



Cambridge IGCSE™

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CHEMISTRY

0620/31

Paper 3 Theory (Core)

October/November 2023

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.

This document has **20** pages. Any blank pages are indicated.

1 A list of substances is shown.

ammonium nitrate
carbon monoxide
copper(II) chloride
ethane
ethene
litmus
methane
methyl orange
sodium chloride
sodium sulfate
sulfur dioxide
thymolphthalein

Answer the following questions using only the substances from the list.
Each substance may be used once, more than once or not at all.

Give the name of the substance that:

(a) turns from blue to colourless when an acid is added

..... [1]

(b) is in many fertilisers

..... [1]

(c) is a salt which has a negative ion with a charge of 2-

..... [1]

(d) is a waste gas from digestion in animals

..... [1]

(e) is a hydrocarbon with a total of five atoms in a molecule

..... [1]

(f) is a compound of a transition element.

..... [1]

[Total: 6]

2 (a) Fig. 2.1 shows the distillation apparatus that can be used to separate water from aqueous copper(II) sulfate.

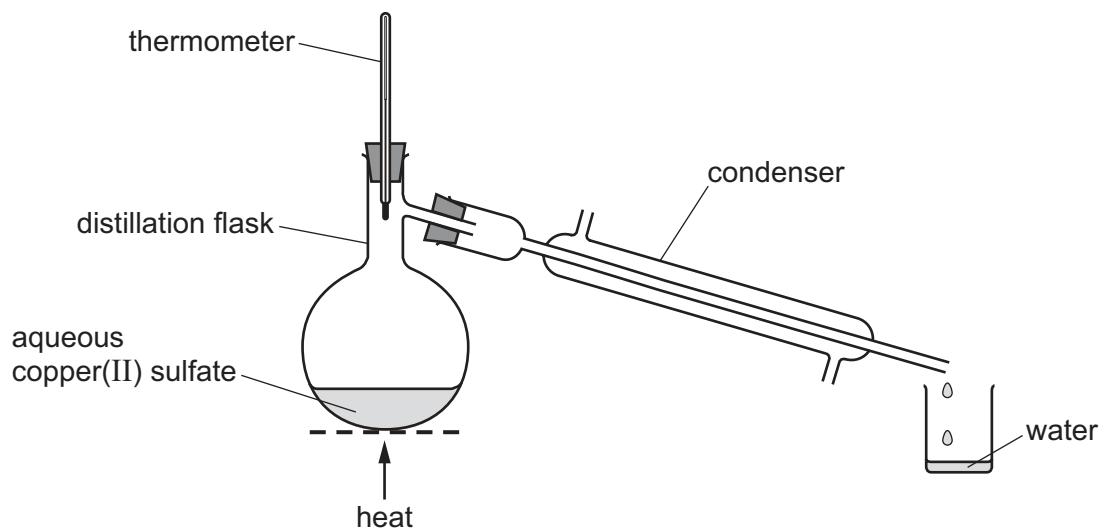


Fig. 2.1

Explain how distillation separates water from aqueous copper(II) sulfate.

.....

.....

[2]

(b) Fig. 2.2 shows a fractionating column for separating petroleum into different hydrocarbon fractions.

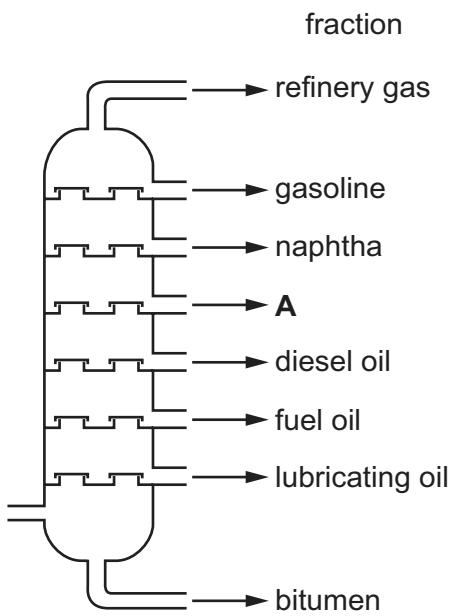


Fig. 2.2

(i) On Fig. 2.2, draw an **X** inside the column to show where the hydrocarbon with the highest viscosity collects. [1]

(ii) Name the fraction labelled **A** in Fig. 2.2.

