

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS  
International General Certificate of Secondary Education

**CHEMISTRY**



Paper 3 (Extended)

**0620/03**

May/June 2005

**1 hour 15 minutes**

Candidates answer on the Question Paper.  
No Additional Materials required.

Candidate  
Name

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Centre  
Number

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Candidate  
Number

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**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 a pencil for any diagrams, graphs or rough working.

WRITE IN THE BOXES PROVIDED ON THE QUESTION PAPER

DO **NOT** WRITE IN THE BARCODE.

DO **NOT** WRITE IN THE GREY AREAS BETWEEN THE PAGES.

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

You may use a calculator.

Answer **all** questions.

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

A copy of the Periodic Table is printed on page 16.

| For Examiner's Use |  |
|--------------------|--|
| 1                  |  |
| 2                  |  |
| 3                  |  |
| 4                  |  |
| 5                  |  |
| 6                  |  |
| <b>Total</b>       |  |

This document consists of **14** printed pages and **2** blank pages.

1 Three of the halogens in Group VII are:

chlorine  
bromine  
iodine

For  
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Use

(a) (i) How does their colour change down the Group?

..... [1]

(ii) How does their physical state (solid, liquid or gas) change down the Group?

..... [1]

(iii) Predict the colour and physical state of fluorine.

colour .....

physical state ..... [2]

(b) Describe how you could distinguish between aqueous potassium bromide and aqueous potassium iodide.

test .....

result with bromide .....

result with iodide ..... [3]

(c) 0.015 moles of iodine react with 0.045 moles of chlorine to form 0.030 moles of a single product. Complete the equation.



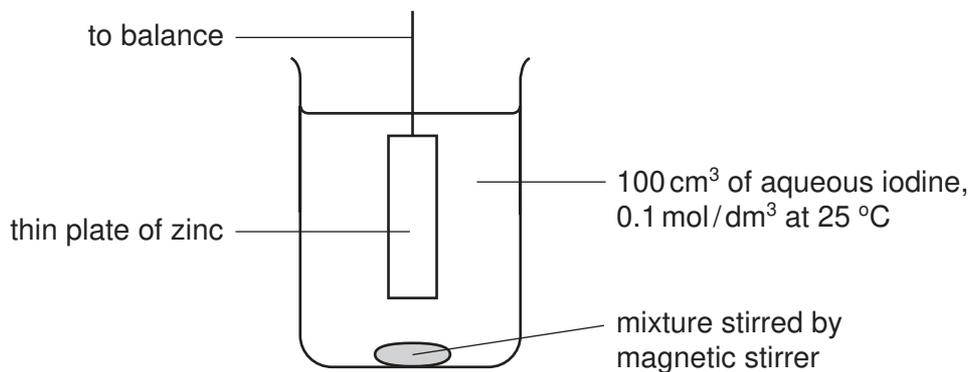
(d) Traces of chlorine can be separated from bromine vapour by diffusion.  
Which gas would diffuse the faster and why?

.....

..... [2]

- 2 The following apparatus was used to measure the rate of the reaction between zinc and iodine.

For  
Examiner's  
Use



The mass of the zinc plate was measured every minute until the reaction was complete.

- (a) Write an ionic equation for the redox reaction that occurred between zinc atoms and iodine molecules.

..... [2]

- (b) Describe how you could show by adding aqueous sodium hydroxide and aqueous ammonia that a solution contained zinc ions.

result with sodium hydroxide .....

