1. How many electrons are in a

A. 10
B. 12
C. 14
D. 22

Your answer

[1]

2(a). Europium, atomic number 63, has two isotopes, ^{151}Eu and ^{153}Eu.

Complete the table to show the number of protons, neutrons and electrons in the $^{153}Eu^{3+}$ ion of europium.

	protons	**neutrons**	**electrons**
$^{153}Eu^{3+}$			

[1]

(b). Atoms of europium have electrons in orbitals within the first five shells. The first three shells of europium are full.

Complete the table to show the number of electrons in the following regions of a europium atom.

[3]

3. X is a particle with 18 electrons and 20 neutrons.

Which of the following particles could be **X**?

1: ^{38}Ar

2: $^{40}Ca^{2+}$

3: $^{39}K^{+}$

A. 1, 2 and 3
B. Only 1 and 2
C. Only 2 and 3
D. Only 1

Your answer

[1]

4. Information about two isotopes of an element is given in the table.

Isotope	Mass number	% Abundance
A	144	24
B	145	9

Which statement is correct?

A. The relative atomic mass of the element is 47.61.
B. Isotope **B** has more protons than isotope **A**.
C. Isotope **B** has fewer neutrons than isotope **A**.
D. The relative isotopic mass of isotope **B** is 145.

Your answer ☐

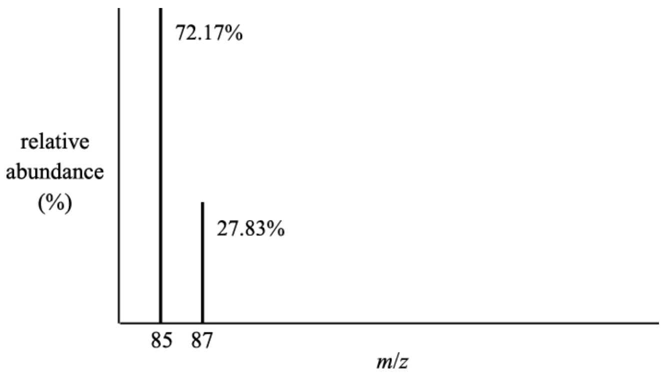
[1]

5. Bromine and mercury are the only two naturally occurring elements that are liquids at room temperature and pressure. Some physical properties of these two elements are given below.

	Appearance at room temperature	Melting point / °C	Boiling point / °C	Electrical conductivity of the liquid
Bromine	dark orange liquid	−7.2	58.8	very low
Mercury	shiny silver liquid	−38.8	356.7	good

Element **X** melts at temperatures reached on very hot summer days.

A sample of element **X** was analysed by mass spectrometry. The mass spectrum is shown below.



i. Calculate the relative atomic mass of element **X**.

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

[2]

ii. Suggest the identity of element **X**.

[1]

6. Which row shows the atomic structure of $^{55}Mn^{2+}$?

	Protons	Neutrons	Electrons
A	25	30	23
B	25	55	23
C	27	30	25
D	30	25	28

[1]

7(a). Antimony, Sb, has atomic number 51.

Antimony exists as a mixture of isotopes.

i. What is meant by the term *isotopes?*

-- **[1]**

ii. Different isotopes of antimony have the same chemical properties.

Explain why.

-- **[1]**

iii. Complete the table below to show the atomic structure of ^{121}Sb.

Protons	Neutrons	Electrons

[1]

(b). The relative atomic mass of antimony is 121.8.

i. Define the term *relative atomic mass*.

[3]

ii. A sample of antimony, A_r = 121.8, was analysed and was found to consist of 60% ^{121}Sb and one other isotope.

Determine the mass number of the other isotope in the sample of antimony.

mass number of the other antimony isotope = ... [1]

8. This question is about the elements with atomic numbers between 58 and 70.

Cerium, atomic number 58, is a metal.

Complete the table to show the relative charge of each particle and the number of each particle found in a $^{140}Ce^{2+}$ ion.

Particle	Relative charge of each particle	Number of each particle present in a $^{140}Ce^{2+}$ ion
proton		
neutron		
electron		

[2]

9. Bromine has two isotopes, Br–79 and Br–81. The relative atomic mass of bromine is 79.9.

Calculate the percentage of Br–79 atoms in a sample of bromine.

[2]

Answer = ... % **[2]**

10. Aluminium forms a sulfide, Al_2S_3.

Al_2S_3 reacts with water to form aluminium hydroxide and hydrogen sulfide, H_2S.

Write an equation for the reaction of Al_2S_3 with water.

-- **[1]**

11. Nitrogen is the most common gas in the atmosphere.

Atoms of nitrogen consist of protons, neutrons and electrons.

Complete the table below.

Particle	Relative mass	Relative charge	Position within the atom
Proton			
Neutron			
Electron			shell

[2]

12. A sample of zinc was found to contain four isotopes with the abundances shown in the table.

Isotope	Abundance (%)
^{64}Zn	49.0
^{66}Zn	27.9
^{67}Zn	4.3
^{68}Zn	18.8

i. Define the term *relative atomic mass*.

____

____

____

[3]

ii. Calculate the relative atomic mass of zinc in this sample.

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

relative atomic mass of zinc = ... **[2]**

13. Which row shows the atomic structure of $^{37}Cl^{-}$?

	protons	neutrons	electrons
A	17	18	20
B	17	20	18
C	18	19	17
D	20	17	21

Your answer ☐

[1]

14. What is the oxidation number of nitrogen in $Mg(NO_3)_2$?

A −3
B +2
C +5
D +6

Your answer

[1]

15(a). A twenty pence coin contains copper and nickel.

Copper and nickel each exist as a mixture of isotopes.

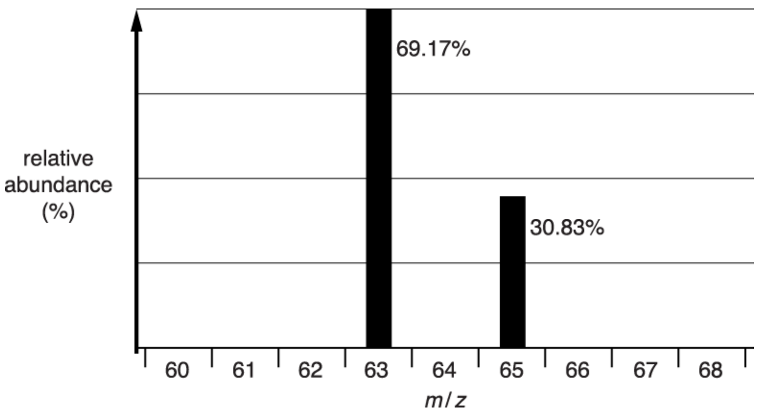
State the similarities and differences between the atomic structure of isotopes of the **same** element.

Similarities
....

Differences...
....

[2]

(b). The copper used to make a batch of coins is analysed by mass spectrometry. The mass spectrum is shown below.



i. Calculate the relative atomic mass of the copper used to make the coins.

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

relative atomic mass = ... **[2]**

ii. One coin has a mass of 5.00 g and contains 84.0% of copper, by mass.

Calculate the number of copper atoms in one coin.

Give your answer in standard form and to **three** significant figures.

number of copper atoms = ... **[2]**

16. Which ion has a different number of electrons from the other three ions?

A Ca^{2+}
B Cl^{-}
C Ga^{3+}
D S^{2-}

Your answer ☐

[1]

17(a). This question is about atomic structure and electron configuration.

Most elements exist as different isotopes.

