightarrow \underset{\text{N-phenylethanamide}}{C_6H_5NHCOCH_3} + C_6H_5NH_3Cl$$

(i) Calculate the % atom economy for the production of *N*-phenylethanamide ($M_r$ = 135.0).

(ii) In a process where 10.0 kg of phenylamine are used, the yield of *N*-phenylethanamide obtained is 5.38 kg.

Calculate the percentage yield of *N*-phenylethanamide.

(iii) Comment on your answers to parts (i) and (ii) with reference to the commercial viability of the process.

**(7)**

(b) Name and outline a mechanism for the reaction in Step 1.

**(5)**

(c) The mechanism of Step 2 involves attack by an electrophile. Write an equation showing the formation of the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

**(4)**

**(Total 16 marks)**

**Q3.** A metal carbonate $MCO_3$ reacts with hydrochloric acid as shown in the following equation.

$$MCO_3 + 2HCl \rightarrow MCl_2 + H_2O + CO_2$$

A 0.548 g sample of $MCO_3$ reacted completely with 30.7 $cm^3$ of 0.424 mol $dm^{-3}$ hydrochloric acid.

(a) (i) Calculate the amount, in moles, of HCl which reacted with 0.548 g $MCO_3$

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**(1)**

(ii) Calculate the amount, in moles, of $MCO_3$ in 0.548 g.

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**(1)**

(iii) Calculate the relative formula mass of $MCO_3$

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**(1)**

(b) Use your answer from part (a)(iii) to deduce the relative atomic mass of metal M and suggest its identity.
(If you have been unable to calculate a value for the relative formula mass of $MCO_3$ you should assume it to be 147.6 but this is not the correct answer.)

Relative atomic mass .....

.....

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Identity of M .....

**(2)**
**(Total 5 marks)**

**Q4.** Titanium(IV) oxide ($TiO_2$, $M_r$ = 79.9) is used as a white pigment in some paints. The pigment can be made as shown in the following equation.

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(aq)$$

(a) (i) Calculate the percentage atom economy for the formation of $TiO_2$

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**(2)**

(ii) In view of the low atom economy of this reaction, suggest how a company can maximise its profits without changing the reaction conditions or the production costs.

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**(1)**

(b) In an experiment 165 g of $TiCl_4$ were added to an excess of water.

(i) Calculate the amount, in moles, of $TiCl_4$ in 165 g.

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**(2)**

(ii) Calculate the maximum amount, in moles, of $TiO_2$ which can be formed in this experiment.

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**(1)**

(iii) Calculate the maximum mass of $TiO_2$ formed in this experiment.

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**(1)**

(iv) In this experiment only 63.0 g of $TiO_2$ were produced. Calculate the percentage yield of $TiO_2$

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**(1)**

**(Total 8 marks)**