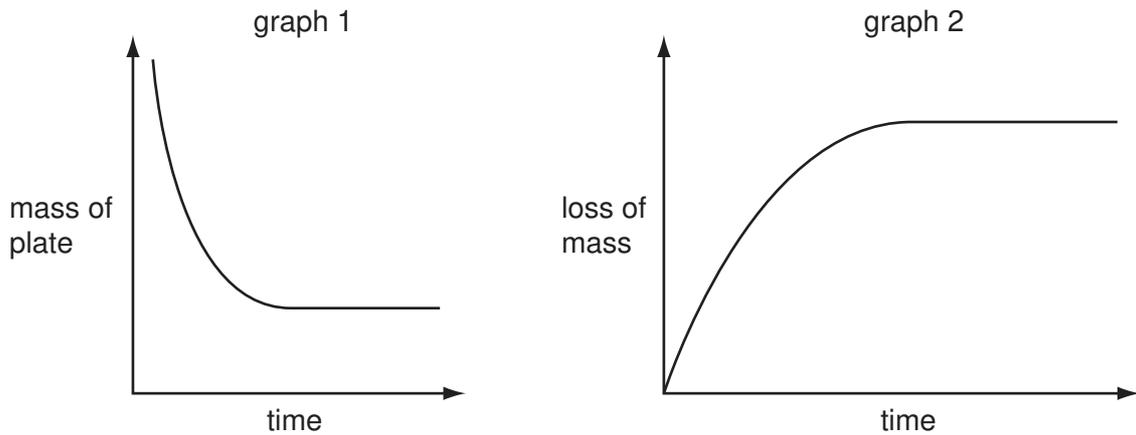
excess sodium hydroxide .....

result with aqueous ammonia .....

excess aqueous ammonia ..... [3]

(c) From the results of this experiment two graphs were plotted.

For  
Examiner's  
Use



(i) Which reagent iodine or zinc was in excess? Give a reason for your choice.

..... [1]

(ii) Describe how the shape of graph 1 would change if  $100\text{cm}^3$  of  $0.05\text{ mol/dm}^3$  iodine had been used.

.....

..... [2]

(iii) On graph 2, sketch the shape if the reaction had been carried out using  $100\text{ cm}^3$  of  $0.1\text{ mol/dm}^3$  iodine at  $35^\circ\text{C}$  instead of at  $25^\circ\text{C}$ . [2]

- 3 A South Korean chemist has discovered a cure for smelly socks. Small particles of silver are attached to a polymer, poly(propene), and this is woven into the socks.

For  
Examiner's  
Use

(a) (i) Give the structural formula of the monomer.

[1]

(ii) Draw the structural formula of the polymer.

[2]

(iii) Suggest which one, monomer or polymer, will react with aqueous bromine and why?

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

(b) To show that the polymer contains silver the following test was carried out.

*The polymer fibres were chopped into small pieces and warmed with nitric acid. The silver atoms were oxidised to silver(I) ions. The mixture was filtered. Aqueous sodium chloride was added to the filtrate and a white precipitate formed.*

(i) Why was the mixture filtered?

..... [1]

(ii) Explain why the change of silver atoms to silver ions is oxidation.

..... [1]

(iii) Give the name of the white precipitate.

..... [1]

(c) The unpleasant smell is caused by carboxylic acids. Bacteria cause the fats on the skin to be hydrolysed to these acids. Silver kills the bacteria and prevents the hydrolysis of the fats.

(i) Fats are esters. Give the name and structural formula of an ester.

name .....

[1]

structural formula

[1]

(ii) Complete the word equation.

Ester + water  $\longrightarrow$  carboxylic acid + .....

[1]

(d) Propanoic acid is a weak acid.

(i) The following equation represents its reaction with ammonia.



Explain why propanoic acid behaves as an acid and ammonia as a base.

.....

..... [3]

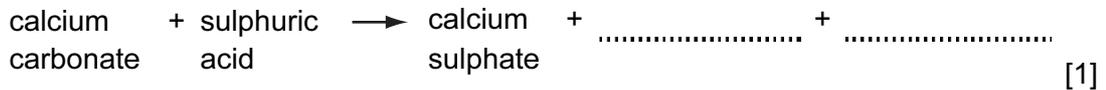
(ii) Explain the expression *weak acid*.

..... [1]

- 4 The Carlsbad caverns in New Mexico are very large underground caves. Although the walls of these caves are coated with gypsum (hydrated calcium sulphate), the caves have been formed in limestone.

(a) It is believed that the caves were formed by sulphuric acid reacting with the limestone.

(i) Complete the word equation.



(ii) Describe how you could test the water entering the cave to show that it contained sulphate ions.

test .....

result ..... [2]

(iii) How could you show that the water entering the cave has a high concentration of hydrogen ions?

..... [1]

(b) Hydrogen sulphide gas which was escaping from nearby petroleum deposits was being oxidised to sulphuric acid.

(i) Complete the equation for this reaction forming sulphuric acid.



