Mark scheme – Atomic Structure and Isotopes

Question			Answer/Indicative content	Marks	Guidance
1		i	(Weighted) mean/average mass of an **atom** ✓ compared with 1/12th mass of carbon-12 **OR** compared with mass of carbon-12 which is 12 ✓	2(AO1.1x2)	**DO NOT ALLOW** mean mass of an element *i.e. 'atom' essential* **Both marks available based on mole**: **ALLOW** mass of **1 mole** of atoms ✓ compared to 1/12th **1 mole**/12 g of carbon-12 ✓ **ALLOW** <u>mass of one mole of atoms</u> ✓ 1/12th mass of one mole/12 g of carbon-12 ✓ <u>**Examiner's Comments**</u> Most candidates were given at least one mark but lost the second mark due to omitting the word "atom", or "mean" or "one-twelfth"
		ii	**Use of isotope data** Use of 87 × 6.9 **AND** 88 × 82.9 **AND** 10.2 anywhere ✓ **Calculation of isotopic mass** $\frac{(100 \times 87.73) - (87 \times 6.9) - (88 \times 82.9)}{10.2}$ = 86 **OR** 86.03 ✓	2(AO1.2x2)	**ALLOW** 877.5 = 10.2A **ALLOW** $87.73 = \frac{(A \times 10.2) + 600.3 + 7295.2}{100}$ **ALLOW** $\frac{8773 - 600.3 - 7295.2}{10.2}$ = 86.03 **ALLOW** $\frac{87.73 - 78.955}{0.102}$ **OR** $\frac{8.775}{0.102}$ = 86 **OR** 86.03 **DO NOT ALLOW** Sr-86 with no working/justification **ALLOW** any unambiguous representation <u>**Examiner's Comments**</u> Algebra was used very well here and allowed most candidates to obtain at least one mark, with the majority obtaining 2 marks
			Total	**4**	

<table>
<tr>
<td>2</td>
<td>a</td>
<td></td>
<td>TWO correct responses from ✓

• Different numbers of neutrons
• Different (atomic) masses/mass numbers
• Different physical properties
Physical required</td>
<td>1 (AO1.1)</td>
<td>IGNORE heavier/lighter

DO NOT ALLOW different relative atomic masses
BUT ALLOW different relative isotopic masses

DO NOT ALLOW different chemical properties
OR different properties

IGNORE different abundancies

<u>Examiner's Comments</u>

Candidates needed to state two differences for 1 mark. Most candidates selected 'different numbers of neutrons' but this was often followed up by different 'relative atomic mass', the weighted mean of different isotopes, rather than 'different mass' for a single isotope. This suggested that many candidates may not have understood the meaning of 'relative' in 'relative atomic mass'.

Misconception

When discussing the mass of individual isotopes, 'mass' or 'mass number' should be used. The relative atomic mass is the weighted average mass of all of the isotopes of an element, and is consequently the incorrect term to use in this context.</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td></td>
<td>
<table>
<tr><th>Element</th><th>Mass number</th><th>Protons</th><th>Neutrons</th><th>Electrons</th><th>Charge</th><th></th></tr>
<tr><td>Fe</td><td>54</td><td>26</td><td>28</td><td>26</td><td>0</td><td>✓</td></tr>
<tr><td>Se</td><td>80</td><td>34</td><td>46</td><td>36</td><td>-2</td><td>✓</td></tr>
</table>

Mark by row</td>
<td>2 AO1.2×2</td>
<td>THREE responses for each mark
Easiest to check element first

ALLOW Se^{2-}
ALLOW names for elements

<u>Examiner's Comments</u>

Candidates answered this question reasonably well but many selected incorrect elements despite having identified the correct mass number and numbers of protons, neutrons and electrons. A common error was a mass number of 55.8 for Fe,</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>clearly a confusion between the mass number of an isotope and relative atomic mass (see also comments for 21(a)). Mn was also a common error for the first element, presumably by matching the mass number of 54 with the relative atomic mass of Mn (54.9).</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>3</td><td></td><td>i</td><td><table><tr><th></th><th>Protons</th><th>Neutrons</th><th>Electrons</th><th></th></tr><tr><td>^{29}Si</td><td>14</td><td>16</td><td>14</td><td>✓</td></tr></table></td><td>1</td><td><u>Examiner’s Comments</u>

