



# 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.

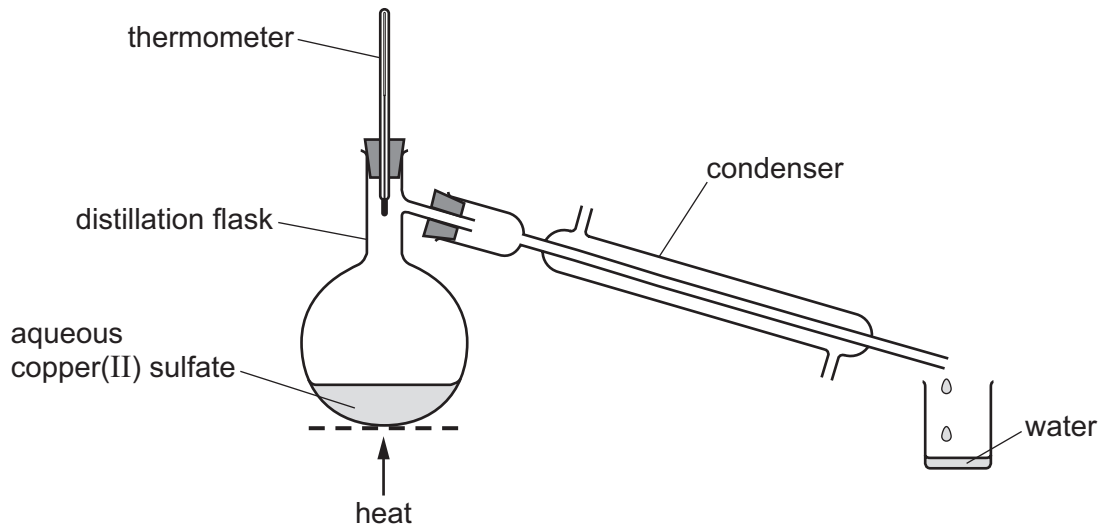


Fig. 2.1

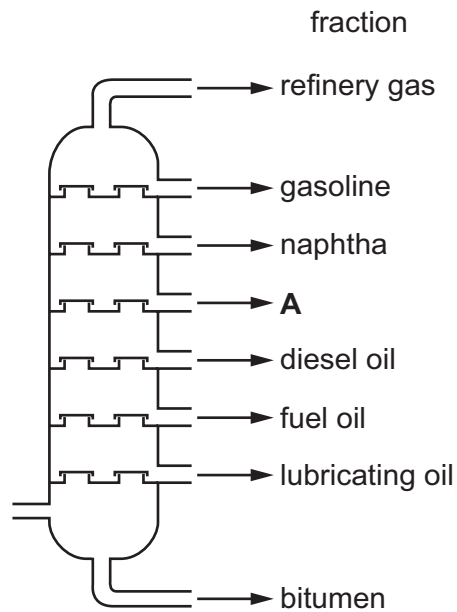
Explain how distillation separates water from aqueous copper(II) sulfate.

.....

.....

..... [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  $\text{ng}/1000\text{cm}^3$ , of air pollutants in four different years.

**Table 3.1**

year	concentration of air pollutant in $\text{ng}/1000\text{cm}^3$				
	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  $250\text{cm}^3$  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.

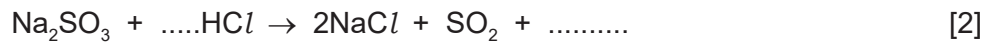
aluminium chloride	<input type="checkbox"/>
calcium oxide	<input type="checkbox"/>
methane	<input type="checkbox"/>
sulfuric acid	<input type="checkbox"/>

[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.



[2]

(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.

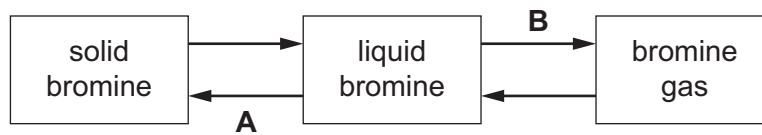


Fig. 4.1

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 .....
- .....
- motion .....
- .....
- bromine gas
- arrangement .....
- .....
- motion .....
- .....