Complete the table for an atom and an ion of two different isotopes of titanium.

Isotope	Protons	Neutrons	Electrons
^{48}Ti	....	....	....
....	....	24	19

[2]

(b). The accurate relative isotopic masses and relative abundances of the isotopes in a sample of bromine are shown below.

Isotope	Relative isotopic mass	Relative abundance (%)
^{79}Br	78.9183361	50.69
^{81}Br	80.9162896	49.31

i. What is the relative atomic mass of bromine in this sample?

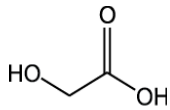
Give your answer to **three** decimal places.

relative atomic mass = ... **[2]**

ii. Write the electron configuration, in terms of all sub-shells, for an atom of bromine.

[1]

18. The compound shown below reacts with a mixture of NaBr and H_2SO_4.



What is the relative molecular mass of the organic product?

A 138.9
B 155.9
C 201.8
D 235.8

Your answer

[1]

19. Which atom is **not** an isotope of iodine?

	Number of neutrons	Mass number
A	72	125
B	74	127
C	75	128
D	77	129

Your answer **[1]**

20. Which calcium compound contains the **greatest** percentage by mass of calcium?

A calcium carbonate
B calcium nitrate
C calcium hydroxide
D calcium sulfate

Your answer [1]

21. Which ion has a different number of electrons from the other three ions?

A Ga^{3+}
B Cl^{-}
C S^{2-}
D Ca^{2+}

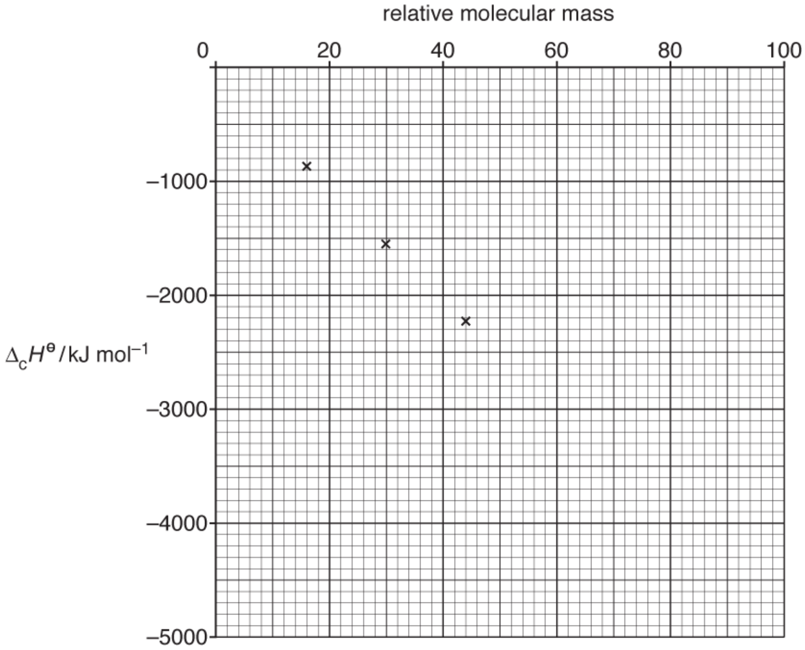
Your answer [1]

22. Data book values for the standard enthalpy changes of combustion, $\Delta_c H^{\theta}$, of the first four alkanes are shown in the table.

Alkane	methane	ethane	propane	butane
$\Delta_c H^{\theta}$ **/ kJ mol**$^{-1}$	–890	–1560	–2219	–2877

i. The values for the first three alkanes are plotted on the graph below.

Plot the value for butane on the graph.



[1]

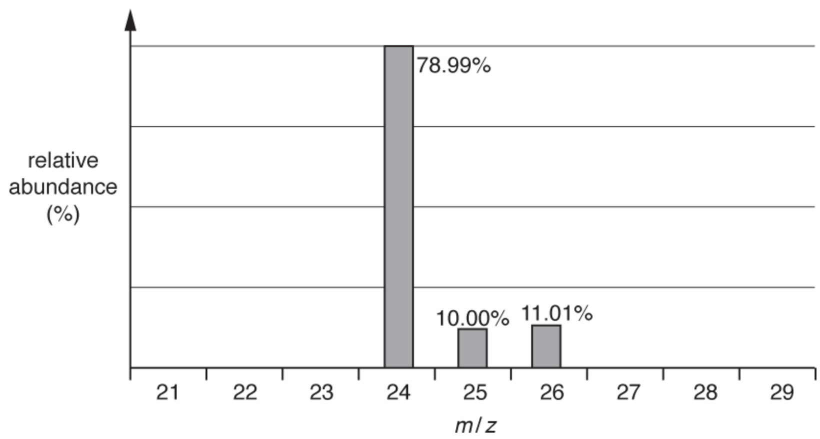
ii. Use the graph to estimate the energy released during complete combustion of 1.80 g of pentane.

Show relevant working below and on the graph.

energy released = ... kJ **[3]**

23. This question is about elements from the s-block and p-block of the periodic table.

A sample of magnesium is analysed by mass spectrometry. The mass spectrum is shown below.



i. The species causing the peaks in the mass spectrum are 1+ ions of magnesium.
Complete the table to show the number of protons, neutrons and electrons in each **1+ ion** of magnesium.

m* / *z	**protons**	**neutrons**	**electrons**
24			
25			
26			

[2]

ii. Calculate the relative atomic mass of the magnesium in the sample.
Give your answer to **two** decimal places.

relative atomic mass = ... **[2]**

24. A sample of boron contains the isotopes ^{10}B and ^{11}B.
The relative atomic mass of the boron sample is 10.8.

What is the percentage of ^{11}B atoms in the sample of boron?

A 8.0%
B 20%
C 80%
D 92%

Your answer [ ] **[1]**

25. This question is about elements from the p-block of the periodic table.

Silicon exists as a mixture of three isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

i. Complete the table to show the atomic structure of ^{30}Si.

	Protons	**Neutrons**	**Electrons**
^{30}**Si**	……………….	……………….	……………….

[1]

ii. A sample of silicon is analysed by mass spectrometry.

The mass spectrum shows peaks with the relative abundances below.

- ^{28}Si 92.23%
- ^{29}Si 4.68%
- ^{30}Si 3.06%

Calculate the relative atomic mass of silicon in the sample.

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

[2]

26. Explain why a small proportion of molecules in water have a relative molecular mass of 20.

[1]

27(a). This question is about atomic structure and the compounds of calcium, nitrogen and oxygen.

Most elements contain different isotopes.

State **two** differences between isotopes of the same element.

[1]

(b). Complete the table for an atom and an ion of two different elements.

Element	Mass number	Protons	Neutrons	Electrons	Charge
....	....	26	28	....	0
....	80	....	....	36	2−

[2]

28. A sample of magnesium, A_r = 24.305, is found to consist of three isotopes. The accurate relative isotopic masses and % abundances of two of the isotopes are shown in the table.

Isotope	Relative isotopic mass	% abundance
^{24}Mg	23.985	78.99%
^{25}Mg	24.986	10.00%

Determine the relative isotopic mass of the third isotope of magnesium in the sample.

Give your answer to **5** significant figures.

relative isotopic mass = ... **[2]**

29. This question is about the properties and reactions of the Group 2 element strontium.

The relative atomic mass of strontium can be determined using a mass spectrometer.

i. Explain what is meant by the term **relative atomic mass** of an element.

[2]

ii. A sample of strontium has a relative atomic mass of 87.73.

