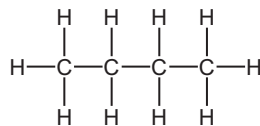
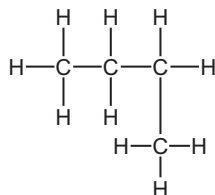


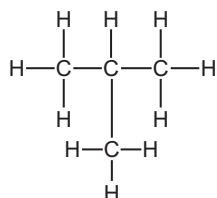
34 Which structures are structural isomers of each other?



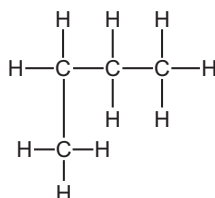
1



2



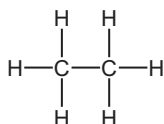
3



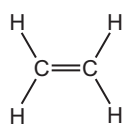
4

- A** 1, 2, 3 and 4  
**B** 1, 2 and 4 only  
**C** 1 and 3 only  
**D** 2 and 4 only

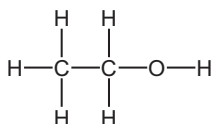
37 The structures of four compounds are shown.



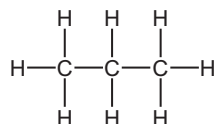
1



2



3



4

Which compounds are members of the same homologous series?

- A** 1, 2 and 3      **B** 1 and 2 only      **C** 1 and 4      **D** 2 and 4

5 This question is about the homologous series of alkanes.

Three general characteristics of alkanes are:

- they are generally unreactive because they do **not** have a functional group
- they show trends in their physical properties, such as melting points and boiling points
- they have similar chemical properties.

(a) Describe **two other** general characteristics of the homologous series of alkanes.

1..... [2]

2..... [2]

(b) (i) State the trend in the boiling points of the alkanes as the carbon chain length increases.

..... [1]

(ii) Name **one other** physical property of alkanes that shows a trend, other than melting points and boiling points.

Describe this trend as the carbon chain length of alkanes increases.

name .....

description..... [2]

(c) State why alkanes are described as saturated.

..... [1]

(d) Propane has the structural formula  $\text{CH}_3\text{CH}_2\text{CH}_3$ .

When propane undergoes a monosubstitution reaction with chlorine at room temperature, **two** organic products can be formed.

(i) State **one** condition needed for this substitution reaction to take place.

..... [1]

(ii) Give the structural formula and state the name of each organic product formed.

- structural formula of product 1

name of product 1 .....

- structural formula of product 2

name of product 2 ..... [4]

(iii) The two products formed are structural isomers of each other.

Define the term structural isomers.

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

[Total: 12]

6 Compound **E** shown in Fig. 6.1 is an ester.

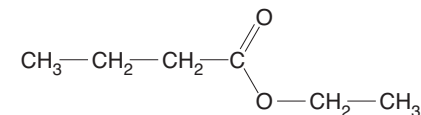


Fig. 6.1

(a) On Fig. 6.1, draw a circle around all the atoms which make up the ester linkage. [1]

(b) Name compound **E**.

..... [1]

(c) Deduce the empirical formula of compound **E**.

..... [1]

(d) Compound **E** is produced when two different compounds react together in the presence of a catalyst.

(i) Name the **two** compounds that react together to produce compound **E**.

1 .....

2 ..... [2]

(ii) Suggest a suitable catalyst for this reaction.

..... [1]

(e) Determine the number of unbranched esters which have the molecular formula  $\text{C}_5\text{H}_{10}\text{O}_2$ .

..... [1]

(f) All unbranched esters with the molecular formula  $\text{C}_5\text{H}_{10}\text{O}_2$  combust completely to form carbon dioxide and water only.

Write the symbol equation for the complete combustion of  $\text{C}_5\text{H}_{10}\text{O}_2$ .

