



**Cambridge International Examinations**  
Cambridge International General Certificate of Secondary Education (9–1)

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**CHEMISTRY**

**0971/31**

Paper 3 Theory (Core)

**May/June 2018**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

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

Write in dark blue or black pen.

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

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

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

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

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

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

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

This document consists of **15** printed pages and **1** blank page.

1 The names of eight gases are given.

**ammonia**  
**argon**  
**carbon dioxide**  
**helium**  
**hydrogen**  
**methane**  
**neon**  
**sulfur dioxide**

(a) Answer the following questions about these gases.  
 Each gas may be used once, more than once or not at all.  
 State which gas:

(i) turns damp red litmus paper blue

..... [1]

(ii) contributes to the formation of acid rain

..... [1]

(iii) is a hydrocarbon which contributes to climate change

..... [1]

(iv) is a product of the reaction of copper(II) carbonate with hydrochloric acid

..... [1]

(v) is a monatomic gas which has atoms with the electronic structure 2,8,8.

..... [1]

(b) (i) Explain why helium and **not** hydrogen is used to fill party balloons.

..... [1]

(ii) Give **one** use of argon.

..... [1]

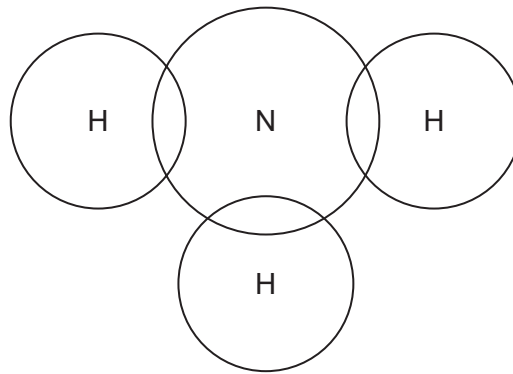
(c) Carbon dioxide is a compound.

What is meant by the term *compound*?

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

3

- (d) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of ammonia. Show outer shell electrons only.



[2]

[Total: 10]

- 2 The table shows the percentage by volume of each of the gases present in the exhaust gases from a petrol engine.

name	percentage by volume
carbon monoxide	1.0
carbon dioxide	
hydrogen	0.2
nitrogen	77.0
nitrogen dioxide	0.3
oxygen	0.7
hydrocarbons	0.3
water vapour	5.0
total	100.0

- (a) (i) Calculate the percentage by volume of carbon dioxide in the exhaust gases.

.....% [1]

- (ii) Which gas shown in the table is present in the lowest percentage by volume?

..... [1]

- (iii) Which **two** elements in the table combine to form nitrogen dioxide?

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

- (iv) Give the formula for nitrogen dioxide.

..... [1]

- (v) Where does the nitrogen in the exhaust gases come from?

..... [1]

- (b) The carbon monoxide in the exhaust gases comes from the incomplete combustion of hydrocarbons.

- (i) What is meant by the term *hydrocarbon*?

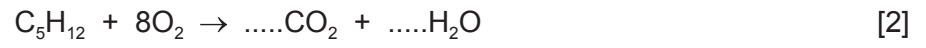
.....  
 ..... [2]

- (ii) Give **one** adverse effect of carbon monoxide on health.

..... [1]

5

(iii) Balance the chemical equation for the complete combustion of pentane.



[Total: 10]

3 Limonene is a volatile liquid which smells of oranges.

(a) A teacher placed a beaker of limonene at the front of a classroom. At first, the students at the back of the classroom could not smell the limonene. After two minutes, the smell of limonene had spread throughout the classroom. The air in the classroom was still and calm.

(i) Explain these observations using the kinetic particle model.

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

(ii) The melting point of limonene is  $-74^{\circ}\text{C}$ .  
The boiling point of limonene is  $176^{\circ}\text{C}$ .

What is the physical state of limonene at  $-80^{\circ}\text{C}$ ?  
Explain your answer.

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

(b) An enzyme present in peppermint plants is a catalyst for the oxidation of limonene.

