Surname	StemUp Model Solution	Centre Number	Candidate Number
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GCE AS

B410U10-1

S23-B410U10-1

eduqas Part of WJEC

TUESDAY, 16 MAY 2023 – MORNING

CHEMISTRY – AS component 1

The Language of Chemistry, Structure of Matter and Simple Reactions

1 hour 30 minutes

For Examiner's use only			
	Question	Maximum Mark	Mark Awarded
Section A	1. to 6.	10	
Section B	7.	10	
	8.	11	
	9.	16	
	10.	15	
	11.	8	
	12	10	
	Total	80	

B410U101
01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.
Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

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

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.10**(b).

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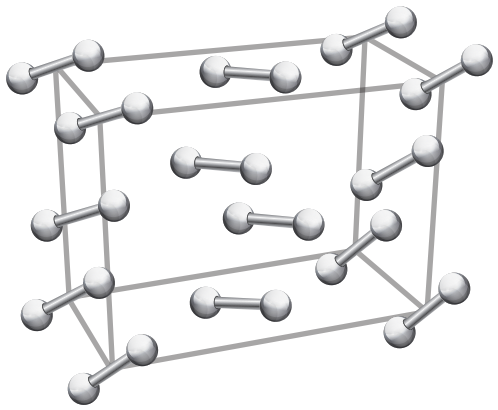
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SECTION A

Answer **all** questions.

1. The diagram below shows the arrangement of molecules in a crystal of iodine.

State the two types of bonding that occur in this structure. [1]



covalent and van der Waals

2. Bromine is made when chlorine is passed through a solution of potassium bromide.

(a) Write an equation to represent this reaction. [1]

$Cl_2 + 2KBr \rightarrow Br_2 + 2KCl$

(b) State why chlorine is described as an oxidising agent in this reaction. [1]

Chlorine removes electrons from the bromide ions (chlorine gains electrons and is reduced; its oxidation state decreases from 0 to −1).

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3. Actinium-236 has a half-life of 72 s.

Calculate the mass remaining from a 16 g sample after 6 minutes. [1]

6 minutes = 360 s; 360 ÷ 72 = 5 half-lives

16 → 8 → 4 → 2 → 1 → 0.5 g

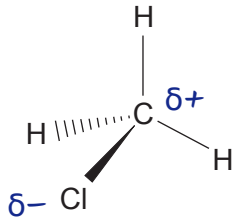
mass = 16 × $(½)^5$ = 0.5 g

Mass = 0.5 g

4. (a) Explain why some covalent bonds are polar. [1]

The atoms bonded have different electronegativities, so the bonding electrons are unequally shared.

(b) On the diagram below mark the **largest** permanent dipole. [1]



5. The first eight ionisation energy values for an element are shown below.

State to which group this element belongs. [1]

	1st	2nd	3rd	4th	5th	6th	7th	8th
Ionisation energy / kJ mol^{-1}	1670	3380	6045	8415	11075	15050	17905	91655

Group 7

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6. (a) Give the meaning of the term empirical formula. [1]

A formula showing the simplest whole number ratio of the atoms of each element present in the compound.

(b) It was found that a compound contained 6.10 g of copper, 5.35 g of iron and 6.16 g of sulfur **only**.

Calculate the empirical formula of this compound. [2]

Cu: 6.10 ÷ 63.5 = 0.0961 Fe: 5.35 ÷ 55.8 = 0.0959

S: 6.16 ÷ 32.1 = 0.192

÷ smallest (0.0959): Cu = 1, Fe = 1, S = 2

ratio Cu : Fe : S = 1 : 1 : 2

Empirical formula $CuFeS_2$

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SECTION B

Answer **all** questions.

7. (a) BF_3 and NF_3 have similar molecular formulae.

Explain why the shapes of their molecules are different. [3]

BF_3: boron has only 3 bonding pairs of electrons and no lone pairs around it.

NF_3: nitrogen has 3 bonding pairs and 1 lone pair (4 electron pairs).

Electron pairs repel to be as far apart as possible (maximum separation, minimum repulsion), so 3 pairs give a trigonal planar BF_3 (120°) whereas 4 pairs give a pyramidal NF_3 (about 107°).

(b) CH_3CH_2OH and CH_3CH_2SH also have similar formulae but they boil at very different temperatures.