..... [1]

[Total: 8]

The Periodic Table of Elements

| Group                      |                             |                                                                |                                 |                             |                              |                             |                              |                              |                                |                               |                               |                              |                             |                             |                               |                              |                            |
|----------------------------|-----------------------------|----------------------------------------------------------------|---------------------------------|-----------------------------|------------------------------|-----------------------------|------------------------------|------------------------------|--------------------------------|-------------------------------|-------------------------------|------------------------------|-----------------------------|-----------------------------|-------------------------------|------------------------------|----------------------------|
| I                          | II                          | Key                                                            |                                 |                             |                              |                             | III                          | IV                           | V                              | VI                            | VII                           | VIII                         |                             |                             |                               |                              |                            |
| 3<br>Li<br>7               | 4<br>Be<br>beryllium<br>9   | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                                 |                             |                              |                             | 1<br>H<br>hydrogen<br>1      | 5<br>B<br>boron<br>11        | 6<br>C<br>carbon<br>12         | 7<br>N<br>nitrogen<br>14      | 8<br>O<br>oxygen<br>16        | 9<br>F<br>fluorine<br>19     | 10<br>Ne<br>neon<br>20      |                             |                               |                              |                            |
|                            |                             |                                                                |                                 |                             |                              |                             |                              |                              |                                |                               |                               |                              |                             | 2<br>He<br>helium<br>4      |                               |                              |                            |
| 11<br>Na<br>sodium<br>23   | 12<br>Mg<br>magnesium<br>24 |                                                                |                                 |                             |                              |                             |                              | 13<br>Al<br>aluminium<br>27  | 14<br>Si<br>silicon<br>28      | 15<br>P<br>phosphorus<br>31   | 16<br>S<br>sulfur<br>32       | 17<br>Cl<br>chlorine<br>35.5 | 18<br>Ar<br>argon<br>40     |                             |                               |                              |                            |
| 19<br>K<br>potassium<br>39 | 20<br>Ca<br>calcium<br>40   | 21<br>Sc<br>scandium<br>45                                     | 22<br>Ti<br>titanium<br>48      | 23<br>V<br>vanadium<br>51   | 24<br>Cr<br>chromium<br>52   | 25<br>Mn<br>manganese<br>55 | 26<br>Fe<br>iron<br>56       | 27<br>Co<br>cobalt<br>59     | 28<br>Ni<br>nickel<br>59       | 29<br>Cu<br>copper<br>64      | 30<br>Zn<br>zinc<br>65        | 31<br>Ga<br>gallium<br>70    | 32<br>Ge<br>germanium<br>73 | 33<br>As<br>arsenic<br>75   | 34<br>Se<br>selenium<br>79    | 35<br>Br<br>bromine<br>80    | 36<br>Kr<br>krypton<br>84  |
| 37<br>Rb<br>rubidium<br>85 | 38<br>Sr<br>strontium<br>88 | 39<br>Y<br>yttrium<br>89                                       | 40<br>Zr<br>zirconium<br>91     | 41<br>Nb<br>niobium<br>93   | 42<br>Mo<br>molybdenum<br>96 | 43<br>Tc<br>technetium<br>— | 44<br>Ru<br>ruthenium<br>101 | 45<br>Rh<br>rhodium<br>103   | 46<br>Pd<br>palladium<br>106   | 47<br>Ag<br>silver<br>108     | 48<br>Cd<br>cadmium<br>112    | 49<br>In<br>indium<br>115    | 50<br>Sn<br>tin<br>119      | 51<br>Sb<br>antimony<br>122 | 52<br>Te<br>tellurium<br>128  | 53<br>I<br>iodine<br>127     | 54<br>Xe<br>xenon<br>131   |
| 55<br>Cs<br>caesium<br>133 | 56<br>Ba<br>barium<br>137   | 57–71<br>lanthanoids                                           | 72<br>Hf<br>hafnium<br>178      | 73<br>Ta<br>tantalum<br>181 | 74<br>W<br>tungsten<br>184   | 75<br>Re<br>rhenium<br>186  | 76<br>Os<br>osmium<br>190    | 77<br>Ir<br>iridium<br>192   | 78<br>Pt<br>platinum<br>195    | 79<br>Au<br>gold<br>197       | 80<br>Hg<br>mercury<br>201    | 81<br>Tl<br>thallium<br>204  | 82<br>Pb<br>lead<br>207     | 83<br>Bi<br>bismuth<br>209  | 84<br>Po<br>polonium<br>—     | 85<br>At<br>astatine<br>—    | 86<br>Rn<br>radon<br>—     |
| 87<br>Fr<br>francium<br>—  | 88<br>Ra<br>radium<br>—     | 89–103<br>actinoids                                            | 104<br>Rf<br>rutherfordium<br>— | 105<br>Db<br>dubnium<br>—   | 106<br>Sg<br>seaborgium<br>— | 107<br>Bh<br>bohrium<br>—   | 108<br>Hs<br>hassium<br>—    | 109<br>Mt<br>meitnerium<br>— | 110<br>Ds<br>darmstadtium<br>— | 111<br>Rg<br>roentgenium<br>— | 112<br>Cn<br>copernicium<br>— | 113<br>Nh<br>nihonium<br>—   | 114<br>Fl<br>flerovium<br>— | 115<br>Mc<br>moscovium<br>— | 116<br>Lv<br>livermorium<br>— | 117<br>Ts<br>tennessine<br>— | 118<br>Og<br>oganeson<br>— |

