



AS Level Chemistry

MOLES & STOICHIOMETRY

9701 - PAPER 2 THEORY

2026 EDITION

Q1

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

6 marks

1 Ethanedioic acid, $\text{HO}_2\text{CCO}_2\text{H}$, has a relative molecular mass of 90.0.

(a) (i) Explain what is meant by the term *relative molecular mass*.

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

(ii) State the empirical formula of ethanedioic acid.

..... [1]

(iii) Calculate how many atoms of carbon are present in 0.18 g of ethanedioic acid, $\text{HO}_2\text{CCO}_2\text{H}$.

Show your working.

atoms of carbon present = ... [3]



Q2

9701/21/M/J/22 Q1(e)(i)-(ii)

3 marks

- (e) A sample of magnesium contains three isotopes, ^{25}Mg , ^{26}Mg and **X**.

The percentage abundance of the three isotopes is shown in Table 1.1.

Table 1.1

isotope of Mg	mass/a.m.u.	percentage abundance/%
X		78.99
^{25}Mg	24.99	10.00
^{26}Mg	25.98	11.01

- (i) The relative atomic mass, A_r , is calculated by comparing the average mass of the isotopes of an element to the unified atomic mass unit.

Define the unified atomic mass unit.

..... [1]

- (ii) Calculate the mass of **X**. Use data from Table 1.1 and A_r (magnesium) = 24.31 in your calculation. Show your working.

mass of **X** = ... [2]

Q3

9701/21/O/N/22 Q1(a)(ii)-(iii)

4 marks

(ii) Define relative atomic mass.

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

(iii) The relative atomic mass of gallium, A_r , is 69.723.
The relative isotopic masses of ^{69}Ga and ^{71}Ga are:

^{69}Ga , 68.926; ^{71}Ga , 70.925.

Use this information to calculate the percentage abundance of ^{69}Ga in elemental gallium.
Show your working.

Assume that the element contains only the ^{69}Ga and ^{71}Ga isotopes.
Give your answer to **four** significant figures.

percentage abundance of ^{69}Ga = ... %
[2]

Q4

9701/23/M/J/23 Q1(b)(i)-(iii)

3 marks

- (b) The relative isotopic masses and natural abundances of the two isotopes in a sample of copper are shown in Table 1.1.

Table 1.1

isotope	relative isotopic mass	% abundance
^{63}Cu	62.930	69.15
^{65}Cu	64.928	30.85

- (i) Define the unified atomic mass unit.

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

- (ii) Define relative atomic mass, A_r , in terms of the unified atomic mass unit.

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

- (iii) Calculate the relative atomic mass, A_r , of copper in this sample using the data in Table 1.1.

Show your working.

$A_r = \dots\dots\dots$ [1]

Q5

9701/21/O/N/24 Q1(c)(i)-(ii)

4 marks

- (c) Table 1.2 shows the relative abundances of isotopes in a sample of an alloy containing rhodium and iridium only.

Table 1.2

isotope	relative isotopic mass	relative abundance in alloy
$^{103}_{45}\text{Rh}$	102.91	50.00
$^{191}_{77}\text{Ir}$	190.96	15.18
$^{193}_{77}\text{Ir}$	192.96	34.82

- (i) Define relative isotopic mass.

.....

 [2]

- (ii) Use Table 1.2 to calculate the relative atomic mass, A_r , of iridium in the alloy.

Give your answer to **two** decimal places.

relative atomic mass of iridium = ... [2]

Q6

9701/21/M/J/25 Q2(b)(i)

2 marks

(b) Fig. 2.1 shows the mass spectrum of the sample of iron.

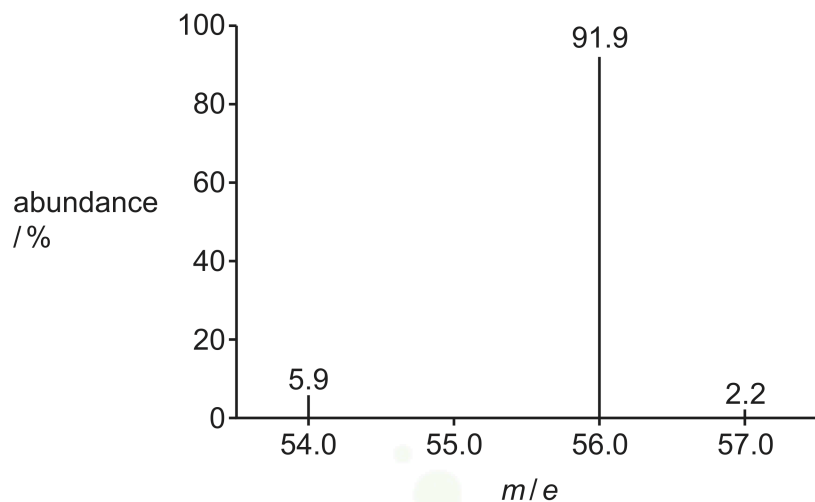


Fig. 2.1

(i) Use Fig. 2.1 to calculate the relative atomic mass, A_r , of iron to **one** decimal place.

Show your working.

A_r of iron = ... [2]

Q7

9701/22/M/J/25 Q2(a)(i)-(ii)

4 marks

- 2 A sample of iron contains three different isotopes and has a relative atomic mass, A_r , of 55.8.

(a) (i) Define relative atomic mass.

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

- (ii) Table 2.1 shows the abundances of two of the isotopes present in the sample of iron.

