



**Cambridge International Examinations**  
Cambridge Ordinary Level

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**CHEMISTRY**

**5070/22**

Paper 2 Theory

**October/November 2014**

**1 hour 30 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

**DO NOT WRITE IN ANY BARCODES.**

**Section A**

Answer **all** questions.

Write your answers in the spaces provided in the Question Paper.

**Section B**

Answer any **three** questions.

Write your answers in the spaces provided in the Question Paper.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

A copy of the Periodic Table is printed on page 20.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **20** printed pages.

## Section A

Answer **all** the questions in this section in the spaces provided.

The total mark for this section is 45.

**A1** The diagram shows part of the Periodic Table. Only some of the elements are shown.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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**(a)** Answer each of the following questions using only those elements shown in the diagram. Each element may be used once, more than once or not at all.

Give one element which

**(i)** is a simple molecular solid at room temperature and pressure,  
 .....[1]

**(ii)** oxidises in the presence of water and air to form rust,  
 .....[1]

**(iii)** has an atom with three occupied electron shells, the outer of which has only 5 electrons,  
 .....[1]

**(iv)** has an oxide which is amphoteric,  
 .....[1]

**(v)** has a chloride of type  $XC\ell_3$  whose aqueous solution forms a reddish-brown precipitate on addition of aqueous ammonia,  
 .....[1]

**(vi)** is a colourless diatomic gas.  
 .....[1]

(b) (i) Arsenic reacts with oxygen to form arsenic(III) oxide,  $\text{As}_2\text{O}_3$ .

Construct the equation for this reaction.

.....[1]

(ii) Arsenic(III) oxide is slightly soluble in water. A weak acid, arsenous acid,  $\text{H}_3\text{AsO}_3$ , is formed.

Use kinetic particle theory to explain why a  $0.05 \text{ mol/dm}^3$  solution of arsenous acid reacts much more slowly with magnesium ribbon than a  $0.05 \text{ mol/dm}^3$  solution of hydrochloric acid.

.....  
.....  
.....  
.....[2]

[Total: 9]

**A2** The table shows some properties of the Group I metals.

| metal     | density<br>in g/cm <sup>3</sup> | melting point<br>/°C | boiling point<br>/°C |
|-----------|---------------------------------|----------------------|----------------------|
| lithium   | 0.53                            | 181                  | 1342                 |
| sodium    | 0.97                            | 98                   | 883                  |
| potassium | 0.86                            | 63                   |                      |
| rubidium  | 1.53                            | 39                   | 686                  |
| caesium   | 1.88                            | 29                   | 669                  |

**(a) (i)** Describe the general trend in the density of the Group I metals.

.....[1]

**(ii)** Predict the boiling point of potassium.

.....[1]

**(iii)** What is the physical state of caesium at 35 °C? Explain your answer.

.....  
 .....[1]

**(b) (i)** Describe the trend in reactivity of the Group I metals with water.

.....[1]

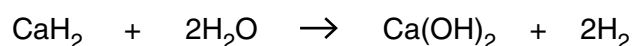
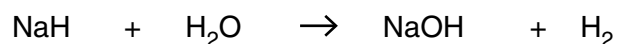
**(ii)** Construct the equation for the reaction of rubidium with water.

.....[1]

**(iii)** The reaction of rubidium with water is exothermic.  
 What is meant by the term *exothermic*?

.....[1]

**(c)** Sodium and calcium form ionic hydrides containing the hydride ion, H<sup>-</sup>.  
 Sodium and calcium hydrides react with water to form the hydroxide and hydrogen.



Deduce the general ionic equation for these reactions.

.....[1]

(d) Sodium is a soft metal with little catalytic activity.  
Nickel is a hard metal which is often used as a catalyst.

(i) Describe two **other** differences in the physical properties of sodium and nickel.

1 .....

.....

2 .....

.....

[2]

(ii) State one industrial use of nickel as a catalyst.

.....[1]

(iii) Explain why an alloy of nickel and copper is less malleable than copper alone.

.....

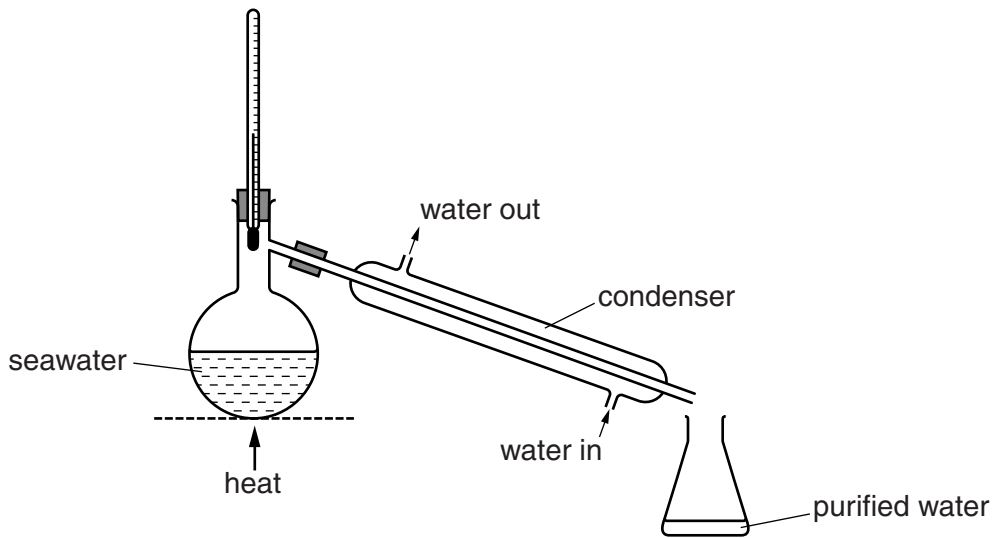
.....