Explain the difference in boiling temperatures. [3]

Ethanol (CH_3CH_2OH) has an O–H group, so hydrogen bonding occurs between its molecules, whereas only van der Waals / dipole-dipole forces occur between ethanethiol (CH_3CH_2SH) molecules.

Hydrogen bonds are stronger than van der Waals / dipole-dipole forces, so more energy is needed to separate the ethanol molecules and ethanol has the higher boiling temperature.

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(c) A student completed two titration experiments but made some fundamental errors in the analysis of the results.

(i) Using the following results from the first experiment he determined the mean volume to be 24.48 cm^3.

Explain the error that he made and calculate the correct value. [2]

Titration	1	2	3
Initial reading / cm^3	0.00	0.30	0.10
Final reading / cm^3	24.85	24.55	24.45
Titre / cm^3	24.85	24.25	24.35

He used all three titres in the mean; titre 1 is not concordant, so only the two concordant titres (2 and 3) should be used.

mean = (24.25 + 24.35) ÷ 2 = 24.30 cm^3

Correct value = *24.30* cm^3

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(ii) In another experiment the student found that 29.95 cm^3 of sulfuric acid of concentration 0.100 mol dm^{-3} neutralised 25.00 cm^3 of an aqueous solution of sodium hydroxide.

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

He incorrectly calculated the concentration of sodium hydroxide to be 0.120 mol dm^{-3}.

Calculate the correct value and hence identify the student's error. [2]

$n(H_2SO_4) = 0.100 \times 29.95 \div 1000 = 2.995 \times 10^{-3}$ mol

$n(NaOH) = 2 \times 2.995 \times 10^{-3} = 5.99 \times 10^{-3}$ mol

$[NaOH] = 5.99 \times 10^{-3} \div 0.02500 = 0.240$ mol dm^{-3}

Correct value = 0.240 mol dm^{-3}

He used a 1:1 ratio; he did not recognise that the alkali to acid ratio is 2:1 (2 mol NaOH react with 1 mol H_2SO_4).

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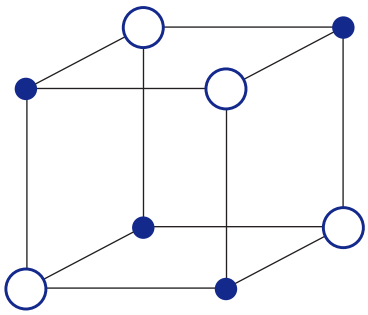
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8. Ionic compounds are very useful in everyday life.

(a) Sodium chloride is a white crystalline solid.

Complete and label the diagram below to show the arrangement of ions in the sodium chloride lattice. [1]

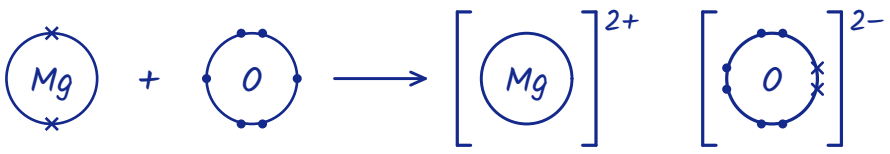


(b) For the ionic compound caesium chloride, state the coordination number of the caesium ion **only**. [1]

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(c) Magnesium oxide is formed from the reaction of magnesium with oxygen.

Using outer electrons only, draw a dot and cross diagram to show the formation of magnesium oxide. [2]



Mg loses its 2 outer electrons (x) to O

x = Mg electron · = O electron

(d) Suggest, with a reason, whether you would expect the coordination of magnesium ions in magnesium oxide to be like that in sodium chloride or that in caesium chloride. [1]

Like sodium chloride (6:6), because Mg^{2+} and O^{2-} have a similar relative ratio of ion sizes to Na^+ and Cl^-.

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(e) (i) One of the many uses of magnesium sulfate is as a muscle relaxant and it is one of the components in some mineral bath salts.

Explain why many ionic compounds dissolve easily in water. [2]

Water molecules are polar ($O^{\delta-}$, $H^{\delta+}$).

The $\delta-$ O atoms are attracted to the positive ions and the $\delta+$ H atoms to the negative ions; these attractions break apart (disrupt) the ionic lattice and the ions become hydrated.