This question was an easy starter to the paper with most candidates producing the correct answer.</td></tr>
<tr><td></td><td></td><td>ii</td><td>FIRST CHECK ANSWER ON THE ANSWER LINE
IF answer = 28.11 (to 2 DP) award 2 marks

$\frac{(28 \times 92.23) + (29 \times 4.68) + (30 \times 3.09)}{100}$

OR 28.1086 OR 28.109 ✓

= 28.11 (to 2 DP) ✓</td><td>2</td><td>For 1 mark: ALLOW ECF → to 2 DP if:

• %s used with wrong isotopes ONCE

OR

• transposed decimal places for ONE %

<u>Examiner’s Comments</u>

Almost all candidates followed a well-learnt procedure to complete the calculation. Despite being in the rubric to the question, some candidates did not give an answer to two decimal places. Others made a rounding error in reducing 28.1086 to two decimal places, with 28.10 and 28.12 being common errors.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>4</td><td></td><td>i</td><td><table><tr><th>m/z</th><th>protons</th><th>neutrons</th><th>electrons</th></tr><tr><td>24</td><td>12</td><td>12</td><td>11</td></tr><tr><td>25</td><td>12</td><td>13</td><td>11</td></tr><tr><td>26</td><td>12</td><td>14</td><td>11</td></tr></table></td><td>2</td><td></td></tr>
</table>

			Mark vertically: protons **AND** neutrons ✓ electrons ✓		**Examiner's Comments** This straightforward question was generally well answered. Some candidates completed the table for atoms rather than 1+ ions, with 12, rather than 11 electrons.
		ii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **If answer = 24.32 award 2 marks** $\frac{(24 \times 78.99) + (25 \times 10.00) + (26 \times 11.01)}{100}$ **OR** 24.320 **OR** 24.3202 ✓ = 24.32 (to 2 DP) ✓	**2**	**ALLOW ECF** for a correct calculation to 2 DP if: • %s have been used with wrong isotopes **ONCE** **OR** • decimal places for **ONE** % have been transposed **Examiner's Comments** This stock calculation proved to be one of the easiest questions on the paper. When an error was seen, it was inevitably for not showing the answer to two decimal places.
			Total	**4**	
5	a		**Similarities:** (Same) **number** of protons **AND** electrons ✓ **Differences:** (Different) **number** of neutrons ✓	2	**ALLOW** same electron configuration **ALLOW** 'amount' for 'number' **IGNORE** different masses/mass numbers (*Question asks for atomic structures*) **Examiner's Comments** Most candidates identified that different isotopes had the same number of protons but then omitted electrons. The different number of neutrons was usually seen although sometimes atomic mass was shown instead.
	b	i	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 63.62 award 2 marks**	2	

<table>
<tr><td></td><td></td><td></td><td>

$\frac{(63 \times 69.17) + (65 \times 30.83)}{100}$

OR 63.6166 **OR** 63.617 ✓

= 63.62 (to 2 DP) ✓

IGNORE *any units with* A_r

</td><td></td><td>

ALLOW ECF for a correct calculation to 2 DP if:

- %s have been used with wrong isotopes i.e. $\frac{(63 \times 30.83) + (65 \times 69.17)}{100}$ → **64.38**

OR

- decimal places for **ONE** % have been transposed,

i.e. 69.71 → **63.96**; 30.38 → **63.32**

<u>**Examiner's Comments**</u>

This part was mostly correct. Low-scoring candidates sometimes produced errors in averaging or rounding. Most final answers were given to the required two decimal places.

Answer = 63.62

</td></tr>
<tr><td></td><td></td><td>ii</td><td>

FIRST CHECK ANSWER ON THE ANSWER LINE
If answer = 3.97 × 10^{22} (from 63.62) award 2 marks
If answer = 3.98 × 10^{22} (from 63.5) award 2 marks

Using 63.62: *correct* A_r *of Cu from 21(b)(i)*
See bottom of answer zone

n(Cu) = $\frac{5.00 \times 0.840}{63.62} = \frac{4.2}{63.62}$ = 0.066(0) (mol) ✓

Cu atoms = 0.0660 × 6.02 × 10^{23} = **3.97 × 23 10^{22}** ✓
Must be calculated in standard form ***AND*** *to 3 SF*

