



AS Level Chemistry

STATES OF MATTER

9701 - PAPER 2 THEORY

2026 EDITION

Q1 Easy

9701/22/F/M/21 Q1(b)(i), (iii)

4 marks

(b) The Boltzmann distribution assumes that the particles behave as an ideal gas.

(i) State **two** assumptions of the kinetic theory as applied to an ideal gas.

1

.....

2

.....

[2]

(iii) State and explain the conditions at which krypton behaves most like an ideal gas.

.....

.....

.....

.....

[2]

Q2 Hard

9701/21/M/J/21 Q2(c)(i)-(ii)

3 marks

(c) Both carbon monoxide and nitrogen are gases at room temperature and pressure.

They both behave like ideal gases under certain conditions.

(i) State the **two** conditions necessary for these two gases to approach ideal gas behaviour.

.....

.....

[1]

(ii) Explain why $\text{N}_2(\text{g})$ behaves more like an ideal gas than $\text{CO}(\text{g})$ does at 20.0°C and 101 kPa .

.....

.....

.....

[2]

(c) Nitrogen, N_2 , is also a gas at room temperature and pressure. Neither CO nor N_2 is an ideal gas.

(i) State two assumptions that are made about the behaviour of particles in an ideal gas.

1

.....

2

.....

[2]

(ii) Explain why N_2 does not behave as an ideal gas at very high pressures.

.....

.....

.....

..... [2]



Q4 Easy

9701/22/F/M/21 Q1(b)(ii)

3 marks

(ii) 2.00 g of krypton gas, Kr(g), is placed in a sealed 5.00 dm³ container at 120 °C.

Calculate the pressure, in Pa, of Kr(g) in the container.
Assume Kr(g) behaves as an ideal gas.

Show your working.

pressure = ... Pa [3]

Q5 Easy

9701/21/M/J/21 Q2(d)

3 marks

(d) Calculate the amount, in mol, of pure nitrogen gas which occupies 100 cm³ at 101 kPa and 20.0 °C.

Use relevant information from the *Data Booklet*. Show your working.

Assume nitrogen behaves as an ideal gas.

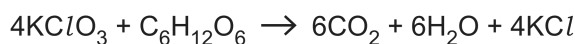
..... mol
[3]

Q6 Hard

9701/21/O/N/23 Q3(d)(i)-(ii) | also 9701/23/O/N/23

3 marks

(d) Molten KClO_3 reacts with glucose, $\text{C}_6\text{H}_{12}\text{O}_6$.



KClO_3 melts at 630 K. At this temperature, both CO_2 and H_2O are gases.

- (i) Use the ideal gas equation to calculate the volume, in m^3 , of one mole of gas at 630 K and $1.00 \times 10^5 \text{ Pa}$.

Show your working. Give your answer to 3 significant figures.

volume of 1 mol of gas = ... m^3
[1]

- (ii) 5.00 g of $\text{C}_6\text{H}_{12}\text{O}_6$ reacts completely with molten KClO_3 .

Use your answer to (d)(i) to calculate the total volume of gas released at 630 K and $1.00 \times 10^5 \text{ Pa}$ in this reaction.

(If you were unable to answer (d)(i), use 0.0463 m^3 in this question. This is **not** the correct answer to (d)(i).)

total volume of gas released = ... m^3
[2]

Q7 Hard

9701/22/O/N/22 Q2(d)

3 marks

- (d) A 3.30 g sample of a Period 3 chloride is heated to 500 K in a sealed flask. At this temperature, the chloride is a gas of volume 250 cm^3 and the pressure in the flask is 323 kPa.

Use the ideal gas equation $pV = nRT$ to calculate the M_r of the Period 3 chloride. Deduce its formula.

$M_r = \dots\dots\dots$

formula of Period 3 chloride = $\dots\dots\dots$
[3]



Q8 Hard

9701/22/F/M/23 Q1(e)(ii)

3 marks

Table 1.2

compound	O=C=O	O=S=O	S=C=S	S=C=O

(ii) At 150 °C and 103 kPa, all of the compounds listed in Table 1.2 are gases.

