CHAPTER 4

TYPES OF CHEMICAL REACTIONS AND SOLUTION STOICHIOMETRY

Questions

13. a. Polarity is a term applied to covalent compounds. Polar covalent compounds have an unequal sharing of electrons in bonds that results in unequal charge distribution in the overall molecule. Polar molecules have a partial negative end and a partial positive end. These are not full charges as in ionic compounds but are charges much smaller in magnitude. Water is a polar molecule and dissolves other polar solutes readily. The oxygen end of water (the partial negative end of the polar water molecule) aligns with the partial positive end of the polar solute, whereas the hydrogens of water (the partial positive end of the polar water molecule) align with the partial negative end of the solute. These opposite charge attractions stabilize polar solutes in water. This process is called hydration. Nonpolar solutes do not have permanent partial negative and partial positive ends; nonpolar solutes are not stabilized in water and do not dissolve.

    b. KF is a soluble ionic compound, so it is a strong electrolyte. KF(aq) actually exists as separate hydrated K^+ ions and hydrated F^- ions in solution: $C_6H_{12}O_6$ is a polar covalent molecule that is a nonelectrolyte. $C_6H_{12}O_6$ is hydrated as described in part a.

    c. RbCl is a soluble ionic compound, so it exists as separate hydrated Rb^+ ions and hydrated Cl^- ions in solution. AgCl is an insoluble ionic compound, so the ions stay together in solution and fall to the bottom of the container as a precipitate.

    d. HNO_3 is a strong acid and exists as separate hydrated H^+ ions and hydrated NO_3^- ions in solution. CO is a polar covalent molecule and is hydrated as explained in part a.

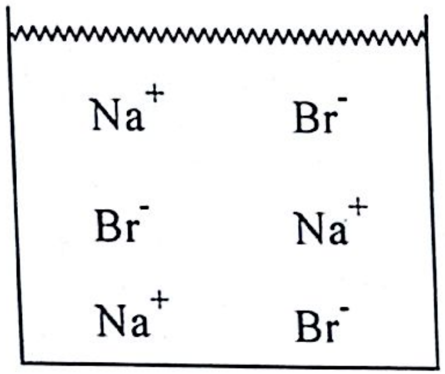
14. 2.0 L × 3.0 mol/L = 6.0 mol HCl; the 2.0 L of solution contains 6.0 mol of the solute. HCl is a strong acid; it exists in aqueous solution as separate hydrated H^+ ions and hydrated Cl^- ions. So the solution will contain 6.0 mol of H^+(aq) and 6.0 mol of Cl^- (aq). For the acetic acid solution, $HC_2H_3O_2$ is a weak acid instead of a strong acid. Only some of the 6.0 moles of $HC_2H_3O_2$ molecules will dissociate into H^+(aq) and $C_2H_3O_2^-$(aq). The 2.0 L of 3.0 *M* $HC_2H_3O_2$ solution will contain mostly hydrated $HC_2H_3O_2$ molecules but will also contain some hydrated H^+ ions and hydrated $C_2H_3O_2^-$ ions.

15. Only statement b is true. A concentrated solution can also contain a nonelectrolyte dissolved in water, e.g., concentrated sugar water. Acids are either strong or weak electrolytes. Some ionic compounds are not soluble in water, so they are not labeled as a specific type of electrolyte.

Exercises

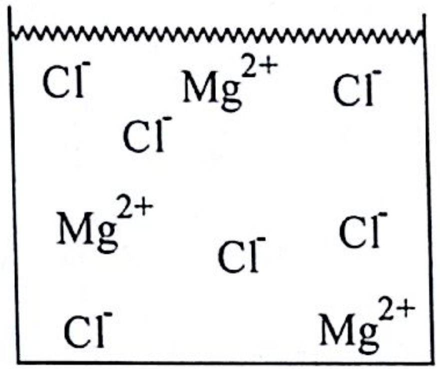
Aqueous Solutions: Strong and Weak Electrolytes

23. a. $NaBr(s) \rightarrow Na^+(aq) + Br^-(aq)$



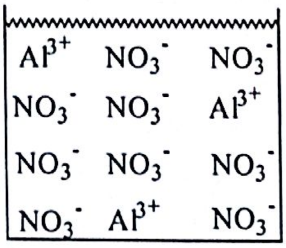
Your drawing should show equal number of Na^+ and Br^- ions.

b. $MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2\ Cl^-(aq)$

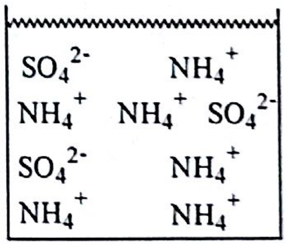


Your drawing should show twice the number of Cl^- ions as Mg^{2+} ions.