.....[2]

[Total: 12]

**A3** Seawater contains a variety of dissolved salts.

- (a) The diagram shows a simple distillation apparatus that can be used to produce purified water from seawater.



Explain how distillation purifies seawater.

.....

.....

.....

.....[3]

- (b) Magnesium chloride,  $MgCl_2$ , is present in seawater at a concentration of  $1.26\text{ g/dm}^3$ .

(i) Write the formulae for the ions present in magnesium chloride.

.....[1]

(ii) Calculate the concentration of chloride ions, in  $\text{mol/dm}^3$ , arising from the magnesium chloride in seawater.

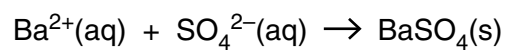
concentration = .....  $\text{mol/dm}^3$  [1]

(iii) Aqueous silver nitrate is added to a small sample of seawater. Describe what you would observe.

.....[1]

- (c) The concentration of sulfate ions in seawater is  $1.24 \text{ g/dm}^3$ .  
Excess aqueous barium chloride is added to a  $50.0 \text{ cm}^3$  sample of seawater.

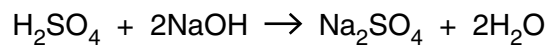
Calculate the mass of barium sulfate precipitated in this reaction.



mass = ..... g [3]

[Total: 9]

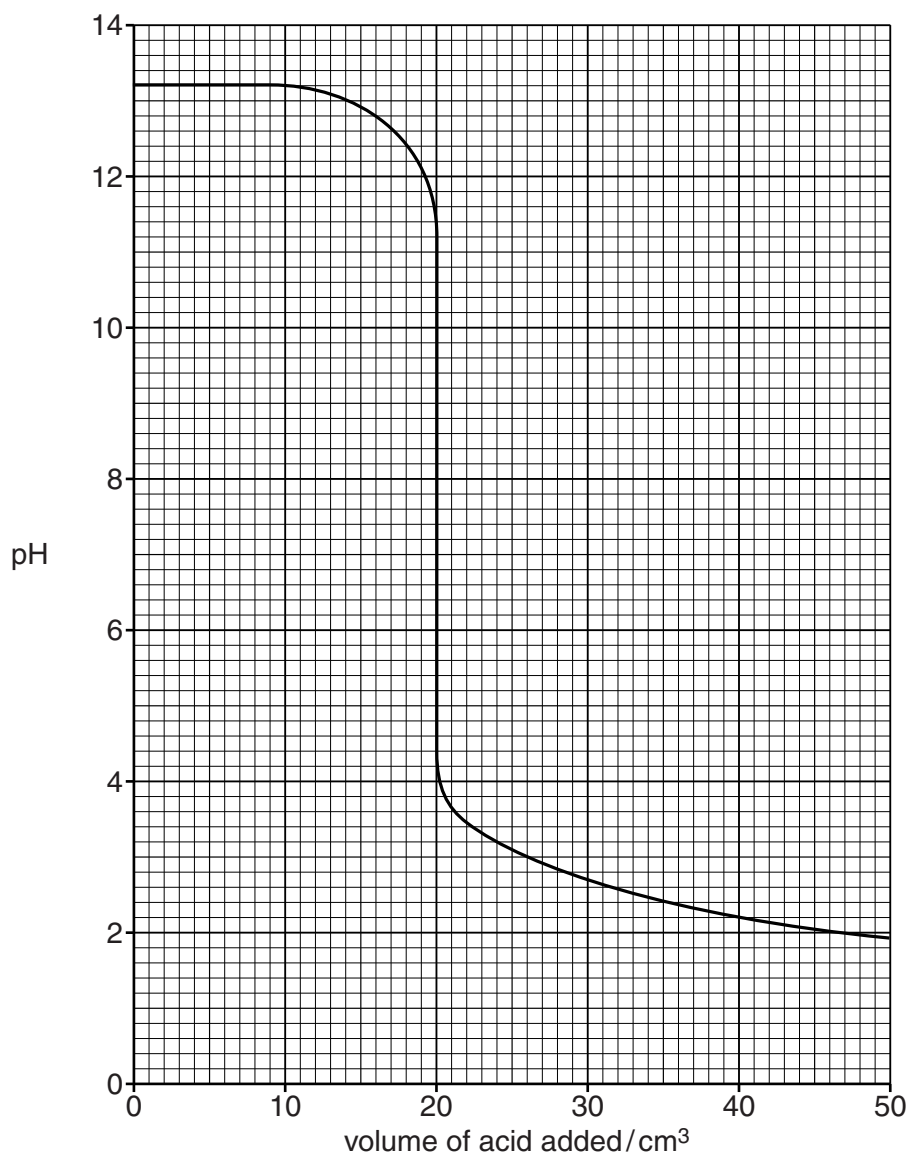
**A4** Sulfuric acid reacts with the alkali sodium hydroxide.