..... [1]

(iii) State the name of the fraction in Fig. 2.2 which has the lowest boiling point.

..... [1]

(iv) State **one** use of the bitumen fraction.

..... [1]

[Total: 6]

3 (a) Table 3.1 shows the average concentrations, in ng/1000 cm³, of air pollutants in four different years.

Table 3.1

| year | concentration of air pollutant in ng/1000 cm ³ | | | | |
|------|---|--------------|--------------------|--------------|----------------|
| | ammonia | hydrocarbons | oxides of nitrogen | particulates | sulfur dioxide |
| 2019 | 10.6 | 12.0 | 15.3 | 30.1 | 20.5 |
| 2020 | 11.2 | 13.0 | 21.6 | 28.2 | 20.0 |
| 2021 | 14.3 | 15.2 | 23.5 | 26.5 | 25.0 |
| 2022 | 15.5 | 9.0 | 14.0 | 25.2 | 18.2 |

(i) Name the pollutant that has the lowest concentration in 2019.

..... [1]

(ii) Name the pollutant that shows a continuous decrease in concentration from 2019 to 2022.

..... [1]

(iii) Calculate the average mass, in ng, of sulfur dioxide in a 250 cm³ sample of polluted air in 2020.

mass = ng [1]

(b) (i) State **one** source of sulfur dioxide in the atmosphere.

..... [1]

(ii) State **one** adverse effect of sulfur dioxide in the atmosphere.

..... [1]

(iii) Choose the compound used to remove sulfur dioxide in flue gas desulfurisation.

Tick (✓) **one** box.

| | |
|--------------------|--------------------------|
| aluminium chloride | <input type="checkbox"/> |
| calcium oxide | <input type="checkbox"/> |
| methane | <input type="checkbox"/> |
| sulfuric acid | <input type="checkbox"/> |

[1]

(iv) Hydrochloric acid reacts with sodium sulfite.

The products are sodium chloride, sulfur dioxide and a liquid which turns anhydrous cobalt(II) chloride pink.

Complete the symbol equation for this reaction.



(v) Name the acidified solution used to test for sulfur dioxide gas and state the observations.

acidified solution

observations

[2]

(c) Ammonia forms an alkaline solution in water.

(i) Give the formula of the ion that is present in all alkaline solutions.

..... [1]

(ii) Choose from the list the pH value for an alkaline solution.

Draw a circle around your chosen answer.

pH 1 **pH 4** **pH 7** **pH 13** [1]

[Total: 12]

4 Bromine is a liquid at room temperature.

(a) State **two** general properties of a liquid.

1

2

[2]

(b) Fig. 4.1 shows the physical states of bromine.

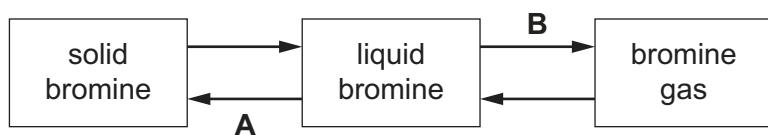


Fig. 4.1

Name the changes of physical states **A** and **B**.

A

B

[2]

(c) Describe liquid bromine and bromine gas in terms of the arrangement and motion of the particles.

liquid bromine

arrangement

.....

bromine gas

arrangement

.....

motion

[4]

(d) A sealed gas syringe contains 80 cm^3 of bromine gas.

State how decreasing the pressure affects the volume of bromine gas in the gas syringe when the temperature remains constant.

..... [1]

[Total: 9]

5 This question is about metals and metal compounds.

(a) Table 5.1 shows some properties of some Group I metals.

Table 5.1

| metal | melting point in °C | boiling point in °C | observations on reaction with water | solubility of metal hydroxide in g/dm ³ at room temperature |
|-----------|------------------------|------------------------|--|--|
| sodium | 98 | 883 | bubbles form rapidly but no flame | |
| potassium | 63 | 760 | | 1130 |
| rubidium | | 686 | explodes | 1980 |
| caesium | 29 | 669 | explodes | 3860 |

Use the information in Table 5.1 to predict:

(i) the melting point of rubidium [1]

(ii) the solubility of sodium hydroxide at room temperature [1]

(iii) the observations when potassium reacts with water

..... [1]

(iv) the physical state of caesium at 20 °C. Give a reason for your answer.

physical state

reason

[2]

(b) Iron is extracted in a blast furnace by reduction of iron(III) oxide, Fe_2O_3 , with carbon monoxide.