OR

Using 63.5: A_r *of Cu from periodic table*

n(Cu) = $\frac{5.00 \times 0.840}{63.5} = \frac{4.2}{63.5}$ = 0.0661 (mol) ✓

Cu atoms = 0.0661 × 6.02 × 10^{23} = **3.98 × 10^{22}** ✓
Must be calculated in standard form ***AND*** *to 3 SF*

</td><td>2</td><td>

If there is an alternative answer, check to see if there is any **ECF** credit possible

SEE answer from **21b(i)** at bottom of answer zone

ALLOW correct answer from 3 SF up to calculator value of 0.06601697579

ALLOW incorrect n(Cu) × 6.02 × 10^{23} correctly
calculated to 3 SF **AND** in standard form
For ***ECF***, A_r ***must*** *have been used for n(Cu)*

ALLOW correct answer from 3 SF up to calculator value of 0.06614173228

ALLOW incorrect n(Cu) × 6.02 × 10^{23} correctly calculated to 3 SF **AND** in

</td></tr>
</table>

					standard form *For **ECF**, A_r **must** have been used for n(Cu)* ______________________________ **Common errors** **Using 63.62:** 3.984×10^{22} 1 mark (SF) 4.73×10^{22} 1 mark (ECF: omitting 0.840) **Using 63.5:** 3.982×10^{22} 1 mark (SF) 4.74×10^{22} 1 mark (ECF: omitting 0.840) **<u>Examiner's Comments</u>** This part was generally well answered with most candidates processing the data correctly. Candidates sometimes failed to consider 84% or rounded incorrectly in places. Answer = 3.97×10^{22} atoms
			Total	**6**	
6		i	M1 The (weighted) mean **mass** of an **atom** (of an element) ✓ M2 Compared with 1/12th (the mass) ✓ M3 Of (one atom of) carbon-12 ✓	3	**ALLOW** 'average' for 'mean' **ALLOW** 'mean mass of isotope**s**' but **DO NOT ALLOW** 'mean mass of isotope' (singular) **DO NOT ALLOW** 'mean mass of an element' For M2 and M3 **ALLOW** compared with the mass of carbon-12 which is 12 **ALLOW** for three marks Mass of **one mole** of **atoms** Compared to 1/12th (mass of) **one mole OR 12 g** of carbon-12 **ALLOW** for three marks <u>Mass of **one mole** of **atoms**</u> 1/12th (mass of) **one mole OR 12 g** of carbon-12 **Examiner's Comments** This commonly asked for definition was well answered by all.

		ii	First check the answer line. If answer = 65.44 award 2 marks. $\frac{(64 \times 49.0) + (66 \times 27.9) + (67 \times 4.3) + (68 \times 18.8)}{100}$ **OR** 31.36(0) + 18.414 + 2.881 + 12.784 **OR** 65.439 ✓ = 65.44 ✓	2	**ALLOW** one mark for ECF from transcription error in the first sum provided the final answer is to **two** decimal places and is between 64 and 68 and is a correct calculation of the transcription **Examiner's Comments** The vast majority were able to calculate the relative atomic mass of zinc to two decimal places.
			Total	**5**	
7			(table below) Relative mass column ✓; Relative charge AND position columns ✓	2	For relative masses **ALLOW** 1/1800 to 1/2000 for electron value (0.0005–0.00056) **ALLOW** 'negligible' for electron value **IGNORE** '+' in front of correct values **DO NOT ALLOW** '–' in front of 1/2000 **DO NOT ALLOW** 'nil' OR 'zero' for mass of electron For relative charges **ALLOW** 1+ and 'neutral' and 1– **IGNORE** '–' (ie a dash) for neutron **DO NOT ALLOW** '+' or '–' without '1' **DO NOT ALLOW** '1' without charge For position within the atom **IGNORE** 'middle **OR** 'centre' for 'nucleus' **Examiner's Comments** This was well-answered but it was evident that this basic material, usually covered very early in the syllabus had been forgotten by a few.
			Total	**2**	
8			55% ✓	1	**Examiner's Comments** Although some very good algebraic attempts were seen in this variant of an A_r calculation, it was clear from the working shown that even when the right answer was given, some candidates had not got to this answer in a systematic way but often in a very muddled and confused manner.
			Total	**1**	

Table for question 7:

particle	relative mass	relative charge	position within the atom
proton	1	+ 1	nucleus
neutron	1	nil/0	nucleus
electron	1/2000	-1	shell

