Q1. Write the equation that relates amount of a substance to mass.

\[
\text{Amount of substance (in mol)} = \frac{\text{mass of substance}}{\text{formula weight}} \quad \text{or} \quad n = \frac{m}{M}
\]

Q2. Calculate the mass of 1.87 mol of sulfur trioxide.

\[
\text{Molecular weight of SO}_3 = 32.07 \text{ (S)} + (3 \times 16.00 \text{ (O)}) = 80.07
\]

\[
\text{Mass of 1.87 mol of SO}_3 = 1.87 \times 80.07 = 149.73 = 150 \text{ g (3 significant figures)}
\]

Q3. Calculate the amount (in mol) present in 200.0 g of silicon tetrachloride.

\[
\text{Molecular weight of SiCl}_4 = 28.09 + (4 \times 35.45) = 169.89
\]

\[
n = \frac{m}{M} = \frac{200.0}{169.89} = 1.1772 = 1.177 \text{ (4 significant figures)}
\]

Q4. Calculate the mass of \(2.00 \times 10^{20}\) molecules of water.

\[
\text{Molecular weight of H}_2\text{O} = (2 \times 1.008 \text{ (H)}) + 16.00 \text{ (O)} = 18.016
\]

\[
n = \frac{\text{number of atoms}}{\text{Avogadro's number}} = \frac{2.00 \times 10^{20}}{6.022 \times 10^{23}} \text{ mol}
\]

\[
m = n \times M = \left(\frac{2.00 \times 10^{20}}{6.022 \times 10^{23}}\right) \times 18.016 = 5.9834 \times 10^{-3} = 5.98 \times 10^{-3} \text{ g (3 significant figures)}
\]

Q5. Calculate the volume (in L) present in \(5.45 \times 10^{22}\) atoms of helium at STP.

\[
n = \frac{\text{number of atoms}}{\text{Avogadro's number}} = \frac{5.45 \times 10^{22}}{6.022 \times 10^{23}} \text{ mol}
\]

\[
\text{Volume occupied} = n \times 22.4 = \frac{5.45 \times 10^{22}}{6.022 \times 10^{23}} \times 22.4 = 2.027 = 2.03 \text{ L (3 significant figures)}
\]
Q6. Calculate the relative atomic mass of a natural sample of zinc, which contains the isotopes with masses and abundances given:

<table>
<thead>
<tr>
<th>isotope</th>
<th>atomic weight</th>
<th>abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{64}\text{Zn}$</td>
<td>63.929</td>
<td>48.6%</td>
</tr>
<tr>
<td>$^{66}\text{Zn}$</td>
<td>65.926</td>
<td>27.9%</td>
</tr>
<tr>
<td>$^{67}\text{Zn}$</td>
<td>66.927</td>
<td>4.1%</td>
</tr>
<tr>
<td>$^{68}\text{Zn}$</td>
<td>67.925</td>
<td>18.8%</td>
</tr>
<tr>
<td>$^{70}\text{Zn}$</td>
<td>69.925</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

\[
\text{atomic weight} = \left(63.929 \times \frac{48.6}{100}\right) + \left(65.926 \times \frac{27.9}{100}\right) + \left(66.927 \times \frac{4.1}{100}\right) + \left(67.925 \times \frac{18.8}{100}\right) + \left(69.925 \times \frac{0.6}{100}\right) = 65.3963 = 65.4 \text{ (3 significant figures)}
\]

Q7. An iron supplement is used to treat anaemia and 50 mg ($i.e. 50 \times 10^{-3} \text{ g}$) of $\text{Fe}^{2+}$ is required per tablet. If the iron compound used in the tablet is $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, what mass of this compound would be required per tablet to provide the desired amount of $\text{Fe}^{2+}$?

**Formula weight of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$:**

\[
55.85 \text{ (Fe)} + 32.07 \text{ (S)} + (4 \times 16.00 \text{ (O)}) + 7 \times (2 \times 1.008 \text{ (H)} + 16.00 \text{ (O)}) = 278.032
\]

\[
50 \text{ mg of Fe} = \frac{\text{mass (in g)}}{\text{atomic mass (in g mol}^{-1}\text{)}} = \frac{50 \times 10^{-3}}{55.85} \text{ mol}
\]

\[
\text{Mass of } \text{FeSO}_4 \cdot 7\text{H}_2\text{O} = \text{number of moles} \times \text{formula mass} = \frac{50 \times 10^{-3}}{55.85} \times 278.032 = 0.24891 = 0.25 \text{ g (2 significant figures)}
\]

Q8. Write the equation that relates concentration of a solution to amount of solute and volume of solution.

\[
\text{concentration (in M)} = \frac{\text{number of moles of solute (in mol)}}{\text{volume of solute (in L)}}
\]

Q9. Write the net ionic equation for the reaction that occurs when a solution of barium nitrate is mixed with a solution of sodium sulfate. A white precipitate of barium sulfate forms.

\[
\text{Ba}^{2+}(aq) + \text{SO}_4^{2-}(aq) \rightarrow \text{BaSO}_4(s)
\]

continues on the next page
Q10. One of the components of petrol is octane, $C_8H_{18}$.

(i) Write the balanced equation for the complete combustion of octane to form carbon dioxide gas and liquid water.

$$C_8H_{18}(l) + \frac{25}{2} O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$$

(ii) What amount (in mol) of carbon dioxide is formed when 5.5 mol (1 L) of petrol is burnt?

