Questions

Q1.

This question is about the structure of the atom and isotopes.

The following excerpt is taken from the book *Inorganic Chemistry* by Bailey and Snellgrove, fourth impression 1938.

> *"Some of the electrons are also contained in the nucleus, whilst the remainder are ..... arranged in rings revolving round the nucleus ..... The two isotopes [of chlorine] have therefore 18 and 20 electrons respectively in the nucleus and 17 [electrons] external to it."*

(a) Identify and correct **two** errors in the excerpt.

(2)

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(b) What is the structure of a 1+ ion of the carbon-13 isotope?

(1)

- ☒ **A** six protons, six neutrons and five electrons
- ☒ **B** six protons, seven neutrons and six electrons
- ☒ **C** six protons, seven neutrons and five electrons
- ☒ **D** seven protons, six neutrons and six electrons

(Total for question = 3 marks)

Q2.

Bromine exists as two stable isotopes. The two isotopes are represented by the symbols $^{79}_{35}Br$ and $^{81}_{35}Br$.

Give one similarity and one difference between these two isotopes by referring to the **number of particles** in the nuclei of the two isotopes.

(2)

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(Total for question = 2 marks)

Q3.

This is a question about atoms, isotopes and ions.

The percentage composition of the two bromine isotopes in a sample is given in the table.

Isotope	Relative isotopic mass	Percentage abundance
bromine-79	78.918	50.52
bromine-81	80.916	49.48

Calculate the relative atomic mass of bromine in this sample.
Give your answer to two decimal places.

(2)

(Total for question = 2 marks)

Q4.

This question is about magnesium.

The relative atomic mass of a sample of magnesium was found to be 24.3. The percentage composition for two of the three isotopes is given in the table. Use these data to calculate the percentage composition of the third isotope and hence its relative isotopic mass. Give your answer to an appropriate number of significant figures. You **must** show your working.

Relative isotopic mass	Percentage abundance
25.0	10.00
26.0	11.01

(4)

(Total for question = 4 marks)

Q5.

(i) State what is meant by the term **relative atomic mass**.

(2)

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(ii) A 5.000 g sample of lithium, containing the two isotopes lithium-6 and lithium-7, was found to contain 0.460 g of the isotope lithium-6.

Calculate the relative atomic mass of lithium for this sample. Give your answer to an appropriate number of significant figures.

Isotope	Relative isotopic mass
Lithium-6	6.015
Lithium-7	7.016

(3)

(Total for question = 5 marks)

Q6.

Bromine exists as two stable isotopes. The two isotopes are represented by the symbols $^{79}_{35}Br$ and $^{81}_{35}Br$.

The relative abundance of the two isotopes in a sample cannot be found in a chemical test.

(i) Give the reason why, despite the difference in atomic structure, the isotopes have the same chemical reactions.

(1)

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(ii) State how the relative abundance of the two isotopes can be found.

(2)

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(Total for question = 3 marks)

Q7.

A phosphorus atom has mass number 31.

Phosphorus has one naturally occurring isotope with mass number 31.
Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3.

(2)

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(Total for question = 2 marks)

Q8.

This question is about atoms, molecules and ions.

The mass spectrum of a diatomic molecule, X_2, has peaks at the following *m* / *z* values for the X_2^+ ion:

32, 33, 34, 35, 36

Deduce the formulae of all the species responsible for **each** of the peaks in the mass spectrum of X_2, identifying element X and showing clearly the isotopes present.

(3)

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(Total for question = 3 marks)

Q9.

This question is about hydrogen, the element with atomic number $Z = 1$.

(i) Hydrogen has two stable isotopes, $^{1}_{1}H$ and $^{2}_{1}H$. Complete the table to show the number of subatomic particles present in the nuclei of these two isotopes of hydrogen.

(1)

Isotope	Number of protons	Number of neutrons
$^{1}_{1}H$		
$^{2}_{1}H$		

(ii) Use the data in the table to explain the term isotopes.