Table 2.1

isotope	relative isotopic mass	abundance / %
^{54}Fe	53.9	6.0
^{56}Fe	55.9	91.9

Use Table 2.1 to calculate the relative isotopic mass of the third isotope of iron in the sample. Show your working.

relative isotopic mass = ... [2]

Q8

9701/23/M/J/21 Q3(c)

3 marks

(c) Tungsten oxide, W_xO_y , is used to give colour to ceramic materials.

A sample of W_xO_y contains 79.29% tungsten by mass.

Calculate the empirical formula of W_xO_y .

Show your working.

empirical formula = ... [3]

Q9

9701/21/M/J/22 Q4(a)

3 marks

4 Compound **V** is a liquid.

V contains 77.2% carbon, 11.4% hydrogen and 11.4% oxygen by mass.

V has a relative molecular mass of 280.

(a) Calculate the molecular formula of **V**. Show your working.

molecular formula of **V** = ... [3]



Q10

9701/22/M/J/22 Q6(b), 6(c)(i)

2 marks

(b) Table 6.2 shows the percentage by mass of each element present in **Z**.

Table 6.2

element	percentage by mass / %
carbon	41.38
hydrogen	3.45
oxygen	55.17

Using the data in Table 6.2, demonstrate that the empirical formula of **Z** is CHO.
Show your working.

[1]



Q10 (continued)

9701/22/M/J/22 Q6(b), 6(c)(i)

2 marks

(c) Fig. 6.1 shows the mass spectrum of **Z**.

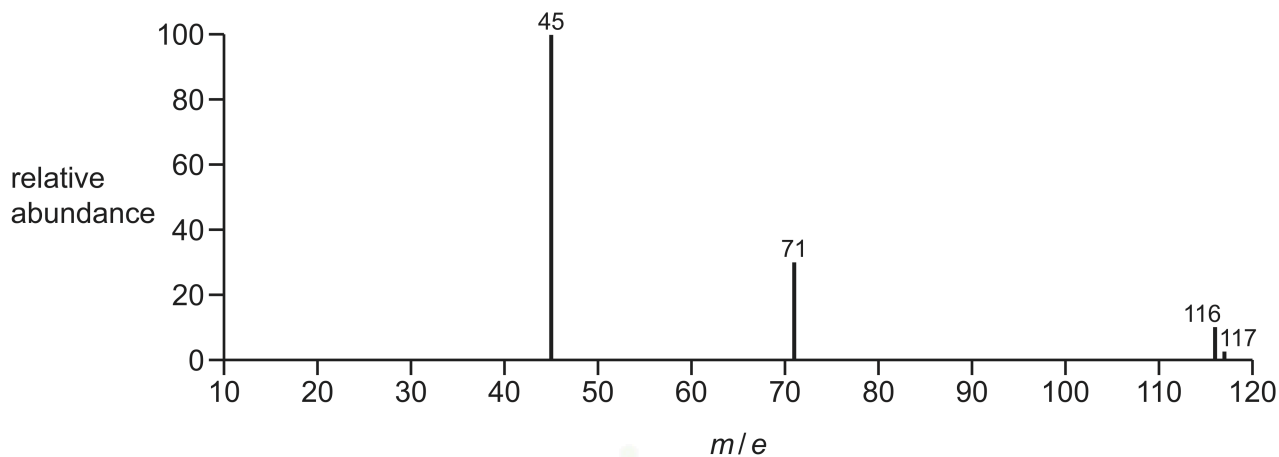


Fig. 6.1

- (i) Deduce the molecular formula of **Z**. Explain your answer by referring to the molecular ion peak in Fig. 6.1 and the empirical formula of **Z**.

[1]

Q11

9701/22/O/N/22 Q1(d)(ii)

2 marks

- (ii) Struvite is a soft hydrated mineral with $M_r = 245.3$. The anhydrous form of the mineral has the formula NH_4MgPO_4 .

Calculate the number of molecules of water of crystallisation in struvite.

Give your answer to the nearest integer. Show your working.

number of molecules of water of crystallisation = ... [2]



Q12

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

1 marks

- (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.

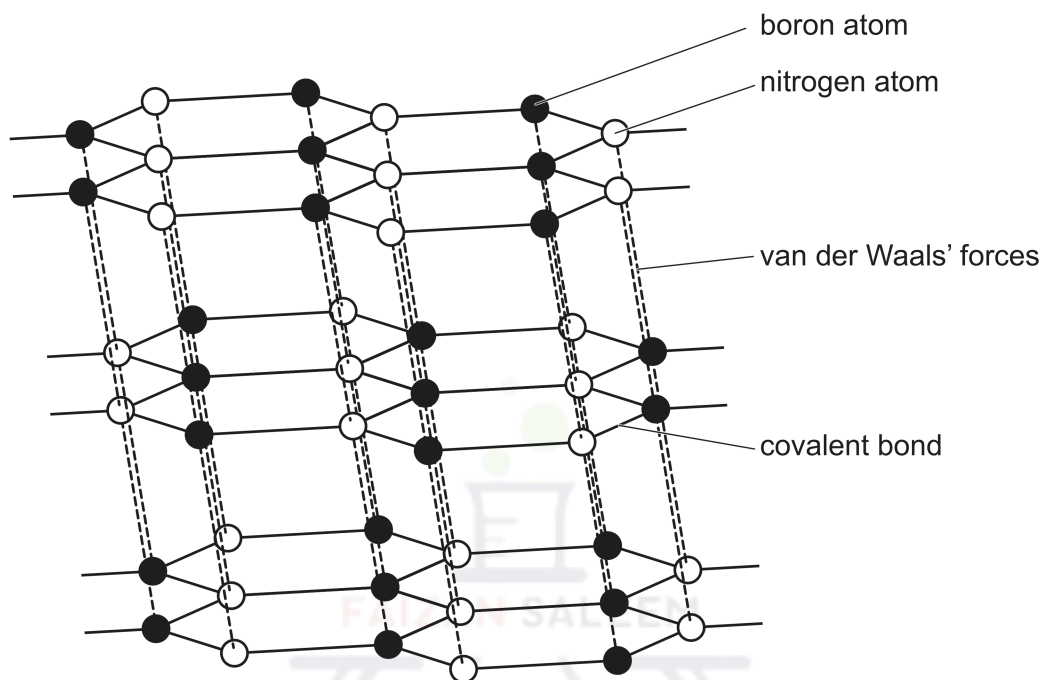


Fig. 2.2

- (i) Use Fig. 2.2 to deduce the empirical formula of boron nitride.