(ii) State why barium sulfate would not be useful as a bath salt. [1]

Barium sulfate is insoluble in water (it would not dissolve).

(iii) A bath contains 0.136 m^3 of water. Calculate the minimum mass of magnesium sulfate needed to make a solution with a concentration of 220 mg dm^{-3}.

Show your working and record your answer to the **appropriate** number of significant figures. [3]

volume of water = 0.136 m^3 = 0.136 × 1000 = 136 dm^3

220 mg dm^{-3} = 0.220 g dm^{-3}

mass needed = 0.220 × 136 = 29.92 g

= 29.9 g (3 significant figures)

Mass = 29.9 g

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9. Lithium and rubidium are both Group 1 metals and there are many similarities in their behaviour.

(a) (i) Write an equation for the reaction of lithium with water. [1]

$2Li + 2H_2O \rightarrow 2LiOH + H_2$

(ii) State the trend in reactivity down the group and use this to suggest how the observations made when rubidium reacts with water would differ from those for lithium. [2]

Reactivity increases down the group.

Rubidium would react far more violently: it would fizz violently, melt and catch fire (may explode), whereas lithium floats and fizzes steadily.

(iii) Calculate the minimum mass of lithium required to produce 50.0 cm^3 of hydrogen gas at 25 °C and 1 atm. [2]

$n(H_2) = 50.0 \div 24500 = 2.04 \times 10^{-3}$ mol ($V_m = 24.5$ dm^3 at 298 K)

$n(Li) = 2 \times 2.04 \times 10^{-3} = 4.08 \times 10^{-3}$ mol

mass $= 4.08 \times 10^{-3} \times 6.94 = 0.0283$ g

Mass = 0.0283 g

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(b) A student noted that lithium and rubidium give similar colours in flame tests.

(i) State the colour seen. [1]

red

(ii) The flame colour for rubidium corresponds to a wavelength of 780 nm.

Calculate the energy released, in kJ mol^{-1}, when this colour is observed. [3]

$E = hc / \lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) \div (780 \times 10^{-9})$

$E = 2.55 \times 10^{-19}$ J (per atom)

per mole: $2.55 \times 10^{-19} \times 6.02 \times 10^{23} = 1.535 \times 10^{5}$ J mol^{-1}

$= 1.535 \times 10^{5} \div 1000 = 154$ kJ mol^{-1}

Energy released = 154 kJ mol^{-1}

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(c) (i) Give the electronic structure of the lithium ion formed by the loss of one electron. [1]

$1s^2$

(ii) Give the meaning of the term first ionisation energy. [1]

The energy required to remove one mole of electrons from one mole of gaseous atoms (to form one mole of gaseous 1+ ions).

(iii) Explain why the first ionisation energies of lithium and rubidium are very different. [2]

Rubidium has more shells of electrons, so its outer electron is further from the nucleus with more shielding.

Its outer electron is lost much more easily, so the first ionisation energy of rubidium is much lower.

(d) The flame colours of lithium and rubidium are due to their emission of visible light.

The hydrogen emission spectrum consists of several series of lines. State which series is in the visible region and explain why this series cannot be used to calculate the first ionisation energy of the hydrogen atom. [3]

The Balmer series is in the visible region.

The Balmer series comes from electron transitions down to n = 2 (from higher levels).

Ionisation of a hydrogen atom is the complete loss of the electron from the ground state n = 1 (to n = ∞), so the convergence limit of the series involving n = 1 (Lyman) must be used.

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10. Many essential industrial processes, like the production of ammonia, are reversible reactions.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.4\,kJ\,mol^{-1}$$

The yield for such reactions is lower than desirable because a dynamic equilibrium is reached.

(a) Give the meaning of the term dynamic equilibrium. [1]

A reversible reaction in a closed system in which the forward and backward reactions occur at the same rate, so concentrations stay constant.

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(b) Use Le Chatelier's principle to explain the ideal temperature and pressure conditions needed to produce the maximum yield of ammonia. Explain why these conditions need to be adapted to achieve the optimum yield in the industrial process.

Recall of the specific conditions for the process is not required. [6 QER]

Le Chatelier's principle: if a change is made to a system at equilibrium, the position of equilibrium shifts to oppose the change.