[4]

(d) A sealed gas syringe contains  $80\text{ cm}^3$  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 <sup>3</sup> 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,  $\text{Fe}_2\text{O}_3$ , 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]

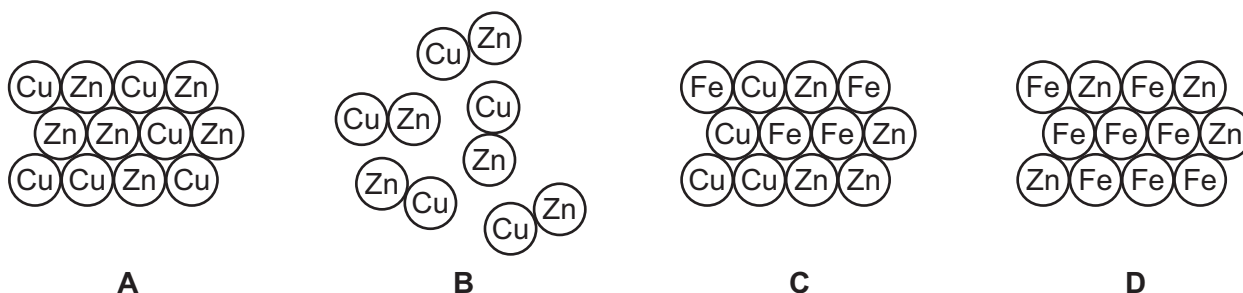
(c) Stainless steel is an alloy of iron.

(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  $\longrightarrow$  most reactive

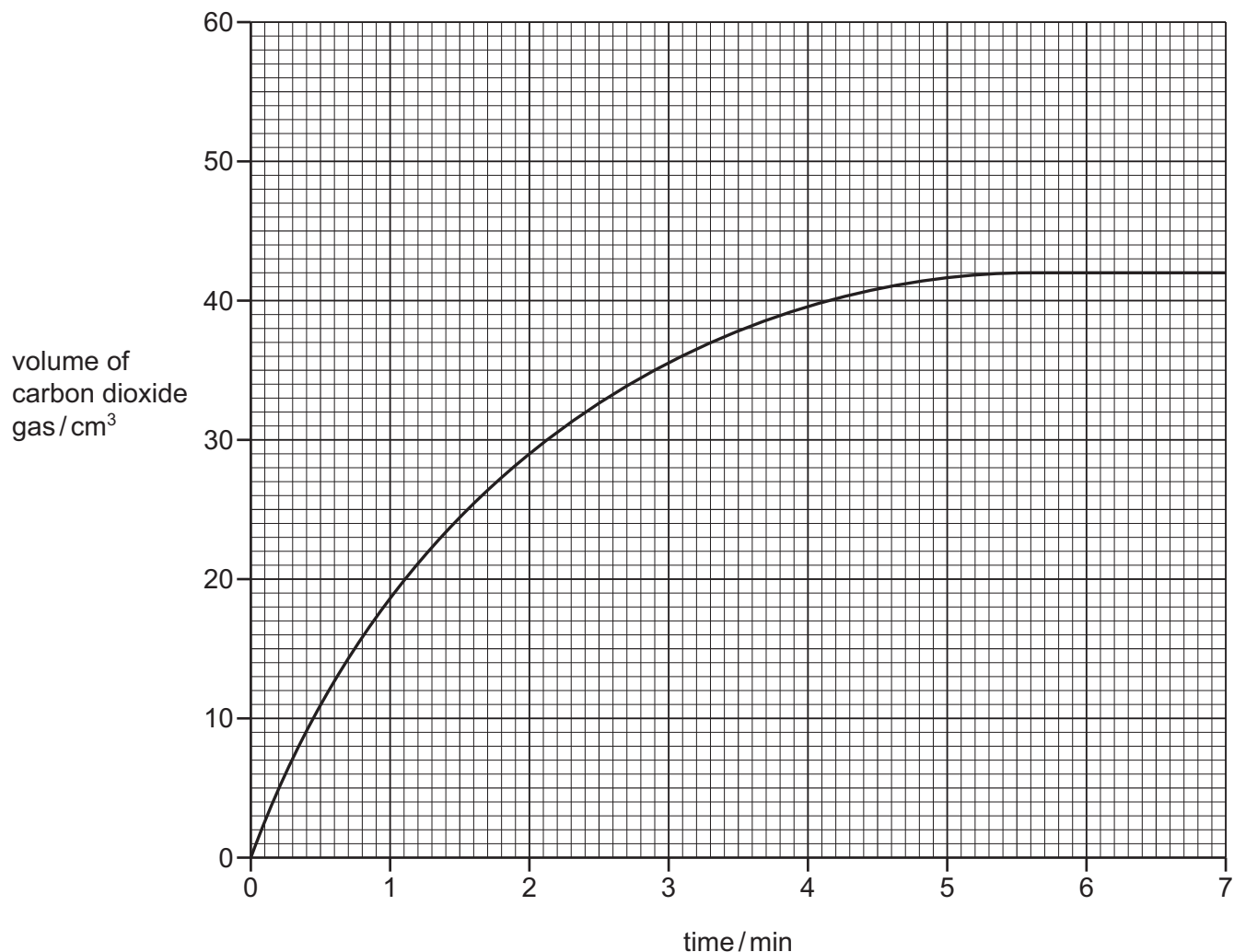
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[2]