anthanoids

actinoids

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

6 This question is about organic compounds.

(a) Organic compound **Q** has the following composition by mass.

C, 50.00%; H, 5.56%; O, 44.44%

Calculate the empirical formula of compound **Q**.

empirical formula = ..... [3]

(b) Organic compound **R** has the empirical formula CHO and a relative molecular mass of 116.

Determine the molecular formula of compound **R**.

molecular formula = ..... [1]

(c) Carboxylic acids react with alcohols to form esters.

(i) Name the other product that is formed when a carboxylic acid reacts with an alcohol.

..... [1]

(ii) Name the **type** of catalyst that is used when a carboxylic acid reacts with an alcohol.

..... [1]

(iii) Ester **S** has the structural formula CH<sub>3</sub>CH<sub>2</sub>COOCH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>.

Name the carboxylic acid and the alcohol which react together to form ester **S**.

carboxylic acid .....

alcohol .....

- (d) Fig. 6.1 shows part of a polymer structure.

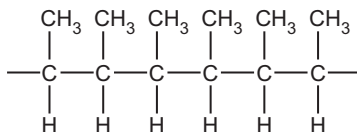


Fig. 6.1

- (i) Name the type of polymerisation that is used to produce this polymer.  
..... [1]
- (ii) Suggest why it is **not** possible to write the molecular formula of this polymer.  
..... [1]
- (iii) State the number of monomer units that are needed to make the part of the polymer structure shown in Fig. 6.1.  
..... [1]
- (iv) Draw the displayed formula of the monomer used to make this polymer.

[2]

- (e) Fig. 6.2 shows part of the general structure of an amino acid.

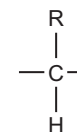


Fig. 6.2

- (i) Complete Fig. 6.2 to show all the atoms and all the bonds in the two functional groups of the amino acid.  
[2]
- (ii) Part of a natural polyamide structure is shown in Fig. 6.3.

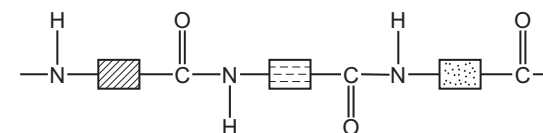


Fig. 6.3

On Fig. 6.3, draw a circle around **one** amide linkage. [1]

- (iii) State the name given to natural polyamides made from amino acids.  
..... [1]

[Total: 17]