..... [1]

Q13

9701/23/M/J/24 Q3(c)(ii)

2 marks

(c) Boron carbide is a hard crystalline solid that has a melting point greater than 2000 °C.

(ii) 100 g of pure boron carbide contains 78.26 g of boron.

Calculate the empirical formula of boron carbide.

Show your working.

empirical formula of boron carbide [2]



Q14

9701/21/O/N/24 Q1(d)(i)

2 marks

- (d) Hydrated rhodium(III) chloride, $\text{RhCl}_3 \cdot x\text{H}_2\text{O}$, catalyses the conversion of ethene to but-2-ene.

Both stereoisomers of but-2-ene are formed in the reaction.

- (i) Hydrated rhodium(III) chloride contains 20.5% by mass of water of crystallisation.

Deduce the integer value of x in $\text{RhCl}_3 \cdot x\text{H}_2\text{O}$.

Show your working.

$x = \dots\dots\dots$
[2]



Q15

9701/22/F/M/25 Q1(a)(iii)

2 marks

- (iii) The third compound of phosphorus and chlorine, **W**, has a relative molecular mass, M_r , between that of PCl_3 and PCl_5 . The compound contains 69.6% by mass of chlorine.

Determine the molecular formula of **W**.

molecular formula of **W** = ... [2]



Q16

9701/22/M/J/25 Q5(a), 5(b)(i)-(ii)

4 marks

- 5 The structure of vitamin C is shown in Fig. 5.1.

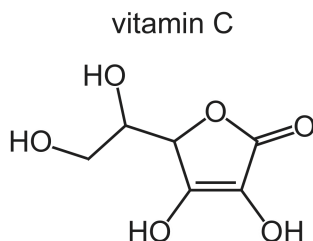


Fig. 5.1

- (a) Deduce the empirical formula of vitamin C.

..... [1]

- (b) The mass of vitamin C present in 150.0 g of lemon is found in an experiment.

stage 1 All the vitamin C in 150.0 g of lemon is extracted and dissolved in water to make 100.0 cm³ of solution L.

stage 2 A 25.0 cm³ sample of solution L is titrated with 5.00 × 10⁻³ mol dm⁻³ I₂(aq).

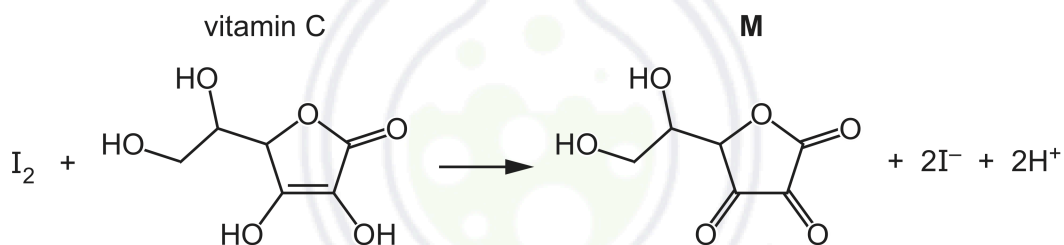


Fig. 5.2

Exactly 36.65 cm³ of I₂(aq) reacts with the 25.0 cm³ sample of solution L.

[M_r: vitamin C, 176]

- (i) Calculate the amount, in mol, of I₂(aq) added in the titration.

amount of I₂(aq) = ... mol [1]

Q16 (continued)

9701/22/M/J/25 Q5(a), 5(b)(i)-(ii)

4 marks

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

- (ii) Use your answer to (b)(i) to calculate the percentage by mass of vitamin C present in 150.0g of lemon.

(If you were unable to calculate a value for the amount of $I_2(aq)$ in (b)(i), use the value 7.65×10^{-4} mol. This is **not** the correct value.)

percentage by mass = ...% [2]



Q17

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

1 mark

(f) (i) The element copper has a relative atomic mass of 63.5.

Calculate how many atoms are present in 1.05 g of copper.

atoms of copper present = ... [1]



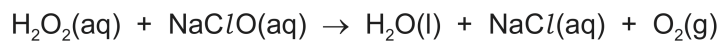
Q18

9701/23/M/J/21 Q1(e)

3 marks

(e) The concentration of NaClO in bleach **S** is $x \text{ g dm}^{-3}$.

NaClO reacts with $\text{H}_2\text{O}_2(\text{aq})$ as shown.



A 5.00 cm^3 sample of **S** completely reacts with $\text{H}_2\text{O}_2(\text{aq})$. The volume of $\text{O}_2(\text{g})$ produced is 24.0 cm^3 under room conditions.

Assume that only the NaClO in **S** reacts with $\text{H}_2\text{O}_2(\text{aq})$.

Calculate x . Show your working.

$x = \dots\dots\dots \text{ g dm}^{-3}$
[3]

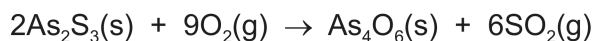
Q19

9701/21/O/N/21 Q1(d)(i)

4 marks

- (d) The compound As_2S_3 is a common mineral.