**(a)** Write the ionic equation for this reaction.

.....[1]

**(b)** The graph below shows how the pH changes when aqueous sulfuric acid is added slowly to 45.0 cm<sup>3</sup> of 0.150 mol/dm<sup>3</sup> sodium hydroxide until the acid is in excess.



**(i)** What volume of acid has been added when the pH is 7?

.....[1]



- (ii) Use your answer to part (i) to calculate the concentration, in mol/dm<sup>3</sup>, of the sulfuric acid.

concentration = ..... mol/dm<sup>3</sup> [3]

- (c) The experiment was repeated using ethanoic acid of the same concentration as the sulfuric acid. The same volume and concentration of aqueous sodium hydroxide was used.

- (i) The volume of ethanoic acid required to neutralise the aqueous sodium hydroxide was twice as great compared with the volume of sulfuric acid.

Explain why.

.....  
.....[1]

- (ii) Suggest the value of the pH after excess ethanoic acid has been added.  
.....[1]

- (d) Sulfuric acid is one of the acids present in acid rain.

- (i) Suggest how sulfuric acid is formed in the atmosphere.  
.....  
.....  
.....[2]

- (ii) State one effect of acid rain on human health.  
.....[1]

[Total: 10]

**A5** The table below shows the reactivity of five metals with either cold water or steam or with both.

| metal     | reactivity   |
|-----------|--|
| barium    | reacts rapidly with cold water                           |
| copper    | no reaction with steam or cold water                     |
| magnesium | reacts very slowly with cold water but reacts with steam |
| sodium    | reacts very rapidly with cold water                      |
| nickel    | only reacts when powdered and heated strongly in steam   |

**(a)** Deduce the order of reactivity of these metals using the information in the table.

most reactive

↑

.....

.....

.....

.....

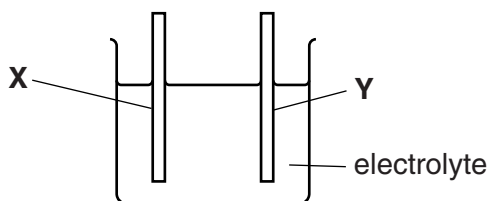
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least reactive

[1]

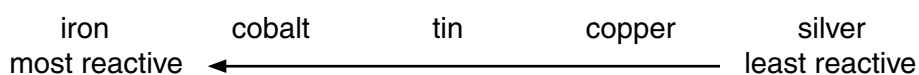
**(b)** A simple electrochemical cell contains two electrodes in an electrolyte.

**(i)** Complete the diagram below to show how you could measure the voltage between the two different metal electrodes **X** and **Y**.



[1]

**(ii)** The order of reactivity of some metals is shown below.



Which combination of metals from this list would produce the highest voltage when used as electrodes in an electrochemical cell?

.....[1]

- (c) Strips of zinc can be attached to the hull of a ship to stop the steel from rusting. Explain how these strips of zinc stop the steel from rusting.

.....  
.....  
.....[2]

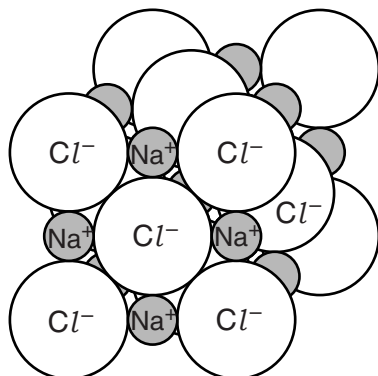
[Total: 5]

**Section B**

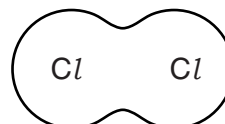
Answer **three** questions from this section in the spaces provided.

The total mark for this section is 30.

**B6** The structures of sodium chloride and chlorine are shown below.



sodium chloride



chlorine

- (a) The melting point of sodium chloride is  $801\text{ }^{\circ}\text{C}$ .  
The melting point of chlorine is  $-101\text{ }^{\circ}\text{C}$ .

Explain, in terms of structure and bonding, the difference between the melting points of these two substances.

.....