Under these conditions, 0.284 g of one of the compounds occupies a volume of 127 cm³.

Use this information to calculate the M_r of the compound. Hence, identify the compound from those given in Table 1.2.

Show your working.

M_r = ... identity of compound = ... [3]

Q9 Hard

9701/24/M/J/25 Q6(b)

2 marks

- (b) **Q** is a volatile hydrocarbon.
0.194 g of gaseous **Q** occupies a volume of 71.5 cm³ at 100 °C and 100 kPa.

Use the ideal gas equation to calculate the M_r of **Q**.

M_r of **Q** = ... [2]



Q10 Easy

9701/22/M/J/21 Q2(a)(i)-(ii)

3 marks

2 The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

(a) Lithium sulfide, Li_2S , is a crystalline solid with a melting point of 938°C . It conducts electricity when it is molten.

(i) Give the formulae of the particles present in solid lithium sulfide.

..... [1]

(ii) Explain, in terms of the structure of the crystalline solid, why lithium sulfide has a high melting point.

.....
 [2]

Q11 Easy

9701/22/M/J/22 Q1(a)

2 marks

1 (a) Magnesium has a melting point of 650°C and high electrical conductivity.

Explain these properties of magnesium by referring to its structure and bonding.

.....
 [2]

Q12 Easy

9701/23/M/J/22 Q1(f)(ii)

2 marks

(ii) Copper has a melting point of 1085°C and a high electrical conductivity.

Explain these properties of copper by referring to its structure and bonding.

.....

 [2]

Q13 Easy

9701/21/O/N/22 Q2(a) | also 9701/23/O/N/22

2 marks

2 Magnesium shows reactions typical of a Group 2 metal.

(a) Draw a labelled diagram to show the bonding in magnesium metal.

[2]

Q14 Easy

9701/22/O/N/22 Q2(f)(i)

2 marks

(f) Bismuth is a dense metal in the same group as phosphorus.

(i) Draw a labelled diagram to show the bonding in bismuth metal.

[2]

Q15 Easy

9701/22/F/M/23 Q2(a)(i)-(ii)

3 marks

2 The Group 2 elements Mg to Ba are all silvery-white reactive metals.

(a) (i) Draw a labelled diagram to show the bonding and structure of the Group 2 metals at room temperature.

[2]

(ii) Explain why Mg has a higher electrical conductivity than Na.

.....
 [1]

Q16 Easy

9701/23/M/J/23 Q1(a)(i)-(ii)

2 marks

1 Copper is used in electrical equipment. It has a melting point of 1085 °C.

(a) (i) Identify the lattice structure of copper.

..... [1]

(ii) Draw a labelled diagram to show the bonding present in copper.

[1]

Q17 Easy

9701/22/F/M/24 Q1(a)

1 marks

1 Bismuth is an element in Group 15 of the Periodic Table.

(a) Bismuth has metallic bonding.

Draw a labelled diagram to show the metallic bonding in bismuth.

[1]

Q18 Easy

9701/22/M/J/24 Q1(c)

1 marks

(c) Draw a labelled diagram to show the structure and bonding in sodium.

[1]

Q19 Easy

9701/22/F/M/25 Q2(a)

2 marks

2 (a) The Group 2 elements show metallic bonding.

Define metallic bonding.

.....
 [2]

- 1 (a) Solid sodium conducts electricity. Sodium oxide conducts electricity when molten but not when solid.

- (i) Name the type of bonding present in sodium and in sodium oxide.

bonding in sodium

bonding in sodium oxide

[1]

- (ii) Explain how solid sodium conducts electricity.

