1. Consider the composition of the species W, X, Y and Z below. Which species is an anion?

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of protons</th>
<th>Number of neutrons</th>
<th>Number of electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>9</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>X</td>
<td>11</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Y</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Z</td>
<td>13</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>

A. W  
B. X  
C. Y  
D. Z

2. Energy levels for an electron in a hydrogen atom are

A. evenly spaced.  
B. farther apart near the nucleus.  
C. closer together near the nucleus.  
D. arranged randomly.

3. Which is related to the number of electrons in the outer main energy level of the elements from the alkali metals to the halogens?

   I. Group number  
   II. Period number  

A. I only  
B. II only  
C. Both I and II  
D. Neither I nor II

4. How do bond length and bond strength change as the number of bonds between two atoms increases?

<table>
<thead>
<tr>
<th>Bond length</th>
<th>Bond strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. increases</td>
<td>increases</td>
</tr>
<tr>
<td>B. increases</td>
<td>decreases</td>
</tr>
<tr>
<td>C. decreases</td>
<td>increases</td>
</tr>
<tr>
<td>D. decreases</td>
<td>decreases</td>
</tr>
</tbody>
</table>
5. Which of the following is true for CO₂?

<table>
<thead>
<tr>
<th>C=O bond</th>
<th>CO₂ molecule</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. polar</td>
<td>non-polar</td>
</tr>
<tr>
<td>B. non-polar</td>
<td>polar</td>
</tr>
<tr>
<td>C. polar</td>
<td>polar</td>
</tr>
<tr>
<td>D. non-polar</td>
<td>non-polar</td>
</tr>
</tbody>
</table>

6. The molar masses of C₂H₆, CH₃OH and CH₃F are very similar. How do their boiling points compare?

A. C₂H₆ < CH₃OH < CH₃F
B. CH₃F < CH₃OH < C₂H₆
C. CH₃OH < CH₃F < C₂H₆
D. C₂H₆ < CH₃F < CH₃OH

7. What is the electron configuration for an atom with Z = 22?

A. 1s²2s²2p⁶3s²3p⁶3d⁴
B. 1s²2s²2p⁶3s²3p⁶4s²4p²
C. 1s²2s²2p⁶3s²3p⁶3d²4p²
D. 1s²2s²2p⁶3s²3p⁶4s²3d²

8. What is the correct number of each particle in a fluoride ion, ¹⁹F⁻?

<table>
<thead>
<tr>
<th>protons</th>
<th>neutrons</th>
<th>electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 9</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>B. 9</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>C. 9</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>D. 9</td>
<td>19</td>
<td>10</td>
</tr>
</tbody>
</table>

9. Which statement is correct for the emission spectrum of the hydrogen atom?

A. The lines converge at lower energies.
B. The lines are produced when electrons move from lower to higher energy levels.
C. The lines in the visible region involve electron transitions into the energy level closest to the nucleus.
D. The line corresponding to the greatest emission of energy is in the ultraviolet region.

10. Which is the correct description of polarity in F₂ and HF molecules?

A. Both molecules contain a polar bond.
B. Neither molecule contains a polar bond.
C. Both molecules are polar.
D. Only one of the molecules is polar.

11. Which types of bonding are present in \( \text{CH}_3\text{CHO} \) in the liquid state?
   I. Single covalent bonding
   II. Double covalent bonding
   III. Hydrogen bonding
   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II and III

12. Which statement(s) is/are generally true about the melting points of substances?
   I. Melting points are higher for compounds containing ions than for compounds containing molecules.
   II. A compound with a low melting point is less volatile than a compound with a high melting point.
   III. The melting point of a compound is decreased by the presence of impurities.
   A. I only
   B. I and III only
   C. II and III only
   D. I, II and III

13. What is the correct sequence for the processes occurring in a mass spectrometer?
   A. vaporization, ionization, acceleration, deflection
   B. vaporization, acceleration, ionization, deflection
   C. ionization, vaporization, acceleration, deflection
   D. ionization, vaporization, deflection, acceleration

14. How many valence electrons are present in an atom of an element with atomic number 16?
   A. 2
   B. 4
   C. 6
15. How many protons, neutrons and electrons are there in the species $^{26}\text{Mg}^{2+}$?