State what is meant by the terms:

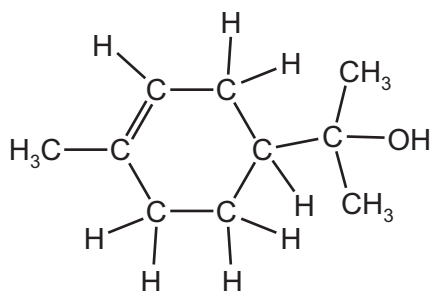
(i) *catalyst*

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

(ii) *oxidation*

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

- (c) Limonene can be made from a colourless compound called  $\alpha$ -terpineol. The structure of  $\alpha$ -terpineol is shown.



- (i) What feature of the structure of the  $\alpha$ -terpineol molecule shows that it is an unsaturated compound?

..... [1]

- (ii) Describe how the colour of aqueous bromine changes when an excess of  $\alpha$ -terpineol is added to it.

from ..... to ..... [2]

[Total: 10]

4 This question is about iron and its compounds.

(a) The table shows how easy it is to reduce four metal oxides by heating with carbon.

metal oxide	ease of reduction with carbon
chromium(III) oxide	only reduced above 1700 °C
iron(III) oxide	only reduced above 650 °C
magnesium oxide	<b>not</b> reduced at 1750 °C
nickel(II) oxide	only reduced above 300 °C

Use this information to put the metals in order of their reactivity. Put the least reactive metal first.

least reactive  $\xrightarrow{\hspace{15em}}$  most reactive

--	--	--	--

[2]

(b) Iron is a transition element. Potassium is an element in Group I of the Periodic Table.

Describe **three** ways in which the properties of iron differ from those of potassium.

- 1 .....
- 2 .....
- 3 .....

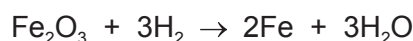
[3]

(c) Iron wire burns in oxygen.

Balance the chemical equation for this reaction.



(d) Pure iron can be made by reducing iron(III) oxide,  $\text{Fe}_2\text{O}_3$ , with hydrogen.



How does this equation show that iron(III) oxide is reduced?

.....

..... [1]



(e) When iron reacts with dilute hydrochloric acid, iron(II) chloride is formed.

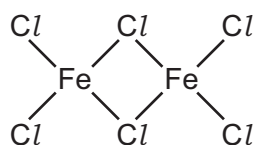
(i) Describe a test for iron(II) ions.

test .....

result .....

[2]

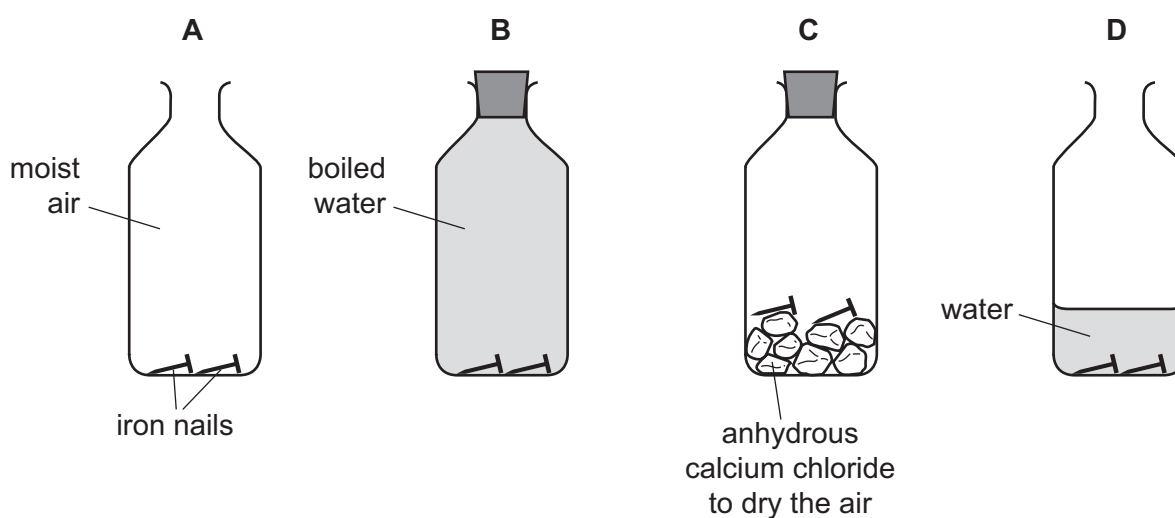
(ii) Another chloride of iron has the structure shown.