(2)

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(Total for question = 3 marks)

Q10.

This question is about isotopes.

The table shows data for some isotopes of potassium.

Isotope	Relative isotopic mass	Abundance %
^{39}K	38.9637	93.218
^{40}K	39.9340	0.012
^{41}K	40.9618	6.770

(i) State what is meant by the terms 'relative isotopic mass' and 'relative atomic mass'.

(3)

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(ii) State what is meant by the term 'isotopes'. Illustrate your answer by referring to the isotopes of potassium.

(2)

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(iii) Use the data in the table to calculate the relative atomic mass of potassium. Give your answer to 4 significant figures.

(2)

(Total for question = 7 marks)

Q11.

This question is about isotopes.

State, in terms of subatomic particles, what is meant by the term **isotopes**.

(2)

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(Total for question = 2 marks)

Q12.

This question is about chlorine.

Chlorine has two isotopes with mass numbers 35 and 37.

(i) Complete the table to show the numbers of subatomic particles in a ^{35}Cl atom and a $^{37}Cl^-$ ion.

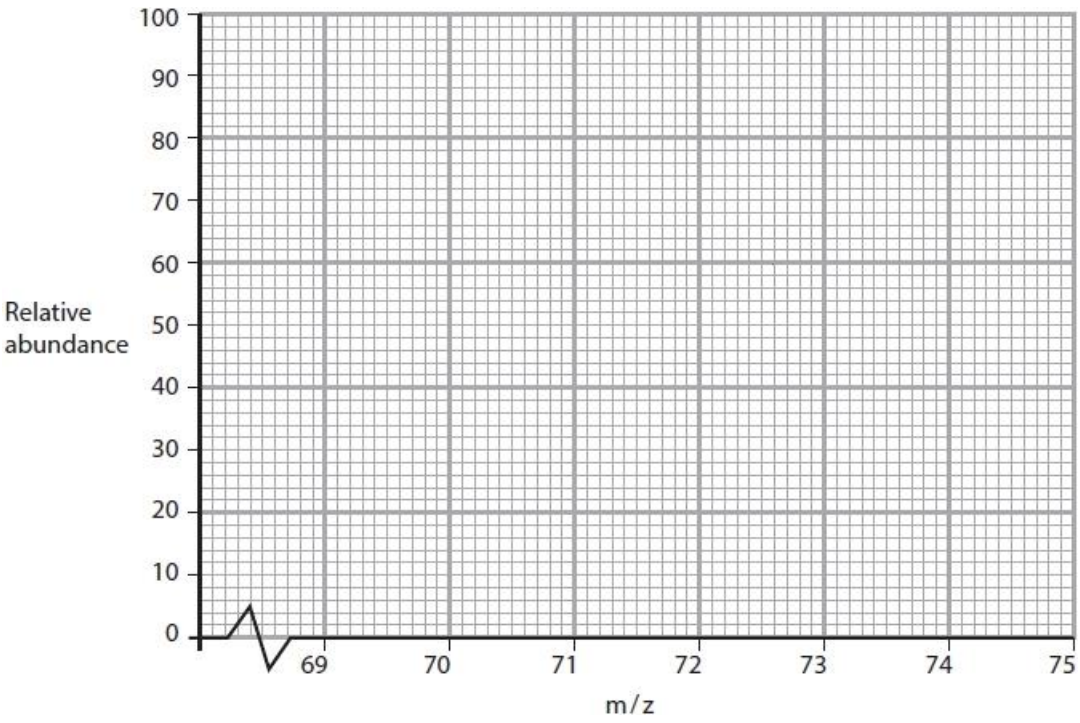
(2)

Particle	Protons	Neutrons	Electrons
^{35}Cl atom			
$^{37}Cl^-$ ion			

(ii) A sample of chlorine contained 75 % of ^{35}Cl and 25 % of ^{37}Cl.