<table>
<thead>
<tr>
<th>Protons</th>
<th>Neutrons</th>
<th>Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>B.</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>C.</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>D.</td>
<td>14</td>
<td>12</td>
</tr>
</tbody>
</table>

16. What is the total number of p orbitals containing one or more electrons in germanium (atomic number 32)?

A. 2
B. 3
C. 5
D. 8

17. A certain sample of element Z contains 60% of $^{69}\text{Z}$ and 40% of $^{71}\text{Z}$. What is the relative atomic mass of element Z in this sample?

A. 69.2
B. 69.8
C. 70.0
D. 70.2

18. What is the difference between two neutral atoms represented by the symbols $^{59}_{27}\text{Co}$ and $^{59}_{28}\text{Ni}$?

A. The number of neutrons only.
B. The number of protons and electrons only.
C. The number of protons and neutrons only.
D. The number of protons, neutrons and electrons.

19. A certain sample of element Z contains 60% of $^{69}\text{Z}$ and 40% of $^{71}\text{Z}$. What is the relative atomic mass of element Z in this sample?

A. 69.2
B. 69.8
C. 70.0
D. 70.2

20. Which ion would undergo the greatest deflection in a mass spectrometer?
A. \( ^{16}\text{O}^+ \)
B. \( ^{16}\text{O}^{2+} \)
C. \( ^{18}\text{O}^{2+} \)
D. \( (^{16}\text{O}^{18}\text{O})^+ \)

21. How many electrons are there in one \( ^{24}\text{Mg}^{2+} \) ion?

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

22. The electron arrangement of sodium is 2.8.1. How many occupied main electron energy levels are there in an atom of sodium?

A. 1  
B. 3  
C. 10  
D. 11

23. How many electrons are there in all the d orbitals in an atom of xenon?

A. 10  
B. 18  
C. 20  
D. 36

24. Information is given about four different atoms:

<table>
<thead>
<tr>
<th>atom</th>
<th>neutrons</th>
<th>protons</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>X</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Y</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Z</td>
<td>20</td>
<td>18</td>
</tr>
</tbody>
</table>

Which two atoms are isotopes?

A. W and Y  
B. W and Z  
C. X and Z
25. Which statement is correct about a line emission spectrum?
   A. Electrons absorb energy as they move from low to high energy levels.
   B. Electrons absorb energy as they move from high to low energy levels.
   C. Electrons release energy as they move from low to high energy levels.
   D. Electrons release energy as they move from high to low energy levels.

26. How many neutrons are there in the ion $^{18}_{\text{O}}^2$–?
   A. 8
   B. 10
   C. 16
   D. 20

27. What is the electron arrangement of silicon?
   A. 2.4
   B. 2.8
   C. 2.8.4
   D. 2.8.8

28. Which is correct about the element tin (Sn) (Z = 50)?

<table>
<thead>
<tr>
<th>Number of main energy levels containing electrons</th>
<th>Number of electrons in highest main energy level</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 4</td>
<td>4</td>
</tr>
<tr>
<td>B. 4</td>
<td>14</td>
</tr>
<tr>
<td>C. 5</td>
<td>4</td>
</tr>
<tr>
<td>D. 5</td>
<td>14</td>
</tr>
</tbody>
</table>

29. Which statement is correct about the isotopes of an element?
   A. They have the same mass number
   B. They have the same electron arrangement
   C. They have more protons than neutrons
   D. They have the same numbers of protons and neutrons

30. What is the total number of electrons in p orbitals in an atom of iodine?
   A. 5
   B. 7
31. What is the difference between two neutral atoms represented by the symbols \(^{210}_{84}\)Po and \(^{210}_{85}\)At?

A. The number of neutrons only.
B. The number of protons and electrons only.
C. The number of protons and neutrons only.
D. The number of protons, neutrons and electrons.

32. Which statements are correct for the emission spectrum of the hydrogen atom?

I. The lines converge at lower energies.
II. Electron transition to n =1 are responsible for lines in the UV region.
III. Lines are produced when electrons move from higher to lower energy levels.

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

33. A transition metal ion \(X^{2+}\) has the electronic configuration [Ar]3d\(^9\). What is the atomic number of the element?