Carbon monoxide is produced by the reaction of carbon with carbon dioxide.



(i) Explain how this equation shows that carbon dioxide is reduced.

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

(ii) Name the type of chemical reaction where oxidation and reduction take place simultaneously.

..... [1]

(iii) Calcium carbonate is added to the blast furnace.

The calcium carbonate undergoes thermal decomposition.

State the meaning of the term thermal decomposition.

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

(c) Stainless steel is an alloy of iron.

(i) Give **one** reason why alloys are more useful than pure metals.

..... [1]

(ii) Brass is an alloy.

Choose the diagram, **A**, **B**, **C** or **D**, in Fig. 5.1 that best shows the structure of brass.

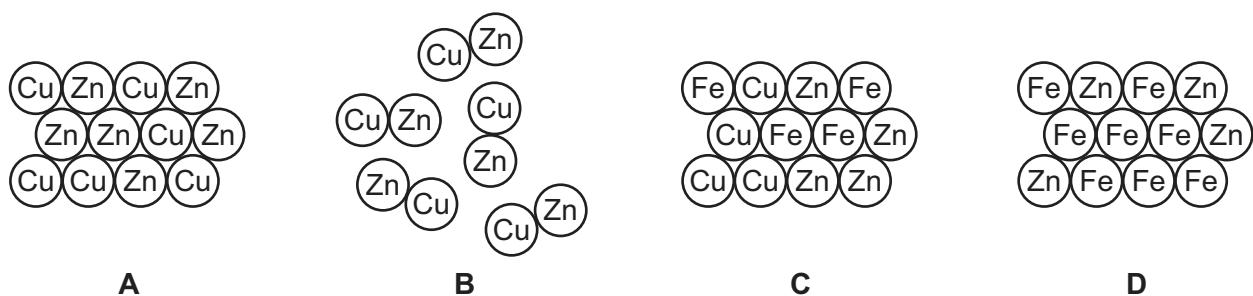


Fig. 5.1

diagram [1]

(d) Table 5.2 gives some observations about the reactivity of four metals with dilute hydrochloric acid.

Table 5.2

| metal | observations |
|-----------|---------------------------|
| iron | bubbles form slowly |
| magnesium | bubbles form very quickly |
| mercury | no bubbles form |
| tin | bubbles form very slowly |

Put the four metals in order of their reactivity.

Put the least reactive metal first.

least reactive  most reactive

| | | | |
|----------------------|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> |
|----------------------|----------------------|----------------------|----------------------|

[2]

[Total: 13]

6 A student investigates the reaction of large pieces of magnesium carbonate with dilute hydrochloric acid at 20 °C. The magnesium carbonate is in excess.

(a) Fig. 6.1 shows the volume of carbon dioxide gas released as the reaction proceeds.