Complete the mass spectrum to show the peaks you would expect for the molecular ion Cl_2^+ from this sample of chlorine gas.

(2)



(Total for question = 4 marks)

Q13.

This question is about isotopes.

The element gallium has a relative atomic mass of 69.735 and only contains two isotopes.

A sample of gallium contained the isotope ^{69}Ga, with a relative abundance of 63.25 %.

Calculate the mass number of the other isotope.
You **must** show all your working.

(2)

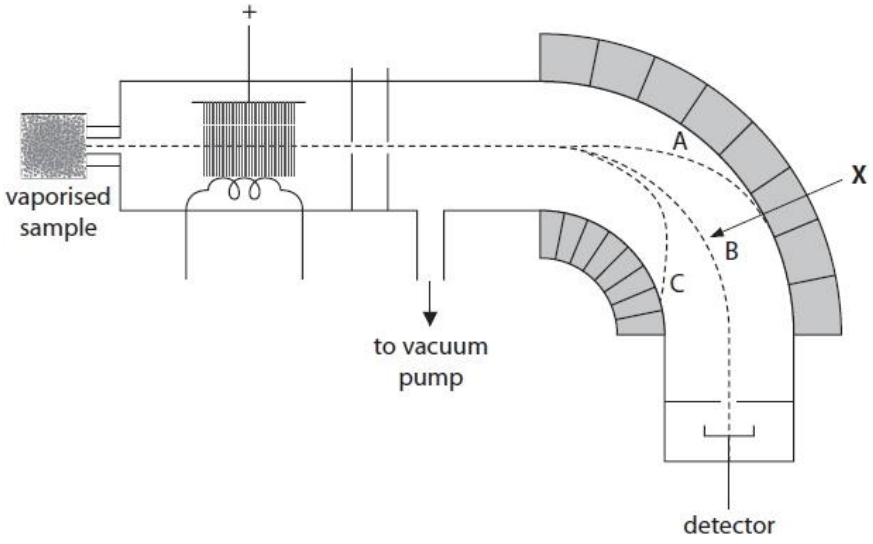
(Total for question = 2 marks)

Q14.

This question is about isotopes.

The relative isotopic abundances of an element can be measured using a mass spectrometer.

A simplified and incompletely labelled diagram of a mass spectrometer is shown.



(i) Name the feature of the mass spectrometer responsible for the behaviour of the ions in the region indicated by the arrow **X**.

(1)

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(ii) Explain the three ion pathways, A, B and C, shown in the region indicated by the arrow **X**.

(3)

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(iii) Give a reason why the mass spectrometer must be operated under vacuum.

(1)

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(Total for question = 5 marks)

Q15.

This question is about atoms, molecules and ions.

Lithium exists as two isotopes.

Complete the table to show the numbers of subatomic particles in a ^{6}Li **atom** and a $^{7}Li^{+}$ **ion**.

(2)

Particle	Protons	Neutrons	Electrons
^{6}Li			
$^{7}Li^{+}$			

(Total for question = 2 marks)

Q16.

This question is about hydrogen, the element with atomic number $Z = 1$.

The relative atomic mass of hydrogen in the Periodic Table is 1.0.
This is correct to two significant figures.

The table gives data for the relative isotopic mass and natural abundance of the two stable isotopes of hydrogen.

Isotope	Relative isotopic mass	Percentage abundance
$^{1}_{1}H$	1.007825	99.9885
$^{2}_{1}H$	2.014101	0.0115

(i) Using the data in the table, give a reason why it can be estimated that the relative atomic mass of hydrogen is greater than 1.0.

(1)

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(ii) Calculate the relative atomic mass of hydrogen from these data, giving your answer to **four** decimal places.

(2)

(Total for question = 3 marks)

Q17.

This question is about magnesium.

Magnesium exists as three stable isotopes. One isotope has a relative isotopic mass of 25.0.

State what is meant by the term **relative isotopic mass**.

