Q1.

(a) Atoms which have the same number of protons (or same element) but different numbers of neutrons (1)

(b) (i) $^{35}\text{Cl}$ (1)

(ii) $^{37}\text{Cl}$ (1)

(c) H Cl line at 36 has rel. abundance of 90 \[ \begin{array}{c} 38 \\ 30 \end{array} \] (1)

These show $^{35}\text{Cl}$ and $^{37}\text{Cl}$ in ratio 3:1 (1)

[or use of 35 and 37] (2)

(d) Mean of the two isotopes \[ \frac{3 \times 35 + 1 \times 37}{4} = 35.5 \] (1)

[Total: 6]

Q2.
Q3.

(a) same proton no./atomic no./no. of protons
   different mass no./nucleon no./no. of neutrons
   
<table>
<thead>
<tr>
<th>isotope</th>
<th>protons</th>
<th>neutrons</th>
<th>electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{56}$Fe</td>
<td>26</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td>$^{56}$Co</td>
<td>27</td>
<td>32</td>
<td>27</td>
</tr>
</tbody>
</table>

   give one mark for each correct column
   allow (1) if no column is correct but one row is correct

(c) (i) weighted mean/average mass
       of an atom (not element)
       compared with $^{12}$C
       one atom of $^{16}$C has a mass of exactly 12
       [relative to $\frac{1}{12}$ the mass of a $^{12}$C atom would get 2]

       or

       mass of 1 mol of atoms
       compared with $^{12}$C
       1 mol of $^{12}$C has a mass of 12 g

   (ii) $A_r = \frac{54 \times 5.84 + 56 \times 9.16 + 57 \times 2.17}{100}$

       $= \frac{557.13}{100} = 5.57$ to 3 sf

   allow 5.59 if $A_r$ is calculated using 99.69 instead of 100

   [Total: 10]

Q3.

(e) (i) an acid that is partially dissociated into ions

(ii) $H_2S(q) + H_2O(l) \rightarrow H_3O^+(aq) + HS^-(aq)$

   or

   $H_2S(q) + aq \rightarrow H^+(aq) + HS^-(aq)$

   or

   $H_2S(aq) \rightarrow H^+(aq) + HS^-(aq)$

   equation (1) state symbols (1)

Q4.
Q5.

(a)  \( F(g) \rightarrow F^+(g) + e^- \)

correct equation (1)

correct state symbols (1)  [2]

(b) from Na to Ar, electrons

are added to the same shell/have same shielding (1)

are subject to increasing nuclear charge/proton number (1)

are closer to the nucleus or atom gets smaller (1)  [3]

(c) (i) Al and Mg

in Al outermost electron is in 3p rather than 3s (1)

3p electron is at higher energy or is further away/is more shielded from nucleus (1)

(ii) P and S

for P 3p sub-shell is singly filled and for S one 3p orbital has paired electrons (1)

paired electrons repel (1)  [4]

Q6.

1 (a) Al  \( 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^1 \) (1)

Ti  \( 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 3d^4 \ 4s^2 \) or

\( 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^2 \) penalise any error (1)  [2]
(a) (i) \( \text{Ca}^+(q) \rightarrow \text{Ca}^{2+}(q) + e^- \)  

equation (1)  

state symbols (1)  

(ii) \( 590 + 1150 = +1740 \text{kJ mol}^{-1} \)  

(1) [3]  

Q7.  

1 (a) (i) 

\[
\begin{array}{c}
2s \\
\text{1s} \\
\text{nucleus} \\
\end{array}
\begin{array}{c}
2p_x \\
2p_y \\
2p_z \\
\end{array}
\]

correct 1s and 2s (1)  

correct 2p_x, 2p_y, and 2p_z (1)
Q8.

(ii) spherical s orbital (1)

double lobe p orbital along one axis (1)

both orbitals correctly labelled (1)

(iii)

\[ \begin{array}{c}
\uparrow \\
\uparrow \\
\uparrow \\
\uparrow \\
\uparrow \\
\uparrow \\
\uparrow \\
\uparrow \\
\end{array} \] \hspace{1cm}

\[ \begin{array}{c}
\uparrow \\
\uparrow \\
\uparrow \\
\uparrow \\
\end{array} \]

nitrogen oxygen

both correct (1)

(b) (i) N 1400 kJ mol\(^{-1}\) O 1310 kJ mol\(^{-1}\) both (1)

(ii) N is all singly filled 2p orbitals or O has one filled/paired 2p orbital (1) these paired 2p electrons in the O atom repel one another (1)