The Periodic Table of Elements

| Group                        |                             |                                                                |                                 |                             |                              |                             |                               |                              |                                |                               |                               |                               |                              |                              |                               |                              |                            |  |
|------------------------------|-----------------------------|----------------------------------------------------------------|---------------------------------|-----------------------------|------------------------------|-----------------------------|-------------------------------|------------------------------|--------------------------------|-------------------------------|-------------------------------|-------------------------------|------------------------------|------------------------------|-------------------------------|------------------------------|----------------------------|--|
| I                            | II                          | Key                                                            |                                 |                             |                              |                             |                               |                              |                                |                               |                               | III                           | IV                           | V                            | VI                            | VII                          | VIII                       |  |
|                              |                             | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                                 |                             |                              |                             |                               |                              |                                |                               |                               | 1<br>H<br>hydrogen<br>1       |                              |                              |                               |                              |                            |  |
| 3<br>Li<br>lithium<br>7      | 4<br>Be<br>beryllium<br>9   |                                                                |                                 |                             |                              |                             |                               |                              |                                |                               |                               | 5<br>B<br>boron<br>11         | 6<br>C<br>carbon<br>12       | 7<br>N<br>nitrogen<br>14     | 8<br>O<br>oxygen<br>16        | 9<br>F<br>fluorine<br>19     | 10<br>Ne<br>neon<br>20     |  |
| 11<br>Na<br>sodium<br>23     | 12<br>Mg<br>magnesium<br>24 |                                                                |                                 |                             |                              |                             |                               |                              |                                |                               |                               | 13<br>Al<br>aluminium<br>27   | 14<br>Si<br>silicon<br>28    | 15<br>P<br>phosphorus<br>31  | 16<br>S<br>sulfur<br>32       | 17<br>Cl<br>chlorine<br>35.5 | 18<br>Ar<br>argon<br>40    |  |
| 19<br>K<br>potassium<br>39   | 20<br>Ca<br>calcium<br>40   | 21<br>Sc<br>scandium<br>45                                     | 22<br>Ti<br>titanium<br>48      | 23<br>V<br>vanadium<br>51   | 24<br>Cr<br>chromium<br>52   | 25<br>Mn<br>manganese<br>55 | 26<br>Fe<br>iron<br>56        | 27<br>Co<br>cobalt<br>59     | 28<br>Ni<br>nickel<br>59       | 29<br>Cu<br>copper<br>64      | 30<br>Zn<br>zinc<br>65        | 31<br>Ga<br>gallium<br>70     | 32<br>Ge<br>germanium<br>73  | 33<br>As<br>arsenic<br>75    | 34<br>Se<br>selenium<br>79    | 35<br>Br<br>bromine<br>80    | 36<br>Kr<br>krypton<br>84  |  |
| 37<br>Rb<br>rubidium<br>85   | 38<br>Sr<br>strontium<br>88 | 39<br>Y<br>yttrium<br>89                                       | 40<br>Zr<br>zirconium<br>91     | 41<br>Nb<br>niobium<br>93   | 42<br>Mo<br>molybdenum<br>96 | 43<br>Tc<br>technetium<br>— | 44<br>Ru<br>ruthenium<br>101  | 45<br>Rh<br>rhodium<br>103   | 46<br>Pd<br>palladium<br>106   | 47<br>Ag<br>silver<br>108     | 48<br>Cd<br>cadmium<br>112    | 49<br>In<br>indium<br>115     | 50<br>Sn<br>tin<br>119       | 51<br>Sb<br>antimony<br>122  | 52<br>Te<br>tellurium<br>128  | 53<br>I<br>iodine<br>127     | 54<br>Xe<br>xenon<br>131   |  |
| 55<br>Cs<br>caesium<br>133   | 56<br>Ba<br>barium<br>137   | 57–71<br>lanthanoids                                           | 72<br>Hf<br>hafnium<br>178      | 73<br>Ta<br>tantalum<br>181 | 74<br>W<br>tungsten<br>184   | 75<br>Re<br>rhenium<br>186  | 76<br>Os<br>osmium<br>190     | 77<br>Ir<br>iridium<br>192   | 78<br>Pt<br>platinum<br>195    | 79<br>Au<br>gold<br>197       | 80<br>Hg<br>mercury<br>201    | 81<br>Tl<br>thallium<br>204   | 82<br>Pb<br>lead<br>207      | 83<br>Bi<br>bismuth<br>209   | 84<br>Po<br>polonium<br>—     | 85<br>At<br>astatine<br>—    | 86<br>Rn<br>radon<br>—     |  |
| 87<br>Fr<br>francium<br>—    | 88<br>Ra<br>radium<br>—     | 89–103<br>actinoids                                            | 104<br>Rf<br>rutherfordium<br>— | 105<br>Db<br>dubnium<br>—   | 106<br>Sg<br>seaborgium<br>— | 107<br>Bh<br>bohrium<br>—   | 108<br>Hs<br>hassium<br>—     | 109<br>Mt<br>meitnerium<br>— | 110<br>Ds<br>darmstadtium<br>— | 111<br>Rg<br>roentgenium<br>— | 112<br>Cn<br>copernicium<br>— | 113<br>Nh<br>nihonium<br>—    | 114<br>Fl<br>flerovium<br>—  | 115<br>Mc<br>moscovium<br>—  | 116<br>Lv<br>livermorium<br>— | 117<br>Ts<br>tennessine<br>— | 118<br>Og<br>oganeson<br>— |  |
| lanthanoids                  |                             |                                                                |                                 |                             |                              |                             |                               |                              |                                |                               |                               |                               |                              |                              |                               |                              |                            |  |
| 57<br>La<br>lanthanum<br>139 | 58<br>Ce<br>cerium<br>140   | 59<br>Pr<br>praseodymium<br>141                                | 60<br>Nd<br>neodymium<br>144    | 61<br>Pm<br>promethium<br>— | 62<br>Sm<br>samarium<br>150  | 63<br>Eu<br>europium<br>152 | 64<br>Gd<br>gadolinium<br>157 | 65<br>Tb<br>terbium<br>159   | 66<br>Dy<br>dysprosium<br>163  | 67<br>Ho<br>holmium<br>165    | 68<br>Er<br>erbium<br>167     | 69<br>Tm<br>thulium<br>169    | 70<br>Yb<br>ytterbium<br>173 | 71<br>Lu<br>lutetium<br>175  |                               |                              |                            |  |
| 89<br>Ac<br>actinium         | 90<br>Th<br>thorium<br>232  | 91<br>Pa<br>protactinium<br>231                                | 92<br>U<br>uranium<br>238       | 93<br>Np<br>neptunium<br>—  | 94<br>Pu<br>plutonium<br>—   | 95<br>Am<br>americium<br>—  | 96<br>Cm<br>curium<br>—       | 97<br>Bk<br>berkelium<br>—   | 98<br>Cf<br>californium<br>—   | 99<br>Es<br>einsteinium<br>—  | 100<br>Fm<br>fermium<br>—     | 101<br>Md<br>mendelevium<br>— | 102<br>No<br>nobelium<br>—   | 103<br>Lr<br>lawrencium<br>— |                               |                              |                            |  |
| actinoids                    |                             |                                                                |                                 |                             |                              |                             |                               |                              |                                |                               |                               |                               |                              |                              |                               |                              |                            |  |