(ii) Explain why all the hydrogen sulphide should be removed from the petroleum before it is used as a fuel.

.....

..... [1]

- (iii) Draw a diagram to show the arrangement of the valency electrons in one molecule of the covalent compound hydrogen sulphide.  
Use o to represent an electron from a sulphur atom.  
Use x to represent an electron from a hydrogen atom.

For  
Examiner's  
Use

[2]

- (c) Sulphuric acid is manufactured by the Contact Process. Sulphur dioxide is oxidised to sulphur trioxide by oxygen.



- (i) Name the catalyst used in this reaction.

..... [1]

- (ii) What temperature is used for this reaction?

..... [1]

- (iii) Describe how sulphur trioxide is changed into sulphuric acid.

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

- (d) Gypsum is hydrated calcium sulphate,  $\text{CaSO}_4 \cdot x\text{H}_2\text{O}$ . It contains 20.9% water by mass. Calculate x.

$M_r$ :  $\text{CaSO}_4$ , 136;  $\text{H}_2\text{O}$ , 18.

79.1 g of  $\text{CaSO}_4$  = ..... moles

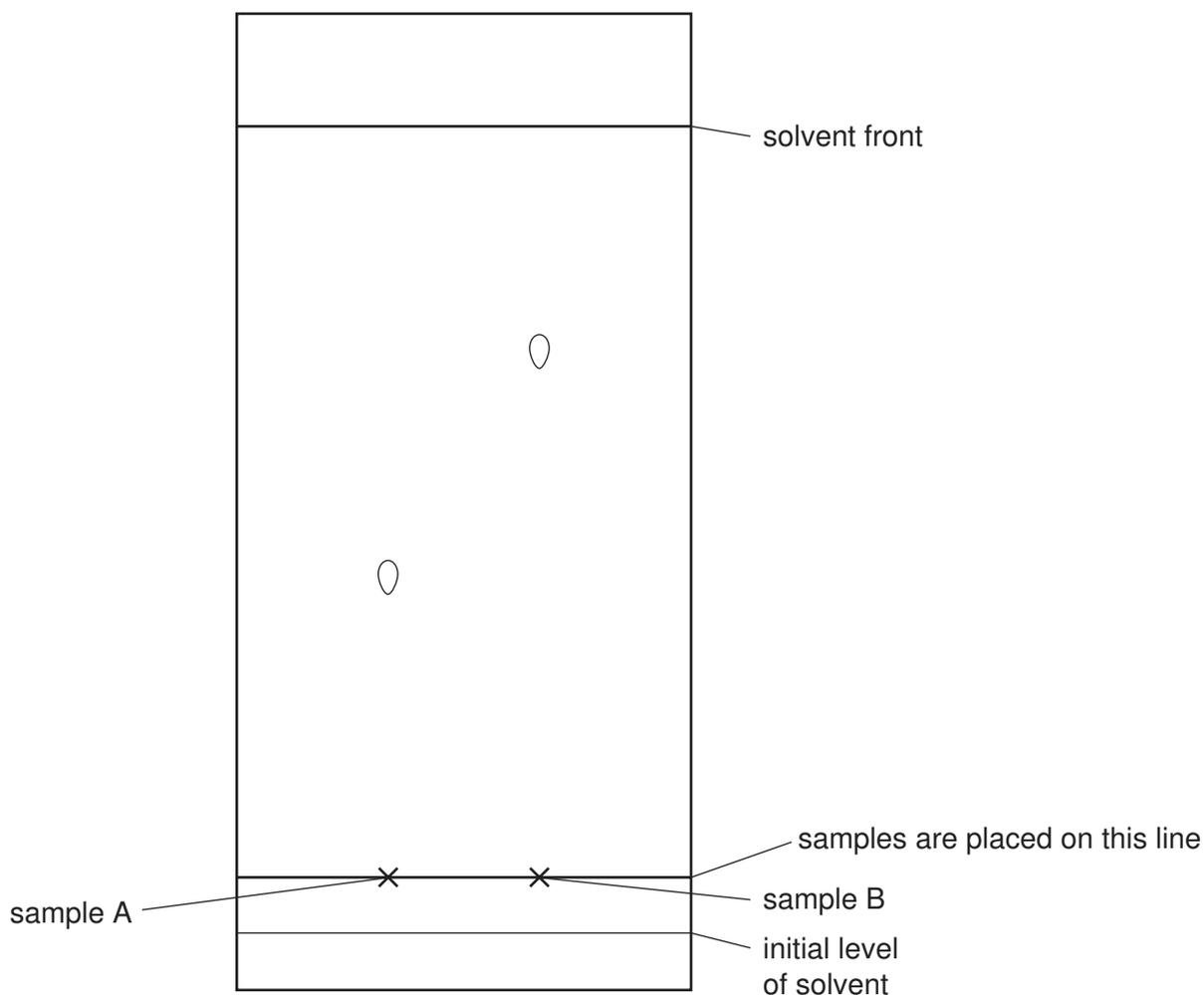
20.9 g of  $\text{H}_2\text{O}$  = ..... moles