[Total: 9]
2 (a) the energy required to remove one electron from each atom (1) in one mole of gaseous atoms (1) or the enthalpy change in kJ mol\(^{-1}\) for (1) 
\[ \text{M(g)} \rightarrow \text{M}^+ (g) + \text{e}^- (1) \] [2]

(b) (i) first ionisation energy decreases down Group 1 (1) outermost electron is further from nucleus or has greater shielding (1)

(ii) outermost electron experiences less attraction or formation of \(\text{M}^+\) cation becomes easier down Group 1 (1) [3]

(c) (i) \( n(\text{Li}) = \frac{0.83}{6.9} = 0.12 \) (1)

(ii) \( 2 \text{ mol Li} \rightarrow 1 \text{ mol H}_2 \)  
\[ 0.12 \text{ mol Li} \rightarrow \frac{1 \times 0.12}{2} = 0.06 \text{ mol H}_2 \] (1)  
volume of \(\text{H}_2\) = 0.06 × 24.0 = 1.44 dm\(^3\) (1)

(iii) \( 2 \text{ mol Li} \rightarrow 2 \text{ mol LiOH} \)  
0.12 mol Li \(\rightarrow\) 0.12 mol LiOH in 0.50 dm\(^3\) (1)  
\[ [\text{LiOH}] = \frac{0.12 \times 1}{0.50} = 0.24 \text{ mol dm}^{-3} \] (1) [5]

(d) sodium burns with a yellow flame or white solid formed or colour of chlorine disappears (1)  
\[ 2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl} \] (1) [2]

[Total: 12]

Q9.
Q10.

1. (a) Energy required to remove one electron from each atom in one mole of gaseous atoms of an element (*Energy change when one mole of gaseous atoms loses one mole of electrons* would score all three marks.)

(b) \( X^+(\text{g}) \rightarrow X^{2+}(\text{g}) + e^- \) equation state symbols

(c) Group 5 sharp rise in successive ionisation energies between 5\(^{th}\) and 6\(^{th}\) IEs indicating change to a different shell/energy level or outer shell contains 5 electrons

(d) down the Group atomic radii increase/outer electrons are increasingly further away electrons are added to new shells/more shells more shielding despite increase in nuclear charge

[Total: 12]
Q11.

1 (a) same proton number/atomic number
   different mass number/nucleon number

(b) \[ A_e = \frac{(24 \times 78.60) + (25 \times 10.11) + (26 \times 11.29)}{100} \]
    \[ = \frac{1886.4 + 252.75 + 293.54}{100} = \frac{2432.69}{100} \]
    which gives \( A_e = 24.33 \)
    penalise \((-1)\) for misuse of significant figures

(c)

<table>
<thead>
<tr>
<th>isotopes</th>
<th>protons</th>
<th>neutrons</th>
<th>electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{226}\text{Ra})</td>
<td>88</td>
<td>136</td>
<td>88</td>
</tr>
<tr>
<td>(^{238}\text{U})</td>
<td>92</td>
<td>146</td>
<td>92</td>
</tr>
</tbody>
</table>

allow one mark for each correct column
if there are no correct columns,
allow maximum one mark for a correct row
Q12.

1 (a) atoms of the same element / with same proton (atomic) number / same number of protons (1) different numbers of neutrons / nucleon number / mass number (1) [2]

(b)

<table>
<thead>
<tr>
<th>isotope</th>
<th>no. of protons</th>
<th>no. of neutrons</th>
<th>no. of electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{24}\text{Mg}$</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>$^{26}\text{Mg}$</td>
<td>12</td>
<td>14</td>
<td>12</td>
</tr>
</tbody>
</table>

each correct row (1) [2]

(c) $A_i = \frac{24 \times 7.660 + 25 \times 10.11 + 26 \times 11.29}{100}$ (1)

$= \frac{1886.40 + 252.75 + 293.54}{100}$

gives 24.33 to 4 sig fig (same as data in question)
do not credit wrong number of sig figs or incorrect rounding up/down (1) [2]

(d) $\text{Mg} + \text{Cl}_2 \rightarrow \text{MgCl}_2$ (1) [1]
Q13.