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

**33** The structural formula of methyl ethanoate is CH<sub>3</sub>COOCH<sub>3</sub>.

Which compounds are structural isomers of methyl ethanoate?

- 1 HCOOCH<sub>2</sub>CH<sub>3</sub>
- 2 CH<sub>3</sub>CH<sub>2</sub>COOH
- 3 HOCH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>OH

**A** 1, 2 and 3      **B** 1 and 2 only      **C** 2 and 3 only      **D** 3 only

**34** Which row describes two characteristics of members of the same homologous series?

|          | characteristic 1                                                | characteristic 2              |
|----------|-----------------------------------------------------------------|-------------------------------|
| <b>A</b> | same functional group                                           | trend in physical properties  |
| <b>B</b> | same physical properties                                        | same functional group         |
| <b>C</b> | same general formula                                            | different chemical properties |
| <b>D</b> | differing from one member to the next by a CH <sub>3</sub> unit | similar chemical properties   |

6 The structural formulae of two compounds, **A** and **B**, are shown.

| <b>A</b>                    | <b>B</b>                             |
|-----------------------------|--------------------------------------|
| $\text{CH}_2=\text{CHCH}_3$ | $\text{CH}_3\text{CH}=\text{CHCH}_3$ |

**A** and **B** are members of the same homologous series.

(a) Give **two** reasons why the structural formulae of **A** and **B** show they are members of the same homologous series.

1 .....

2 .....

[2]

(b) Explain why **A** and **B** are both hydrocarbons.

..... [1]

(c) Write the symbol equation for the complete combustion of **A**.

..... [2]

(d) Deduce the empirical formula of **A**.

..... [1]

(e) Name compound **B**.

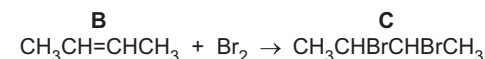
..... [1]

(f) A structural isomer of **B** is a member of the same homologous series.

Draw the displayed formula of this structural isomer of **B**.

[1]

(g) Compound **B** reacts with aqueous bromine at room temperature to form product **C**. The equation is shown.



(i) State why this is an addition reaction.

..... [1]

(ii) Describe the colour change in aqueous bromine during this reaction.

from ..... to ..... [1]

(iii) Name product **C**.

..... [1]

(h) Under certain conditions, **one** mole of **B** reacts with oxygen to form **two** moles of carboxylic acid **D**.

Carboxylic acid **D** has **two** carbon atoms.

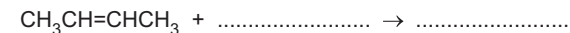
(i) Draw the displayed formula of carboxylic acid **D**.

[1]

(ii) Name carboxylic acid **D**.

..... [1]

(iii) Complete the symbol equation for this reaction.