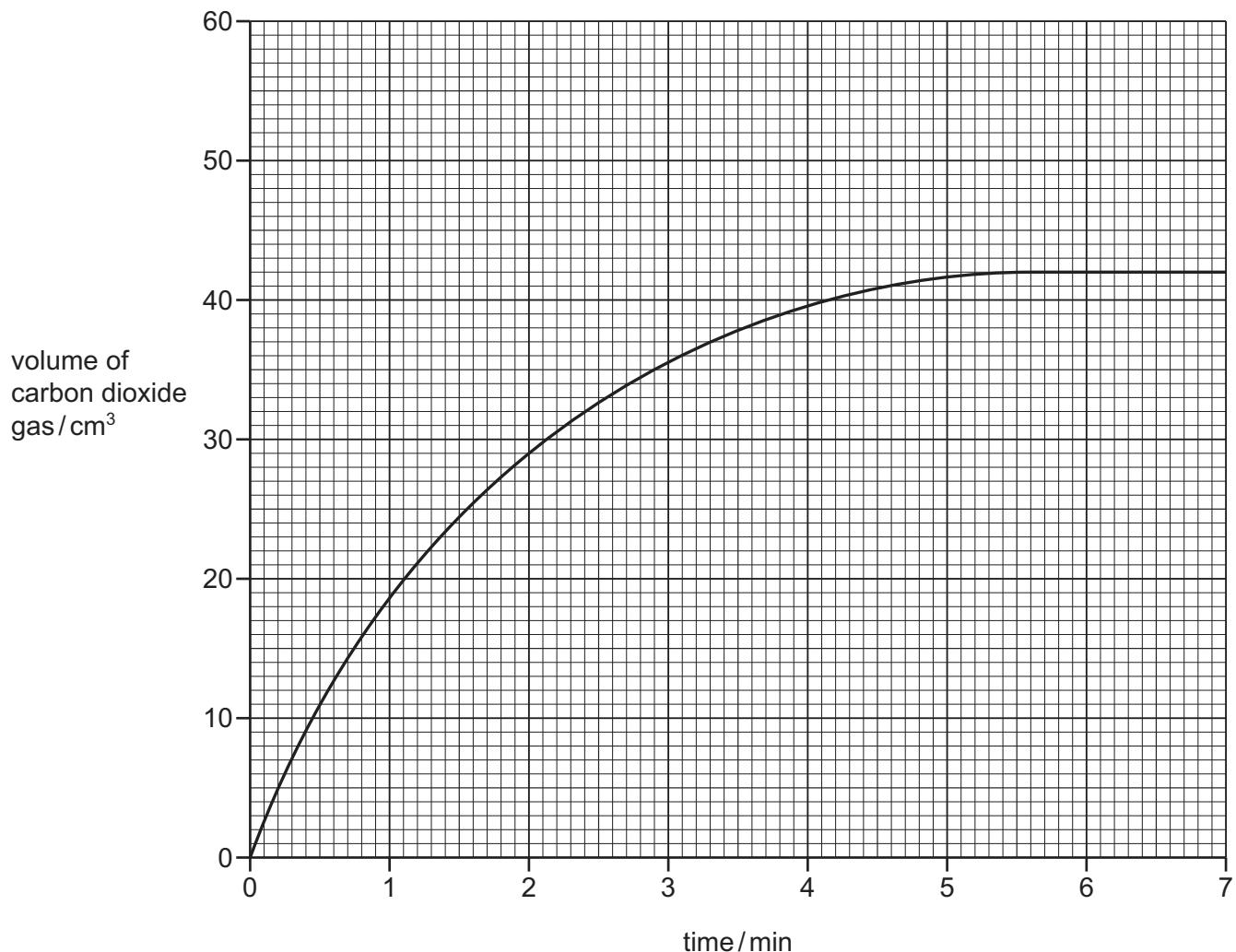


Fig. 6.1

(i) Deduce the volume of carbon dioxide gas released after 2 minutes.

$$\text{volume of carbon dioxide} = \dots \text{cm}^3 \quad [1]$$

(ii) The student repeats the experiment using the same volume of hydrochloric acid but with a higher concentration. The magnesium carbonate is still in excess.

All other conditions stay the same.

Draw a line on the grid in Fig. 6.1 to show the volume of carbon dioxide released when hydrochloric acid with a higher concentration is used. [2]

(b) (i) The student repeats the experiment using smaller pieces of magnesium carbonate.

All other conditions stay the same.

Describe how the rate of reaction differs when smaller pieces of magnesium carbonate are used.

..... [1]

(ii) The student repeats the experiment at 10 °C.

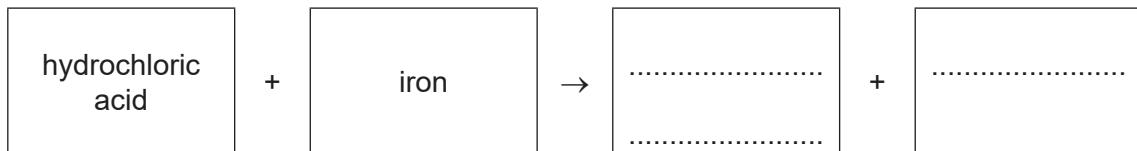
All other conditions stay the same.

Describe how the rate of reaction differs when the temperature is 10 °C.

..... [1]

(c) Hydrochloric acid reacts with iron.