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.....[4]

- (b) Explain why molten sodium chloride conducts electricity but solid sodium chloride does not.

.....

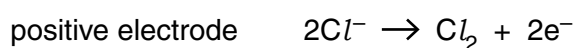
.....

.....[1]

(c) Draw a 'dot-and-cross' diagram for sodium chloride, showing all the electron shells.

[2]

(d) The electrode reactions occurring when molten sodium chloride is electrolysed are shown below.



Refer to these equations to explain why this electrolysis involves both oxidation and reduction.

.....  
 .....  
 .....[2]

(e) Chlorine reacts with excess ammonia,  $\text{NH}_3$ , to form hydrogen chloride and nitrogen. Construct an equation for this reaction.

.....[1]

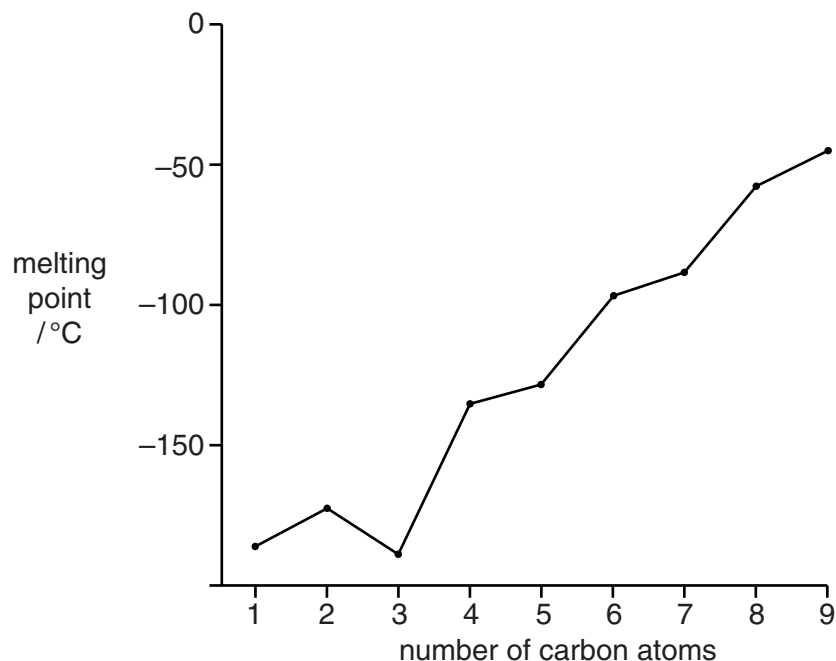
[Total: 10]

**B7** The alkanes are a homologous series of hydrocarbons.

(a) Give the name of another homologous series of hydrocarbons.

.....[1]

(b) The graph below shows how the melting points of the first nine alkanes vary with the number of carbon atoms.



Describe how the melting points of the alkanes with more than two carbon atoms vary as the number of carbon atoms increases.

.....  
 .....  
 .....[2]

(c) Nonane is an alkane with nine carbon atoms.  
 Give the molecular formula for nonane.

.....[1]

(d) One mole of undecane,  $C_{11}H_{24}$ , is cracked to form a mixture containing one mole of ethene, one mole of propene and one mole of another hydrocarbon.

(i) Construct the equation for this reaction.

.....[1]

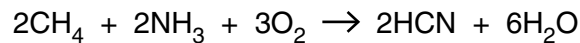
(ii) Explain why oil companies crack the longer chain hydrocarbons.

.....

.....

.....[2]

(e) Hydrogen cyanide, HCN, is manufactured by reacting methane with ammonia and oxygen.



(i) Calculate the mass of hydrogen cyanide that can be formed from 500 g of methane if the percentage yield of hydrogen cyanide is 65%.

mass = .....g [2]

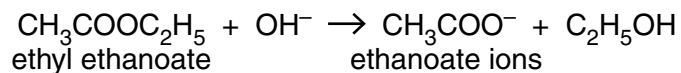
(ii) Hydrogen cyanide reacts with calcium hydroxide to form calcium cyanide and water. The formula of the cyanide ion is  $CN^-$ .

Construct the equation for this reaction.