Pressure: increasing the pressure shifts the equilibrium to the side with fewer moles of gas. There are 4 mol of gaseous reactants but only 2 mol of gaseous product, so high pressure moves the position to the right and gives a higher yield of NH_3.

Temperature: increasing the temperature shifts the equilibrium in the endothermic direction to reduce the temperature. The forward reaction is exothermic ($\Delta H = -92.4$ kJ mol^{-1}), so a low temperature gives the maximum yield of NH_3.

Compromise for the optimum yield: the pressure cannot be too high as very high pressures are more dangerous and too expensive to generate and contain.

The temperature cannot be too low because the rate of reaction would be too slow, so a moderate temperature is used.

A lower yield in a short time is acceptable because unreacted N_2 and H_2 are recycled back to the reaction chamber. An iron catalyst increases the rate, allowing a lower operating temperature.

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(c) Ammonia is converted to nitric acid in a multi-step process. The first stage involves the oxidation of ammonia to produce a mixture of nitrogen monoxide and water.

(i) Balance the equation for this reaction. [1]

4 NH_3 + 5 O_2 ⟶ 4 NO + 6 H_2O

(ii) Under certain conditions an 80% conversion of ammonia to nitrogen monoxide is possible.

Calculate the minimum mass of ammonia required to produce 12 000 tonnes of nitrogen monoxide. [2]

$n(NO) = 12\,000 \times 10^6\ g \div 30.0 = 4.00 \times 10^8\ mol$

at 80%: $n(NH_3) = 4.00 \times 10^8 \times 100/80 = 5.00 \times 10^8\ mol$

$mass\ NH_3 = 5.00 \times 10^8 \times 17.03 = 8.515 \times 10^9\ g$

$= 8515$ tonnes

Mass of ammonia = 8515 tonnes

(iii) Nitric acid is a strong acid. Calculate the pH of 500 cm^3 of an aqueous solution of nitric acid containing 2.05×10^{23} hydrogen ions. [3]

$n(H^+) = 2.05 \times 10^{23} \div 6.02 \times 10^{23} = 0.341\ mol$

$[H^+] = 0.341 \div 0.500 = 0.681\ mol\ dm^{-3}$

$pH = -\log[H^+] = -\log 0.681 = 0.167$

pH = 0.167

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(iv) Ammonium nitrate is easily dissolved in water to produce ammonium ions (NH_4^+) and nitrate ions. A solution of ammonium ions behaves as a weak acid.

I. Give the meaning of the term acid. [1]

An acid is a proton (H^+) donor.

II. Suggest an equation to show the action of an ammonium ion as a weak acid. [1]

$NH_4^+ \rightleftharpoons NH_3 + H^+$

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11. (a) Write a general equation for the thermal decomposition of a Group 2 metal carbonate, using M to represent the metal. [1]

$MCO_3 \rightarrow MO + CO_2$

(b) State the trend in ease of decomposition for Group 2 metal carbonates down the group. [1]

They become more difficult to decompose down the group.

(c) 0.490 g of an unknown Group 2 metal carbonate decomposed completely at 790 °C and 1 atm. 425 cm^3 of carbon dioxide gas was produced.

Use the data to calculate the relative formula mass (M_r) of the metal carbonate and hence deduce the identity of the metal. [4]

$pV = nRT$, so $n = pV / RT$ and $M_r = mRT / pV$

$T = 790 + 273 = 1063$ K; $V = 425 \times 10^{-6}$ m^3; $p = 1.01 \times 10^5$ Pa

$n(CO_2) = (1.01 \times 10^5 \times 425 \times 10^{-6}) \div (8.31 \times 1063)$

$= 4.86 \times 10^{-3}$ mol

$n(MCO_3) = n(CO_2) = 4.86 \times 10^{-3}$ mol

$M_r = 0.490 \div 4.86 \times 10^{-3} = 100.8$

A_r of metal $= 100.8 - 12.0 - (3 \times 16.0) = 40.8$

closest A_r is Ca (40.1), so the metal is calcium

$M_r =$ 100.8

Metal calcium

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(d) A student was investigating the thermal decomposition of another metal carbonate. They decided that they would heat the metal carbonate until it had all decomposed and then find the loss in mass.

(i) Suggest how the student confirmed that all of the metal carbonate had decomposed. [1]

Heated the solid to constant mass: reheated and reweighed until two consecutive masses were the same.