Complete the word equation for this reaction.



[2]

(d) Acids are used as catalysts in many chemical reactions.

State the meaning of the term catalyst.

..... [2]

[Total: 9]

7 (a) Fig. 7.1 shows the displayed formula of compound **S**.

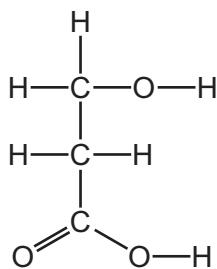


Fig. 7.1

(i) On Fig. 7.1, draw a circle around the carboxylic acid functional group. [1]

(ii) Deduce the molecular formula of compound **S**.

..... [1]

(b) Compound **S** can be converted to acrylic acid.
The molecular formula of acrylic acid is $C_3H_4O_2$.

(i) Complete Table 7.1 to calculate the relative molecular mass of acrylic acid.

Table 7.1

| atom | number of atoms | relative atomic mass | |
|----------|-----------------|----------------------|--------------------|
| carbon | 3 | 12 | $3 \times 12 = 36$ |
| hydrogen | | 1 | |
| oxygen | | 16 | |

relative molecular mass = [2]

(ii) Acrylic acid is an unsaturated compound.

Describe a test for an unsaturated compound.

test

observations

[2]

(iii) When left in the air, acrylic acid forms a polymer.

State the meaning of the term polymer.

..... [2]

(iv) Poly(ethene) is also a polymer.

Choose from the list the type of polymerisation that occurs when poly(ethene) is made.

Draw a circle around your chosen answer.

substitution

oxidation

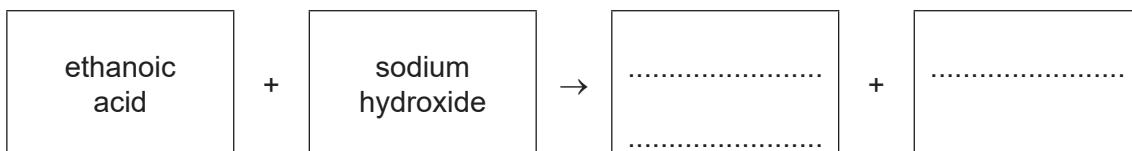
neutralisation

addition

[1]

(c) Ethanoic acid is a carboxylic acid.

Complete the word equation for the reaction of ethanoic acid with sodium hydroxide.



[2]

(d) Ethanoic acid can be converted to ethanol.

Name the **two** products formed when ethanol undergoes complete combustion.

..... and [2]

[Total: 13]

8 Lithium bromide is a compound with ionic bonding.

(a) State the meaning of the term ionic bond.

..... [2]

(b) Complete Fig. 8.1 to show:

- the electronic configuration of a lithium ion
- the charge on the ion.

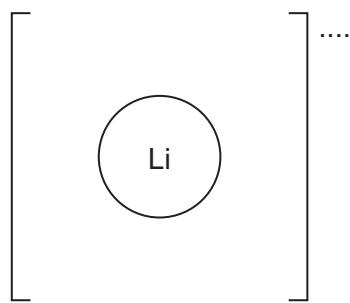


Fig. 8.1

[2]

(c) Deduce the number of protons and neutrons in the bromide ion shown.



number of protons

number of neutrons

[2]

(d) Molten lithium bromide is electrolysed using graphite electrodes.

State the names of the product at each electrode and give the observations at the positive electrode.

product at the negative electrode

product at the positive electrode

observations at the positive electrode

..... [3]

(e) Fig. 8.2 shows the structure of graphite.

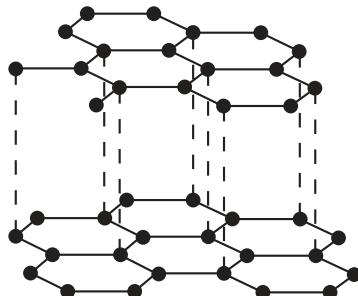


Fig. 8.2

(i) State the type of bonding in graphite.

..... [1]

(ii) Explain by referring to Fig. 8.2 why graphite is used as a lubricant.

..... [1]

(iii) Graphite and diamond are both forms of carbon.

State **one** use of diamond.