x = ..... [3]

5 Enzymes are biological catalysts. They are used both in research laboratories and in industry.

For  
Examiner's  
Use

(a) Enzymes called proteases can hydrolyse proteins to amino acids. The amino acids can be separated and identified by chromatography. The diagram below shows a typical chromatogram.



(i) The  $R_f$  value of a sample =  $\frac{\text{distance travelled by sample}}{\text{distance travelled by solvent front}}$

Some  $R_f$  values for amino acids are:

glutamic acid = 0.4      glycine = 0.5      alanine = 0.7      leucine = 0.9

Identify the two amino acids on the chromatogram.

A is ..... B is ..... [2]

(ii) Explain why the chromatogram must be exposed to a locating agent before  $R_f$  values can be measured.

..... [1]

- (iii) Measuring  $R_f$  values is one way of identifying amino acids on a chromatogram. Suggest another.

..... [1]

- (iv) The synthetic polymer, nylon, has the same linkage as proteins. Draw the structural formula of nylon.

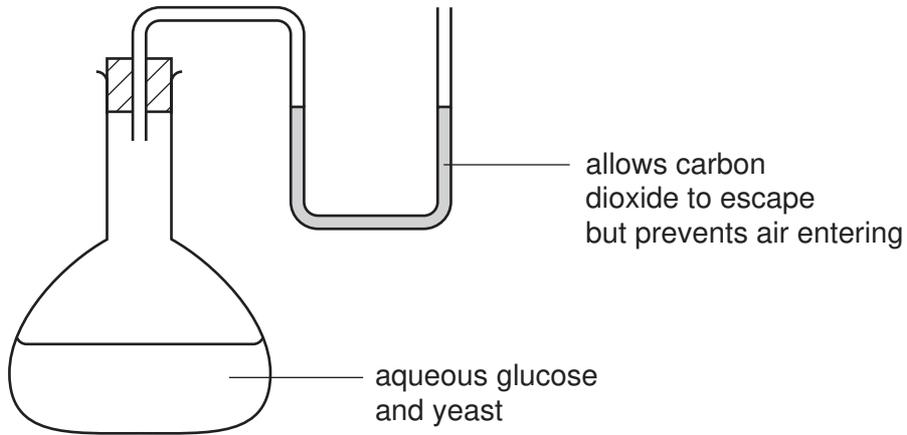
[3]

- (b) Enzymes called carbohydrases can hydrolyse complex carbohydrates to simple sugars which can be represented as  $\text{HO} - \square - \text{OH}$ . Draw the structure of a complex carbohydrate.

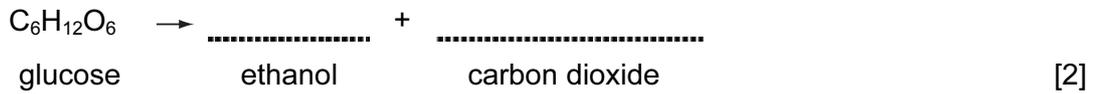
[2]

(c) Fermentation can be carried out in the apparatus drawn below. After a few days the reaction stops. It has produced a 12% aqueous solution of ethanol.

For  
Examiner's  
Use



(i) Complete the equation.



(ii) Zymase catalyses the anaerobic respiration of glucose. Define the term *respiration*.