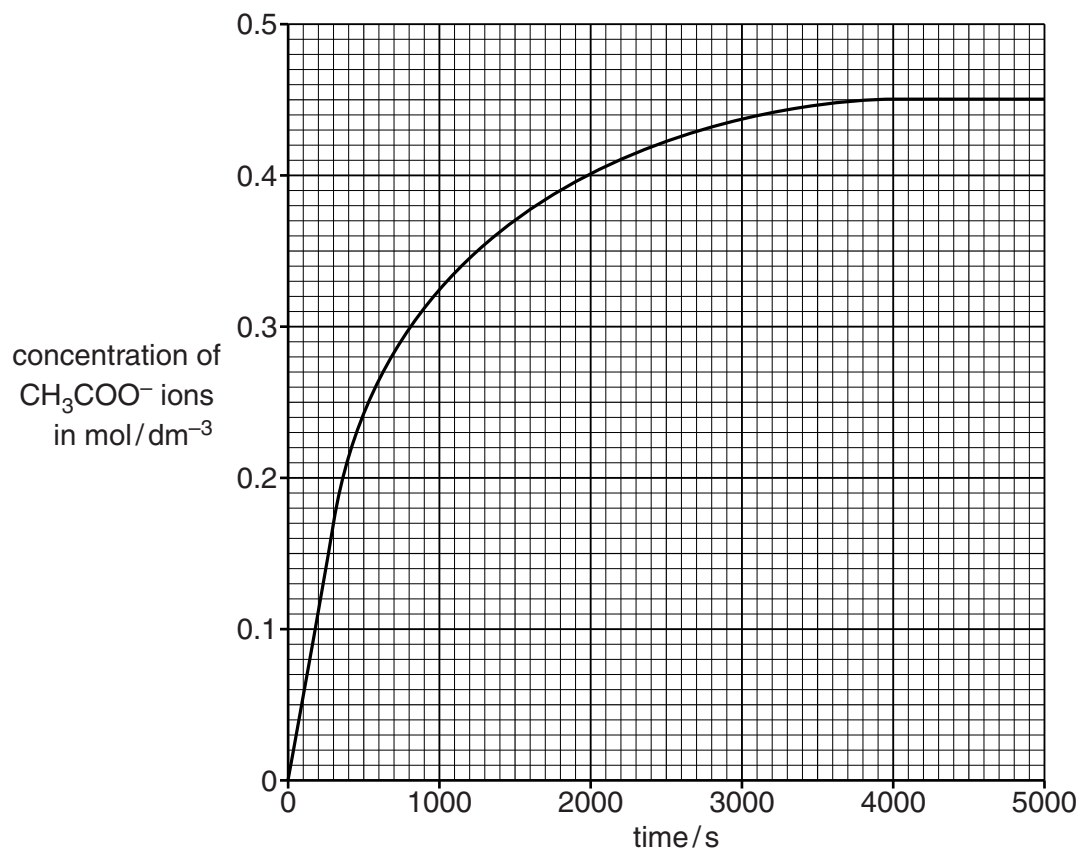
.....[1]

[Total: 10]

**B8** The ester, ethyl ethanoate, reacts with hydroxide ions to form ethanoate ions and ethanol.



- (a) The graph shows how the concentration of ethanoate ions,  $\text{CH}_3\text{COO}^-$ , changes as the reaction proceeds.



- (i) Use the information in the graph to deduce the mass of ethanoate ions in  $200\text{cm}^3$  of solution when the reaction is complete.

mass = .....g [2]



- (ii) Use the information in the graph to calculate the average rate of reaction, in mol/dm<sup>3</sup>/s, during the first 300 seconds.

average rate of reaction .....mol/dm<sup>3</sup>/s [1]

- (iii) Describe and explain, using the kinetic particle theory, the change in the rate of reaction with time.

.....  
.....  
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.....  
.....[3]

- (b) Aqueous sodium hydroxide reacts with aqueous iron(II) sulfate, FeSO<sub>4</sub>. Construct the ionic equation, with state symbols, for this reaction.

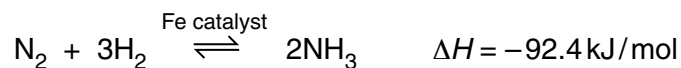
.....[2]

- (c) Iron(II) sulfate can be prepared by reacting excess iron powder with sulfuric acid. Describe the essential practical details to prepare pure dry crystals of iron(II) sulfate.

.....  
.....  
.....  
.....  
.....[2]

[Total: 10]

**B9** Ammonia is manufactured by the Haber process.



The table below shows how the percentage yield of ammonia at equilibrium varies with both temperature and pressure.

| pressure / atmospheres | % yield at 200 °C | % yield at 300 °C | % yield at 400 °C | % yield at 500 °C |
|------------------------|-------------------|-------------------|-------------------|-------------------|
| 30                     | 68                | 32                | 11                | 4                 |
| 100                    | 81                | 51                | 25                | 10                |
| 200                    | 86                | 63                | 36                | 18                |
| 300                    | 88                | 69                | 40                | 24                |

**(a)** Describe how, and explain why, the percentage yield of ammonia at equilibrium changes with temperature.

.....  
 .....  
 .....[2]

**(b)** Describe how, and explain why, the percentage yield of ammonia at equilibrium changes with pressure.

.....  
 .....  
 .....[2]

**(c)** Explain why the conditions for the synthesis of ammonia in most chemical plants are between 350–450 °C and 200–300 atmospheres pressure.

.....  
 .....  
 .....  
 .....[2]

**(d)** Explain how using a catalyst in the Haber process has an economic advantage.

.....  
 .....  
 .....[2]

- (e) Ammonia is used to make fertilisers such as ammonium phosphate,  $(\text{NH}_4)_3\text{PO}_4$ . Calculate the percentage by mass of nitrogen in ammonium phosphate.