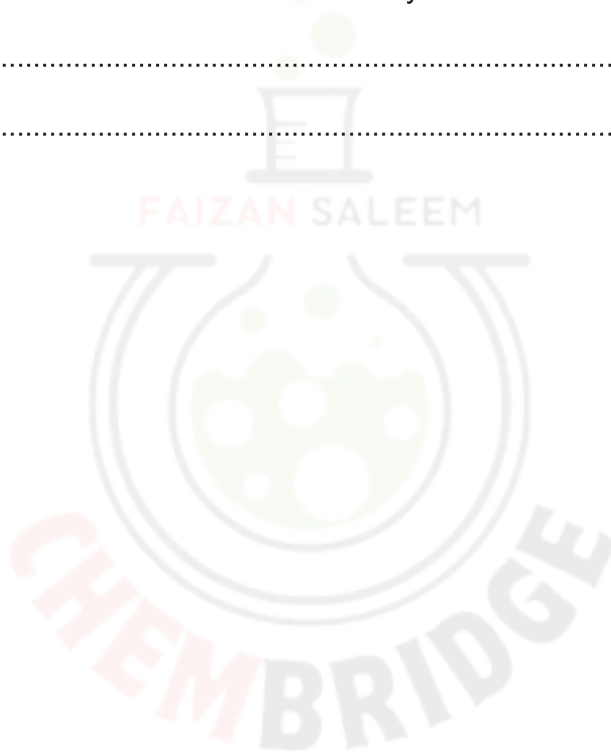
.....

..... [1]

- (iii) Explain why sodium oxide conducts electricity when molten.

.....

..... [1]



Q21 Hard

9701/21/O/N/21 Q3(a)(i) | also 9701/23/O/N/21

3 marks

3 Phosphorus is a reactive Period 3 element.

(a) Phosphorus has several allotropes. Details of two allotropes are given.

allotrope of phosphorus	formula	melting point/°C
white	P ₄	44
red	P	590

(i) White phosphorus and red phosphorus both have covalent bonding.

Suggest the types of structure shown by white phosphorus (P₄) and red phosphorus (P).

Explain why red phosphorus (P) has a higher melting point than white phosphorus (P₄).

structure of P₄

structure of P

explanation

.....

.....

[3]

- (d) Boron nitride is a white solid that melts above 2900 °C.

Fig. 2.2 shows part of the lattice structure of a crystal of boron nitride.

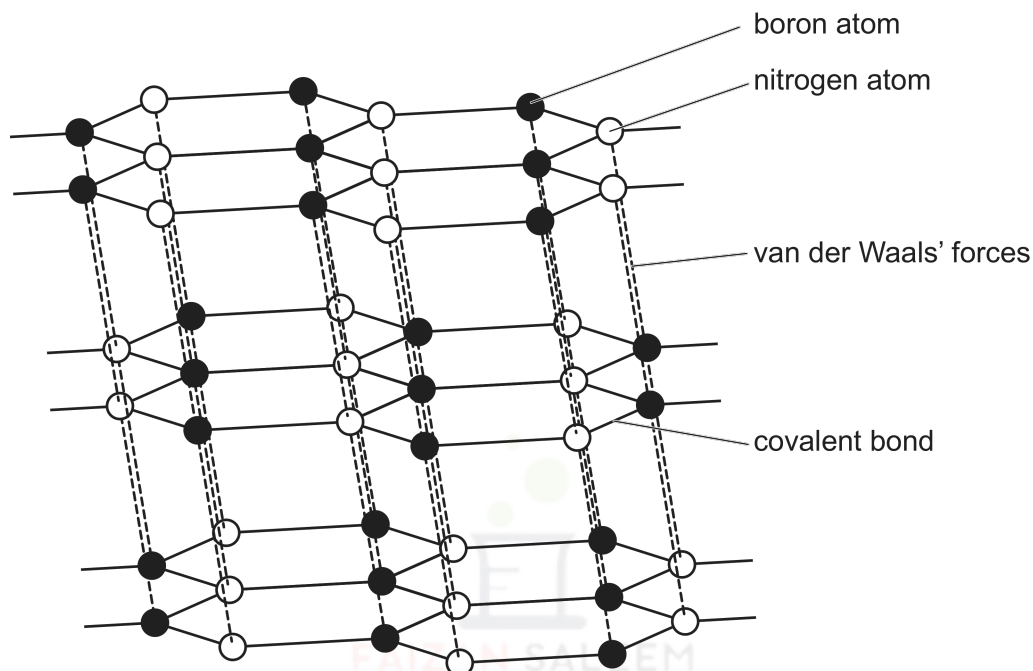


Fig. 2.2

- (i) Use Fig. 2.2 to deduce the empirical formula of boron nitride.
..... [1]
- (ii) Suggest the identity of another crystalline solid that has atoms arranged in layers similar to that of solid boron nitride.
..... [1]

Q23 Easy

9701/22/O/N/24 Q3(d)-(e)

3 marks

- (d) Complete Table 3.1 to show the properties of nitrogen and phosphorus in their standard states.