The sample consists of:

- 82.9% Sr-88
- 6.9% Sr-87
- one other isotope.

Determine the other isotope of strontium in the sample.
[2]

30(a). This question is about atoms, isotopes and mass spectrometry.

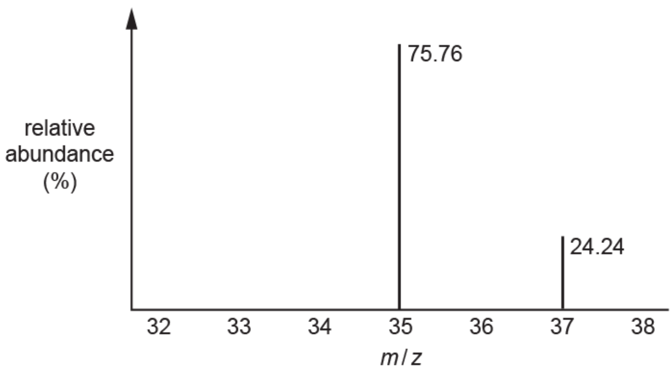
Most elements contain atoms of different isotopes.

State any differences and similarities between the atomic structures of isotopes of the same element.

[2]

(b). Mass spectrometry can be used to identify the isotopes of chlorine.

Part of the mass spectrum of chlorine is shown below.



i. Calculate the relative atomic mass of chlorine.

Give your answer to **2** decimal places.

[2]

ii. The mass spectrum of chlorine, Cl_2, also contains three molecular ion, M^+, peaks.
One of the M^+ peaks has an *m /z* value of 72.

Suggest why an M^+ peak at *m /z* = 72 is observed and predict the *m /z* values of the other two M^+ peaks.

[2]

31. This question is about magnesium, bromine and magnesium bromide.

Relative atomic mass is defined as 'the weighted mean mass compared with 1/12th mass of carbon-12'.

Explain what is meant by the term **weighted mean mass**.

[1]

32(a). This question is about atomic structure.

Selenium, Se, has the atomic number 34.

^{76}Se and ^{82}Se are two isotopes of selenium.

Complete the table to show the numbers of protons, neutrons and electrons in these two isotopes.

	Protons	**Neutrons**	**Electrons**
^{76}Se	....	....	....
^{82}Se	....	....	....

[1]

(b). The relative atomic mass of an element can be determined from its mass spectrum.

The table shows the results of a mass spectrum of a sample of sulfur, S.

Isotope	**Abundance (%)**
^{32}S	94.93
^{33}S	0.78
^{34}S	4.29

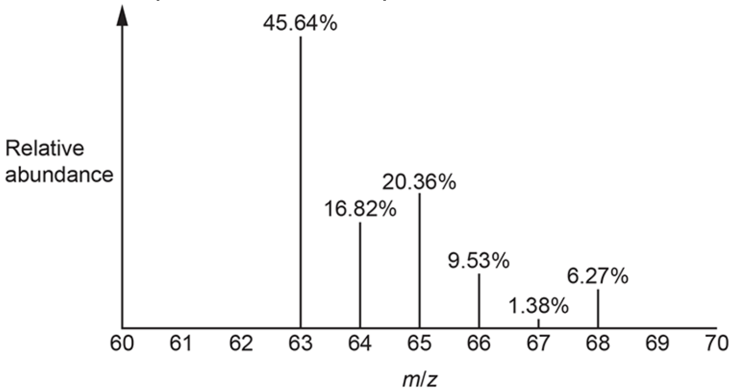
Calculate the relative atomic mass of the sample of sulfur.

Give your answer to **3** decimal places.

relative atomic mass = ... **[2]**

33. Brass is an alloy of copper and zinc.

The mass spectrum of a sample of brass is shown below.



The peaks at *m/z* = 63 and *m/z* = 65 are from the ^{63}Cu and ^{65}Cu isotopes of copper.

The remaining four peaks are from isotopes of zinc.

i. What are the percentage compositions of copper and zinc in the brass sample?

[1]

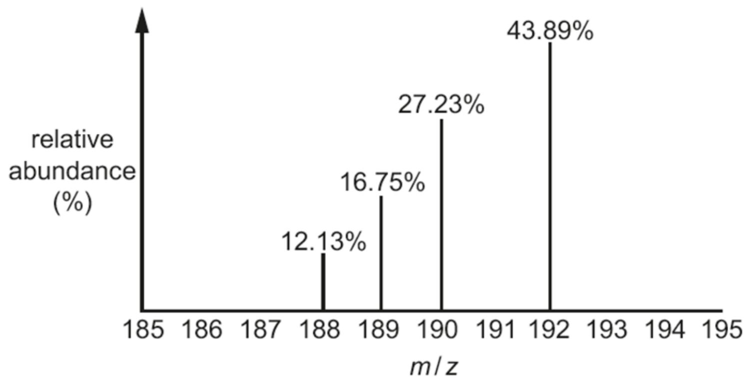
ii. Calculate the relative atomic mass of zinc in the sample of brass.

Give your answer to **2** decimal places.

[2]

34(a). This question is about atomic structure and formulae.

The relative atomic mass of a sample of osmium can be determined from its mass spectrum, shown below.



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

relative atomic mass = ... **[2]**

(b). Complete the table for an atom and an ion of **two** different elements.

Element	Mass number	Protons	Neutrons	Electron configuration	Charge
....	....	28	34	....	0
....	33	....	....	$1s^22s^22p^63s^23p^6$	3-

[2]

35. This question is about titanium (atomic number 22) and its compounds.

Titanium exists as a mixture of five isotopes.

A chemist analyses a sample of titanium using mass spectrometry.

The results are shown in the table below.

Isotope	Abundance (%)
^{46}Ti	8.30
^{47}Ti	7.40
^{48}Ti	73.70
^{49}Ti	5.40
^{50}Ti	5.20

i. Calculate the relative atomic mass of titanium in the sample.

Give your answer to **2** decimal places.

[2]

ii. Complete the electron configuration of a titanium atom.

1s2…

[2]

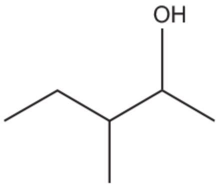
iii. Complete the table to show the number of protons, neutrons and electrons in a $^{48}Ti^{2+}$ ion.

	Protons	Neutrons	Electrons
$^{48}Ti^{2+}$ ion			

[1]

36. This question is about alkenes.

A mixture of alkenes is produced when water is eliminated from alcohol **A**.



Alcohol A

i. What is the systematic name of alcohol **A**?

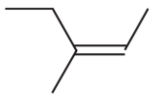
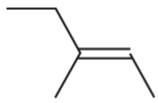
-- **[1]**

ii. Alcohol **A** is refluxed with an acid catalyst. A mixture of alkene isomers B, C and D is formed. Alkenes B and C show E/Z isomerism but alkene D does not.

Construct the equation for the formation of alkene **D** from alcohol **A**.
Show the structure of the organic product.

[2]

iii. The skeletal formulae of alkenes **B** and **C** are shown below.

	Alkene B	**Alkene C**
Skeletal formula		
Isomer	*Z*	*E*

Use the Cahn-Ingold-Prelog priority rules to explain why alkene B is the Z isomer.

[2]

37. A mixture of concentrated nitric and hydrochloric acid is called 'aqua regia'. Aqua regia can dissolve gold.

The reaction of aqua regia with gold is a redox reaction which forms chlorauric acid, $HAuCl_4$.

i. Balance the half-equation for the oxidation process in this reaction.