A. 27
B. 28
C. 29
D. 30

34. What is the symbol for a species that contains 15 protons, 16 neutrons and 18 electrons?

A. \(^{31}\text{S}\)
B. \(^{31}\text{S}^{3-}\)
C. \(^{31}\text{P}^{-}\)
D. \(^{31}\text{P}^{3-}\)

35. What is the electron arrangement of an Al\(^{3+}\) ion?

A. 2, 8
B. 2, 3
C. 2, 8, 3
36. What will happen to the volume of a fixed mass of gas if the pressure and the Kelvin temperature are both doubled?
   A. It will remain the same.
   B. It will be double its initial volume.
   C. It will be one-half its initial volume.
   D. It will be four times its initial volume.

37. How many orbitals are there in the n = 3 level of an atom?
   A. 3
   B. 5
   C. 7
   D. 9

38. Which species has 54 electrons and 52 protons?
   A. \(^{128}_{52}\text{Te}^{2-}\)
   B. \(^{132}_{54}\text{Xe}^{2+}\)
   C. \(^{132}_{54}\text{Xe}^{2-}\)
   D. \(^{128}_{52}\text{Te}^{2+}\)

39. What is the correct sequence for the processes occurring in a mass spectrometer?
   A. vaporization, ionization, acceleration, deflection
   B. vaporization, acceleration, ionization, deflection
   C. ionization, vaporization, acceleration, deflection
   D. ionization, vaporization, deflection, acceleration

40. What is the electron configuration for the copper(I) ion, \(Z = 29\)?
   A. \([\text{Ar}]4s^23d^9\)
   B. \([\text{Ar}]4s^13d^{10}\)
   C. \([\text{Ar}]4s^13d^9\)
   D. \([\text{Ar}]3d^{10}\)

41. The diagram below (not to scale) represents some of the electron energy levels in the hydrogen atom.
42. Tritium, $^3\text{H}$, is an isotope of hydrogen.

(i) State the number and type of sub-atomic particles in a tritium atom and the location of each type.

(ii) Write balanced equations to represent the formation of the following compounds, starting with T$_2$ or T$_2$O.

NT$_3$: ...............................................................................................................

....................................................................................................................

NaOT: ...............................................................................................................

....................................................................................................................

43. (i) State the full electron configuration for argon.

....................................................................................................................

(1)

(ii) Give the formulas of two oppositely charged ions which have the same electron configuration as argon.

....................................................................................................................

(2)

44. The percentage composition by mass of a hydrocarbon is C = 85.6% and H = 14.4%.

(a) Calculate the empirical formula of the hydrocarbon. (2)
(b) A 1.00 g sample of the hydrocarbon at a temperature of 273 K and a pressure of 
\(1.01 \times 10^5\) Pa (1.00 atm) has a volume of 0.399 dm\(^3\).

(i) Calculate the molar mass of the hydrocarbon.  

(ii) Deduce the molecular formula of the hydrocarbon. 

(Total 5 marks)

45. State the number of protons, electrons and neutrons in the ion \(^{15}_{7}\)N\(^3\)\(^-\). 

(Total 2 marks)

46. A sample of germanium is analysed in a mass spectrometer. The first and last processes in mass spectrometry are vaporization and detection.

(a) (i) State the names of the other three processes in the order in which they occur in a mass spectrometer. 

(ii) For each of the processes named in (a) (i), outline how the process occurs. 

(b) The sample of germanium is found to have the following composition:

<table>
<thead>
<tr>
<th>Isotope</th>
<th>(^{70})Ge</th>
<th>(^{72})Ge</th>
<th>(^{74})Ge</th>
<th>(^{76})Ge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative abundance / %</td>
<td>22.60</td>
<td>25.45</td>
<td>36.73</td>
<td>15.22</td>
</tr>
</tbody>
</table>

(i) Define the term relative atomic mass. 

(ii) Calculate the relative atomic mass of this sample of germanium, giving your answer to two decimal places. 

(Total 9 marks)

47. (a) Use the Aufbau principle to write the electron configuration of an atom of germanium. 