Table 3.1

	nitrogen	phosphorus
state and appearance of standard state	colourless gas	white solid
electrical conductivity		poor
type of bonding		
type of structure	simple	

[2]

- (e) A form of solid nitrogen has a lattice structure similar to solid iodine.

Identify the type of lattice structure of solid nitrogen.

..... [1]

Q24 Easy

9701/22/M/J/25 Q1(a)(i)-(iii)

3 marks

- 1 (a) Diamond and graphite are both crystalline solids made from carbon atoms. Graphite conducts electricity. Diamond does **not** conduct electricity.

- (i) Name the type of lattice structure present in the crystalline solids diamond and graphite.

..... [1]

- (ii) Explain how graphite conducts electricity.

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

- (iii) Explain why diamond does **not** conduct electricity.

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

Q1 - Official MS Easy

9701/22/F/M/21 Q1(b)(i), (iii)

4 marks

1(b)(i)	Any two from: - no VdW forces present / no forces of attraction between particles (ideal gas) particles have no / negligible volume (compared to container) - collisions between (ideal gas) particles / walls of container are perfectly elastic (ideal gas) particles behave as rigid spheres	2
1(b)(iii)	M1: low pressure AND high temperature M2: Either of: - volume of particles is negligible (compared to volume of container) - VdW forces are insignificant (owing to high kinetic energy of particles)	2

Q2 - Official MS Hard

9701/21/M/J/21 Q2(c)(i)-(ii)

3 marks

2(c)(i)	high temperature AND low pressure	1
2(c)(ii)	M1 CO is polar / has a permanent dipole OR N ₂ is non-polar	1
	M2 IMF in CO are (more) significant / larger OR IMF in N ₂ are smaller / less significant	1
	<i>Alternative answer</i> M1 (Size of) N ₂ smaller than CO OR volume of N ₂ molecules / particles smaller	
	<i>Alternative answer</i> M2 volume of N ₂ molecules / particles is more negligible ORA	

Q3 - Official MS Easy

9701/22/M/J/21 Q2(c)(i)-(ii)

4 marks

2(c)(i)	Any two assumptions about the behaviour of particles in an ideal gas from (particles / molecules have mass but) negligible size / volume (compared to total volume of gas / container) - no / negligible forces / interactions (between particles / molecules) - collisions are elastic	2
2(c)(ii)	M1 IMF become larger / more significant	1
	M2 volume of <u>molecules / particles</u> becomes significant / no longer negligible	1

Q4 - Official MS Easy

9701/22/F/M/21 Q1(b)(ii)

3 marks

1(b)(ii)	M1: moles of krypton = $2.00 \div 83.8$ (= 0.0239 mol) M2: conversion of value into consistent units for $pV = nRT$ M3: $p = \frac{M1 \times 8.31 \times 393}{5.00 \times 10^{-3}} = 15600 \text{ Pa}$	3
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Q5 - Official MS Easy

9701/21/M/J/21 Q2(d)

3 marks

2(d)	M1 correct conversion to consistent units $P = 101\,000$ $V = 100 / 1\,000\,000 = (1 \times 10^{-4})$ $T = 293$	1
	M2 use of all values from M1 in correct relationship, $n = PV / RT$	1
	M3 calculation = $4.15 \times 10^{-3} \text{ mol}$	1

Q6 - Official MS Hard

9701/21/O/N/23 Q3(d)(i)-(ii) | also 9701/23/O/N/23

3 marks

3(d)(i)	$pV = nRT \therefore V = 8.31 \times 630 \div 100\,000 = \underline{0.0524} \text{ (m}^3\text{)}$	1
3(d)(ii)	moles of gas = $12 \times 5.00 / 180$	1
	volume of gas = $M1 \times \text{(d)(i)} = \underline{0.0175} \text{ (m}^3\text{)}$	1