[1]

[Total: 14]

The Periodic Table of Elements

| Group                          |                             |                                                                |                             |                             |                              |                              |                              |                            |                              |                            |                            |                           |                            |                             |                              |                          |                          |                            |                           |                           |                             |                             |                            |                            |                           |                            |                             |                         |                            |                             |                         |                            |                           |                           |                        |                           |                         |                     |                                 |                           |                              |                           |                           |                              |                                |                               |                               |                            |                             |                             |                               |                              |                             |
|--------------------------------|-----------------------------|----------------------------------------------------------------|-----------------------------|-----------------------------|------------------------------|------------------------------|------------------------------|----------------------------|------------------------------|----------------------------|----------------------------|---------------------------|----------------------------|-----------------------------|------------------------------|--------------------------|--------------------------|----------------------------|---------------------------|---------------------------|-----------------------------|-----------------------------|----------------------------|----------------------------|---------------------------|----------------------------|-----------------------------|-------------------------|----------------------------|-----------------------------|-------------------------|----------------------------|---------------------------|---------------------------|------------------------|---------------------------|-------------------------|---------------------|---------------------------------|---------------------------|------------------------------|---------------------------|---------------------------|------------------------------|--------------------------------|-------------------------------|-------------------------------|----------------------------|-----------------------------|-----------------------------|-------------------------------|------------------------------|-----------------------------|
| I                              | II                          | Key                                                            |                             |                             |                              |                              |                              |                            |                              |                            |                            | III                       | IV                         | V                           | VI                           | VII                      | VIII                     |                            |                           |                           |                             |                             |                            |                            |                           |                            |                             |                         |                            |                             |                         |                            |                           |                           |                        |                           |                         |                     |                                 |                           |                              |                           |                           |                              |                                |                               |                               |                            |                             |                             |                               |                              |                             |
|                                |                             | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                             |                             |                              |                              |                              |                            |                              |                            |                            | 1<br>H<br>hydrogen<br>1   |                            |                             |                              |                          |                          |                            |                           |                           |                             |                             |                            |                            |                           |                            |                             |                         |                            |                             |                         |                            |                           |                           |                        |                           |                         |                     |                                 |                           |                              |                           |                           |                              |                                |                               |                               |                            |                             |                             |                               |                              |                             |
| 3<br>Li<br>lithium<br>7        | 4<br>Be<br>beryllium<br>9   |                                                                |                             |                             |                              |                              |                              |                            |                              |                            |                            |                           |                            |                             |                              |                          |                          |                            |                           |                           |                             |                             |                            |                            |                           |                            |                             |                         |                            |                             |                         |                            |                           |                           |                        |                           |                         |                     |                                 |                           |                              |                           |                           |                              |                                |                               |                               |                            |                             |                             |                               |                              |                             |
| 11<br>Na<br>sodium<br>23       | 12<br>Mg<br>magnesium<br>24 | 13<br>Al<br>aluminium<br>27                                    | 14<br>Si<br>silicon<br>28   | 15<br>P<br>phosphorus<br>31 | 16<br>S<br>sulfur<br>32      | 17<br>Cl<br>chlorine<br>35.5 | 18<br>Ar<br>argon<br>40      | 19<br>K<br>potassium<br>39 | 20<br>Ca<br>calcium<br>40    | 21<br>Sc<br>scandium<br>45 | 22<br>Ti<br>titanium<br>48 | 23<br>V<br>vanadium<br>51 | 24<br>Cr<br>chromium<br>52 | 25<br>Mn<br>manganese<br>55 | 26<br>Fe<br>iron<br>56       | 27<br>Co<br>cobalt<br>59 | 28<br>Ni<br>nickel<br>59 | 29<br>Cu<br>copper<br>64   | 30<br>Zn<br>zinc<br>65    | 31<br>Ga<br>gallium<br>70 | 32<br>Ge<br>germanium<br>73 | 33<br>As<br>arsenic<br>75   | 34<br>Se<br>selenium<br>79 | 35<br>Br<br>bromine<br>80  | 36<br>Kr<br>krypton<br>84 |                            |                             |                         |                            |                             |                         |                            |                           |                           |                        |                           |                         |                     |                                 |                           |                              |                           |                           |                              |                                |                               |                               |                            |                             |                             |                               |                              |                             |
| 37<br>Rb<br>rubidium<br>85.468 | 38<br>Sr<br>strontium<br>88 | 39<br>Y<br>yttrium<br>89                                       | 40<br>Zr<br>zirconium<br>91 | 41<br>Nb<br>niobium<br>93   | 42<br>Mo<br>molybdenum<br>96 | 43<br>Tc<br>technetium<br>—  | 44<br>Ru<br>ruthenium<br>101 | 45<br>Rh<br>rhodium<br>103 | 46<br>Pd<br>palladium<br>106 | 47<br>Ag<br>silver<br>108  | 48<br>Cd<br>cadmium<br>112 | 49<br>In<br>indium<br>115 | 50<br>Sn<br>tin<br>119     | 51<br>Sb<br>antimony<br>122 | 52<br>Te<br>tellurium<br>128 | 53<br>I<br>iodine<br>127 | 54<br>Xe<br>xenon<br>131 | 55<br>Cs<br>caesium<br>133 | 56<br>Ba<br>barium<br>137 | 57–71<br>lanthanoids      | 72<br>Hf<br>hafnium<br>178  | 73<br>Ta<br>tantalum<br>181 | 74<br>W<br>tungsten<br>184 | 75<br>Re<br>rhenium<br>186 | 76<br>Os<br>osmium<br>190 | 77<br>Ir<br>iridium<br>192 | 78<br>Pt<br>platinum<br>195 | 79<br>Au<br>gold<br>197 | 80<br>Hg<br>mercury<br>201 | 81<br>Tl<br>thallium<br>204 | 82<br>Pb<br>lead<br>207 | 83<br>Bi<br>bismuth<br>209 | 84<br>Po<br>polonium<br>— | 85<br>At<br>astatine<br>— | 86<br>Rn<br>radon<br>— | 87<br>Fr<br>francium<br>— | 88<br>Ra<br>radium<br>— | 89–103<br>actinoids | 104<br>Rf<br>rutherfordium<br>— | 105<br>Db<br>dubnium<br>— | 106<br>Sg<br>seaborgium<br>— | 107<br>Bh<br>bohrium<br>— | 108<br>Hs<br>hassium<br>— | 109<br>Mt<br>meitnerium<br>— | 110<br>Ds<br>darmstadtium<br>— | 111<br>Rg<br>roentgenium<br>— | 112<br>Cn<br>copernicium<br>— | 113<br>Nh<br>nihonium<br>— | 114<br>Fl<br>flerovium<br>— | 115<br>Mc<br>moscovium<br>— | 116<br>Lv<br>livermorium<br>— | 117<br>Ts<br>tennessine<br>— | 118<br>Og<br>oganesson<br>— |

