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.

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

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

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

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

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

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

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>$^{64}$Zn</td>
<td>63.929</td>
<td>48.6%</td>
</tr>
<tr>
<td>$^{66}$Zn</td>
<td>65.926</td>
<td>27.9%</td>
</tr>
<tr>
<td>$^{67}$Zn</td>
<td>66.927</td>
<td>4.1%</td>
</tr>
<tr>
<td>$^{68}$Zn</td>
<td>67.925</td>
<td>18.8%</td>
</tr>
<tr>
<td>$^{70}$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. $50 \times 10^{-3}$ g) of Fe$^{2+}$ is required per tablet. If the iron compound used in the tablet is FeSO$_4$$\cdot$7H$_2$O, what mass of this compound would be required per tablet to provide the desired amount of Fe$^{2+}$?

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

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

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

\[
\text{Mass of FeSO}_4$$\cdot$7H$_2$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, C₈H₁₈.

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

\[
\text{C}_8\text{H}_{18}(l) + \frac{25}{2} \text{O}_2(g) \rightarrow 8\text{CO}_2(g) + 9\text{H}_2\text{O}(l)
\]

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

1 mol of C₈H₁₈(l) produces 8 mol of CO₂(g)
\[\therefore 5.5 \text{ mol of C}_8\text{H}_{18}(l) \text{ produces } 8 \times 5.5 = 44 \text{ mol of CO}_2(\text{g})\]

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

Volume occupied = 44 \times 22.4 = 985.6 = 9.9 \times 10^2 \text{ 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?

\[
\text{Amount of HI} = \frac{\text{volume (in L)}}{22.4 \text{ L}} = \frac{5.0}{22.4} = 0.2232 \text{ mol}
\]

\[
\text{Molarity of solution} = \frac{\text{number of moles (in mol)}}{\text{volume (in L)}} = \frac{0.2232}{1.0} = 0.22 \text{ M (2 significant figures)}
\]

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?

\[
\text{Formula weight of NaOH} = 22.99 (\text{Na}) + 16.00 (\text{O}) + 1.008 (\text{H}) = 39.998
\]

\[
\text{Formula weight of KOH} = 39.10 (\text{K}) + 16.00 (\text{O}) + 1.008 (\text{H}) = 56.108
\]

\[
\text{HCl} + \text{MOH} \rightarrow \text{H}_2\text{O} + \text{MCl} \quad (\text{M} = \text{K or Na})
\]

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

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

Therefore 0.02676 mol of HCl is required.

\[
\text{Volume (in L)} = \frac{\text{number of moles (in mol)}}{\text{concentration (in M)}} = \frac{0.02676}{0.200} = 0.1338 \text{ L}
\]

\[= 134 \text{ mL (3 significant figures)}\]
Q10. A solution was prepared by dissolving nickel (II) nitrate-6-water, Ni(NO₃)₂·6H₂O, (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.

Formula weight of Ni(NO₃)₂·6H₂O:

\[
58.69 \text{ (Ni)} + 2 \times (14.01 \text{ (N)} + 3 \times 16.00 \text{ (O)}) + 6 \times (2 \times 1.008 \text{ (H)} + 16.00 \text{ (O)}) = 290.806
\]

Amount of Ni(NO₃)₂·6H₂O = \[
\frac{\text{mass (in g)}}{\text{formula mass (in g mol}^{-1})} = \frac{29.1}{290.806} = 0.100 \text{ mol (3 significant figures)}
\]

Concentration of solution = \[
\frac{\text{number of moles (in mol)}}{\text{volume (in L)}} = \frac{0.100}{1.00 \text{ L}} = 0.100 \text{ M}
\]

Each Ni(NO₃)₂·6H₂O dissociates to give one Ni²⁺ (aq) ion.

Amount of Ni²⁺ ions in 100 mL = concentration (in M) \times 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 Ni(NO₃)₂·6H₂O dissociates to give two NO₃⁻ (aq) ions.

Amount of NO₃⁻ ions in 100 mL = concentration (in M) \times 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.

Number of Ni²⁺ ions = number of moles \times Avogadro’s number
\[
= 0.0100 \times (6.022 \times 10^{23}) = 6.022 \times 10^{21}
\]

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

\[
\text{AgNO}_3 + \text{NaCl} \rightarrow \text{AgCl} + \text{NaNO}_3
\]

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

\[\therefore \text{Amount of AgNO}_3 \text{ required} = 0.0080 \times 0.020\]

\[
\text{Volume of AgNO}_3 \text{ required} = \frac{\text{number of moles (in mol)}}{\text{concentration (in M)}}
\]

\[= \frac{0.0080}{0.010} = 0.016 \text{ L} = 16 \text{ mL (2 significant figures)}\]