[2]

[Total: 10]

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**DATA SHEET**  
**The Periodic Table of the Elements**

| Group                          |                                  |                                |                              |                               |                                    |                                  |                                    |                                |                                   |                                |                                 |                               |                                   |                                   |                                  |                                   |                                    |                               |                                 |                                 |                                 |                               |                                  |                                    |                                  |                                   |                                  |                                  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                 |                                    |                                  |                                    |                                   |  |                                  |                                     |                                     |                                     |                                  |                                     |                                       |                                       |                                    |  |                                     |                                       |
| 7<br><b>Li</b><br>Lithium<br>3 | 9<br><b>Be</b><br>Beryllium<br>4 | 1<br><b>H</b><br>Hydrogen<br>1 | 11<br><b>B</b><br>Boron<br>5 | 12<br><b>C</b><br>Carbon<br>6 | 13<br><b>Al</b><br>Aluminium<br>13 | 14<br><b>Si</b><br>Silicon<br>14 | 15<br><b>P</b><br>Phosphorus<br>15 | 16<br><b>S</b><br>Sulfur<br>16 | 17<br><b>Cl</b><br>Chlorine<br>17 | 18<br><b>Ar</b><br>Argon<br>18 | 19<br><b>F</b><br>Fluorine<br>9 | 20<br><b>Ne</b><br>Neon<br>10 | 21<br><b>Sc</b><br>Scandium<br>21 | 22<br><b>Ti</b><br>Titanium<br>22 | 23<br><b>V</b><br>Vanadium<br>23 | 24<br><b>Cr</b><br>Chromium<br>24 | 25<br><b>Mn</b><br>Manganese<br>25 | 26<br><b>Fe</b><br>Iron<br>26 | 27<br><b>Co</b><br>Cobalt<br>27 | 28<br><b>Ni</b><br>Nickel<br>28 | 29<br><b>Cu</b><br>Copper<br>29 | 30<br><b>Zn</b><br>Zinc<br>30 | 31<br><b>Ga</b><br>Gallium<br>31 | 32<br><b>Ge</b><br>Germanium<br>32 | 33<br><b>As</b><br>Arsenic<br>33 | 34<br><b>Se</b><br>Selenium<br>34 | 35<br><b>Br</b><br>Bromine<br>35 | 36<br><b>Kr</b><br>Krypton<br>36 | 37<br><b>Rb</b><br>Rubidium<br>37 | 38<br><b>Sr</b><br>Strontium<br>38 | 39<br><b>Y</b><br>Yttrium<br>39 | 40<br><b>Ca</b><br>Calcium<br>20 | 41<br><b>Nb</b><br>Niobium<br>41 | 42<br><b>Mo</b><br>Molybdenum<br>42 | 43<br><b>Tc</b><br>Technetium<br>43 | 44<br><b>Ru</b><br>Ruthenium<br>44 | 45<br><b>Rh</b><br>Rhodium<br>45 | 46<br><b>Pd</b><br>Palladium<br>46 | 47<br><b>Ag</b><br>Silver<br>47 | 48<br><b>Cd</b><br>Cadmium<br>48 | 49<br><b>In</b><br>Indium<br>49 | 50<br><b>Sn</b><br>Tin<br>50 | 51<br><b>Sb</b><br>Antimony<br>51 | 52<br><b>Te</b><br>Tellurium<br>52 | 53<br><b>I</b><br>Iodine<br>53 | 54<br><b>Xe</b><br>Xenon<br>54 | 55<br><b>Cs</b><br>Caesium<br>55 | 56<br><b>Ba</b><br>Barium<br>56 | 57<br><b>La</b><br>Lanthanum<br>57 | 58<br><b>Ce</b><br>Cerium<br>58 | 59<br><b>Pr</b><br>Praseodymium<br>59 | 60<br><b>Nd</b><br>Neodymium<br>60 | 61<br><b>Pm</b><br>Promethium<br>61 | 62<br><b>Sm</b><br>Samarium<br>62 | 63<br><b>Eu</b><br>Europium<br>63 | 64<br><b>Gd</b><br>Gadolinium<br>64 | 65<br><b>Tb</b><br>Terbium<br>65 | 66<br><b>Dy</b><br>Dysprosium<br>66 | 67<br><b>Ho</b><br>Holmium<br>67 | 68<br><b>Er</b><br>Erbium<br>68 | 69<br><b>Tm</b><br>Thulium<br>69 | 70<br><b>Yb</b><br>Ytterbium<br>70 | 71<br><b>Lu</b><br>Lutetium<br>71 | 72<br><b>Fr</b><br>Francium<br>87 | 73<br><b>Ra</b><br>Radium<br>88 | 74<br><b>Ac</b><br>Actinium<br>89 | 75<br><b>Th</b><br>Thorium<br>90 | 76<br><b>Pa</b><br>Protactinium<br>91 | 77<br><b>U</b><br>Uranium<br>92 | 78<br><b>Np</b><br>Neptunium<br>93 | 79<br><b>Pu</b><br>Plutonium<br>94 | 80<br><b>Am</b><br>Americium<br>95 | 81<br><b>Cm</b><br>Curium<br>96 | 82<br><b>Bk</b><br>Berkelium<br>97 | 83<br><b>Cf</b><br>Californium<br>98 | 84<br><b>Es</b><br>Einsteinium<br>99 | 85<br><b>Fm</b><br>Fermium<br>100 | 86<br><b>Md</b><br>Mendelevium<br>101 | 87<br><b>No</b><br>Nobelium<br>102 | 88<br><b>Lr</b><br>Lawrencium<br>103 | 89<br><b>Fr</b><br>Francium<br>87 | 90<br><b>Ra</b><br>Radium<br>88 | 91<br><b>Ac</b><br>Actinium<br>89 | 92<br><b>Th</b><br>Thorium<br>90 | 93<br><b>Pa</b><br>Protactinium<br>91 | 94<br><b>U</b><br>Uranium<br>92 | 95<br><b>Np</b><br>Neptunium<br>93 | 96<br><b>Pu</b><br>Plutonium<br>94 | 97<br><b>Am</b><br>Americium<br>95 | 98<br><b>Cm</b><br>Curium<br>96 | 99<br><b>Bk</b><br>Berkelium<br>97 | 100<br><b>Cf</b><br>Californium<br>98 | 101<br><b>Es</b><br>Einsteinium<br>99 | 102<br><b>Fm</b><br>Fermium<br>100 | 103<br><b>Md</b><br>Mendelevium<br>101 | 104<br><b>No</b><br>Nobelium<br>102 | 105<br><b>Lr</b><br>Lawrencium<br>103 | 106<br><b>Fr</b><br>Francium<br>87 | 107<br><b>Ra</b><br>Radium<br>88 | 108<br><b>Ac</b><br>Actinium<br>89 | 109<br><b>Th</b><br>Thorium<br>90 | 110<br><b>Pa</b><br>Protactinium<br>91 | 111<br><b>U</b><br>Uranium<br>92 | 112<br><b>Np</b><br>Neptunium<br>93 | 113<br><b>Pu</b><br>Plutonium<br>94 | 114<br><b>Am</b><br>Americium<br>95 | 115<br><b>Cm</b><br>Curium<br>96 | 116<br><b>Bk</b><br>Berkelium<br>97 | 117<br><b>Cf</b><br>Californium<br>98 | 118<br><b>Es</b><br>Einsteinium<br>99 | 119<br><b>Fm</b><br>Fermium<br>100 | 120<br><b>Md</b><br>Mendelevium<br>101 | 121<br><b>No</b><br>Nobelium<br>102 | 122<br><b>Lr</b><br>Lawrencium<br>103 | 123<br><b>Fr</b><br>Francium<br>87 | 124<br><b>Ra</b><br>Radium<br>88 | 125<br><b>Ac</b><br>Actinium<br>89 | 126<br><b>Th</b><br>Thorium<br>90 | 127<br><b>Pa</b><br>Protactinium<br>91 | 128<br><b>U</b><br>Uranium<br>92 | 129<br><b>Np</b><br>Neptunium<br>93 | 130<br><b>Pu</b><br>Plutonium<br>94 | 131<br><b>Am</b><br>Americium<br>95 | 132<br><b>Cm</b><br>Curium<br>96 | 133<br><b>Bk</b><br>Berkelium<br>97 | 134<br><b>Cf</b><br>Californium<br>98 | 135<br><b>Es</b><br>Einsteinium<br>99 | 136<br><b>Fm</b><br>Fermium<br>100 | 137<br><b>Md</b><br>Mendelevium<br>101 | 138<br><b>No</b><br>Nobelium<br>102 | 139<br><b>Lr</b><br>Lawrencium<br>103 | 140<br><b>Ce</b><br>Cerium<br>58 | 141<br><b>Pr</b><br>Praseodymium<br>59 | 142<br><b>Nd</b><br>Neodymium<br>60 | 143<br><b>Pm</b><br>Promethium<br>61 | 144<br><b>Nd</b><br>Neodymium<br>60 | 145<br><b>Sm</b><br>Samarium<br>62 | 