When As_2S_3 is heated strongly in air, it forms a mixture of products, as shown.



- (i) A sample containing 0.198 g As_2S_3 is placed in 0.100 dm^3 of pure oxygen, an excess, in a reaction chamber connected to a gas syringe at room temperature.

The reactants are heated until no further change is observed. The products are then allowed to cool to room temperature.

Calculate the volume, in dm^3 , of gas present at the end of the experiment.

The molar volume of gas is $24.0 \text{ dm}^3 \text{ mol}^{-1}$ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.



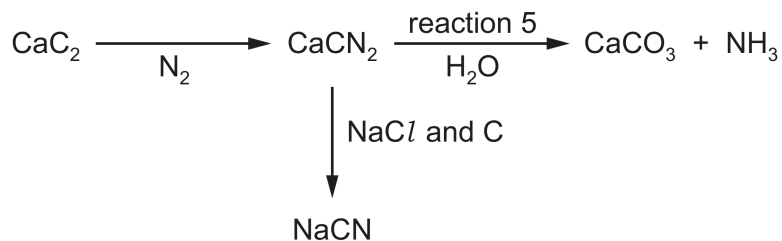
volume of gas remaining = ... dm^3
[4]

Q20

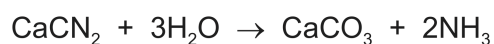
9701/21/O/N/21 Q2(d)(i)

2 marks

(d) The flowchart shows some reactions of CaC_2 .



(i) Reaction 5 can be used to prepare NH_3 .



Calculate the minimum mass, in tonnes, of calcium cyanamide, CaCN_2 , that is required to produce 1.50×10^6 tonnes of NH_3 .

Show your working.

$$1 \text{ tonne} = 1.00 \times 10^6 \text{ g}$$

minimum mass of CaCN_2 = ... tonnes
[2]

Q21

9701/22/F/M/21 Q2(f)(ii)

2 marks

(f) 0.020 mol of element **Z** reacts with excess Cl_2 to form 0.020 mol of a liquid chloride.

The liquid chloride has formula ZCl_n , where n is an integer.

ZCl_n reacts vigorously with water at room temperature to give an acidic solution and a white solid.

When excess $\text{AgNO}_3(\text{aq})$ is added to the solution, 11.54 g of $\text{AgCl}(\text{s})$ forms.

(ii) Calculate the value of n in ZCl_n .

$n = \dots\dots\dots$ [2]



Q22

9701/22/M/J/21 Q1(c)

3 marks

1 A Group 2 metal combines with bromine to form a crystalline solid, MBr_2 .

(c) A 0.250 g sample of pure MBr_2 contains 8.415×10^{-4} mol MBr_2 .

Calculate the relative formula mass, M_r , of MBr_2 . Use this to identify **M**.

Show your working.

$M_r = \dots\dots\dots$

M = $\dots\dots\dots$
[3]



Q23

9701/22/F/M/23 Q2(d)(ii)

3 marks

- (ii) Compound **X**, an anhydrous Group 2 bromide, is dissolved in water and titrated against aqueous silver nitrate.

A solution containing 0.250 g of **X** requires 33.65 cm³ of 0.0500 mol dm⁻³ AgNO₃(aq) for complete reaction.

Identify **X**.

Show your working.

X = ... [3]

Q24

9701/24/M/J/25 Q6(a)(i)-(ii)

3 marks

6 **P**, **Q** and **R** are three different hydrocarbon molecules.

(a) (i) Define empirical formula.

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

(ii) Hydrocarbon **P** contains 85.7% by mass of carbon.

Calculate the empirical formula of **P**.

Show your working.

empirical formula of **P** = ... [2]



Q25

9701/22/M/J/25 Q3(b)(i)

1 marks

- (b) $\text{H}_2(\text{g})$ and nickel are added to alkene **X**. Fig. 3.2 shows how the concentration of **X** changes with time.

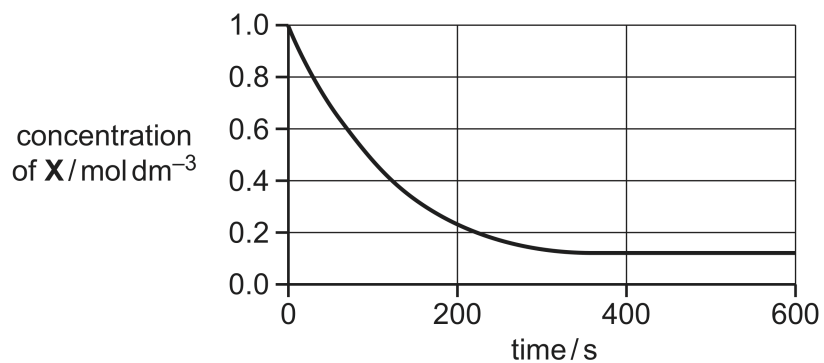


Fig. 3.2

- (i) Use Fig. 3.2 to identify the limiting reagent in this reaction. Explain your answer.

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

Q26

9701/21/M/J/25 Q4(b)(i)-(ii)

3 marks

- (b) The concentration of vitamin C is found by titration with $I_2(aq)$.