Au + ...HC*l* → ....H^+ + $AuCl_4^-$ + ...e^-

[1]

ii. In the reduction process in this reaction, HNO_3 and H^+ react together to form 2 oxides: **X** (M_r = 30) and **Z** (M_r = 18).

Determine the formulae of **X** and **Z** and write the half-equation for this reduction.

[3]

38. This question is about periodicity and the reaction of some Group 2 metals.

Periodicity is the repeating trend in properties of elements across different periods in the periodic table.

i. Complete the table below with the electron configurations and blocks.

	Group 2	**Group 17 (7)**
Period 2	Be $1s^2$	F $1s^2$ ....
Period 3	Mg $1s^2$	C*l* $1s^2$ ....
Block	....	....

[3]

ii. Use your answers to **(i)** to explain why electron configuration is an example of a periodic trend.

-- **[2]**

iii. Mg forms 2+ ions but C*l* usually forms 1− ions in their reactions. Explain why.

-- **[2]**

iv. Magnesium reacts with oxygen in the air.

Write the equation for this reaction.

-- **[1]**

39. Which row shows the atomic structure of $^{25}Mg^{2+}$?

	Protons	Neutrons	Electrons
A	10	12	13
B	10	15	12
C	12	13	10
D	12	13	14

[1]

40. This question is about iron.

A sample of iron is isolated from a meteorite and analysed by mass spectrometry.

The mass spectrum shows peaks with the relative abundances below.

Isotope	^{54}Fe	^{56}Fe	^{57}Fe	^{58}Fe
Relative abundance	78.54%	8.88%	5.10%	7.48%

Calculate the relative atomic mass of the iron in the sample.

Give your answer to **2** decimal places.

[2]

41. 1.35 g of ethylamine gas, $CH_3CH_2NH_2$ (M_r = 45.0), is reacted with 20 cm^3 of 2.0 mol dm^{-3} hydrochloric acid forming a solution of ethylammonium chloride.

$CH_3CH_2NH_2(g) + HCl(aq) \rightarrow CH_3CH_2NH_3^+(aq) + Cl^-(aq)$

What is the concentration of ethylammonium chloride in mol dm^{-3}?

A 0.03
B 0.67
C 1.50
D 2.00

[1]

42. α-Amino acids have the general formula $RCH(NH_2)COOH$.

The R group in an α-amino acid contains C and H only.

This R group has a molar mass of 91 g mol^{-1}.

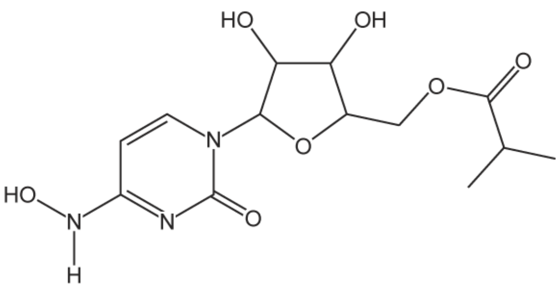
A polymer is formed from 500 molecules of this α-amino acid.

Determine the molar mass of this polymer.

Give your answer to the nearest whole number.

molar mass of polymer = ... g mol^{-1} **[3]**

43. Compound **B**, shown below, is an antiviral medicine



compound B

i. What is the molecular formula of compound **B**

-- **[1]**

ii. How many chiral carbon atoms are there in one molecule of compound **B**?

[1]

iii. A research chemist synthesises two related compounds, compound **C** and compound **D**, from compound **B**.

- In compound **C**, the N atoms in compound **B** had been replaced by P atoms.
- In compound **D**, the O atoms in compound **B** had been replaced by S atoms.

What is the difference between the relative molecular masses of compound C and compound D?

[2]

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			A	1	
			Total	**1**	
2	a		63 p 90 n 60 e	1	
	b		2 (1) 2 (1) 18 (1)	3	
			Total	**4**	
3			A	1	
			Total	**1**	
4			D	1	
			Total	**1**	
5		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**	
6			A	1	
			Total	**1**	
7	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** $\frac{\text{mass of one mole of atoms}}{\text{1/12th mass of one mole OR 12g of carbon-12}}$ **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**	

<table>
<tr><td>8</td><td></td><td></td><td>
<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 ✓ ✓</td><td>2</td><td>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.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
<tr><td>9</td><td></td><td></td><td>55% ✓</td><td>1</td><td>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.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>10</td><td></td><td></td><td>$Al_2S_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2S$ ✓</td><td>1</td><td>IGNORE state symbols
ALLOW correct multiples

Examiner's Comments

This question discriminated well between the most able, who found no difficulty writing and balancing the equation and the least able who frequently were not able to give the correct formula of the product, aluminium hydroxide. Those who managed to obtain the correct symbols often failed to provide the correct balancing number before the water.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
</table>

<table>
<tr>
<td>11</td><td></td><td></td>
<td>
<table>
<tr><th>particle</th><th>relative mass</th><th>relative charge</th><th>position within the atom</th></tr>
<tr><td>proton</td><td>1</td><td>+ 1</td><td>nucleus</td></tr>
<tr><td>neutron</td><td>1</td><td>nil/0</td><td>nucleus</td></tr>
<tr><td>electron</td><td>1/2000</td><td>-1</td><td>shell</td></tr>
</table>
Relative mass column ✓;

Relative charge AND position columns ✓
</td>
<td>2</td>
<td>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.</td>
</tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
<tr>
<td>12</td><td></td><td>i</td>
<td>M1
The (weighted) mean mass of an atom (of an element) ✓

M2
Compared with 1/12$_{th}$ (the mass) ✓

M3
Of (one atom of) carbon-12 ✓</td>
<td>3</td>
<td>ALLOW ‘average’ for ‘mean’
ALLOW ‘mean mass of isotopes’ 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
$\frac{\text{Mass of one mole of atoms}}{1/12^{th}\text{ (mass of) one mole OR 12 g of carbon-12}}$</td>
</tr>
</table>

					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**	
13			B	1	**Examiner's Comments** Generally scored well.
			Total	**1**	
14			C	1	**ALLOW** +5 **OR** 5+ in box **Examiner's Comments** Generally scored well.
			Total	**1**	
15	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** $\frac{(63 \times 69.17) + (65 \times 30.83)}{100}$ **OR** 63.6166 **OR** 63.617 ✓ = 63.62 (to 2 DP) ✓ ***IGNORE*** *any units with* A_r	2	**ALLOW ECF** for a correct calculation to 2 DP if: • %s have been used with wrong isotopes i.e. $\frac{(63 \times 30.83) + (65 \times 69.17)}{100} \rightarrow$ **64.38** **OR** • decimal places for **ONE** % have been transposed, i.e. 69.71 → **63.96**; 30.38 → **63.32** **Examiner's Comments** 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
		ii	**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 $n(\text{Cu}) = \frac{5.00 \times 0.840}{63.62} = \frac{4.2}{63.62} = 0.066(0)$ (mol) ✓ Cu atoms = 0.0660 × 6.02 × 10^{23} = **3.97 × 23 10^{22}** ✓ *Must be calculated in standard form* ***AND*** *to 3 SF*	2	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

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

Using 63.5: A_r of Cu from periodic table

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

Cu atoms = $0.0661 \times 6.02 \times 10^{23}$ = 3.98×10^{22} ✓
Must be calculated in standard form AND to 3 SF</td><td></td><td>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 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)

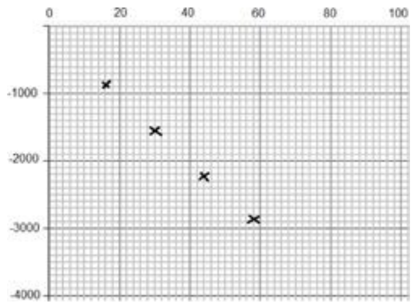
<u>Examiner's Comments</u>

This part was generally well answered with most candidates processing the data correctly. Candidates sometimes failed to consider 84% or rounded incorrectly in places.