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

(iii) Suggest a reason why the reaction stops after a few days.

..... [1]

(iv) Why is it essential that there is no oxygen in the flask?

..... [1]

(v) What technique is used to concentrate the aqueous ethanol?

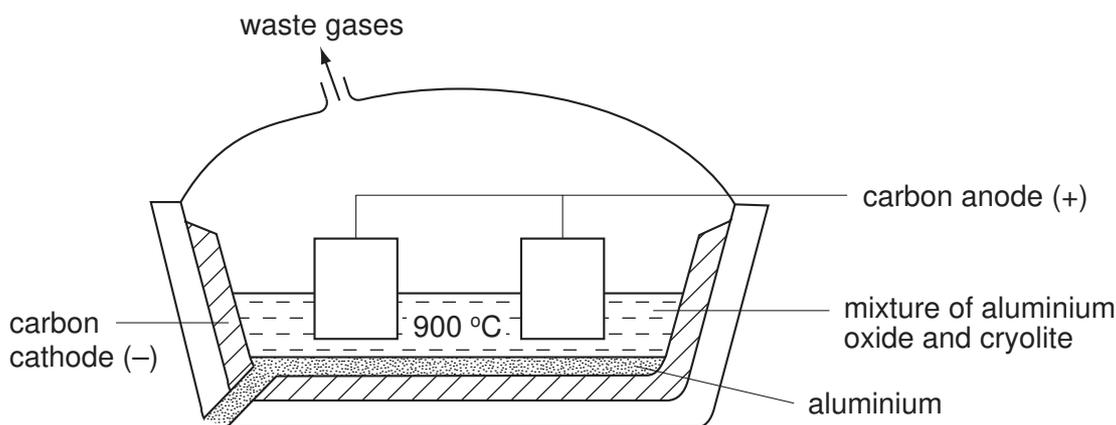
..... [1]

6 The position of aluminium in the reactivity series of metals is shown below.

- magnesium
- aluminium
- zinc
- copper

For  
Examiner's  
Use

(a) Aluminium is extracted by the electrolysis of its molten oxide.



(i) Name the main ore of aluminium.

..... [1]

(ii) Why does the molten electrolyte contain cryolite?

..... [1]

(iii) Oxygen is produced at the positive electrode (anode). Name another gas which is given off at this electrode.

..... [1]

(b) Aluminium reacts very slowly with aqueous copper(II) sulphate.



(i) Which of the two metals has the greater tendency to form ions?

..... [1]

(ii) Describe what you would see when this reaction occurs.

..... [1]

(iii) Explain why aluminium reacts so slowly.

..... [1]

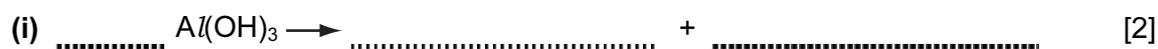
- (c) Complete the following table by writing "reaction" or "no reaction" in the spaces provided.

For  
Examiner's  
Use

| oxide     | type of oxide | reaction with acid | reaction with alkali |
|-----------|---------------|--------------------|----------------------|
| magnesium | basic         | .....              | .....                |
| aluminium | amphoteric    | .....              | .....                |

[2]

- (d) Predict the equations for the decomposition of the following aluminium compounds.