lanthanoids

actinoids

|                              |                            |                                 |                              |                             |                             |                             |                               |                            |                               |                              |                           |                               |                              |                              |
|------------------------------|----------------------------|---------------------------------|------------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------------|----------------------------|-------------------------------|------------------------------|---------------------------|-------------------------------|------------------------------|------------------------------|
| 57<br>La<br>lanthanum<br>139 | 58<br>Ce<br>cerium<br>140  | 59<br>Pr<br>praseodymium<br>141 | 60<br>Nd<br>neodymium<br>144 | 61<br>Pm<br>promethium<br>— | 62<br>Sm<br>samarium<br>150 | 63<br>Eu<br>europium<br>152 | 64<br>Gd<br>gadolinium<br>157 | 65<br>Tb<br>terbium<br>159 | 66<br>Dy<br>dysprosium<br>163 | 67<br>Ho<br>holmium<br>165   | 68<br>Er<br>erbium<br>167 | 69<br>Tm<br>thulium<br>169    | 70<br>Yb<br>ytterbium<br>173 | 71<br>Lu<br>lutetium<br>175  |
| 89<br>Ac<br>actinium<br>—    | 90<br>Th<br>thorium<br>232 | 91<br>Pa<br>protactinium<br>231 | 92<br>U<br>uranium<br>238    | 93<br>Np<br>neptunium<br>—  | 94<br>Pu<br>plutonium<br>—  | 95<br>Am<br>americium<br>—  | 96<br>Cm<br>curium<br>—       | 97<br>Bk<br>berkelium<br>— | 98<br>Cf<br>californium<br>—  | 99<br>Es<br>einsteinium<br>— | 100<br>Fm<br>fermium<br>— | 101<br>Md<br>mendelevium<br>— | 102<br>No<br>nobelium<br>—   | 103<br>Lr<br>lawrencium<br>— |

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