(b) The successive ionization energies of germanium are shown in the following table:

<table>
<thead>
<tr>
<th>Ionization energy / kJ mol(^{-1})</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>760</td>
<td>1540</td>
<td>3300</td>
<td>4390</td>
<td>8950</td>
<td></td>
</tr>
</tbody>
</table>

(i) Identify the sub-level from which the electron is removed when the first ionization energy of germanium is measured. 

(ii) Write an equation, including state symbols, for the process occurring when
measuring the second ionization energy of germanium.  

(iii) Explain why the difference between the 4th and 5th ionization energies is much greater than the difference between any two other successive values.  

(Total 5 marks)

48. Define the following terms.

(i) atomic number  

(ii) mass number  

49. State the electron arrangements of the following species:

Si ................................................................. .................................................................

P³⁻ ................................................................. .................................................................

50. Identify the numbers of protons, neutrons and electrons in the species $^{33}\text{S}^{2-}$.

........................................................................................................................................

........................................................................................................................................

51. State the electron arrangement for atoms of aluminium, nitrogen and fluorine.

52. The relative atomic mass of chlorine is 35.45. Calculate the percentage abundance of the two isotopes of chlorine, $^{35}\text{Cl}$ and $^{37}\text{Cl}$ in a sample of chlorine gas.

53. (a) Describe the following stages in the operation of the mass spectrometer.

(i) ionization  

(ii) deflection  

(iii) acceleration  

(b) (i) State the meaning of the term isotopes of an element.  

(ii) Calculate the percentage abundance of the two isotopes of rubidium $^{85}\text{Rb}$ and $^{87}\text{Rb}$.  

(iii) State two physical properties that would differ for each of the rubidium isotopes.  

(iv) Determine the full electron configuration of an atom of Si, an Fe$^{3+}$ ion and a P$^{3-}$ ion.  

54. Naturally occurring copper has a relative atomic mass, ($A_r$), of 63.55 and consists of two
isotopes $^{63}\text{Cu}$ and $^{65}\text{Cu}$.

(i) Define the term \textit{relative atomic mass}, $A_r$.  

(ii) State and explain which is the more abundant isotope. 

55. (i) Explain why successive ionization energies of an element increase.  

(ii) Explain how successive ionization energies account for the existence of three main energy levels in the sodium atom.

56. The element vanadium has two isotopes, $^{50}_{23}\text{V}$ and $^{51}_{23}\text{V}$, and a relative atomic mass of 50.94.

(a) Define the term \textit{isotope}.  

(b) State the number of protons, electrons and neutrons in $^{50}_{23}\text{V}$.  

(c) State and explain which is the more abundant isotope.  

(d) State the name and the mass number of the isotope relative to which all atomic masses are measured.

57. (a) State a physical property that is different for isotopes of an element.  

(b) Chlorine exists as two isotopes, $^{35}\text{Cl}$ and $^{37}\text{Cl}$. The relative atomic mass of chlorine is 35.45. Calculate the percentage abundance of each isotope.

58. (a) Define the term \textit{isotope}.  

(b) A sample of argon exists as a mixture of three isotopes.

<table>
<thead>
<tr>
<th>Mass Number</th>
<th>Relative Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>0.337%</td>
</tr>
<tr>
<td>38</td>
<td>0.0630%</td>
</tr>
<tr>
<td>40</td>
<td>99.6%</td>
</tr>
</tbody>
</table>

Calculate the relative atomic mass of argon.

(c) State the number of electrons, protons and neutrons in the ion $^{56}\text{Fe}^{3+}$.

59. (a) Define the term \textit{isotope}.  

(b) A sample of gallium exists as two isotopes, $^{69}\text{Ga}$, relative abundance 61.2%, and $^{71}\text{Ga}$, relative abundance 38.8%. Calculate the relative atomic mass of gallium.  

(Total 3 marks)
60. (a) Evidence for the existence of energy levels in atoms is provided by line spectra. State how a line spectrum differs from a continuous spectrum. 

(b) On the diagram below draw four lines in the visible line spectrum of hydrogen.

(c) Explain how the formation of lines indicates the presence of energy levels.

61. The element bromine exists as the isotopes $^{79}$Br and $^{81}$Br, and has a relative atomic mass of 79.90.

(a) Complete the following table to show the numbers of sub-atomic particles in the species shown.