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

|                                   |                                    | Group                              |                                      |                                    |                                     |                                     |  |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
|-----------------------------------|------------------------------------|------------------------------------|--------------------------------------|------------------------------------|-------------------------------------|-------------------------------------|--|----------------------------------|-------------------------------------|------------------------------------|-----------------------------------|------------------------------------|------------------------------------|-----------------------------------|-------------------------------------|------------------------------------|-----------------------------------|----------------------------------|------------------------------------|--|-------------------------------------|---------------------------------------|---------------------------------------|----------------------------------|-------------------------------------|---------------------------------------|------------------------------------|------------------------------------|------------------------------------|----------------------------------|---------------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|------------------------------------|----------------------------------|------------------------------------|-----------------------------------|----------------------------------|-------------------------------|-----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|-----------------------------------|----------------------------------|------------------------------------|---------------------------------|------------------------------------|----------------------------------|-------------------------------------|-------------------------------------|----------------------------------|------------------------------------|---------------------------------|----------------------------------|---------------------------------|------------------------------|-----------------------------------|------------------------------------|--------------------------------|--------------------------------|----------------------------------|----------------------------------|----------------------------------|-----------------------------------|------------------------------------|---------------------------------|-----------------------------------|--------------------------------|----------------------------------|------------------------------------|------------------------------------|---------------------------------|-----------------------------------|---------------------------------|---------------------------------|
| I                                 | II                                 | III                                | IV                                   | V                                  | VI                                  | VII                                 | 0                                      |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
|                                   |                                    | 1<br><b>H</b><br>Hydrogen<br>1     |                                      |                                    |                                     |                                     | 4<br><b>He</b><br>Helium<br>2          |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
| 7<br><b>Li</b><br>Lithium<br>3    | 9<br><b>Be</b><br>Beryllium<br>4   |                                    |                                      |                                    |                                     |                                     | 20<br><b>Ne</b><br>Neon<br>10          |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
| 23<br><b>Na</b><br>Sodium<br>11   | 24<br><b>Mg</b><br>Magnesium<br>12 |                                    | 12<br><b>C</b><br>Carbon<br>6        | 14<br><b>N</b><br>Nitrogen<br>7    | 16<br><b>O</b><br>Oxygen<br>8       | 19<br><b>F</b><br>Fluorine<br>9     | 35.5<br><b>Cl</b><br>Chlorine<br>17    |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