(ii) The student carried out the experiment and weighed by difference using a 2 decimal place balance. They determined the loss in mass to be 0.47 g.

Calculate the percentage error in their mass. [1]

each reading ±0.005 g, two readings (by difference) = ±0.01 g

% error = 0.01 ÷ 0.47 × 100 = 2.13 %

Percentage error = *2.13* %

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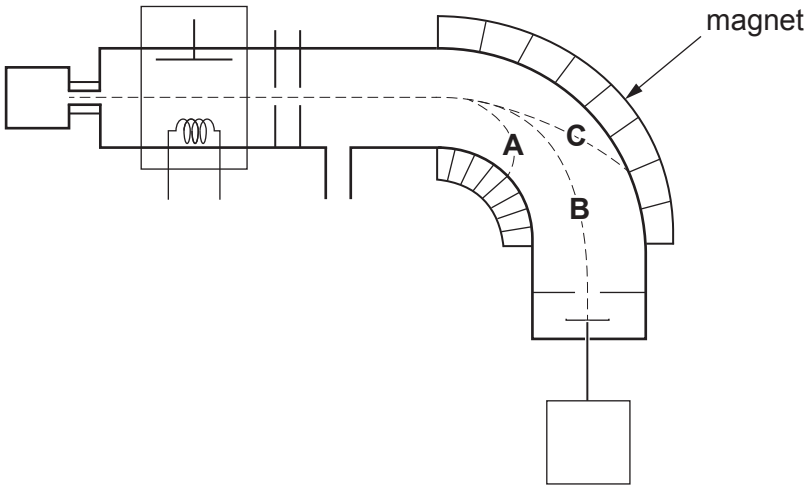
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12. Mass spectrometry can be used to investigate the isotopes of elements and enables accurate relative atomic mass values to be calculated.

(a) Give the meaning of the term relative atomic mass. [2]

The average mass of one atom of the element relative to 1/12 of the mass of one atom of carbon-12.

(b) The diagram shows one type of mass spectrometer and the paths of three particles, **A**, **B** and **C**.



(i) State the purpose of the magnet. [1]

The magnet deflects the positive ions (by an amount depending on their m/z).

(ii) **B** and **C** are particles of two different elements.

State why particle **C** is not detected. [1]

Particle C is too heavy: its m/z value is too high, so it is deflected too little to reach the detector.

(iii) Particles **A** and **B** are of identical mass.

Suggest why particle **A** has been deflected far more than particle **B**. [1]

Particle A is a 2+ ion (its z value is higher than 1), so its m/z is lower and it is deflected more.

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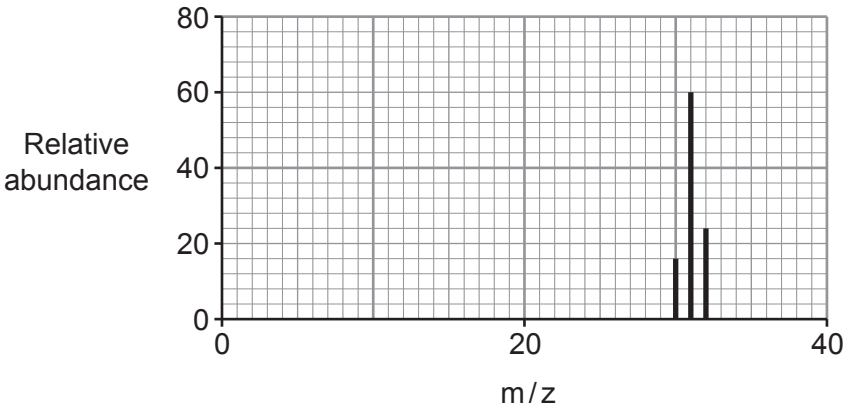
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(c) The mass spectrum below was obtained from an artificial sample of an unknown element.

Use the spectrum to calculate the relative atomic mass for this sample of the element.

You **must** show your working. [2]



m/z 30: 16%, m/z 31: 60%, m/z 32: 24%

$A_r = [(30 \times 16) + (31 \times 60) + (32 \times 24)] \div 100 = 31.08$

A_r = 31.08

(d) Technetium is the lightest element whose isotopes are all radioactive. Technetium-99 is a short-lived gamma-emitting isotope. It is used in nuclear medicine for a wide variety of tests such as bone cancer diagnoses.