(2)

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(Total for question = 2 marks)

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An answer that makes reference to any **two** of the following: • no electrons are found within the nucleus **(1)** • the isotopes of chlorine have 18 and 20 neutrons not electrons **(1)** • electrons are not in rings around the nucleus but in orbitals **(1)**	Answers can be given in either order. Check for answers alongside the written text if not given on the lines provided. Allow chlorine only has 17 electrons/ chlorine doesn't have 35/37 electrons Allow isotopes have different number of neutrons not electrons Allow isotopes have same number of electrons Allow regions / energy levels / shells / sub shells	**(2)**
Question Number	**Answer**		**Mark**
(b)	C (six protons, seven neutrons and five electrons)		**(1)**

Q2.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • both atoms have 35 protons (1) • one atom has 44 neutrons and the other has 46 neutrons (1)	Ignore the isotopes have the same number of electrons Allow the second isotope has two more neutrons If no other mark is scored allow (1) for they both have the same number of protons but different numbers of neutrons	(2)

Q3.

Question Number	Answer	Additional Guidance	Mark
	• correct expression (1) • evaluation of calculation and answer to 2 dp (1)	Example of calculation RAM= $\frac{(50.52 \times 78.918)+(49.48 \times 80.916)}{100}$ (= 79.9066104) = 79.91 ALLOW units of g mol^{-1} only Do not award units of % Correct answer without working scores (2)	(2)

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• calculates percentage of 3rd isotope **(1)** this is a standalone mark • lays out suitable equation including unknown **(1)** • consolidates **(1)** • 24.0 **(1)**	Example of calculation (100 - (10.00 + 11.01)) = 78.99 $\frac{(78.99 \times \text{isotopic mass}) + (25.0 \times 10.00) + (26.0 \times 11.01)}{100} = 24.3$ 78.99 x isotopic mass = 1893.74 Isotopic mass = $\frac{1893.74}{78.99}$ = 24.0 (23.97443) must be 3 s.f Correct answer with some further working scores last 3 marks Correct answer with no working scores last mark Allow 24 provided there is clear calculation.	(4)

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • the (weighted) **average mass / mean mass** of an atom of an element **(1)** • compared to **1/12th** the mass of an atom of **carbon-12**/ compared to a scale where one atom of **carbon-12** has a mass of (exactly) **12** **(1)**	The word 'atom' must be used at least once in the answer for both marks to be awarded. Do not award 12**g** This can be written as a mathematical expression.	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• calculation of the percentages of the two lithium isotopes **(1)** • calculation of RAM **(1)** • evaluation of correct answer to 2/3/4 s.f. **(1)** **or** • calculation of the mass of lithium-7 and the numerator of the RAM expression **(1)** • dividing by 5 and calculating the RAM **(1)** • evaluation of correct answer to 2/3/4 s.f. **(1)**	<u>Example of calculation:</u> Lithium-6 percentage =(0.460 ÷ 5.000 x 100=) 9.2% Lithium-7 percentage = 4.540 ÷ 5.000 x 100=) 90.8% RAM =((0.092 x 6.015) + (0.908 x 7.016))= 6.9239 RAM = 6.9 / 6.92 / 6.924 <u>Alternative example of calculation:</u> Mass of lithium-7 = 4.54 RAM = ((0.460 x 6.015) + (4.54 x 7.016)) ÷ 5 = 6.9239 RAM = 6.9 / 6.92 / 6.924 Correct answer to 2/3/4 s.f. with no working scores 3 marks Ignore g mol^{-1} / amu Reject g / %	**(3)**

Q6.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • they have the same electronic configuration / structure or they both have $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$	Allow they have the same number of electrons / they have 35 electrons Ignore an incorrect electronic configuration Do not award just 'they have the same number of electrons in their outermost shell'	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • compare the intensity of signal / number of particles of each isotope detected (1) • in a mass spectrometer (1)	Allow measure for compare	(2)

Q7.