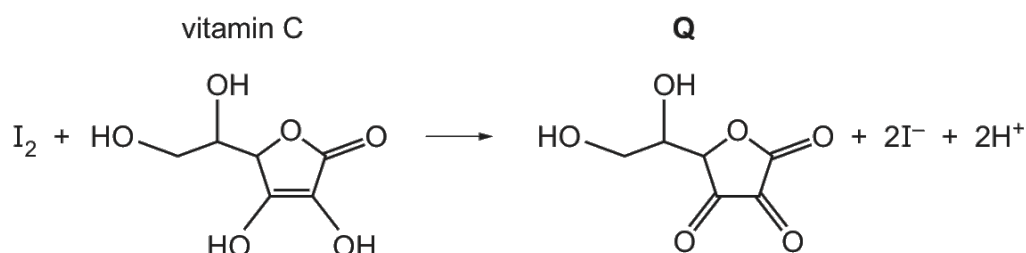


Fig. 4.2

A vitamin C tablet is dissolved in water to produce 200.0 cm^3 of vitamin C solution.
 5.00 cm^3 of this vitamin C solution is added to a flask with approximately 150 cm^3 of water and an indicator.
 Exactly 28.40 cm^3 of $5.00 \times 10^{-4}\text{ mol dm}^{-3}$ $I_2(aq)$ reacts with the sample of vitamin C solution in the flask.

$[M_r: \text{vitamin C}, 176]$

- (i) Calculate the amount, in mol, of $I_2(aq)$ added to the flask in this titration.

amount of $I_2(aq)$ = ... mol [1]

- (ii) Use your answer to (b)(i) to calculate the mass, in g, of vitamin C in the tablet. Show your working.

(If you were unable to calculate a value for the amount of $I_2(aq)$ in (b)(i), use the value $2.64 \times 10^{-4}\text{ mol}$. This is **not** the correct value.)

mass of vitamin C in tablet = ... g [2]

Q27

9701/21/M/J/23 Q2(b)(i)

1 marks

- 2 A neutralisation reaction occurs when NaOH(aq) is added to H₂SO₄(aq).



- (b) An experiment is carried out to calculate ΔH_{neut} for the reaction between NaOH(aq) and H₂SO₄(aq).

100 cm³ of 1.00 mol dm⁻³ NaOH(aq) is added to 75 cm³ of 1.00 mol dm⁻³ H₂SO₄(aq) in a polystyrene cup and stirred. Results from the experiment are shown in Table 2.1.

Table 2.1

initial temperature of NaOH(aq) / °C	20.0
initial temperature of H ₂ SO ₄ (aq) / °C	20.0
maximum temperature of mixture / °C	27.8

- (i) Use equation 1 to calculate the amount, in mol, of H₂SO₄(aq) that is neutralised in the experiment.

amount of H₂SO₄(aq) neutralised = ... mol [1]

Q28

9701/22/M/J/23 Q2(e)(ii)-(iii)

4 marks

- (ii) Sodium chlorate(I), NaClO , reacts with hydrogen peroxide to produce sodium chloride, water and oxygen gas.

Construct an equation for this reaction.

..... [1]

- (iii) A sample of bleach **W** contains an unknown concentration of sodium chlorate(I).

10.0cm^3 of **W** is diluted with distilled water to make a total volume of 100cm^3 of bleach solution. 25.0cm^3 of this diluted bleach solution is added to an excess of hydrogen peroxide and the volume of gas produced measured under room conditions. The experiment is repeated and on average 25.0cm^3 of diluted bleach solution produces 42.0cm^3 of gas.

Calculate the concentration, in g dm^{-3} , of sodium chlorate(I) in **W**.

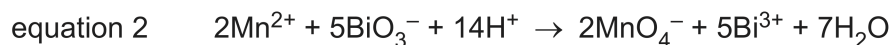
concentration of NaClO in **W** = ... g dm^{-3} [3]

Q29

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

3 marks

- (e) NaBiO_3 can be used to determine the concentration of $\text{Mn}^{2+}(\text{aq})$. The ionic equation for the reaction is shown in equation 2.



A student uses the following procedure in an experiment.

- Add 100.0 cm^3 of a saturated solution of $\text{Mn}^{2+}(\text{aq})$ to a volumetric flask.
- Add distilled water to the flask to make a 1.00 dm^3 diluted solution.
- Titrate a 25.00 cm^3 sample of the diluted solution with 0.100 mol dm^{-3} $\text{NaBiO}_3(\text{aq})$.

The 25.00 cm^3 sample of the diluted solution of $\text{Mn}^{2+}(\text{aq})$ reacts completely with exactly 21.50 cm^3 of 0.100 mol dm^{-3} $\text{NaBiO}_3(\text{aq})$.

Calculate the concentration, in mol dm^{-3} , of $\text{Mn}^{2+}(\text{aq})$ in the saturated solution.

Show your working.

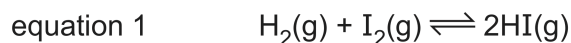
concentration of $\text{Mn}^{2+}(\text{aq})$ in the saturated solution = ... mol dm^{-3} [3]

Q30

9701/24/M/J/25 Q3(a)(i)-(ii)

3 marks

- 3 $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ react to form $\text{HI}(\text{g})$ in a reversible reaction, as shown in equation 1.



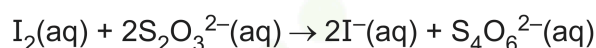
In three separate experiments, a student combines different amounts of two or more of the gases from equation 1. In each experiment, the gases are left to reach equilibrium at a given temperature.

- (a) In experiment 1, $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ are combined.

Water is then added to the equilibrium mixture to produce 1.00 dm^3 of solution **A**.

The amount of $\text{I}_2(\text{aq})$ present in 1.00 dm^3 of solution **A** is found by titration with $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.

Exactly 32.90 cm^3 of $0.200 \text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3$ reacts with all of the I_2 in a 25.0 cm^3 sample of solution **A**.