1 mol of $C_8H_{18}(l)$ produces 8 mol of CO$_2$(g)

∴ 5.5 mol of $C_8H_{18}(l)$ produces $8 \times 5.5 = 44$ mol of CO$_2$(g)

(iii) What volume of carbon dioxide would this represent at STP?

Volume occupied = $44 \times 22.4 = 985.6 = 9.9 \times 10^2$ L (2 significant figures)

Q11. Hydrogen iodide gas (5.0 L at STP) is dissolved in water and the volume made up to 1.0 L. What is the molarity of the solution?

Amount of HI = $\frac{Volume \ (in \ L)}{22.4 \ L} = \frac{5.0}{22.4} = 0.2232$ mol

Molarity of solution = $\frac{Number \ of \ moles \ (in \ mol)}{Volume \ (in \ L)} = \frac{0.2232}{1.0} = 0.22$ M (2 significant figures)

Q12. What volume of 0.200 M hydrochloric acid would be needed to react completely with a mixture of 0.500 g of sodium hydroxide and 0.800 g of potassium hydroxide?

Formula weight of NaOH = $22.99 \ (Na) + 16.00 \ (O) + 1.008 \ (H) = 39.998$

Formula weight of KOH = $39.10 \ (K) + 16.00 \ (O) + 1.008 \ (H) = 56.108$

$$HCl + MOH \rightarrow H_2O + MCl \hspace{1cm} (M = K \ or \ Na)$$

Total amount of MOH = $\frac{mass \ of \ NaOH \ (in \ g)}{formula \ mass \ of \ NaOH \ (in \ g \ \text{mol}^{-1})} + \frac{mass \ of \ KOH \ (in \ g)}{formula \ mass \ of \ KOH \ (in \ g \ \text{mol}^{-1})}$

= $\left( \frac{0.500}{39.998} \right) + \left( \frac{0.800}{56.108} \right) = 0.02676 \text{ mol}$

Therefore 0.02676 mol of HCl is required.

Volume (in L) = $\frac{number \ of \ moles \ (in \ mol)}{concentration \ (in \ M)} = \frac{0.02676}{0.200} = 0.1338 \ L$ = 134 mL (3 significant figures)
Q10. A solution was prepared by dissolving nickel (II) nitrate-6-water, \( \text{Ni(NO}_3\text{)}_2\cdot6\text{H}_2\text{O} \), (29.1 g) in some water and making the volume up to 1.00 L with water. Assuming complete dissociation of the solid into ions, calculate:

(i) The amount (in mol) of nickel(II) ions in 100 mL of this solution.

<table>
<thead>
<tr>
<th>Formula weight of ( \text{Ni(NO}_3\text{)}_2\cdot6\text{H}_2\text{O} ):</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 58.69 \text{ (Ni)} + 2 \times (14.01 \text{ (N)} + 3 \times 16.00 \text{ (O)}) + 6 \times (2 \times 1.008 \text{ (H)} + 16.00 \text{ (O)}) = 290.806 )</td>
</tr>
</tbody>
</table>

\[
\text{Amount of } \text{Ni(NO}_3\text{)}_2\cdot6\text{H}_2\text{O} = \frac{\text{mass (in g)}}{\text{formula mass (in g mol}^{-1}\text{)}} = \frac{29.1}{290.806} = 0.100 \text{ mol (3 significant figures)}
\]

<table>
<thead>
<tr>
<th>Concentration of solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{\text{number of moles (in mol)}}{\text{volume (in L)}} = \frac{0.100}{1.00 \text{ L}} = 0.100 \text{ M} )</td>
</tr>
</tbody>
</table>

Each \( \text{Ni(NO}_3\text{)}_2\cdot6\text{H}_2\text{O} \) dissociates to give one \( \text{Ni}^{2+} \text{(aq)} \) ion.

\[
\text{Amount of } \text{Ni}^{2+} \text{ ions in 100 mL} = \text{concentration (in M)} \times \text{volume (in L)}
\]

\[
= 0.100 \times \frac{100}{1000} = 0.0100 \text{ mol}
\]

(ii) The amount (in mol) of nitrate ions in 100 mL of this solution.

Each \( \text{Ni(NO}_3\text{)}_2\cdot6\text{H}_2\text{O} \) dissociates to give two \( \text{NO}_3^2^- \text{(aq)} \) ions.

\[
\text{Amount of } \text{NO}_3^2^- \text{ ions in 100 mL} = \text{concentration (in M)} \times \text{volume (in L)}
\]

\[
= 2 \times 0.100 \times \frac{100}{1000} = 0.0200 \text{ mol}
\]

(iii) The number of individual nickel(II) ions in 100 mL of solution.

\[
\text{Number of } \text{Ni}^{2+} \text{ ions} = \text{number of moles} \times \text{Avogadro’s number}
\]

\[
= 0.0100 \times (6.022 \times 10^{23}) = 6.022 \times 10^{21}
\]

continues on the next page
Q14. What volume of 0.010 M silver nitrate solution will exactly react with 20 mL of 0.0080 M sodium chloride solution?

AgNO₃ + NaCl → AgCl + NaNO₃

Amount of NaCl = volume (in L) × concentration (in M) = \( \frac{20}{1000} \times 0.080 \text{ mol} \)

∴ Amount of AgNO₃ required = 0.0080 × 0.020

Volume of AgNO₃ required = \( \frac{\text{number of moles (in mol)}}{\text{concentration (in M)}} \) = \( \frac{0.0080}{0.010} = 0.016 \text{ L} = 16 \text{ mL (2 significant figures)} \)