Q7 - Official MS Hard

9701/22/O/N/22 Q2(d)

3 marks

2(d)	M1 value of n based on re-arranged equation for 'n' and substitution of correct values $n = \frac{3.23 \times 10^5 \cdot 250 \times 10^{-6}}{8.31 \cdot 500} = 0.0194(34416)$	1
	M2 calculated value of M_r based on M1 $M_r = 3.30 \div n = 170$	1
	M3 period 3 chloride which matches M_r in M2 (formula) SiCl_4	1

Q8 - Official MS Hard

9701/22/F/M/23 Q1(e)(ii)

3 marks

1(e)(ii)	conversion of units 103000 Pa $127 \times 10^{-6} \text{ m}^3$ 423 K	1
	Use of $pV = (m / M_r) RT$ $M_r = \frac{0.284 \times 8.31 \times 423}{103000 \times 127 \times 10^{-6}}$	1
	$M_r = 76.3$ AND compound = CS_2	1

Q9 - Official MS Hard

9701/24/M/J/25 Q6(b)

2 marks

6(b)	M1 convert temp to 373 K (and use)	2
	M2 correct rearrangement and use $7.15 = n \cdot 8.31(4) \times T$ to find n AND $M_r = 0.194 / n$ $M_r = 84.1$	

Q10 - Official MS Easy

9701/22/M/J/21 Q2(a)(i)-(ii)

3 marks

2(a)(i)	Li ⁺ AND S ²⁻	1
2(a)(ii)	M1 giant	1
	M2 (many) strong force(s) of attraction between oppositely charged ions OR (many) strong ionic bond(s)	1

Q11 - Official MS Easy

9701/22/M/J/22 Q1(a)

2 marks

1(a)	M1 comment explaining high melting point of Mg in terms of many strong metallic bonds OR many strong (electrostatic) attractions between cations and delocalised electrons OR strong bonds in giant metallic structure. M2 comment explaining electrical conductivity of Mg in terms of movement of delocalised electrons delocalised electrons can move through the structure	2
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Q12 - Official MS Easy

9701/23/M/J/22 Q1(f)(ii)

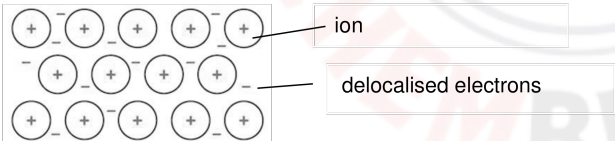
2 marks

1(f)(ii)	M1 comment explaining high melting point of Cu many strong metallic bonds OR many strong (electrostatic) attractions between cations and delocalised electrons OR strong bonds in giant metallic structure. M2 comment explaining electrical conductivity of Cu delocalised electrons are free to move through the structure (owtte)	2
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Q13 - Official MS Easy

9701/21/O/N/22 Q2(a) | also 9701/23/O/N/22

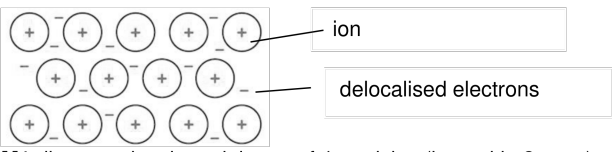
2 marks

2(a)	 M1 diagram showing minimum of 4 particles (in total in two rows) (circles) - circles containing Mg⁺ do not have to be labelled - must be labelled as 'ion' OR empty circles / circles with Mg must be labelled + ion / positive ion / cation / Mg⁺ AND - circles surrounded by electrons shown as e⁻ / - - OR in an area around the circles labelled as 'electrons' OR little circles labelled electrons - OR electrons drawn only on perimeter of structure M2 label / legend showing <u>delocalised</u> electrons	1
		1

Q14 - Official MS Easy

9701/22/O/N/22 Q2(f)(i)