- (i) Calculate the amount, in mol, of $\text{S}_2\text{O}_3^{2-}$ that reacts in the titration.

amount of $\text{S}_2\text{O}_3^{2-} = \dots\dots\dots \text{ mol}$ [1]

- (ii) Use your answer to (a)(i) to calculate the amount, in mol, of I_2 present in 1.00 dm^3 of solution **A**.

(If you were unable to obtain an answer in (a)(i), then use $9.42 \times 10^{-3} \text{ mol}$. This is **not** the correct answer.)

amount of I_2 in 1.00 dm^3 of solution **A** = $\dots\dots\dots \text{ mol}$ [2]

Q1 - Official MS

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

6 marks

1(a)(i)	option 1 M1 the mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecule(s)	1
	option 1 and M2 relative / compared to 1 / 12 (the mass) of an atom of carbon-12	1
	OR on a scale in which a carbon-12 atom / isotope has a mass of (exactly) 12 (units) option 2 M1 mass of one mol of molecules	
	option 2 M2 relative / compared to 1 / 12 (the mass) of 1 mol of C-12 OR which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g	
1(a)(ii)	CO ₂ H	1
1(a)(iii)	$0.18/90 \times 2 \times 6.02 \times 10^{23} = 2.408 \times 10^{21}$ (atoms) OR 2.4(1) $\times 10^{21}$ (atoms) M1 no mole ethanedioic acid $0.18 / 90 = 0.0020$	1
	M2 no mole ethanedioic acid $\times 2$ $0.0020 \times 2 = 0.0040$	1
	M3 no mole ethanedioic acid $\times 6.02 \times 10^{23}$ 2.4×10^{21}	1

Q2 - Official MS

9701/21/M/J/22 Q1(e)(i)-(ii)

3 marks

1(e)(i)	1 / 12 (one twelfth) the mass of a carbon-12 / ¹² C atom	1
1(e)(ii)	M1 correct expression relating A_r to the mass / % abundance of the three isotopes $24.31 = x \times 0.7899 + 24.99 \times 0.1000 + 25.98 \times 0.1101$	2
	M2 correct answer to 4 sig figs atomic mass of X = 23.99	

Q3 - Official MS

9701/21/O/N/22 Q1(a)(ii)-(iii)

4 marks

1(a)(ii)	M1 (weighted) average / mean mass of the isotopes / average mass of the atom(s) (of an element)	1
	M2 compared to (the mass of) the unified atomic mass unit	1
1(a)(iii)	$69.723 = 68.926x + 70.925(1 - x) \therefore x = 0.6013$ $/ 69.723 = \frac{68.926x + 70.925(100 - x)}{100}$	1
	60.13%	1

Q4 - Official MS

9701/23/M/J/23 Q1(b)(i)-(iii)

3 marks

1(b)(i)	(the mass of) one twelfth of the mass of a C-12 / ¹² C atom (or isotope)	1
1(b)(ii)	average mass of the isotopes of an element compared to the unified atomic mass unit	1
1(b)(iii)	$(62.93 \times 69.15) \div 100 + (64.928 \times 30.85) \div 100 = 63.55 / 63.546$	1

Q5 - Official MS		9701/21/O/N/24 Q1(c)(i)-(ii)	4 marks
1(c)	mass of an atom of an isotope		1
	compared to the mass of the unified atomic mass unit (amu) OR on a scale on which a carbon-12 atom has a mass of exactly 12 units OR divided by $\frac{1}{12}$ mass of a carbon-12 atom		1
1(c)(ii)	$\frac{190.96 \times 15.18 + 192.96 \times 34.82}{50.00}$		1
	= 192.35		1

Q6 - Official MS		9701/21/M/J/25 Q2(b)(i)	2 marks
2(b)(i)	M1 method showing each abundance multiplied by m/e value • (5.9 × 54) and (91.9 × 56) and (2.2 × 57) OR • (0.59 × 54) and (9.19 × 56) and (0.22 × 57) M2 the three values from M1 expressed as a percentage and added together correctly with final answer to 1 d.p. $\frac{5.9}{100} \times 54 + \frac{91.9}{100} \times 56 + \frac{2.2}{100} \times 57 = 55.9$		2

Q7 - Official MS		9701/22/M/J/25 Q2(a)(i)-(ii)	4 marks
2(a)(i)	route 1 M1 average (weighted) mass of (an) atom(s) (of an element) OR average (weighted) mass of the isotope(s) (of an element) M2 compared to the mass of the unified atomic mass unit OR on a scale in which a carbon-12 atom / isotope has a mass of exactly 12 (units) OR on a scale in which the mass of a carbon-12 atom/isotope is exactly 12 (units) OR compared to $\frac{1}{12}$ mass of one atom of C-12 route 2 M1 average mass of one mol of isotopes / atoms (of an element) M2 relative / compared to $\frac{1}{12}$ of the mass of one mol of C-12 atoms/isotopes OR when the mass of one mol C-12 atoms / isotopes is exactly 12 (000) g		2
2(a)(ii)	M1 relative abundance of unknown isotope = (100 – 91.9 – 6.0) = 2.1% M2 55.8 = (53.9 × 6.0 + 55.9 × 91.9 + ? × M1) / 100 = 56.9		2

Q8 - Official MS		9701/23/M/J/21 Q3(c)	3 marks
3(c)	% of O M1 100 – 79.29 (= 20.71)		1
	M2 express W and O as mol by / 183.8 and / 16 respectively		1
	M3 divide each by smallest number to give empirical formula WO ₃		1
Question		Answer	Marks