9			<table><tr><th>Particle</th><th>Relative charge</th><th>Number of particles present in a $^{140}Ce^{2+}$ ion.</th></tr><tr><td>Protons</td><td>+1</td><td>58</td></tr><tr><td>Neutrons</td><td>Nil (or 0)</td><td>82</td></tr><tr><td>Electrons</td><td>–1</td><td>56</td></tr></table>One mark per column ✓ ✓	2	**DO NOT ALLOW** '+' or '-' without '1' **DO NOT ALLOW** 1 without charge **ALLOW** 1+ **AND** 1– **IGNORE** '–' (ie a dash) for relative charge of a neutron **Examiner's Comments** Virtually every candidate made a good start to the paper by securing at least one mark of the two available. Less able candidates gave the mass of the sub-atomic particles rather than their charge and a few gave 140 as the number of neutrons but such errors were a minority.
			Total	**2**	
10	a	i	**Atom(s)** of an element **AND** with different numbers of neutrons (and with different masses) ✓	1	**ALLOW** for 'atoms of an element': **Atoms** of the same element **OR** **Atoms** with the same number of protons **OR** **Atoms** with the same atomic number **IGNORE** different relative atomic masses **IGNORE** different mass number **IGNORE** same number of electrons **DO NOT ALLOW** different number of electrons **DO NOT ALLOW** 'atoms of elements' for 'atoms of an element' **DO NOT ALLOW** 'an element with different numbers of neutrons) (ie atom(s) is essential) **Examiner's Comments** This question was well answered. The one common error made was to omit any reference to 'atoms' and so answers in terms of the same element having different number of neutrons received no credit. Candidates should be advised to avoid unnecessary references to isotopes having the same number of electrons.
		ii	same number of electrons in outer shell **OR** same electron configuration **OR** electron structure ✓	1	**IGNORE** same number of protons **IGNORE** same number of electrons **IGNORE** they are the same element **Examiner's Comments** The key reason why isotopes show similar

					chemical properties (ie because they have an identical numbers of electrons in the outer shell) was not always understood. Weaker candidates struggled and gave answers referring to the number of protons remaining the same. Even slightly improved answers referring to the total number of electrons remaining the same did not deliver the required level of detail.
		iii	51p 70n 51e ✓	1	**Examiner's Comments** This straightforward question saw virtually every candidate secure this mark.
	b	i	The (weighted) mean **mass** of an **atom** (of an element) **OR** The (weighted) average **mass** of an **atom** (of an element) ✓ compared with 1 / 12th (the mass) ✓ of (one atom of) carbon-12 ✓	3	**ALLOW** average atomic mass **DO NOT ALLOW** mean mass of an element **ALLOW** mean mass of isotopes **OR** average mass of isotopes **DO NOT ALLOW** the singular 'isotope' For second **AND** third marking points **ALLOW** compared with (the mass of) carbon-12 which is 12 For three marks; **ALLOW** mass of **one mole** of **atoms** compared to 1 / 12th (mass of) one mole **OR** 12g of carbon **OR** **ALLOW** $\frac{\text{mass of one mole of atoms}}{\text{1/12th mass of } \textbf{one mole OR} \text{ 12}\textbf{g} \text{ of carbon-12}}$ **Examiner's Comments** This familiar recall question was well answered by all candidates. In the past there have been problems with weaker candidates omitting reference to average or mean mass, or muddling comparisons by referring to a single atom of the element and then a mole of carbon-12. On this occasion, however, such errors were rare and the answers seen were extremely strong.
		ii	123 ✓	1	**ALLOW** ^{123}Sb **OR** Sb-123 **OR** antimony-123 **ALLOW** 123.0 **IGNORE** working **Examiner's Comments** This question analysed the methodology of determining relative atomic mass in a more

					unusual way compared to the normal calculation from data about the constituent isotopes. As a result those candidates who had simply committed a method to memory without real understanding of what they were doing found themselves somewhat exposed here and consequently this question proved to be challenging for many. Stronger candidates scored well, however.
			Total	**7**	
11		i	$\frac{(85.00 \times 72.17)+(87.00 \times 27.83)}{2}$ (1) = 85.56 (to 2 d.p.) (1)	2	
		ii	Rubidium **OR** Rb	1	
			Total	**3**	
12	a		63 p 90 n 60 e	1	
	b		2 (1) 2 (1) 18 (1)	3	
			Total	**4**	