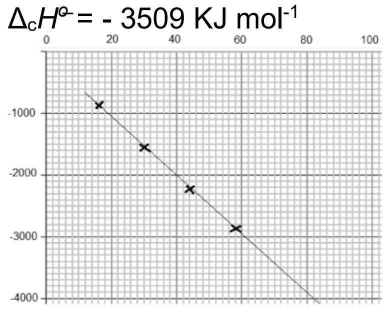
Answer = 3.97×10^{22} atoms</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>6</td><td></td></tr>
<tr><td>16</td><td></td><td></td><td>C</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>17</td><td>a</td><td></td><td><table><tr><th>Isotope</th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr><tr><td>^{48}Ti</td><td>...22...</td><td>...26...</td><td>...22...</td></tr><tr><td>...$^{46}Ti^{3+}$...</td><td>...22...</td><td>24</td><td>19</td></tr></table></td><td>2</td><td>Mark by row</td></tr>
</table>

	b	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 79.904 award 2 marks .... $\frac{(78.9183361 \times 50.69) + (80.9162896 \times 49.31)}{100}$ **OR** 79.90352697 ✓ = 79.904 (to 3 DP) ✓	2	**ALLOW** value > 3 DP for 1st mark
		ii	$1s^22s^22p^63s^23p^63d^{10}4s^24p^5$ ✓	1	**ALLOW** 4s before 3d, i.e. $1s^22s^22p^63s^23p^6\mathbf{4s^23d^{10}}4p^5$ **ALLOW** upper case D, etc and subscripts, e.g. ......$4S_23D_{10}$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ Look carefully at $1s^22s^22p^63s^23p^6$ – there may be a mistake
			Total	**5**	
18			**A**	1	
			Total	**1**	
19			**D**	1	**Examiner's Comments** Questions **2, 3** and **5** were the most successfully answered with each of these having a success rate of over 90%. Question **11** was the most difficult with less than 50% of the candidates giving a correct response. Many opted for distractor B.
			Total	**1**	
20			**C**	1	
			Total	**1**	
21			A	**1**	**Examiner's Comments** The majority of candidates provided the correct answer with only the very

					weakest candidates not achieving the mark.
			Total	**1**	
22		i	Value for butane plotted accurately on the graph ✓	**3**	relative molecular mass = 58 Δ_cH° = -2877 kJ mol^{-1}



					Check accuracy: • There must be a visible point • Vertically: touching the 58 line • Horizontally: between 2800 and 2900 **Examiner's Comments** Most, but not all, candidates were able to plot the value for butane accurately on the graph.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF energy released = 87.5 (minimum) to 90 (maximum)** **AND line is extrapolated to 72 (molar mass) award 3 marks** **IF energy released <87.5 OR > 90.0 check the estimated value of Δ_cH° from the graph** *Estimation of A_cH°* extrapolated (straight) line of best fit (see graph) **AND** correctly estimated value Δ_cH° from graph ✓ *Calculation of energy released* *n*(C5H12) = 0.0250 mol ✓ *energy released*	**3**	relative molecular mass = 72 Δ_cH° = - 3509 KJ mol^{-1}



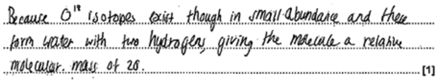
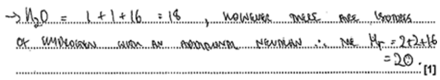
Expected value within range: (–)3500 to (–)3600 (kJ mol^{-1})

moles = 1.80/72.0

			= 0.0250 × correctly estimated value of $\Delta_c H^{\circ}$ ✓		**IGNORE** sign **ALLOW ECF** from incorrectly calculated moles of pentane **OR** incorrectly estimated $\Delta_c H^{\circ}$ **Examiner's Comment:** A good proportion of candidates scored full marks for their estimate but some did not extrapolate the line on the graph and many did not calculate the amount of pentane. This restricted their answer to an estimate of the energy released by one mole of pentane and this could only score one mark.
			Total	**4**	
23		i	<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> Mark vertically: protons AND neutrons ✓ electrons ✓	**2**	**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.
23		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**	
24			**C**	**1**	**Examiner's Comments** The majority of candidates were able to calculate the correct answer.
			Total	**1**	
25		i	<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>	**1**	**Examiner's Comments** This question was an easy starter to the paper with most candidates producing the correct answer.
		ii	**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) ✓	**2**	**For 1 mark: ALLOW ECF** → to 2 DP if: • %s used with wrong isotopes **ONCE** **OR** • transposed decimal places for **ONE** % **Examiner's Comments** 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.
			Total	**3**	
26			(Molecules) contain • ^{2}H **OR** deuterium/D • ^{3}H **OR** tritium/T **OR** O/H atoms have more neutrons (than ^{1}H) **OR** (different) O/H isotopes are present **OR** (Molecules are) D_2O ✓	1	**ALLOW** Molecules contain ^{18}O Idea of **isotopes** is critical **……..BUT** **DO NOT ALLOW** isotopes of elements different from H and O (e.g. C) **<u>Examiner's Comments</u>** Many candidates recognised that the presence of hydrogen or oxygen isotopes could explain the high relative molecular mass of water. The best responses discussed D_2O or molecules with other combinations of isotopes including ^{18}O and even ^{3}H. Exemplar 1 shows a good response which explains the relative molecular mass of 20 in terms of the presence of ^{18}O. Many candidates claimed that some water molecules had the formula of H_4O, often bringing lone pairs and hydrogen bonds into their explanations, as shown in Exemplar 2. D_2O is encountered in proton NMR spectroscopy, so candidates will have encountered it during their studies, but many candidates were unable to link this to the relative molecular mass of 20. **Exemplar 1**

					 Because O^{18} isotopes exist though in small abundance and these form water with two hydrogens giving the molecule a relative molecular mass of 20. [1] **Exemplar 2**  → H_2O = 1+1+16 = 18, however ... M_r = 2+2+16 = 20. [1]
			Total	**1**	
27	a		**TWO correct responses from** ✓ • Different numbers of neutrons • Different (atomic) masses/mass numbers • Different **physical** properties *Physical required*	1	**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.