(i) Suggest a reason why gamma-emitting isotopes are suitable for such tests but alpha-emitting isotopes are not. [1]

Gamma rays can pass through the skin and body tissue and be detected outside the body, whereas alpha particles cannot pass through tissue.

(ii) In certain circumstances, technetium-99 is used as a source of beta particles.

Write an equation for this emission. [2]

$^{99}_{43}Tc \rightarrow {}^{99}_{44}Ru + {}^{0}_{-1}\beta$

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TUESDAY, 16 MAY 2023 – MORNING

CHEMISTRY – AS component 1
Data Booklet

Avogadro constant	N_A	$= 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	R	$= 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
molar gas volume at 273 K and 1 atm	V_m	$= 22.4\ \text{dm}^3\ \text{mol}^{-1}$
molar gas volume at 298 K and 1 atm	V_m	$= 24.5\ \text{dm}^3\ \text{mol}^{-1}$
Planck constant	h	$= 6.63 \times 10^{-34}\ \text{J s}$
speed of light	c	$= 3.00 \times 10^{8}\ \text{m s}^{-1}$
density of water	d	$= 1.00\ \text{g cm}^{-3}$
specific heat capacity of water	c	$= 4.18\ \text{J g}^{-1}\ \text{K}^{-1}$
ionic product of water at 298 K	K_w	$= 1.00 \times 10^{-14}\ \text{mol}^2\ \text{dm}^{-6}$
fundamental electronic charge	e	$= 1.60 \times 10^{-19}\ \text{C}$

temperature (K) = temperature (°C) + 273

$1\ \text{dm}^3 = 1000\ \text{cm}^3$
$1\ \text{m}^3 = 1000\ \text{dm}^3$
1 tonne = 1000 kg
$1\ \text{atm} = 1.01 \times 10^5\ \text{Pa}$

Multiple	Prefix	Symbol
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G

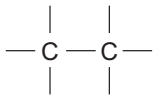
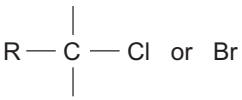
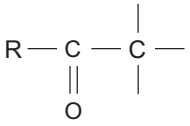
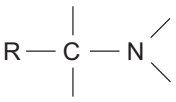
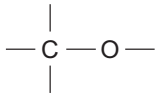
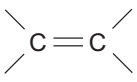
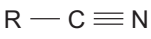
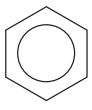
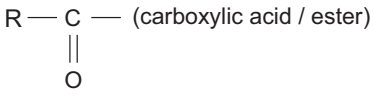
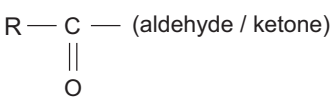
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Infrared absorption values

Bond	Wavenumber / cm^{-1}
C — Br	500 to 600
C — Cl	650 to 800
C — O	1000 to 1300
C = C	1620 to 1670
C = O	1650 to 1750
C ≡ N	2100 to 2250
C — H	2800 to 3100
O — H (carboxylic acid)	2500 to 3200 (very broad)
O — H (alcohol / phenol)	3200 to 3550 (broad)
N — H	3300 to 3500

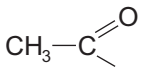
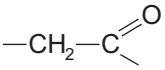
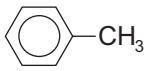
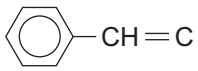
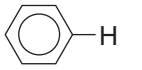
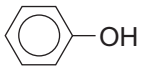
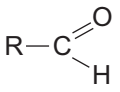
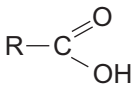
^{13}C NMR chemical shifts relative to TMS = 0

Type of carbon	Chemical shift, δ (ppm)
	5 to 40
	10 to 70
	20 to 50
	25 to 60
	50 to 90
	90 to 150
	110 to 125
	110 to 160
	160 to 185
	190 to 220

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^{1}H NMR chemical shifts relative to TMS = 0