| 39<br><b>K</b><br>Potassium<br>19 | 40<br><b>Ca</b><br>Calcium<br>20   | 27<br><b>Al</b><br>Aluminium<br>13 | 28<br><b>Si</b><br>Silicon<br>14     | 31<br><b>P</b><br>Phosphorus<br>15 | 32<br><b>S</b><br>Sulphur<br>16     | 35.5<br><b>Cl</b><br>Chlorine<br>17 | 40<br><b>Ar</b><br>Argon<br>18         |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
| 85<br><b>Rb</b><br>Rubidium<br>37 | 88<br><b>Sr</b><br>Strontium<br>38 | 70<br><b>Ga</b><br>Gallium<br>31   | 73<br><b>Ge</b><br>Germanium<br>32   | 75<br><b>As</b><br>Arsenic<br>33   | 79<br><b>Se</b><br>Selenium<br>34   | 80<br><b>Br</b><br>Bromine<br>35    | 84<br><b>Kr</b><br>Krypton<br>36       |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
| 133<br><b>Cs</b><br>Caesium<br>55 | 137<br><b>Ba</b><br>Barium<br>56   | 115<br><b>In</b><br>Indium<br>49   | 119<br><b>Sn</b><br>Tin<br>50        | 122<br><b>Sb</b><br>Antimony<br>51 | 128<br><b>Te</b><br>Tellurium<br>52 | 127<br><b>I</b><br>Iodine<br>53     | 131<br><b>Xe</b><br>Xenon<br>54        |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
| 226<br><b>Ra</b><br>Radium<br>88  | 227<br><b>Ac</b><br>Actinium<br>89 | 204<br><b>Tl</b><br>Thallium<br>81 | 207<br><b>Pb</b><br>Lead<br>82       | 209<br><b>Bi</b><br>Bismuth<br>83  | 210<br><b>Po</b><br>Polonium<br>84  | 210<br><b>At</b><br>Astatine<br>85  | 210<br><b>Rn</b><br>Radon<br>86        |                                  |                                     |                                    |                                   |                                    |                                    |                                   |                                     |                                    |                                   |                                  |                                    |  |                                     |                                       |                                       |                                  |                                     |                                       |                                    |                                    |                                    |                                  |                                       |                                   |                                   |                                   |                                   |                                   |                                   |                                    |                                  |                                    |                                   |                                  |                               |                                   |                                  |                                 |                                  |                                  |                                   |                                  |                                    |                                 |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
|                                   |                                    | 65<br><b>Zn</b><br>Zinc<br>30      | 64<br><b>Cu</b><br>Copper<br>29      | 59<br><b>Ni</b><br>Nickel<br>28    | 56<br><b>Fe</b><br>Iron<br>26       | 59<br><b>Co</b><br>Cobalt<br>27     | 58<br><b>Ni</b><br>Nickel<br>28        | 59<br><b>Co</b><br>Cobalt<br>27  | 56<br><b>Fe</b><br>Iron<br>26       | 55<br><b>Mn</b><br>Manganese<br>25 | 52<br><b>Cr</b><br>Chromium<br>24 | 51<br><b>V</b><br>Vanadium<br>23   | 48<br><b>Ti</b><br>Titanium<br>22  | 45<br><b>Sc</b><br>Scandium<br>21 | 40<br><b>Ca</b><br>Calcium<br>20    | 39<br><b>K</b><br>Potassium<br>19  | 37<br><b>Rb</b><br>Rubidium<br>37 | 35<br><b>Br</b><br>Bromine<br>35 | 34<br><b>Se</b><br>Selenium<br>34  | 33<br><b>As</b><br>Arsenic<br>33       | 32<br><b>Ge</b><br>Germanium<br>32  | 31<br><b>Ga</b><br>Gallium<br>31      | 30<br><b>Zn</b><br>Zinc<br>30         | 29<br><b>Cu</b><br>Copper<br>29  | 28<br><b>Ni</b><br>Nickel<br>28     | 27<br><b>Co</b><br>Cobalt<br>27       | 26<br><b>Fe</b><br>Iron<br>26      | 25<br><b>Mn</b><br>Manganese<br>25 | 24<br><b>Cr</b><br>Chromium<br>24  | 23<br><b>V</b><br>Vanadium<br>23 | 22<br><b>Ti</b><br>Titanium<br>22     | 21<br><b>Sc</b><br>Scandium<br>21 | 20<br><b>Ca</b><br>Calcium<br>20  | 19<br><b>K</b><br>Potassium<br>19 | 18<br><b>Ar</b><br>Argon<br>18    | 17<br><b>Cl</b><br>Chlorine<br>17 | 16<br><b>S</b><br>Sulphur<br>16   | 15<br><b>P</b><br>Phosphorus<br>15 | 14<br><b>N</b><br>Nitrogen<br>7  | 13<br><b>Al</b><br>Aluminium<br>13 | 12<br><b>C</b><br>Carbon<br>6     | 11<br><b>B</b><br>Boron<br>5     | 10<br><b>Ne</b><br>Neon<br>10 | 9<br><b>F</b><br>Fluorine<br>9    | 8<br><b>O</b><br>Oxygen<br>8     | 