<table>
<tr><td></td><td>b</td><td></td><td><table><tr><th>Ele-ment</th><th>Mass number</th><th>Pro-tons</th><th>Neu-trons</th><th>Elec-trons</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</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, 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>28</td><td></td><td></td><td>FIRST CHECK THE ANSWER ON ANSWER LINE
If answer = 25.982 award 2 marks

$\frac{78.99 \times 23.985 + 10.00 \times 24.986 + 11.01 \times m}{100}$
=24.305 ✓

Relative isotopic mass = 25.982 (must be 5 SF) ✓</td><td>2</td><td>ALLOW any correct rearrangement of this sum for first mark
eg 11.01 x m = 2430.5 – 1894.575 – 249.86

ALLOW ecf for transcription errors in first sum but answer must be 5 sf

<u>Examiner's Comments</u>

This was mathematically challenging, but candidates who did not arrive at the correct answer were able to get partial credit for showing working.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
<tr><td>29</td><td></td><td>i</td><td>(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 ✓</td><td>2</td><td>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</td></tr>
</table>

					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	**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**	
30	a		**Differences:** (Different number of) neutrons ✓ **Similarities:** (Same number of) protons **AND** electrons ✓	2	**IGNORE** different masses/mass numbers throughout *(Question asks for atomic structures)* **ALLOW** 'amount' for 'number' **ALLOW** 'electron configuration' for electrons **<u>Examiner's Comments</u>** Almost all candidates were aware that different isotopes had different

					numbers of neutrons. For the similarities, 'the same number of protons' was usually identified, but the same number electrons was omitted by many candidates. This suggested that candidates were concentrating on the nucleus and did not read the question closely enough which asked for 'atomic' structures.
	b	i	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 35.48 (to 2 DP) award 2 marks** $\frac{(35 \times 75.76) + (37 \times 24.24)}{100}$ **OR** 35.4848 **OR** 35.485 ✓ = 35.48 (to 2 DP) ✓	2	**For 1 mark: ALLOW ECF** → to 2 DP if: • %s used with wrong isotopes **ONCE** **OR** • transposed decimal places for **ONE** % **AND** • calculated *Ar* is between 35 and 37
		ii	*m/z* = 72: $^{35}Cl^{37}Cl$ **OR** Contains chlorine-35 **AND** chlorine-37✓ *m/z* values: 70 **AND** 74 ✓	2	**Examiner's Comments** This was a high demand question and only the highest scoring answers identified that the peak at 72 was caused by a chlorine molecule containing the chlorine-35 and chlorine-37 isotopes shown in the supplied mass spectrum. Very few candidates went on to predict further peaks with m/z values of 70 (from $^{35}Cl^{35}Cl$) and 74 (from $^{37}Cl^{37}Cl$). There was little pattern in the incorrect responses, suggestion that many were guesses.
			Total	**6**	
31			(The mean/average mass) taking into account the relative abundancies of the isotopes ✓	1	**ALLOW** sum of (isotopic mass × %abundance) sum of (isotopic mass × abundance) / total abundance

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>DO NOT ALLOW average mass of the isotopes</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>32</td><td>a</td><td></td><td>
<table>
<tr><th></th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr>
<tr><td>^{76}Se</td><td>34</td><td>42</td><td>34</td></tr>
<tr><td>^{82}Se</td><td>34</td><td>48</td><td>34</td></tr>
</table>
ALL 6 entries correct for mark ✓</td><td>1</td><td></td></tr>
<tr><td></td><td>b</td><td></td><td>FIRST CHECK ANSWER ON THE ANSWER LINE
IF answer = 32.094 (to 3 DP) award 2 marks

$\frac{(32 \times 94.93) + (33 \times 0.78) + (34 \times 4.29)}{100}$

OR 32.0936 ✓

= 32.094 (to 3 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 %</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>33</td><td></td><td>i</td><td>Cu: 66% AND Zn 34% ✓</td><td>1</td><td><u>Examiner's Comments</u>

Question 1 (b) presented candidates with a mass spectrum of two elements in an alloy. This novel question was answered well, and the introductory part (i) provided candidates with a hint of how to approach the harder part (ii). Almost all candidates analysed the percentages to show that the brass sample contains 66% Cu and 34% Zn, the 34 being required in Question 1 (b) (ii).</td></tr>
<tr><td></td><td></td><td>ii</td><td>FIRST CHECK ANSWER ON THE ANSWER LINE
If answer = 65.42 (to 2 DP) award 2 marks

Numerator from Zn isotopes
(64 × 16.82) + (66 × 9.53) + (67 × 1.38) + (68 × 6.27)</td><td>2</td><td>Refer to answer to 1b(i) for ECF from incorrect % composition of Zn and Cu
ECF ÷ by Zn % in b(i)

Common errors</td></tr>
</table>

			OR 2224.28 ✓ **Relative atomic mass** Numerator ÷ 34 **AND** answer to 2 DP ✓ *Mark **ECF** from numerator* $\frac{(64 \times 16.82) + (66 \times 9.53) + (67 \times 1.38) + (68 \times 6.27)}{34}$ ✓ = 65.42 (to 2 DP) ✓		22.24 ÷100 and answer to 2 DP → *1 mark for numerator* 64.23 All 6 isotopes used → No marks 188.91 All 6 isotopes used → 6423 for numerator ÷34 and 2 DP → 1 mark by ECF **Examiner's Comments** Most candidates produced a stock expression for a relative atomic mass calculation with the numerator comprising the four zinc isotopes with their respective percentage abundances, equating to 2224.28. The second mark required candidates to realise that the numerator needed to be divided by the total zinc percentage abundance of 34% to produce a value of 65.42. Less successful responses divided by 100% to obtain a value of 22.24. Almost all candidates gave their answers to the required two decimal places. The second mark proved to be a very good discriminator, with some candidates usually obtaining both marks with less successful responses still able to obtain the first mark for the numerator.
			Total	**3**	
34	a		**FIRST CHECK ANSWER ON THE ANSWER LINE 2** **IF answer = 190.47 (to 2 DP) award 2 marks** $\frac{(188 \times 12.13) + (189 \times 16.75) + (190 \times 27.23) + (192 \times 43.89)}{100}$ **OR** 190.4677 **OR** 190.468 ✓	2	**For 1 mark: ALLOW ECF** → to 2 DP if: • %s used with wrong isotopes **ONCE** **OR** • transposed decimal places for **ONE %** **Examiner's Comments**

<table>
<tr><td></td><td></td><td></td><td>= 190.47 (to 2 DP) ✓</td><td></td><td>Candidates answered this question very successfully. Few candidates mis-wrote the numbers and even fewer gave answers to the incorrect number of decimal places. This type of question has featured on previous examinations and it was pleasing to see how well it was answered, even with more isotopes being included than in previous instances.</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>Ni</td><td>62</td><td>28</td><td>34</td><td>$1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$</td><td>0</td><td>✓</td></tr><tr><td>P</td><td>33</td><td>15</td><td>18</td><td>$1s^2 2s^2 2p^6 3s^2 3p^6$</td><td>3–</td><td>✓</td></tr></table>Mark by row</td><td>2</td><td>Easiest to check element first
ALLOW P^{3-} **ALLOW** names for elements
IGNORE charges with element in 1st column, even if wrong.
For electron configuration, **ALLOW** $4s^2$ before $3d^8$ i.e. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
ALLOW upper case D, etc and subscripts, e.g. ......$4S_2 3D_1$
ALLOW [Ar)$3d^8 4s^2$

Examiner's Comments

This question produced many mixed responses. Most candidates correctly identified nickel. However, its electron configuration was frequently shown as $3d^{10}$ instead of $3d^8$ and some less successful responses gave nickel's relative atomic mass of 58.7 from the periodic table, instead of the mass number of the isotope provided. Many candidates selected the incorrect element for phosphorus, with argon being a key distractor from the extra 3 electrons in the P^{3-} ion. The numbers of protons and neutrons were largely correct, although the wrong way round for many less successful responses.</td></tr>
<tr><td></td><td></td><td></td><td>**Total**</td><td>**4**</td><td></td></tr>
<tr><td>35</td><td></td><td>i</td><td>**FIRST CHECK ANSWER ON ANSWER LINE**
If answer = 47.92 (to 2 DP) seen award 2 marks

(46 x 8.3) + (47 x 7.4) + (48 x 73.7) + (49 x</td><td>2</td><td>**ALLOW** one mark for **ECF** from **seen** incorrect sum provided final answer between 46 and 50 and to 2 **DP**