[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.

volume of carbon dioxide = ..... cm<sup>3</sup> [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.

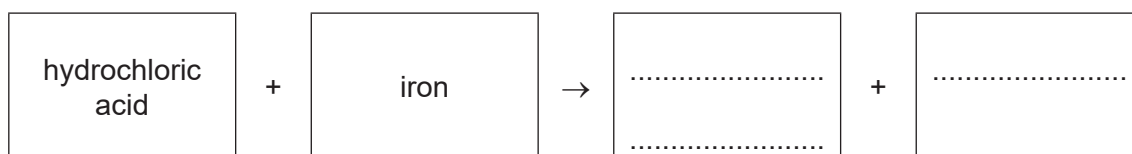
All other conditions stay the same.

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**.

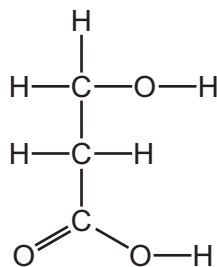


Fig. 7.1

- (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.

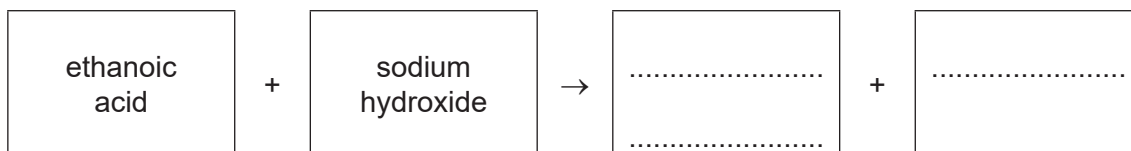
Choose from the list the type of polymerisation that occurs when poly(ethene) is made.

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.

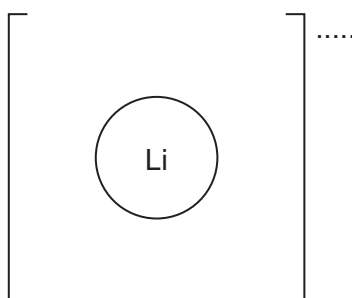


Fig. 8.1

[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.