(a) \( S(q) \rightarrow S'(q) + e^- \)  
   correct equation  
   correct state symbols  

(b) from Na to Ar, 
   electrons are added to the same shell/have same shielding  
   electrons are subject to increasing nuclear charge/proton number  
   electrons are closer to the nucleus or atom gets smaller  

(c) (i) Mg and Al 
   in Mg outermost electron is in 3s and 
   in Al outermost electron is in 3p  
   3p electron is at higher energy or  
   is further away from the nucleus or  
   is more shielded from the nucleus  

(ii) S and P 
   for S one 3p orbital has paired electrons and 
   for P 3p sub-shell is singly filled  
   paired electrons repel  

Q14.
1. (a) same proton number/atomic number
   different mass number/nucleon number

   \[ A_r = \frac{(32 \times 95.00) + (33 \times 0.77) + (34 \times 4.23)}{100} \]
   \[ = \frac{3040 + 25.41 + 143.82}{100} = \frac{3209.23}{100} \]
   which gives \( A_r = 32.09 \)

   (c)

<table>
<thead>
<tr>
<th>isotopes</th>
<th>number of</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>protons</td>
<td>neutrons</td>
<td>electrons</td>
</tr>
<tr>
<td>(^{219}\text{Po})</td>
<td>84</td>
<td>129</td>
<td>84</td>
</tr>
<tr>
<td>(^{232}\text{Th})</td>
<td>90</td>
<td>142</td>
<td>90</td>
</tr>
</tbody>
</table>

   allow one mark for each correct column
   if there are no 'column' marks,
   allow maximum one mark for a correct row

   (d) (i) nucleon no. is 228
        proton no. is 88

   (ii) Ra not radium

   [Total: 10]

Q15.

3. (a) \( C(\gamma) \rightarrow C^*(\gamma) + e^- \)
   correct equation
   correct state symbols

   (b) (i) Na and Mg
   Mg has greater nuclear charge/more protons than Na
   in both atoms, the 3s electrons are in the same orbital/same energy level/same shell

   (ii) Mg and Al
   in Al outermost electron is in 3p rather than 3s
   3p electron is at higher energy or
   is further away/is more shielded from nucleus
(iii) **He and Ne**
both He and Ne have the highest nuclear charges in their Period

(iv) **He, Ne, and Ar**
going down the group,
valence/outer shell electrons are farther from the nucleus
there is greater shielding
attraction between valence electrons and nucleus is less or
effective nuclear charge is less

(c) (i) **from Na to C**
increased nuclear charge/nuclear attraction

(ii) cation has fewer electrons than atom or
cation has lost outer electrons or
cation has fewer shells
but cation has same nuclear charge as atom or
proton number is the same

3 (d) ignore any state symbols

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Product(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO(s) + NaOH(aq)</td>
<td>NO REACTION</td>
</tr>
<tr>
<td>MgO(s) + 2HC2O(aq)</td>
<td>MgCl₂ + H₂O</td>
</tr>
<tr>
<td>Al₂O₃(s) + 2NaOH(aq) + 3H₂O(l)</td>
<td>2NaAl(OH)₄ or</td>
</tr>
<tr>
<td>Al₂O₃(s) + 2NaOH(aq) + H₂O(l)</td>
<td>2NaAlO₂ + 2H₂O or</td>
</tr>
<tr>
<td>Al₂O₃(s) + 6NaOH(aq) + 3H₂O(l)</td>
<td>2Na₂Al(OH)₆</td>
</tr>
<tr>
<td>Al₂O₃(s) + 6HC2O(aq)</td>
<td>2AlCl₆ + 3H₂O or</td>
</tr>
<tr>
<td>Al₂O₃(s) + 6HC₂O(aq)</td>
<td>Al₂C₂O₆ + 3H₂O</td>
</tr>
<tr>
<td>SO₂(g) + NaOH(aq)</td>
<td>NaHSO₃ or</td>
</tr>
<tr>
<td>SO₂(g) + 2NaOH(aq)</td>
<td>Na₂SO₃ + H₂O</td>
</tr>
<tr>
<td>SO₂(g) + HC₂O(aq)</td>
<td>NO REACTION</td>
</tr>
</tbody>
</table>

[Total: 19]

Q16.
1. (a) (i) from Na to Cl
   nuclear charge increases
   electrons are in the same shell/have the same shielding
   nuclear attraction increases

   (ii) argon does not form any bonds/compounds or
        argon exists as single atoms/is monatomic

(b) (i)

<table>
<thead>
<tr>
<th></th>
<th>radius of cation/nm</th>
<th>radius of anion/nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>0.095</td>
<td>0.212</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>0.065</td>
<td>0.184</td>
</tr>
<tr>
<td>Al³⁺</td>
<td>0.050</td>
<td>0.181</td>
</tr>
</tbody>
</table>

(ii) cations contain fewer electrons than the corresponding atoms or
     cations contain fewer electrons than they do protons
     nucleus has a greater attraction

(iii) anions contain more electrons than the corresponding atoms or
     anions contain more electrons than they do protons
     nucleus has a smaller attraction