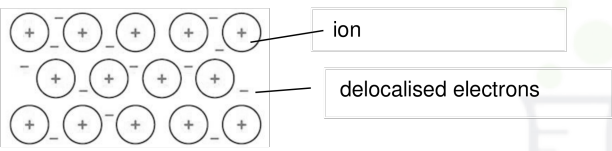
2 marks

2(f)(i)	 M1 diagram showing minimum of 4 particles (in total in 2 rows) - circles containing Bi^{n+} do not have to be labelled  must be labelled as 'ion' OR empty circles / circles with Bi must be labelled + ion / positive ion / cation / Bi^{n+} AND - with the circles surrounded by electrons shown as e^- / – OR little circles labelled electrons	1
	M2 label / legend showing <u>delocalised</u> electrons	1

Q15 - Official MS Easy

9701/22/F/M/23 Q2(a)(i)-(ii)

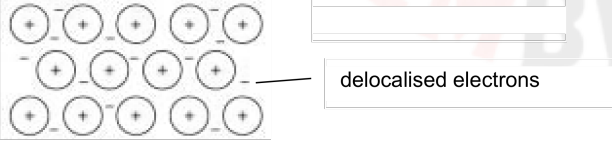
3 marks

2(a)(i)	 M1 diagram showing minimum of 4 particles (in total in 2 rows) - circles containing X^{n+} do not have to be labelled  must be labelled as 'ion' OR empty circles / circles with X must be labelled + ion / positive ion / cation / X^{n+} AND with the circles surrounded by electrons shown as e^- / – OR little circles labelled electrons	1
	M2 label / legend showing delocalised electrons	1
2(a)(ii)	Mg has more delocalised e^- (than Na)	1

Q16 - Official MS Easy

9701/23/M/J/23 Q1(a)(i)-(ii)

2 marks

1(a)(i)	giant metallic	1
1(a)(ii)	 M1 diagram showing minimum of 4 particles - circles containing just a + do not have to be labelled - empty circles / circles with Cu must be labelled + ion / positive ion / cation / Cu^{n+} AND with the circles surrounded by electrons shown as e^- / – OR little circles labelled delocalised electrons	1

Q17 - Official MS Easy

9701/22/F/M/24 Q1(a)

1 marks

1(a)	labelled diagram shows: - regular arrangement of positive ions AND surrounded by / (sea of) delocalised electrons	1
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Q18 - Official MS Easy

9701/22/M/J/24 Q1(c)

1 marks

1(c)	labelled diagram shows: - regular arrangement of minimum of 2×2 circles containing + for positive ions AND surrounded by (sea of) delocalised electrons	1
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Q19 - Official MS Easy

9701/22/F/M/25 Q2(a)

2 marks

2(a)	electrostatic attraction between positive metal ions / cations and delocalised electrons	2
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Q20 - Official MS Easy

9701/21/M/J/25 Q1(a)(i)-(iii)

3 marks

1(a)(i)	sodium – metallic AND sodium oxide – ionic	1
1(a)(ii)	delocalised electrons move (through the structure)	1
1(a)(iii)	(sodium and oxide) ions move (through the liquid)	1

Q21 - Official MS Hard

9701/21/O/N/21 Q3(a)(i) | also 9701/23/O/N/21

3 marks

3(a)(i)	M1 simple molecular M2 giant molecular M3 weak IMFs (overcome) in P_4 AND strong (covalent) bonds (broken) in P	3
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Q22 - Official MS **Hard**

9701/21/M/J/24 Q2(d)(i)-(ii)

2 marks

2(d)(i)	BN	1
2(d)(ii)	graphite	1

Q23 - Official MS **Easy**

9701/22/O/N/24 Q3(d)-(e)

3 marks

3(d)	element	nitrogen	phosphorus	2
	state and appearance	colourless gas	white solid	
	electrical conductivity	• poor	poor	
	type of bonding	• covalent	• covalent	
	type of structure	simple	• simple	
3(e)	simple molecular (lattice structure)			1

Q24 - Official MS **Easy**

9701/22/M/J/25 Q1(a)(i)-(iii)

3 marks

1(a)(i)	(both) giant molecular	1
1(a)(ii)	delocalised electrons move through the structure OR delocalised electrons move through / between the layers	1
1(a)(iii)	no delocalised electrons (to carry charge through the structure) OR <u>all</u> (4) outer electrons are used in bonding	1