Question Number	Answer	Additional Guidance	Mark
	• all 4 ion formulae **(1)** • all 4 *m/z* values **(1)** **or** • any two *m/z* values with corresponding ion formulae **(1)** • the other two *m/z* values with corresponding ion formulae **(1)**	Example of answer: ions — *m/z* $P(^{35}Cl)_3^+$ — 136 $P(^{35}Cl)_2{}^{37}Cl^+$ — 138 $P^{35}Cl(^{37}Cl)_2^+$ — 140 $P(^{37}Cl)_3^+$ — 142 Allow any other unambiguous way of representing the formulae e.g. with brackets or in words Positive charge only needs to be shown on one of the ions Ignore mass number on P	**(2)**

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • identification of oxygen / O **(1)** • identification of isotopes corresponding to any 3 *m/z* values **(1)** • Conditional on M2 awarded identification of isotopes corresponding to other 2 *m/z* values **(1)**	Isotopes in ions at each *m/z* value: (32 –) $^{16}O=^{16}O^+$ / $^{16}O_2^+$ (33 –) $^{16}O=^{17}O^+$ (34 –) $^{16}O=^{18}O^+$ **and** $^{17}O=^{17}O^+$ / $^{17}O_2^+$ (35 –) $^{17}O=^{18}O^+$ (36 –) $^{18}O=^{18}O^+$ / $^{18}O_2^+$ Allow single bonds Allow any other unambiguous ways of showing the masses of the isotopes for each *m/z* value e.g. $16+16, {}_2O^{16}$ Allow use of X / another symbol e.g. Cl instead of O for M2 and M3 Ignore missing charges as given in question Penalise negative charge once only	**(3)**

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	(^1_1H) protons **1**, neutrons **0** (^2_1H) protons **1**, neutrons **1**	All four correct needed	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • (atoms that) have the same number of protons **(1)** • but a different number of neutrons **(1)**	Ignore any references to electrons	**(2)**

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • (relative isotopic mass refers to) the mass of an atom of that isotope **(1)** • (relative atomic mass refers to) the weighted average / mean mass of an atom **(1)** • (both are) relative to $1/12^{th}$ the mass of a C-12 atom **(1)**	Penalise omission of 'atom' once only in the answer Do not award any reference to ' average' for relative isotopic mass	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	A description that makes reference to the following points: • (atoms with the) same number of protons but different numbers of neutrons **(1)** • comparison between any 2 or all 3 of the 3 quoted isotopes of potassium, referring to the correct numbers of protons and neutrons **(1)**	Allow 'atoms with the same atomic number but different mass number' Example: allow ^{40}K has one more neutron than ^{39}K	**(2)**

isotope	number of protons	number of neutrons
^{39}K	19	20
^{40}K	19	21
^{41}K	19	22

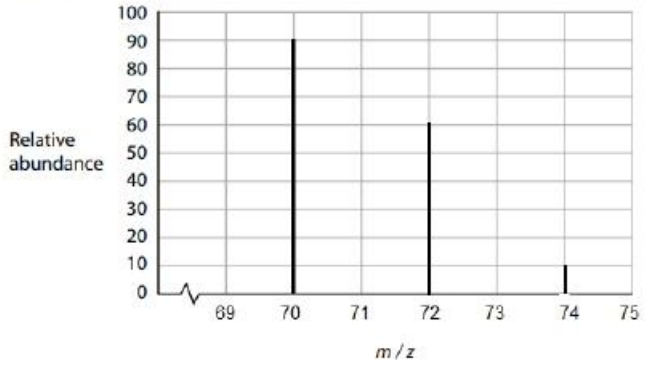
Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• correct calculation **(1)** • evaluation to 4 SF only **(1)**	Example of calculation: Using relative isotopic mass $\frac{(38.9637 \times 93.218) + (39.9340 \times 0.012) + (40.9618 \times 6.770)}{100}$ = 39.09908781 = 39.10 Use of $\frac{(39 \times 93.218) + (40 \times 0.012) + (41 \times 6.770)}{100}$ = 39.13552 = 39.14 scores M2 only An answer of 39.10/39.1 4 with no working scores (1) Ignore all units	**(2)**