<table>
<thead>
<tr>
<th></th>
<th>an atom of $^{79}$Br</th>
<th>an ion of $^{81}$Br$^{-}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>protons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>neutrons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>electrons</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) State and explain which of the two isotopes $^{79}$Br and $^{81}$Br is more common in the element bromine.

(c) The element calcium is in the same period of the Periodic Table as bromine.

(i) Write the electron arrangement for an atom of calcium.

(ii) Deduce the formula of the compound calcium bromide.

62. Some vaporized magnesium is introduced into a mass spectrometer. One of the ions that reaches the detector is $^{25}$Mg$^{+}$.

(a) Identify the number of protons, neutrons and electrons in the $^{25}$Mg$^{+}$ ion.

(b) State how this ion is accelerated in the mass spectrometer.

(c) The $^{25}$Mg$^{2+}$ ion is also detected in this mass spectrometer by changing the magnetic field. Deduce and explain, by reference to the $m/z$ values of these two ions of magnesium, which of the ions $^{25}$Mg$^{2+}$ and $^{25}$Mg$^{+}$ is detected using a stronger magnetic field.

63. (a) List the following types of electromagnetic radiation in order of increasing wavelength (shortest first).

I. Yellow light
II. Red light

III. Infrared radiation

IV. Ultraviolet radiation

(b) Distinguish between a continuous spectrum and a line spectrum.

(c) The thinning of the ozone layer increases the amount of UV-B radiation that reaches the Earth’s surface.

<table>
<thead>
<tr>
<th>Type of Radiation</th>
<th>Wavelength / nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV-A</td>
<td>320–380</td>
</tr>
<tr>
<td>UV-B</td>
<td>290–320</td>
</tr>
</tbody>
</table>

Based on the information in the table above explain why UV-B rays are more dangerous than UV-A.

(Total 5 marks)
87. B
88. D
89. B
90. C
91. C
92. B
93. D
94. D
95. C
96. C
97. D
98. A
99. A
100. D
101. A
102. A
103. D
104.

(i) line starting at \( n = 1 \);
    line finishing at \( n = \infty \) (not above \( \infty \));
    upward arrow;
    \( 3 \) correct [2], \( 2 \) correct [1].

(ii) Line from \( n = 3 \) to \( n = 2 \);
    Arrow pointing downward (in any transition);

105. (i) \( 2n \quad \text{;} \)
    \( 1e^{-} \)
p, n in nucleus; \[ \text{e}'\text{ orbiting/}
\text{outside} \right\};

[1] for number and type of particles and [1] for location.

(ii) \[ \text{N}_2 + \text{3T}_2 \rightarrow \text{2NT}_3; \]
Correct formulas [1], balancing of correct equation [1].

\[ \text{2Na} + \text{2T}_2\text{O} \rightarrow \text{2NaOT} + \text{T}_2; \]
Correct formulas [1], balancing of correct equation [1].
If H is used instead of T in any of the equations [3 max].
Accept any other suitable equation for both parts.

106. (i) \[ \text{1s}^2\text{2s}^2\text{2p}^6\text{3s}^2\text{3p}^6; \]
Do not accept [Ne] \[ \text{3s}^2\text{3p}^6 \] or \[ 2, 8, 8. \]

(ii) \[ \text{K}^+ /\text{Ca}^{2+} /\text{Sc}^{3+} /\text{Ti}^{4+}; \]
\[ \text{Cl}^- /\text{S}^{2-} /\text{P}^{3-}; \]
Accept other suitable pairs of ions.

107. (a) mole ratio C:H = \[ \frac{85.6}{12.01} \cdot \frac{14.4}{1.01} = 7.13:4.3; \]
No penalty for using integer atomic masses.
empirical formula is \[ \text{CH}_2; \]

(b) (i) number of moles of gas \[ n = \frac{\text{PV}}{\text{RT}} = \frac{\text{mass}}{\text{mol mass}}; \]
\[ 1.01 \times 10^3 \text{kPa} (0.399 \text{dm}^3); \]
\[ 8.314 \times \frac{1}{\text{mol K}} (273 \text{K}); \]
\[ \frac{1.00 \text{g}}{0.017 \text{mol}} = 56.3 \text{ (g mol}^{-1}) \]
OR
molar mass is the \frac{\text{mass of the molar volume}}{22.4 \text{dm}^3}\text{ at STP;}
\[ = \frac{1.00 \times 22.4}{0.399} = 56.1 \text{ (g mol}^{-1}) \]
Accept answers in range 56.0 to 56.3.
Accept two, three or four significant figures.