Q9 - Official MS		9701/21/M/J/22 Q4(a)	3 marks
4(a)	M1 % / A_r for C H O M2 each % / A_r for C H O divided by the smallest value for % / A_r to give simplest whole number ratio / empirical formula M3 compare M_r from M2 ratio with 280 to deduce the actual molecular formula C H O 77.2 / 12 = 6.433 11.4 / 1 = 11.4 11.4 / 16 = 0.7125 9(.03) 16 1 $M_r(C_9H_{16}O) = 140$ so molecular formula of V = $C_{18}H_{32}O_2$	3	
Q10 - Official MS		9701/22/M/J/22 Q6(b), 6(c)(i)	2 marks
6(b)	C : H : O 41.38 / 12 3.45 / 1 55.17 / 16 3.45 3.45 3.45 (so $C_{(1)}H_{(1)}O_{(1)}$)	1	
6(c)(i)	Look for some reference to 116 as the mass of the molecular ion AND mass of $C_{(1)}H_{(1)}O_{(1)} = 29$ to conclude molecular formula is $C_4H_4O_4$ $116 / 29 = 4$ so $C_4H_4O_4$	1	
Q11 - Official MS		9701/22/O/N/22 Q1(d)(ii)	2 marks
1(d)(ii)	(molecular mass of NH_4MgPO_4) = 137.3	1	
	$(245.3 - M_r(NH_4MgPO_4) \div 18.0)$ = 6	1	
Q12 - Official MS		9701/21/M/J/24 Q2(d)(i)	1 mark
2(d)(i)	BN	1	
Q13 - Official MS		9701/23/M/J/24 Q3(c)(ii)	2 marks
3(c)(ii)	M1 give correct expression or calculate mol B compared to mol C $78.26 / 10.8 (= 7.246 / 7.25 \text{ mol B})$ AND $21.74 / 12 (= 1.81(2) \text{ mol C})$ M2 Find B : C ratio AND use this to state empirical formula 7.246 to $7.25 / 1.817$ to $1.82 = 3.99$ to $3.98 \text{ mol B} : 1 \text{ mol C}$ (so) B_4C OR CB_4	2	

Q14 - Official MS

9701/21/O/N/24 Q1(d)(i)

2 marks

1(d)(i)	M1 $\frac{79.5}{209.4} : \frac{20.5}{18.0} = 0.380 : 1.14 = 1:3$ OR $18x / (102.9 + 3(35.5) + 18x) = 0.205$ $x = 3$ OR $(102.9 + 3(35.5)) / (209.4 + 18x) = 0.795$ $x = 3$ M2 $x = 3$	1
		1

Q15 - Official MS

9701/22/F/M/25 Q1(a)(iii)

2 marks

1(a)(iii)	ratio of moles of P : Cl = $\frac{30.4}{31.0} : \frac{69.6}{35.5} = 0.98 : 1.96 (= 1 : 2)$ molecular formula = P_2Cl_4	2
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Q16 - Official MS

9701/22/M/J/25 Q5(a), 5(b)(i)-(ii)

4 marks

5(a)	$C_3H_4O_3$	1
5(b)(i)	$5.00 \times 10^{-3} \times 36.65 / 1000$ $= 1.833 \times 10^{-4} / 1.8325 \times 10^{-4}$	1
5(b)(ii)	M1 expression and / or correct calculation to show how the amount of vitamin C in 150 g of lemon peel is calculated $1.8325 \times 10^{-4} \text{ mol} \times 176 \times 4$ M2 correct calculation based on $(M1 / 150) \times 100 = 0.086(\%)$ Using 1.8325×10^{-4} for M1 , M2 = 0.086 OR 0.087(%) Alternative answer using 7.65×10^{-4} : M1 $7.65 \times 10^{-4} \times 176 \times 4 = 0.5386 / 0.539$ M2 correct calculation based on $(M1 / 150) \times 100 = 0.359 / 0.36 (\%)$	2

Q17 - Official MS

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

1 mark

1(f)(i)	$M_r = 63.5$ $(1.05 / 63.5) \times 6.022 \times 10^{23} = 9.958 \times 10^{21}$ OR 9.96×10^{21}	1
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Q18 - Official MS

9701/23/M/J/21 Q1(e)

3 marks

1(e)	M1 Use volume O_2 to express / find no mol O_2 produced $24 / 24\,000 \text{ mol } O_2 \text{ produced} = 1 \times 10^{-3} (\text{mol})$	1
	M2 Use 1:1 ratio to deduce no mol NaClO in 1000 cm^3 sample $M1 \times 1000 / 5 = 0.2 (\text{mol dm}^{-3})$	1
	M3 Use amount of NaClO and its molecular mass (74.5) to find the mass of NaClO added $24 / 24\,000 \times 1000 / 5 \times 74.5 = 14.9 (\text{g dm}^{-3})$	1

Q19 - Official MS

9701/21/O/N/21 Q1(d)(i)

4 marks

1(d)(i)	M1 moles of $\text{As}_2\text{S}_3 = 0.198 / 246.1 / 8.05 \times 10^{-4}$ M2 moles SO_2 (using moles of As_2S_3 as limiting factor) = $2.41(36) \times 10^{-3}$ moles ($6 / 2 \times 8.05 \times 10^{-4}$) Volume $\text{SO}_2 = 2.41(36) \times 10^{-3} \times 24 = 0.0579 \text{ dm}^3$ M3 Moles O_2 used in reaction = $8.05 \times 10^{-4} \times 9 / 2 = 3.62 \times 10^{-3}$ Volume O_2 used in reaction = $3.62 \times 10^{-3} \times 24 = 0.0869 \text{ dm}^3$ M4 Final total volume gas = $(0.1 - 0.0869) + 0.0579 = [0.0131 + 0.0579] = 0.071(0) \text{ dm}^3$ M4 ONLY award 4th mark if the final answer rounds to <u>0.071</u> Answer to minimum of 2 sig figs MAX 3 for using ecf from M1 to M2 to M3 and M4 Award all 4 marks if final answer rounds to 0.071	4
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Q20 - Official MS