146<br><b>Eu</b><br>Europium<br>63 | 147<br><b>Pm</b><br>Promethium<br>61 | 148<br><b>Sm</b><br>Samarium<br>62 | 149<br><b>Eu</b><br>Europium<br>63 | 150<br><b>Sm</b><br>Samarium<br>62 | 151<br><b>Gd</b><br>Gadolinium<br>64 | 152<br><b>Eu</b><br>Europium<br>63 | 153<br><b>Tb</b><br>Terbium<br>65 | 154<br><b>Dy</b><br>Dysprosium<br>66 | 155<br><b>Ho</b><br>Holmium<br>67 | 156<br><b>Er</b><br>Erbium<br>68 | 157<br><b>Tm</b><br>Thulium<br>69 | 158<br><b>Yb</b><br>Ytterbium<br>70 | 159<br><b>Lu</b><br>Lutetium<br>71 | 160<br><b>Fr</b><br>Francium<br>87 | 161<br><b>Ra</b><br>Radium<br>88 | 162<br><b>Ac</b><br>Actinium<br>89 | 163<br><b>Th</b><br>Thorium<br>90 | 164<br><b>Pa</b><br>Protactinium<br>91 | 165<br><b>U</b><br>Uranium<br>92 | 166<br><b>Np</b><br>Neptunium<br>93 | 167<br><b>Pu</b><br>Plutonium<br>94 | 168<br><b>Am</b><br>Americium<br>95 | 169<br><b>Cm</b><br>Curium<br>96 | 170<br><b>Bk</b><br>Berkelium<br>97 | 171<br><b>Cf</b><br>Californium<br>98 | 172<br><b>Es</b><br>Einsteinium<br>99 | 173<br><b>Fm</b><br>Fermium<br>100 | 174<br><b>Md</b><br>Mendelevium<br>101 | 175<br><b>No</b><br>Nobelium<br>102 | 176<br><b>Lr</b><br>Lawrencium<br>103 | 177<br><b>Fr</b><br>Francium<br>87 | 178<br><b>Ra</b><br>Radium<br>88 | 179<br><b>Ac</b><br>Actinium<br>89 | 180<br><b>Th</b><br>Thorium<br>90 | 181<br><b>Pa</b><br>Protactinium<br>91 | 182<br><b>U</b><br>Uranium<br>92 | 183<br><b>Np</b><br>Neptunium<br>93 | 184<br><b>Pu</b><br>Plutonium<br>94 | 185<br><b>Am</b><br>Americium<br>95 | 186<br><b>Cm</b><br>Curium<br>96 | 187<br><b>Bk</b><br>Berkelium<br>97 | 188<br><b>Cf</b><br>Californium<br>98 | 189<br><b>Es</b><br>Einsteinium<br>99 | 190<br><b>Fm</b><br>Fermium<br>100 | 191<br><b>Md</b><br>Mendelevium<br>101 | 192<br><b>No</b><br>Nobelium<br>102 | 193<br><b>Lr</b><br>Lawrencium<br>103 | 194<br><b>Fr</b><br>Francium<br>87 | 195<br><b>Ra</b><br>Radium<br>88 | 196<br><b>Ac</b><br>Actinium<br>89 | 197<br><b>Th</b><br>Thorium<br>90 | 198<br><b>Pa</b><br>Protactinium<br>91 | 199<br><b>U</b><br>Uranium<br>92 | 200<br><b>Np</b><br>Neptunium<br>93 | 201<br><b>Pu</b><br>Plutonium<br>94 | 202<br><b>Am</b><br>Americium<br>95 | 203<br><b>Cm</b><br>Curium<br>96 | 204<br><b>Bk</b><br>Berkelium<br>97 | 205<br><b>Cf</b><br>Californium<br>98 | 206<br><b>Es</b><br>Einsteinium<br>99 | 207<br><b>Fm</b><br>Fermium<br>100 | 208<br><b>Md</b><br>Mendelevium<br>101 | 209<br><b>No</b><br>Nobelium<br>102 | 210<br><b>Lr</b><br>Lawrencium<br>103 | 211<br><b>Fr</b><br>Francium<br>87 | 212<br><b>Ra</b><br>Radium<br>88 | 213<br><b>Ac</b><br>Actinium<br>89 | 214<br><b>Th</b><br>Thorium<br>90 | 215<br><b>Pa</b><br>Protactinium<br>91 | 216<br><b>U</b><br>Uranium<br>92 | 217<br><b>Np</b><br>Neptunium<br>93 | 218<br><b>Pu</b><br>Plutonium<br>94 | 219<br><b>Am</b><br>Americium<br>95 | 220<br><b>Cm</b><br>Curium<br>96 | 221<br><b>Bk</b><br>Berkelium<br>97 | 222<br><b>Cf</b><br>Californium<br>98 | 223<br><b>Es</b><br>Einsteinium<br>99 | 224<br><b>Fm</b><br>Fermium<br>100 | 225<br><b>Md</b><br>Mendelevium<br>101 | 226<br><b>No</b><br>Nobelium<br>102 | 227<br><b>Lr</b><br>Lawrencium<br>103 |

\* 58–71 Lanthanoid series  
† 90–103 Actinoid series

**Key**  

|   |          |
|---|----------|
| a | <b>X</b> |
| b | <b>X</b> |

 a = relative atomic mass  
 X = atomic symbol  
 b = atomic (proton) number

The volume of one mole of any gas is 24 dm<sup>3</sup> at room temperature and pressure (r.t.p.).