(ii) \[ \text{C}_4\text{H}_8; \]
No ECF.

108. 7 protons, 8 neutrons, 10 electrons;

109. (a) (i) ionization, acceleration, deflection/separation;
Award [1] for all three names and [1] for correct order.
Award [1] for two names in correct order.

(ii) ionization: sample bombarded with high-energy or high-speed electrons/\text{OWTTE};
acceleration: electric field/oppositely charged plates;
deflection: (electro)magnet/magnetic field;

(b) (i) average or (weighted) mean of masses of all isotopes of an element;
relative to (one atom of) \[ ^{12}\text{C}; \]

[5]
Both marks available from a suitable expression.

(ii) \( A_r = (70 \times 0.2260) + (72 \times 0.2545) + (74 \times 0.3673) + (76 \times 0.1522); \)
\[ = 72.89; \]

*No other final answer acceptable.*

*Award [2] for correct final answer.*

110. (a) \( 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2 \)[Ar] \( 4s^2 3d^{10} 4p^2; \)

*Do not penalize for interchanging \( 4s^2 \) and \( 3d^{10}. \)

(b) (i) \( 4p; \)

(ii) \( \text{Ge}^+(g) \rightarrow \text{Ge}^{2+}(g) + e^-; \)

*Do not penalize for \( e^- (g). \)

Accept loss of electron on LHS.

(iii) 5th electron removed from energy level closer to nucleus/5th electron removed from 3rd energy level and 4th electron from 4th energy level/\( \text{OWTTE} \);

attraction by nucleus or protons greater (for electrons closer to nucleus)/\( \text{OWTTE} \);

Award [2] [5]

111. (i) number of protons in the nucleus/atom;

*Do not accept protons and electrons.*

(ii) number of protons and neutrons in the nucleus/atom;

Award [2] [2]

112. Si \( 2.8.4/2.8.4; \)

\( P^{3-} \) \( 2.8.8/2.8.8; \)

Award [2] [2]

113. 16 protons and 17 neutrons and 18 electrons;

Award [2] [1]

114. Al \( - 2.8.3; \)

N \( - 2.5; \)

F \( - 2.7; \)

*Award [2] for three correct, [1] for two or one correct.*

Accept correct configuration using \( s,p,d \) notation.

Award [2] [2]

115. \( A_r(\text{Cl}) = 35.45 = \frac{35x + 37(100-x)}{100}; \)

\( 35\text{Cl} = 77.5\% \) and \( 37\text{Cl} = 22.5\%; \)

Award [2] [2]

116. (a) (i) to produce positively charged ions;

by the bombardment of fast moving electrons;

(ii) magnetic field at right angles to path of ions/accept suitably labelled diagram;

moves ions in curve path/deflects ions;

dependent on mass/charge ratio;

*Award [1] each for any 2 points.*

(iii) acceleration of the ions by electric field/towards negative plate/cathode;

Award [1] [1]
(b) (i) atoms with the same number of protons/positive charges/atomic number but different number of neutrons/mass number;  

(ii) \[ A_r(\text{Rb}) = 85.47 = \frac{85x + 87(100-x)}{100}; \]

Accept other valid mathematical alternatives.

\[ 85\text{Rb} = 76.5 \text{ and } 87\text{Rb} = 23.5\%; \]

(iii) mass; density; boiling point; melting point; rate of diffusion in the gas phase; enthalpy of vaporization; enthalpy of fusion; rate of reaction in the gas/liquid phase; Any two for one mark

(iv) Si: \(1s^22s^22p^63s^23p^2;\)

Fe\(^{3+}\): \(1s^22s^22p^63s^23p^63d^5;\)

P\(^{3-}\): \(1s^22s^22p^63s^23p^6;\)

Allow \([1 \text{ max}]\) for 3 correct abbreviated structures using noble gas symbols.