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • same number of protons **(1)** • different numbers of neutrons **(1)**	Ignore number of electrons Ignore references to atom(s) / 'elements' in the answer	**(2)**

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	• all numbers for ^{35}Cl correct (1) • all numbers for $^{37}Cl^-$ correct (1)	Example of table | Particle	Protons	Neutrons	Electrons
^{35}Cl atom	17	18	17
$^{37}Cl^-$ ion	17	20	18	 If no other mark is awarded, allow (1) for any four numbers correct	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• lines at 70 and 72 and 74 (1) • relative abundances 9:6:1 (1)	Example of spectrum  Allow any abundances in an approximate 9:6:1 ratio e.g. 56:37-38:6 as %, or 75 : 50 : 8	(2)

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• correct subtraction to calculate relative abundance of unknown isotope **(1)** • calculation of mass number of unknown isotope of gallium with suitable working **(1)**	Example of calculation 100 – 63.25 = 36.75 **OR** 1.00 – 0.6325 = 0.3675 $\frac{(69 \times 63.25) + (M \times 36.75)}{100} = 69.735$ OR $43.64(25) + \frac{36.75\ M}{100} = 69.735$ M = 71 Ignore any units given with final answer. Correct answer with no working gets M2 only Allow TE from M1	**(2)**

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• (deflection by) (electro)magnetic field	Allow just magnet / electromagnet Allow magnetic / electromagnetic plates Do not award electric field	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • (pathway B), ions are deflected (by the magnetic field (and detected) (1) • pathway A, ions with greater / higher / larger mass / *m/z* are deflected less (1) • pathway C, ions with lower / smaller mass / lower *m/z* are deflected more **or** ions with greater / higher / multiple charge are deflected more (1)	Penalise 'size' once only Allow answers in terms of 'lighter and heavier' in place of mass Answers may make reference to the three dotted lines shown in the diagram	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following point: • to prevent collisions with gas / air molecules / particles (that would deflect the ions)	Allow to prevent collisions/ reaction/interaction with other particles Allow gas/air/other particles could be detected	(1)

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• ^{6}Li – 3 protons **and** 3 neutrons **and** 3 electrons **(1)** • $^{7}Li^{+}$ – 3 protons **and** 4 neutrons **and** 2 electrons **(1)**	Example of table Particle / Protons / Neutrons / Electrons ^{6}Li / 3 / 3 / 3 $^{7}Li^{+}$ / 3 / 4 / 2 If no other mark is scored, allow (1) for any 4 correct numbers Ignore + or - signs	(2)

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to following: • both isotopes have an isotopic mass of greater than 1 / 1.0 / one **OR** • there are no isotopes with an isotopic mass of less than one	Award mark if it is stated that the (only) other isotope is ^2H Ignore calculation of value, even if incorrect.	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• calculation to find A_r **(1)** • value of A_r to 4 DP **(1)**	Example of calculation $A_r = \frac{(1.007825 \times 99.9885) + (2.014101 \times 0.0115)}{100}$ (= 1.0079407) = 1.0079 Correct answer with no working scores (2) Allow TE for M2 for incorrect transfer of data or for one incorrect % abundance (e.g. 1.15%), provided that the final A_r value is between 1 and 2 Ignore units even if incorrect	**(2)**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: Mass of an **atom** of an isotope **(1)** relative to 1/12th mass of an atom of carbon-12. **(1)** OR $\frac{\text{Mass of one atom of an isotope}}{\text{Mass of one atom of carbon-12}} \times 12$ **(2)**	Atom needs only to be mentioned in MP1. Reject just "average / mean mass of an atom" But allow "average / mean mass of an **atom** of an isotope" Ignore mention of moles throughout and 12g in respect to carbon-12.	**(2)**