Examiner's Comments</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>5.4) + (50 x 5.2)
OR
381.8 + 347.8 + 3537.6 + 246.6 + 260
OR
4791.8 ✓

4791.8/100
= 47.92 ✓ **2DP required**</td><td></td><td>Most candidates scored both marks. Some lost marks for minor slips such as not giving their final answer to 2 decimal places or making calculator errors. A few didn't know how to attempt the calculation or calculated the average mass.</td></tr>
<tr><td></td><td></td><td>ii</td><td>$(1s^2)2s^22p^63s^23p^63d^24s^2$ ✓

Look carefully at $(1s^2)$ $2s^22p^63s^23p^6$ – there may be a mistake</td><td>1</td><td>**ALLOW** subscripts

ALLOW 4s before 3d i.e. $(1s^2)2s^22p^63s^23p^64s^23d^2$

ALLOW upper case D, etc and subscripts, e.g. ……$3S_23P^6$

DO NOT ALLOW [Ar] as shorthand for $1s^22s^22p^63s^23p^6$

<u>Examiner's Comments</u>

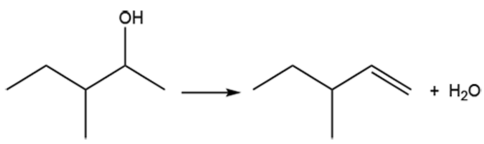
Again, most scored this mark. Common errors included using the mass number for number of electrons, no 4s but $3d^4$ instead, 4d rather than 3d, $4p^2$ instead of $3d^2$ or filling up d orbital $3d^{10}$.</td></tr>
<tr><td></td><td></td><td>iii</td><td><table><tr><td></td><td>Protons</td><td>Neutrons</td><td>Electrons</td></tr><tr><td>$^{48}Ti^{2+}$</td><td>22</td><td>26</td><td>20</td></tr></table> ✓

ALL 3 numbers required for the mark</td><td>1</td><td>**<u>Examiner's Comments</u>**

Most candidates gained this mark. Common errors included giving 24 or 22 for number of electrons, or 48 or 24 for neutrons. A few used the relative atomic mass of 47.9 from the periodic table so gave 24.7 for number of neutrons.

Assessment for learning

Fractional numbers of subatomic particles are not possible. Candidates should be aware that the relative atomic mass is the weighted average of the masses of all of an element's</td></tr>
</table>

					isotopes, and the mass number of an isotope must be used to determine the number of protons and neutrons in the nucleus.
			Total	**4**	
36		i	3-methylpentan-2-ol ✓	1	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylpentane-2-ol **DO NOT ALLOW** 2-methylpentan-3-ol 3-methylpent-2-ol 3-methpentan-2-ol 3-methypentan-2-ol 3-methlypentan-2-ol **<u>Examiner's Comments</u>** A significant number of candidates lost the mark for missing -an- in their answer i.e. 3-methylpent-2-ol. Others lost the mark for incorrect spelling of methyl.
		ii	 Correct structure of organic product ✓ Balanced equation ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** additional reactants such as H^+ or [O] in the equation. **ALLOW** incorrect isomer 3-methylpent-2-ene for balancing mark. **<u>Examiner's Comments</u>** Most candidates did not score either mark here, despite the structures for B and C being given in the table below for (iii). Many thought this was oxidation, showing [O] in equations and giving a carbonyl product. Many had alkenes but still with the -OH present. Some attempted to use structural or displayed formulae but

					errors were made in giving the correct number of H atoms. For those that did have the correct structure, they often did not give an equation, added the acid as a reactant , or missed off the water as a product.
		iii	Priority groups on same side ✓ High(est) priority groups are CH_3CH_2 and CH_3 **OR** Low(est) priority groups are CH_3 and H ✓	2	**ALLOW** suitable alternatives to 'priority' e.g. Groups with highest atomic number or more important groups etc. **ALLOW** priority groups are both on the top **IGNORE** references to relative mass of groups, Ar, Mr, **ALLOW** identification by name e.g. ethyl and methyl, or by circling on the structure. **IF** 'priority' is not mentioned **ALLOW** 1 mark for CH_3CH_2 and CH_3 are on same side **OR** H and CH_3 are on same side **Examiner's Comments** Many responses made no reference to 'priority' and/or discussed alkene C, suggesting that they didn't read the question fully. Candidates often struggled to find the right language to express themselves, such as reference to 'functional groups' or 'molecules' rather than priority groups. Lots discussed using *Mr* to assign priority with only a few stating correctly that it is atomic number that is used for CIP rules. Many, despite stating that priority groups are on the same side, didn't identify these groups so didn't get the second mark.
			Total	**5**	
37		i	Au + 4 HC*l* → 4 H^+ + AuCl_4^- + 3 e^- ✓	1	**Examiner's Comments**

					Most candidates added ‘4’ before HCl and H^+, and 3 before e^- to gain this mark. Where an error was made, it invariably was with the number of electrons, usually $4e^-$.
		ii	**Formulae** **X** = NO ✓ **Z** = H2O ✓ **Equation Independent from ID of X and Z** HNO_3 + 3 H^+ + 3 e^- → NO + 2 H_2O **OR** NO_3^- + 4 H^+ + 3 e^- → NO + 2 H_2O ✓ **CHECK BELOW ANSWER SPACE FOR RESPONSE**	3	If **X** and **Z** in wrong order award 1 out of 2 formula marks i.e. **X** = H_2O and **Z** = NO 1 mark **ALLOW** multiples **<u>Examiner’s Comments</u>** Almost all candidates identified **X** and **Y** as NO and H_2O respectively, but the equation proved to be much more testing. Some candidates were careless, showing NO and H_2O the wrong way round (credited with 1 out of these 2 marks) or with charges. For the equation, candidates needed to consider the oxidation number change of N from +5 to +2, This should have naturally led to $3e^-$ being added on the left-hand side. Many candidates omitted the electrons entirely. Some did add $3e^-$ but on the right. This suggests that candidates would benefit with practising the construction of half equations.
			Total	**4**	
38		i	Be: 1s22s2 F: 1s22s22p5 ✓ Mg: 1s22s22p63s2 Cl: 1s22s22p63s23p5 ✓ Block: s p ✓	3	**1 mark** per correct row **ALLOW** upper case letter S and P, and subscripts, e.g. $2S_22P_5$ **IGNORE** superscripts/numbers given on block (e.g. s^2 and p^5) if the letter is clear **<u>Examiner’s Comments</u>** A very well answered question with most candidates very confident in giving the correct electron configurations and blocks. Errors were rare but included: $2p^5$ or $3p^6$

					ending for Cl; using mass number for number of electrons; and assigning group 17 as d block and giving orbital box diagrams rather than block.
		ii	Across period 2, the (2)s subshell fills first, followed by the (2)p ✓ **same pattern or trend** of filling (the subshells) repeated in other periods ✓	2	**ALLOW** Elements in the same group have same number of electrons in their outer shells or subshell e.g. s^2 in group 2/ s^2p^5 in group 17(7) **ALLOW** Elements in the same period have the same number of energy levels/shells **ALLOW** for both marks for indication that the pattern repeats across each period e.g Across each period, elements repeat the pattern of electrons filling the s-subshell then p-subshell ✓ ✓ **<u>Examiner's Comments</u>** Many found this question challenging despite doing well in Question 2(a)(i). The question states 'use your answers from (a)(i)' but not many candidates wrote about the electron configurations they had given. Many gave very simplistic responses in terms of the number of electrons increasing but made no reference to how those electrons are arranged (e.g. 'number of electrons increases across a period as the electron configuration gets higher' or 'atomic number increases'). Some candidates struggled with terminology, often referring to 'block' or 'orbital' instead of subshell (e.g. 'outer electrons are in same block', 'going across a period the number of orbitals increases', 'elements in same group have their highest energy electron in same block' or 'orbital'). Candidates need clarity on the terminology used for electron configurations and periodic table i.e. blocks, shells, sub-shells and orbitals.