117. (i) ratio of average mass of an atom to \(\frac{1}{12}\) the mass of C-12 isotope/average mass of an atom on a scale where one atom of C-12 has a mass of 12/sum of the weighted average mass of isotopes of an element compared to C-12/OWTTE; Award no mark if ‘element’ is used in place of ‘atom’

(ii) \(^{63}\text{Cu} \) (more abundant) since \(A_r(\text{Cu})\) is closer in mass to 63; Explanation needed for mark

118. (i) same nuclear charge, fewer electrons (thus more energy required to remove successive electrons)/harder to remove an electron from an ion with increasing positive charge/nucleus has greater effect on smaller number of electrons/OWTTE;  

(ii) large increases in IE when 2nd and 10th electron removed; thus, 1st electron further from nucleus than 2nd electron; and 9th electron further from nucleus than 10th electron; large increases indicate changes in main energy levels/OWTTE; OR outermost/3p electron has low IE because it is far/furthest from the nucleus; electron(s) in second shell/2p electrons are much closer (to nucleus) and need much more energy to remove/IE much higher/very high/there is a big jump in IE; electron(s) in first/innermost shell/1s electrons are even closer (to nucleus) and need much more energy to remove (than those in second shell/2s or 2p electrons);
119. (a) atom of same element/same number of protons but with different mass number/number of neutrons; 1

(b) protons 23  
electrons 23  
neutrons 27  

Three correct [2], two correct [1]. 2

(c) $^{51}_{23}$V near to $A_r$ value of 50.94; 1

(d) carbon, $^{12}_{6}$C; 1

[5]

120. (a) mass/density/for gases: rate of effusion or diffusion/melting point/boiling point  

Do not accept mass number. 1

(b) if $^{35}$Cl = $x$, then $(x = 35.00) + (1 - x) 37.00 = 35.45$  

Award [1] for set up. 2

therefore, $x = 0.775$;  

$^{35}$Cl = 77.5% and $^{37}$Cl = 22.5%;  

(need both for mark);  

[3]

121. (a) atoms of the same element/same number of protons/same atomic number;  

having different numbers of neutrons/different (mass number); 2

Award only [1] max if reference made to elements but not atoms.  

(b) relative atomic mass = $\frac{36 \times 0.337 + 38 \times 0.0630 + 40 \times 99.6}{100}$; 2

(c) 23 electrons;  

26 protons;  

30 neutrons; 2


122. (a) atoms of the same element/same atomic number/same number of protons;  

different numbers of neutrons/mass numbers; 2

Award only [1] max if reference made to elements but not atoms.  

(b) relative atomic mass = $\frac{(69 \times 61.2 + 71 \times 38.8)}{100} = 69.8$; 1

$-1$ (SF) possible (treat 69 and 71 as integers)  

[3]

123. (a) continuous spectrum has all colours/wavelengths/frequencies whereas line spectrum has only (lines of) sharp/discrete/specific colours/wavelengths/frequencies; 1

(b) lines get closer together towards high energy; 1

(c) line represents electron transitions between energy levels/OWTTE; 1  

[3]

124. (a)  

<table>
<thead>
<tr>
<th></th>
<th>an atom of $^{79}$Br</th>
<th>an ion of $^{81}$Br$^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>protons</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>neutrons</td>
<td>44</td>
<td>46</td>
</tr>
</tbody>
</table>
(b) $^{79}$Br because $A_r$ is closer to 79/OWTTE; 1

(c) (i) 2,8,8,2/2.8.8.2; 1
(ii) CaBr$_2$; 1

125. (a) 12 protons and 13 neutrons and 11 electrons; 1
(b) electric field/oppositely charged plates/potential difference/OWTTE; 1
(c) $^{25}$Mg$^+$; greater m/z value/less highly charged ions need stronger fields to deflect them/OWTTE; 2

Do not accept greater mass with no reference to charge, or greater mass and smaller charge.

126. (a) IV < I < II < III/ ultra violet radiation < yellow light < red light < infrared radiation; 1
(b) A continuous spectrum has all colours/wavelengths/frequencies whereas a line spectrum has only (lines of) sharp/discrete/specifc colours/ wavelengths/frequencies; 1
(c) UV-B radiation has shorter wavelength; hence, has higher energy; increases risk of damage to skin cells/OWTTE/causes cancer; 3