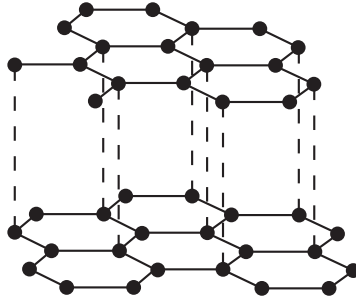


Fig. 8.2

(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							
I	II	III	IV	V	VI	VII	VIII		
3 <b>Li</b> lithium 7	4 <b>Be</b> beryllium 9	1 <b>H</b> hydrogen 1	5 <b>B</b> boron 11	6 <b>C</b> carbon 12	7 <b>N</b> nitrogen 14	8 <b>O</b> oxygen 16	9 <b>F</b> fluorine 19	10 <b>Ne</b> neon 20	2
11 <b>Na</b> sodium 23	12 <b>Mg</b> magnesium 24	<b>Key</b> atomic number atomic symbol name relative atomic mass							
19 <b>K</b> potassium 39	20 <b>Ca</b> calcium 40	26 <b>Fe</b> iron 56	27 <b>Co</b> cobalt 59	28 <b>Ni</b> nickel 59	29 <b>Cu</b> copper 64	30 <b>Zn</b> zinc 65	31 <b>Al</b> aluminium 27	32 <b>Si</b> silicon 28	33 <b>P</b> phosphorus 31
37 <b>Rb</b> rubidium 85	38 <b>Sr</b> strontium 88	44 <b>Ru</b> ruthenium 101	45 <b>Rh</b> rhodium 103	46 <b>Pd</b> palladium 106	47 <b>Ag</b> silver 108	48 <b>Cd</b> cadmium 112	49 <b>In</b> indium 115	50 <b>Sn</b> tin 119	51 <b>Sb</b> antimony 122
55 <b>Cs</b> caesium 133	56 <b>Ba</b> barium 137	76 <b>Os</b> osmium 190	77 <b>Ir</b> iridium 192	78 <b>Pt</b> platinum 195	79 <b>Au</b> gold 197	80 <b>Hg</b> mercury 201	81 <b>Tl</b> thallium 204	82 <b>Pb</b> lead 207	83 <b>Bi</b> bismuth 209
87 <b>Fr</b> francium —	88 <b>Ra</b> radium —	108 <b>Hs</b> hassium —	109 <b>Mt</b> meitnerium —	110 <b>Ds</b> darmstadtium —	111 <b>Rg</b> roentgenium —	112 <b>Cn</b> copernicium —	113 <b>Nh</b> nihonium —	114 <b>Fl</b> flerovium —	115 <b>Mc</b> moscovium —
89–103 actinoids	89–103 actinoids	104 <b>Rf</b> rutherfordium —	105 <b>Db</b> dubnium —	106 <b>Sg</b> seaborgium —	107 <b>Bh</b> bohrium —	108 <b>Hs</b> hassium —	109 <b>Mt</b> meitnerium —	110 <b>Ds</b> darmstadtium —	111 <b>Rg</b> roentgenium —
57 <b>La</b> lanthanum 139	58 <b>Ce</b> cerium 140	62 <b>Sm</b> samarium 150	63 <b>Eu</b> europium 152	64 <b>Gd</b> gadolinium 157	65 <b>Tb</b> terbium 159	66 <b>Dy</b> dysprosium 163	67 <b>Ho</b> holmium 165	68 <b>Er</b> erbium 167	69 <b>Tm</b> thulium 169
89 <b>Ac</b> actinium —	90 <b>Th</b> thorium 232	94 <b>Pu</b> plutonium —	95 <b>Am</b> americium —	96 <b>Cm</b> curium —	97 <b>Bk</b> berkelium —	98 <b>Cf</b> californium —	99 <b>Es</b> einsteinium —	100 <b>Fm</b> fermium —	101 <b>Md</b> mendelevium —
		60 <b>Nd</b> neodymium 144	61 <b>Pm</b> promethium —	62 <b>Sm</b> samarium 150	63 <b>Eu</b> europium 152	64 <b>Gd</b> gadolinium 157	65 <b>Tb</b> terbium 159	66 <b>Dy</b> dysprosium 163	67 <b>Ho</b> holmium 165
		91 <b>Pa</b> protactinium 231	92 <b>U</b> uranium 238	93 <b>Np</b> neptunium —	94 <b>Pu</b> plutonium —	95 <b>Am</b> americium —	96 <b>Cm</b> curium —	97 <b>Bk</b> berkelium —	98 <b>Cf</b> californium —
		59 <b>Pr</b> praseodymium 141	60 <b>Nd</b> neodymium 144	61 <b>Pm</b> promethium —	62 <b>Sm</b> samarium 150	63 <b>Eu</b> europium 152	64 <b>Gd</b> gadolinium 157	65 <b>Tb</b> terbium 159	66 <b>Dy</b> dysprosium 163
		71 <b>Lu</b> lutetium 175	70 <b>Yb</b> ytterbium 173	71 <b>Lu</b> lutetium 175	72 <b>Hf</b> hafnium 178	73 <b>Ta</b> tantalum 181	74 <b>W</b> tungsten 184	75 <b>Re</b> rhenium 186	76 <b>Os</b> osmium 190
		103 <b>Lr</b> lawrencium —	102 <b>No</b> nobelium —	103 <b>Lr</b> lawrencium —	104 <b>Rf</b> rutherfordium —	105 <b>Db</b> dubnium —	106 <b>Sg</b> seaborgium —	107 <b>Bh</b> bohrium —	108 <b>Hs</b> hassium —
		118 <b>Og</b> oganesson —	117 <b>Ts</b> tennessine —	118 <b>Og</b> oganesson —	119 <b>Uu</b> unbinilium —	120 <b>Uub</b> unbinilium —	121 <b>Uut</b> unbinilium —	122 <b>Uuq</b> unbinilium —	123 <b>Uuq</b> unbinilium —

lanthanoids

actinoids

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