					It was rare for candidates to score both marks as this was a question that they were unfamiliar with. However, some did gain a mark for linking the number of outer shell electrons to the group number or stating that elements in the same period have the same number of shells. It was not enough to refer to the highest energy electron being in the s-subshell or p-subshell as this is the link to the block, but all groups in same block will be the same. Some described the trend in other physical or chemical properties. Some examples included: 'Elements have same chemical and physical properties due to similar electronic configuration'; 'as you go across period, number of electrons increase and their boiling and melting points increase'; and 'electrons are more easily lost in a paired orbital, due to greater repulsion and so have lower ionisation energies'. **OCR support** We have produced a transition guide on the topic of atomic structure. It covers content from KS4 and how this is developed at KS5 with a wide range of suggested resources to support teaching. At KS4, candidates are expected to be able to explain how the position of an element in the Periodic Table is related to the arrangement of electrons in its atoms, with development at KS5 to arrangement in to s, p and d orbitals. https://ocr.org.uk/Images/170375-atomic-structure-ks4-ks5.pdf
		iii	Mg loses (2) electrons **AND** Cl gains an electron ✓	2	**ALLOW** Mg is oxidised **AND** Cl is reduced

			To gain a full/complete shell **OR** Noble gas configuration **OR** Stable/full octet✓		**Examiner's Comments** Generally, this question was well answered with a clear understanding of how and why ions are formed. However, approximately a quarter of students only gained 1 mark as they either didn't explain electrons being lost by Mg and gained by Cl or gave no justification. A common slip was stating Cl has one electron in its outer shell. Some described bonding between Mg and Cl, which wasn't what the question asked, but this didn't prevent them from scoring both marks.
		iv	$2Mg + O_2 \rightarrow 2MgO$ ✓	1	**ALLOW** multiples e.g. $Mg + \frac{1}{2}O_2 \rightarrow MgO$ **IGNORE** state symbols even if wrong **Examiner's Comments** Many candidates correctly gave the balanced equation here. However, some didn't balance but had the correct formula. A few gave Mg_2 as a reactant or MgO_2 as a product. Some had O_2 on both sides of the equation.
			Total	**8**	
39			**C**	1	**Examiner's Comments** Most candidates recognised the correct atomic structure, a basic chemical skill taken forward from GCSE.
			Total	**1**	
40			**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 54.63 (to 2 DP) award 2 marks** $\frac{(54 \times 78.54) + (56 \times 8.88) + (57 \times 5.10) + (58 \times 7.48)}{100}$ **OR** 54.6298 **OR** 54.630 ✓	2	**For 1 mark: ALLOW ECF** → to 2 DP if:

			= 54.63 (to 2 DP) ✓		• %s used with wrong isotopes **ONCE** **OR** • transposed decimal places for **ONE** % **<u>Examiner's Comments</u>** Candidates answered this question very well. A few mis-wrote the numbers and even fewer gave responses to the incorrect number of decimal places. This type of question has featured on previous examinations, and it was encouraging to see how well it was answered, even with more isotopes being included than previously.
			Total	**2**	
41			**C**	1	**ALLOW** 1.5(0) **<u>Examiner's Comments</u>** Around two thirds of candidates gave the correct answer C, 1.50 mol dm^{-3} . Those that showed working were more likely to have the correct answer. Some only found the moles of ethylamine from the mass and M_r give so gave 0.03, A. Some candidates struggled to figure out that HC*l* was in excess, so used 0.04 moles of HC*l* to give a concentration of 2.0 mol dm^{-3}, D.
			Total	**1**	
42			**IF** answer on answer line = 73518 **AWARD** 3 marks **IF** answer on answer line = 73500 **AWARD** 2 marks -- M_r of amino acid = 165 ✓ M_r of 500 molecules = 500 × 165 = 82500 ✓ M_r of polymer = 82500 – (499 × 18) = 73518	3	**ALLOW ECF** from incorrect M_r of amino acid **Alternative method:** Mr of repeat unit = 147 ✓ 147 x 500 = 73500 ✓ 73500 + 18 = 73518 ✓ **Common error for 2 marks** 36518 Use of Mr 91 82500 Not shown 165 in working

			✓ *(final answer must be given to nearest whole number)*		**Common error for 1 mark** 45500 Use of Mr 91 **Examiner's Comments** Most candidates managed to score at least one mark here, either for correctly determining the molar mass of the monomer, the repeat unit in the polymer or alternatively they multiplied a molar mass by500. Many candidates gained 2 marks for either 73500 or 82500 but then struggled to account for thewater lost. Some candidates lost marks due to errors in calculating the molar mass of the monomer or some tried toincorporate the use of Avogadro's constant into the calculation. Many misunderstood what atoms wouldbe lost during polymerisation. For example, a common incorrect response seen was found by subtracting2 from the correct molar mass giving 163, followed by multiplication by 500 to give 81500 and finallyadding of 2 to give 81502. Some struggled to understand what was meant by nearest whole number,e.g. rounding 73518 to 74000 or 82500 to 80000.
			Total	**3**	
43		i	$C_{13}H_{19}N_3O_7$ ✓	1	**ALLOW** elements in formula in any order e.g. $C_{13}H_{19}O_7N_3$ **Examiner's Comments** Most candidates made a good attempt at working out the molecular formula of the structure as being $C_{13}H_{19}N_3O_7$. N and O were usually correct with mistakes most common with carbon (especially 12) and hydrogen (especially 17-20).
		ii	4 ✓	1	**Examiner's Comments**

					This question was answered well with the correct answer of 4 being seen on most scripts, reflecting good understanding of chiral carbon centres. The commonest incorrect response was 5, presumably by including the C atom on the bottom right of the structure within the -**C**H(CH_3)$_2$ group.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF difference = 61.7, award 2 marks** -- M_r of **C** = 380 **OR** M_r of **D** = 441.7 ✓ Correct difference = 441.7 - 380 = **61.7** ✓ **AWARD** mark for **correct answer of 61.7 only**	2	**ALLOW** other approaches based on different atoms in **C** and **D**, e.g. Difference = 7 × (32.1 - 16) - 3 × (31 - 14) = 112.7 - 51 = **61.7** ✓ **Check answer from 2c(i) at top of response for ECF** **ALLOW ECF** from incorrect formula from **2c(i)** e.g. From $C_{12}H_{16}N_3O_6$ M_r of **C** = 349 **OR** M_r of **D** = 394.6 ✓ **ECF** difference = 394.6 - 349 = **45.6** ✓ **ECF** **<u>Examiner's Comments</u>** This question was answered extremely well with about three-quarters of candidates securing both marks. Most candidates calculated the molecular masses of compounds **C** and **D** as 380 and 441.7 respectively, to obtain a difference of 61.7. Some candidates adopted a simpler different approach which gives the same correct answer, working out the difference between the masses of nitrogen and phosphorus (for **C**) and oxygen and sulfur (for **D**). ECF was applied to any incorrect molecular formulae from Question 2 (c) (i) from which both marks could be obtained

			Total	**4**	