9701/21/O/N/21 Q2(d)(i)

2 marks

2(d)(i)	M1 moles of $\text{NH}_3 = 1.50 \times 10^6 \times 10^6 \div 17 = 8.82 \times 10^{10}$ M2 mass of $\text{CaCN}_2 = \frac{1/2 \times M1 \times 80.1}{10^6} = 3.53 \times 10^6$	2
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Q21 - Official MS

9701/22/F/M/21 Q2(f)(ii)

2 marks

2(f)(ii)	M1: $11.54 \div 143.4 = 0.0805$ M2: so ratio $\text{Z}:\text{Cl}$ is $1:4 / n = 4$	2
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Q22 - Official MS

9701/22/M/J/21 Q1(c)

3 marks

1(c)	M1 calculate M_r of MBr_2 using $8.415 \times 10^{-4} \text{ mol MBr}_2$ in 0.250 g $M_r = \dots\dots = 297(.1)\dots\dots$	1
	M2 calculate the atomic mass of M using M_r calculated in M1 $297.1 - (2 \times 79.9) = 137(.4)$	1
	M3 identify group 2 element from A_r in M2 Ba / barium	1

Q23 - Official MS

9701/22/F/M/23 Q2(d)(ii)

3 marks

2(d)(ii)	moles of $\text{AgNO}_3 = \frac{33.65}{1000} \times 0.0500 (= 1.68(25) \times 10^{-3})$	1
	moles of $\text{X} = 1/2 \times \text{moles of AgNO}_3 = 0.250 \div M_r(\text{X}) \quad \therefore M_r(\text{X}) = 297.2$	1
	A_r of Group 2 element is $297.2 - 2(79.9) = 137.4$ AND X is BaBr_2	1

Question	Answer	Marks
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Q24 - Official MS

9701/24/M/J/25 Q6(a)(i)-(ii)

3 marks

6(a)(i)	simplest (whole number) ratio of atoms (of the elements) in a compound	1
6(a)(ii)	M1 $\frac{85.7}{12}$ or 7.14 1 C : H : $\frac{14.3}{1}$ or 14.3 : 2 M2 CH_2	2

Q25 - Official MS

9701/22/M/J/25 Q3(b)(i)

1 mark

3(b)(i)	H ₂ / hydrogen AND some X / alkene left(over) / remains (at the end of this reaction)	1
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Q26 - Official MS

9701/21/M/J/25 Q4(b)(i)-(ii)

3 marks

4(b)(i)	$(28.40 / 1000 \times 0.0005) = 1.42 \times 10^{-5} \text{ mol}$	1
4(b)(ii)	$(1.42 \times 10^{-5} \times 176 \times 200 / 5) = 0.099968$ M1 correct method to deduce mass of vit C in 5 cm ³ sample $(1.42 \times 10^{-5} \times 176) = 2.49 \times 10^{-3}$ M2 correct calculation for mass of vit C in original solution $(2.49 \times 10^{-3} \times 200 / 5) = 0.099968$ OR M1 correct method to deduce amount, mol, vit C in 5 cm ³ sample $(1.42 \times 10^{-5} \times 200 / 5) = 5.68 \times 10^{-4}$ M2 correct calculation for mass of vit C in original solution = M1 $\times$ 176 $(5.68 \times 10^{-4}) \times 176 = 0.099968$	2

Q27 - Official MS

9701/21/M/J/23 Q2(b)(i)

1 mark

2(b)(i)	0.05 mol	1
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Q28 - Official MS

9701/22/M/J/23 Q2(e)(ii)-(iii)

4 marks

2(e)(ii)	$\text{NaClO} + \text{H}_2\text{O}_2 \rightarrow \text{O}_2 + \text{NaCl} + \text{H}_2\text{O}$	1
2(e)(iii)	M1 (show how to calculate) mol O ₂ gas 42 cm ³ gas = 42 / 24000 mol oxygen gas (= 1.75×10^{-3} mol) M2 (process to find) amount NaClO in 10 cm ³ sample = 100 cm ³ (diluted) bleach M1 $\times$ 4 (= $4 \times 1.75 \times 10^{-3}$ mol in 10 cm ³ = 0.007) M3 correct calculation using M2 to find concentration = (M2 / 10) $\times$ 1000 $\times$ 74.5 = 52.2 (g / dm ³)	3

Q29 - Official MS

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

3 marks

1(e)	moles of NaBiO_3 = $21.50 / 1000 \times 0.100$ ($= 2.15 \times 10^{-3} \text{ mol}$)	1
	moles of Mn^{2+} in dil. = $2.15 \times 10^{-3} \times 2 / 5 \times 40$ ($= 0.0344 \text{ mol}$)	1
	conc. saturated Mn^{2+} = $0.0344 \times 1000 / 100$ = 0.344 mol dm⁻³	1

Question	Answer	Marks
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Q30 - Official MS

9701/24/M/J/25 Q3(a)(i)-(ii)

3 marks

3(a)(i)	0.00658(0) mol	1
3(a)(ii)	M1 I_2 in 25.0 cm^3 $0.00658 / 2 = 0.00329 \text{ (mol)}$ M2 $0.00329 \times 1000 / 25.0 = 0.132 \text{ (mol)}$ alternative answer using 9.42×10^{-3} : M1 0.00471 M2 0.1884	2