Deduce the molecular formula of this compound showing the number of iron and chlorine atoms.

..... [1]

(f) Some iron nails were placed in bottles under different conditions.



In which bottles will the iron nails **not** rust?  
Give reasons for your answer.

.....  
 .....  
 .....

[2]

[Total: 13]

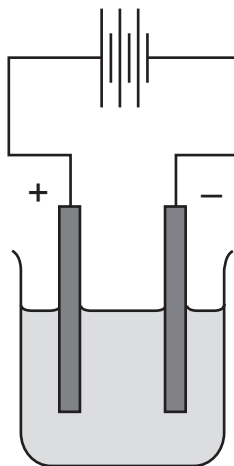
- 5 (a) Complete the sentence about electrolysis using words from the list.

**breakdown**      **compound**      **electricity**      **electroplating**  
**element**      **gaseous**      **heat**      **molten**

Electrolysis is the ..... of an ionic ..... when  
 ..... or in aqueous solution by the passage of .....

[4]

- (b) Molten zinc iodide can be electrolysed using the apparatus shown.



On the diagram, label:

- the anode
- the cathode
- the electrolyte

[2]

- (c) Why are the electrodes made of graphite?

..... [1]

- (d) Predict the products of the electrolysis of molten zinc iodide at:

the negative electrode .....

the positive electrode. .... [2]

- (e) When chlorine is bubbled through a colourless aqueous solution of zinc iodide, the solution turns brown.

Name the brown substance. Suggest, using ideas about reactivity of the halogens, why this reaction occurs.

.....

..... [2]

[Total: 11]



7 This question is about Group I elements and their compounds.

(a) The properties of some Group I elements are shown in the table.

element	boiling point / °C	atomic radius / pm	relative thermal conductivity	observations when it reacts with cold water
sodium	883	186	3.9	rapid bubbling but does <b>not</b> burst into flame
potassium	759	227		very rapid bubbling and bursts into flame
rubidium	688		1.6	
caesium	671	265	1.0	explodes

(i) Complete the table to estimate:

- the relative thermal conductivity of potassium
- the atomic radius of rubidium.

[2]

(ii) Describe the trend in the boiling points of the Group I elements.

..... [1]

(iii) Use the information in the table to predict what you would observe when rubidium reacts with cold water.

..... [1]

(b) Which **one** of the statements about the formation of a sodium ion from a sodium atom is correct?

Tick **one** box.

A sodium atom gains an electron.

A sodium atom loses an electron.

A sodium atom loses a proton.

A sodium atom gains a proton.

[1]

- (c) Is sodium oxide an acidic oxide or a basic oxide?  
Give a reason for your answer.

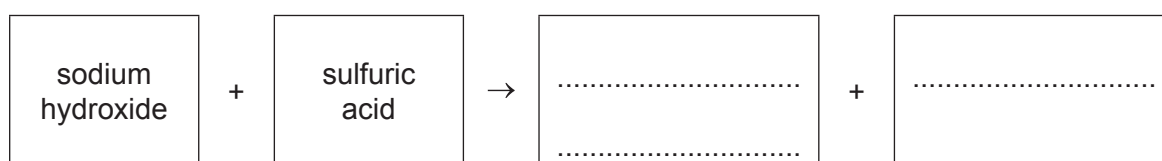
.....  
..... [1]

- (d) A compound of sodium has the formula  $C_4H_5Na$ .

Calculate the relative formula mass of  $C_4H_5Na$ .  
Show all your working.  
Use your Periodic Table to help you.

relative formula mass = ..... [2]