..... [1]

[Total: 12]

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The Periodic Table of Elements

| Group | | Group | | | | | | | | | | | | | | | | | | |
|-------|----|-----------------------------|----------------------------------|---------------------------------|----------------------------------|-------------------------------|------------------------------|----------------------------------|-------------------------------|--------------------------------|-------------------------------|-------------------------------|--------------------------------|------------------------------|--------------------------------|-----------------------------|-------------------------------|------------------------------|-------------------------------|------------------------------|
| | | I | | II | | III | | IV | | V | | VI | | VII | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 3 | 4 | Li lithium 7 | Be beryllium 9 | Sc scandium 45 | Ti titanium 48 | V vanadium 51 | Cr chromium 52 | Mn manganese 55 | Fe iron 56 | Co cobalt 59 | Ni nickel 59 | Cu copper 64 | Zn zinc 65 | Ga gallium 70 | Ge germanium 73 | As arsenic 75 | Se selenium 79 | Br bromine 80 | Kr krypton 84 | |
| 11 | 12 | Na sodium 23 | Mg magnesium 24 | Ca calcium 40 | Y yttrium 89 | Zr zirconium 91 | Nb niobium 93 | Mo molybdenum 96 | Tc technetium — | Ru ruthenium 101 | Rh rhodium 103 | Pd palladium 106 | Ag silver 108 | Cd cadmium 112 | In indium 115 | Sn tin 119 | Te tellurium 122 | I iodine 128 | Xe xenon 131 | |
| 19 | 20 | K potassium 39 | Sr strontium 88 | Rb rubidium 85 | Yt yttrium 89 | Zr zirconium 91 | Nb niobium 93 | Mo molybdenum 96 | Tc technetium — | Ru ruthenium 101 | Rh rhodium 103 | Pt platinum 106 | Au gold 197 | Tl thallium 195 | Pb lead 207 | Bi bismuth 209 | Po polonium — | At astatine — | Rn radon — | |
| 37 | 38 | Cs caesium 133 | Ba barium 137 | Fr francium — | La lanthanum 139 | La lanthanum 139 | Ce cerium 140 | Pr praseodymium 141 | Nd neodymium 144 | Pm promethium — | Sm samarium 150 | Eu europium 152 | Gd gadolinium 157 | Tb terbium 159 | Dy dysprosium 163 | Ho holmium 165 | Er erbium 167 | Tm thulium 169 | Yb ytterbium 173 | Lu lutetium 175 |
| 55 | 56 | Ca calcium 133 | La lanthanoid 57–71 | Fr actinoid 89–103 | Th thorium 232 | Hf hafnium 178 | Ta tantalum 181 | W tungsten 184 | Re rhodium 186 | Os osmium 190 | Ir iridium 192 | Pt platinum 195 | Au gold 197 | Hg mercury 201 | Tl thallium 204 | Pb lead 207 | Bi bismuth 209 | Po polonium — | At astatine — | Rn radon — |
| 87 | 88 | Ra radium — | Rf rutherfordium — | Ac actinium — | Pa protactinium 231 | Db dubnium — | Sg seaborgium — | Bh bohrium — | Mt meitnerium — | Ds darmstadtium — | Rg roentgenium — | Fm ferrovium — | Cn copernicium — | Nh nihonium — | Fl florium — | Mc moscovium — | Lv livmorium — | Ts tennessine — | Og oganesson — | |

| | | | | | | | | | | | | | | | | |
|--------------------|----|----|-----------------------------|----------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|--------------------------------|-----------------------------|--------------------------------|-----------------------------|-------------------------------|-----------------------------|-------------------------------|------------------------------|
| lanthanoids | 57 | 58 | Ce cerium 140 | Pr praseodymium 141 | Nd neodymium 144 | Pm promethium — | Sm samarium 150 | Eu europium 152 | Gd gadolinium 157 | Tb terbium 159 | Dy dysprosium 163 | Ho holmium 165 | Er erbium 167 | Tm thulium 169 | Yb ytterbium 173 | Lu lutetium 175 |
| actinoids | 89 | 90 | Th thorium 232 | Pa protactinium 231 | U uranium 238 | Np neptunium — | Am americium — | Pu plutonium — | Cm curium — | Bk berkelium — | Cf californium — | Fm fermium — | Md mendelevium — | No nobelium — | Lr lawrencium — | U — |

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