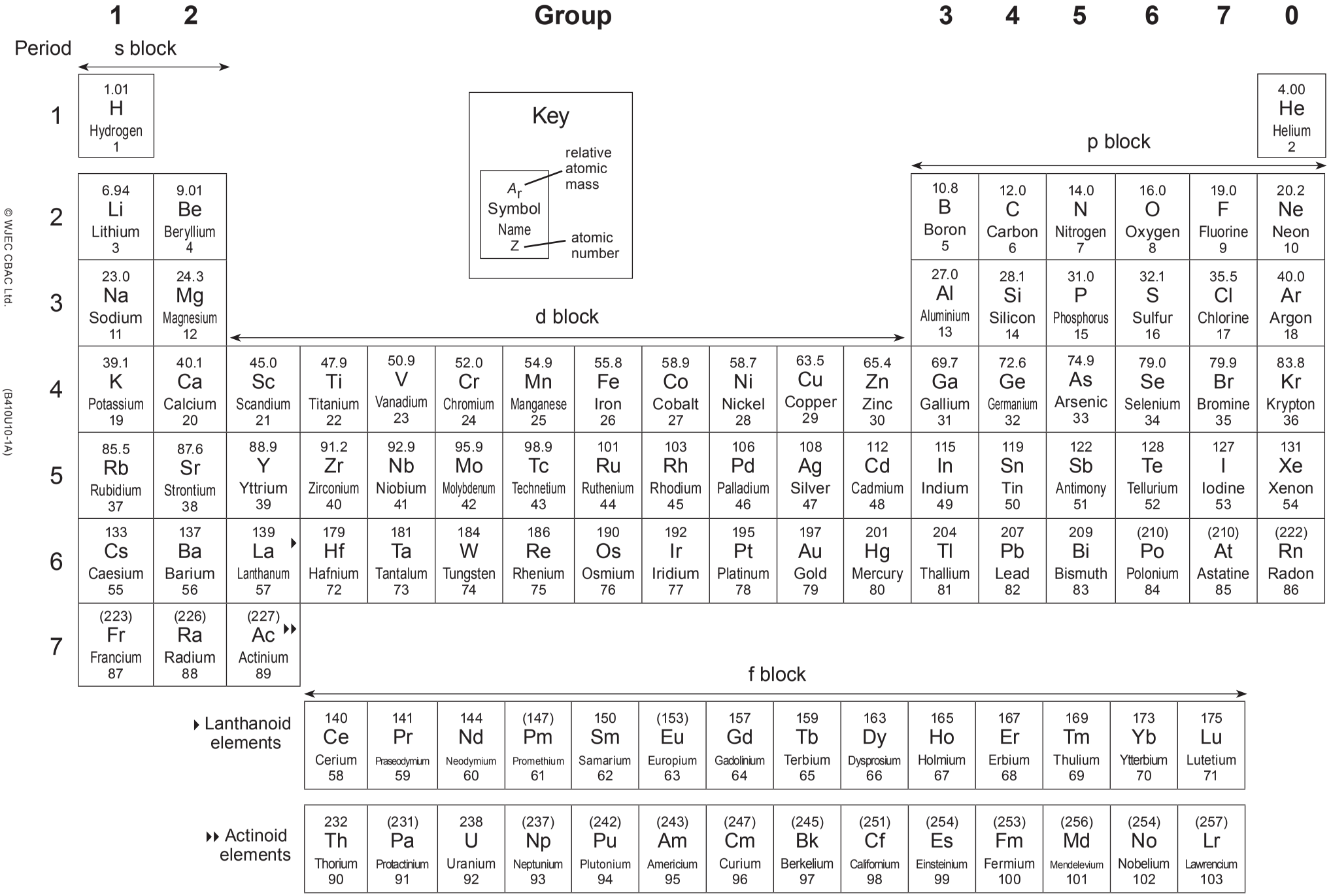
Type of proton	Chemical shift, δ (ppm)
$-CH_3$	0.1 to 2.0
$R-CH_3$	0.9
$R-CH_2-R$	1.3
$CH_3-C\equiv N$	2.0
	2.0 to 2.5
	2.0 to 3.0
	2.2 to 2.3
$HC-Cl$ or $HC-Br$	3.1 to 4.3
$HC-O$	3.3 to 4.3
$R-OH$	4.5 *
$-C=CH$	4.5 to 6.3
$-C=CH-CO$	5.8 to 6.5
	6.5 to 7.5
	6.5 to 8.0
	7.0 *
	9.8 *
	11.0 *

*variable figure dependent on concentration and solvent

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THE PERIODIC TABLE



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