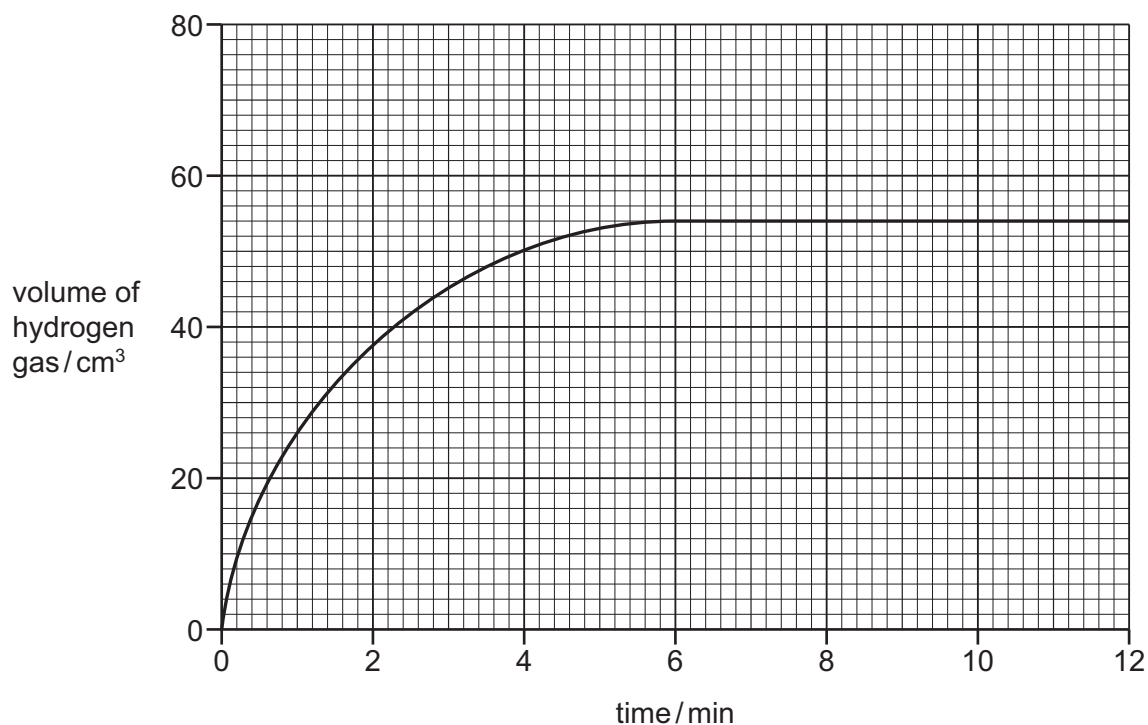
- (e) Complete the word equation for the reaction of sodium hydroxide with sulfuric acid.



[2]

[Total: 10]

- 8 When zinc reacts with hydrochloric acid, hydrogen gas is produced. The graph shows how the volume of hydrogen gas produced changes with time when an excess of zinc is reacted with  $0.2 \text{ mol/dm}^3$  hydrochloric acid.



- (a) Explain why the volume of hydrogen gas remains constant after six minutes.

..... [1]

- (b) What volume of hydrogen gas was released in the first **two** minutes of the reaction?

..... [1]

- (c) The experiment is repeated using the same volume of  $0.1 \text{ mol/dm}^3$  hydrochloric acid. All other conditions are kept the same.

**On the grid**, draw the graph for the experiment using  $0.1 \text{ mol/dm}^3$  hydrochloric acid. [2]

- (d) Give the name of the salt formed when zinc reacts with hydrochloric acid.

..... [1]

- (e) Which **one** of the following pH values could be the pH of dilute hydrochloric acid? Draw a circle around the correct answer.

pH 1      pH 7      pH 9      pH 13      [1]

[Total: 6]