7<br><b>N</b><br>Nitrogen<br>7  | 6<br><b>C</b><br>Carbon<br>6     | 5<br><b>B</b><br>Boron<br>5      | 4<br><b>He</b><br>Helium<br>2     | 3<br><b>Li</b><br>Lithium<br>3   | 2<br><b>Be</b><br>Beryllium<br>4   | 1<br><b>H</b><br>Hydrogen<br>1  |                                    |                                  |                                     |                                     |                                  |                                    |                                 |                                  |                                 |                              |                                   |                                    |                                |                                |                                  |                                  |                                  |                                   |                                    |                                 |                                   |                                |                                  |                                    |                                    |                                 |                                   |                                 |                                 |
|                                   |                                    | 159<br><b>Tb</b><br>Terbium<br>65  | 157<br><b>Gd</b><br>Gadolinium<br>64 | 152<br><b>Eu</b><br>Europium<br>63 | 150<br><b>Sm</b><br>Samarium<br>62  | 144<br><b>Nd</b><br>Neodymium<br>60 | 141<br><b>Pr</b><br>Praseodymium<br>59 | 140<br><b>Ce</b><br>Cerium<br>58 | 139<br><b>La</b><br>Lanthanum<br>57 | 137<br><b>Ba</b><br>Barium<br>56   | 133<br><b>Cs</b><br>Caesium<br>55 | 127<br><b>Po</b><br>Polonium<br>84 | 125<br><b>At</b><br>Astatine<br>85 | 124<br><b>Rn</b><br>Radon<br>86   | 123<br><b>Yb</b><br>Ytterbium<br>70 | 121<br><b>Lu</b><br>Lutetium<br>71 | 119<br><b>Tm</b><br>Thulium<br>69 | 117<br><b>Er</b><br>Erbium<br>68 | 115<br><b>Fm</b><br>Fermium<br>100 | 113<br><b>Md</b><br>Mendelevium<br>101 | 111<br><b>No</b><br>Nobelium<br>102 | 109<br><b>Lr</b><br>Lawrencium<br>103 | 107<br><b>Es</b><br>Einsteinium<br>99 | 105<br><b>Cm</b><br>Curium<br>96 | 103<br><b>Bk</b><br>Berkelium<br>97 | 101<br><b>Cf</b><br>Californium<br>98 | 99<br><b>Am</b><br>Americium<br>95 | 97<br><b>Pu</b><br>Plutonium<br>94 | 95<br><b>Np</b><br>Neptunium<br>93 | 93<br><b>U</b><br>Uranium<br>92  | 91<br><b>Pa</b><br>Protactinium<br>91 | 90<br><b>Th</b><br>Thorium<br>90  | 89<br><b>Ac</b><br>Actinium<br>89 | 88<br><b>Ra</b><br>Radium<br>88   | 87<br><b>Fr</b><br>Francium<br>87 | 86<br><b>Rn</b><br>Radon<br>86    | 85<br><b>At</b><br>Astatine<br>85 | 84<br><b>Po</b><br>Polonium<br>84  | 83<br><b>Bi</b><br>Bismuth<br>83 | 82<br><b>Pb</b><br>Lead<br>82      | 81<br><b>Tl</b><br>Thallium<br>81 | 80<br><b>Hg</b><br>Mercury<br>80 | 79<br><b>Au</b><br>Gold<br>79 | 78<br><b>Pt</b><br>Platinum<br>78 | 77<br><b>Ir</b><br>Iridium<br>77 | 76<br><b>Os</b><br>Osmium<br>76 | 75<br><b>Re</b><br>Rhenium<br>75 | 74<br><b>W</b><br>Tungsten<br>74 | 73<br><b>Ta</b><br>Tantalum<br>73 | 72<br><b>Hf</b><br>Hafnium<br>72 | 71<br><b>La</b><br>Lanthanum<br>57 | 70<br><b>Y</b><br>Yttrium<br>39 | 69<br><b>Zr</b><br>Zirconium<br>40 | 68<br><b>Nb</b><br>Niobium<br>41 | 67<br><b>Mo</b><br>Molybdenum<br>42 | 66<br><b>Tc</b><br>Technetium<br>43 | 65<br><b>Rh</b><br>Rhodium<br>45 | 64<br><b>Pd</b><br>Palladium<br>46 | 63<br><b>Ag</b><br>Silver<br>47 | 62<br><b>Cd</b><br>Cadmium<br>48 | 61<br><b>In</b><br>Indium<br>49 | 60<br><b>Sn</b><br>Tin<br>50 | 59<br><b>Sb</b><br>Antimony<br>51 | 58<br><b>Te</b><br>Tellurium<br>52 | 57<br><b>I</b><br>Iodine<br>53 | 56<br><b>Xe</b><br>Xenon<br>54 | 55<br><b>Br</b><br>Bromine<br>35 | 54<br><b>Kr</b><br>Krypton<br>36 | 53<br><b>As</b><br>Arsenic<br>33 | 52<br><b>Se</b><br>Selenium<br>34 | 51<br><b>P</b><br>Phosphorus<br>15 | 50<br><b>S</b><br>Sulphur<br>16 | 49<br><b>Cl</b><br>Chlorine<br>17 | 48<br><b>Ar</b><br>Argon<br>18 | 47<br><b>Si</b><br>Silicon<br>14 | 46<br><b>Al</b><br>Aluminium<br>13 | 45<br><b>Mg</b><br>Magnesium<br>12 | 44<br><b>Na</b><br>Sodium<br>11 | 43<br><b>Be</b><br>Beryllium<br>4 | 42<br><b>Li</b><br>Lithium<br>3 | 41<br><b>H</b><br>Hydrogen<br>1 |

\*58-71 Lanthanoid series  
90-103 Actinoid series

**Key**

|   |          |                            |
|---|----------|----------------------------|
| a | <b>X</b> | a = relative atomic mass   |
| b | <b>X</b> | X = atomic symbol          |
| b | <b>X</b> | b = proton (atomic) number |

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