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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	13 <b>Al</b> aluminium 27	14 <b>Si</b> silicon 28	15 <b>P</b> phosphorus 31
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	13 <b>Al</b> aluminium 27	14 <b>Si</b> silicon 28	15 <b>P</b> phosphorus 31
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 —	116 <b>Lv</b> livermorium —	117 <b>Tl</b> thallium 204	118 <b>Xe</b> xenon 131
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>Gd</b> gadolinium 157	63 <b>Tb</b> terbium 159	64 <b>Dy</b> dysprosium 163	65 <b>Ho</b> holmium 165	66 <b>Er</b> erbium 167	67 <b>Tm</b> thulium 169
		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 —	99 <b>Md</b> mendelevium —
		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
		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 —
		58 <b>Ce</b> cerium 140	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
		89 <b>Th</b> thorium 232	90 <b>Pa</b> protactinium 231	91 <b>U</b> uranium 238	92 <b>Np</b> neptunium —	93 <b>Pu</b> plutonium —	94 <b>Am</b> americium —	95 <b>Cm</b> curium —	96 <b>Bk</b> berkelium —
		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	77 <b>Ir</b> iridium 192	78 <b>Pt</b> platinum 195
		103 <b>La</b> lanthanum 139	104 <b>Ce</b> cerium 140	105 <b>Pr</b> praseodymium 141	106 <b>Nd</b> neodymium 144	107 <b>Pm</b> promethium —	108 <b>Sm</b> samarium 150	109 <b>Eu</b> europium 152	110 <b>Gd</b> gadolinium 157
		86 <b>Rn</b> radon —	87 <b>Fr</b> francium —	88 <b>Ra</b> radium —	89 <b>Ac</b> actinium —	90 <b>Th</b> thorium 232	91 <b>Pa</b> protactinium 231	92 <b>U</b> uranium 238	93 <b>Np</b> neptunium —
		84 <b>Kr</b> krypton 84	85 <b>Rb</b> rubidium 85	86 <b>Rn</b> radon —	87 <b>Fr</b> francium —	88 <b>Ra</b> radium —	89 <b>Ac</b> actinium —	90 <b>Th</b> thorium 232	91 <b>Pa</b> protactinium 231
		82 <b>Pb</b> lead 207	83 <b>Bi</b> bismuth 209	84 <b>Po</b> polonium —	85 <b>At</b> astatine —	86 <b>Rn</b> radon —	87 <b>Fr</b> francium —	88 <b>Ra</b> radium —	89 <b>Ac</b> actinium —
		54 <b>Xe</b> xenon 131	55 <b>Cs</b> caesium 133	56 <b>Ba</b> barium 137	57 <b>La</b> lanthanoids —	58 <b>Ce</b> cerium 140	59 <b>Pr</b> praseodymium 141	60 <b>Nd</b> neodymium 144	61 <b>Pm</b> promethium —
		52 <b>Te</b> tellurium 128	53 <b>I</b> iodine 127	54 <b>Xe</b> xenon 131	55 <b>Cs</b> caesium 133	56 <b>Ba</b> barium 137	57 <b>La</b> lanthanoids —	58 <b>Ce</b> cerium 140	59 <b>Pr</b> praseodymium 141
		36 <b>Kr</b> krypton 84	37 <b>Rb</b> rubidium 85	38 <b>Sr</b> strontium 88	39 <b>Y</b> yttrium 89	40 <b>Zr</b> zirconium 91	41 <b>Nb</b> niobium 93	42 <b>Mo</b> molybdenum 96	43 <b>Tc</b> technetium —
		34 <b>Se</b> selenium 79	35 <b>Br</b> bromine 80	36 <b>Kr</b> krypton 84	37 <b>Rb</b> rubidium 85	38 <b>Sr</b> strontium 88	39 <b>Y</b> yttrium 89	40 <b>Zr</b> zirconium 91	41 <b>Nb</b> niobium 93
		18 <b>Ar</b> argon 40	19 <b>K</b> potassium 39	20 <b>Ca</b> calcium 40	21 <b>Sc</b> scandium 45	22 <b>Ti</b> titanium 48	23 <b>V</b> vanadium 51	24 <b>Cr</b> chromium 52	25 <b>Mn</b> manganese 55
		16 <b>S</b> sulfur 32	17 <b>Cl</b> chlorine 35.5	18 <b>Ar</b> argon 40	19 <b>K</b> potassium 39	20 <b>Ca</b> calcium 40	21 <b>Sc</b> scandium 45	22 <b>Ti</b> titanium 48	23 <b>V</b> vanadium 51
		10 <b>Ne</b> neon 20	11 <b>Na</b> sodium 23	12 <b>Mg</b> magnesium 24	13 <b>Al</b> aluminium 27	14 <b>Si</b> silicon 28	15 <b>P</b> phosphorus 31	16 <b>S</b> sulfur 32	17 <b>Cl</b> chlorine 35.5
		2 <b>He</b> helium 4	3 <b>Li</b> lithium 7	4 <b>Be</b> beryllium 9	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

lanthanoids

actinoids

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