c. $Al(NO_3)_3(s) \rightarrow Al^{3+}(aq) + 3\ NO_3^-(aq)$



d. $(NH_4)_2SO_4(s) \rightarrow 2\ NH_4^+(aq) + SO_4^{2-}(aq)$



For e-i, your drawings should show equal numbers of the cations and anions present because each salt is a 1 : 1 salt. The ions present are listed in the following dissolution reactions.

e. $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

f. $FeSO_4(s) \rightarrow Fe^{2+}(aq) + SO_4^{2-}(aq)$

g. $KMnO_4(s) \rightarrow K^+(aq) + MnO_4^-\ (aq)$

h. $HClO_4(aq) \rightarrow H^+(aq) + ClO_4^-(aq)$

i. $NH_4C_2H_3O_2(s) \rightarrow NH_4^+(aq) + C_2H_3O_2^-(aq)$

24. a. $Ba(NO_3)_2(aq) \rightarrow Ba^{2+}(aq) + 2\ NO_3^-(aq)$; picture iv represents the Ba^{2+} and NO_3^- ions present in $Ba(NO_3)_2(aq)$.

b. $NaCl(aq) \rightarrow Na^+(aq) + Cl^-(aq)$; picture ii represents NaCl(aq).

c. $K_2CO_3(aq) \rightarrow 2\ K^+(aq) + CO_3^{2-}(aq)$; picture iii represents $K_2CO_3(aq)$.

d. $MgSO_4(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq)$; picture i represents $MgSO_4(aq)$.

$HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$. Picture ii best represents the strong acid HNO_3. Strong acids are strong electrolytes. $HC_2H_3O_2$ only partially dissociates in water; acetic acid is a weak electrolyte. None of the pictures represent weak electrolyte solutions; they all are representations of strong electrolytes.

25. $CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2\ Cl^-(aq)$

26. $MgSO_4(s) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq)$; $NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$

Solution Concentration: Molarity

27. a. $5.623\ g\ NaHCO_3 \times \dfrac{1\ mol\ NaHCO_3}{84.01\ g\ NaHCO_3} = 6.693 \times 10^{-2}\ mol\ NaHCO_3$

$$M = \frac{6.693 \times 10^{-2}\ mol}{250.0\ mL} \times \frac{1000 mL}{L} = 0.2677\ M\ NaHCO_3$$

b. $0.1846\text{ g } K_2Cr_2O_7 \times \frac{1\text{ mol } K_2Cr_2O_7}{294.20\text{ g } K_2Cr_2O_7} = 6.275 \times 10^{-4}\text{ mol } K_2Cr_2O_7$

$$M = \frac{6.275 \times 10^{-4}\text{ mol}}{500.0 \times 10^{-3}\text{ L}} = 1.255 \times 10^{-3}\ M\ K_2Cr_2O_7$$

c. $0.1025\text{ g Cu} \times \frac{1\text{ mol Cu}}{63.55\text{ g Cu}} = 1.613 \times 10^{-3}\text{ mol Cu} = 1.613 \times 10^{-3}\text{ mol } Cu^{2+}$

$$M = \frac{1.613 \times 10^{-3}\text{ mol } Cu^{2+}}{200.0\text{ mL}} \times \frac{1000\text{ mL}}{\text{L}} = 8.065 \times 10^{-3}\ M\ Cu^{2+}$$

28. $75.0\text{ mL} \times \frac{0.79\text{ g}}{\text{mL}} \times \frac{1\text{ mol}}{46.07\text{ g}} = 1.3\text{ mol } C_2H_5OH$; molarity $= \frac{1.3\text{ mol}}{0.250\text{ L}} = 5.2\ M\ C_2H_5OH$

29. a. $M_{Ca(NO_3)_2} = \frac{0.100\text{ mol } Ca(NO_3)_2}{0.100\text{ L}} = 1.00\ M$

$Ca(NO_3)_2(s) \rightarrow Ca^{2+}(aq) + 2\ NO_3^-(aq)$; $M_{Ca^{2+}} = 1.00\ M$; $M_{NO_3^-} = 2(1.00) = 2.00\ M$

b. $M_{Na_2SO_4} = \frac{2.5\text{ mol } Na_2SO_4}{1.25\text{ L}} = 2.0\ M$

$Na_2SO_4(s) \rightarrow 2\ Na^+(aq) + SO_4^{2-}(aq)$; $M_{Na^+} = 2(2.0) = 4.0\ M$; $M_{SO_4^{2-}} = 2.0\ M$

c. $5.00\text{ g } NH_4Cl \times \frac{1\text{ mol } NH_4Cl}{53.49\text{ g } NH_4Cl} = 0.0935\text{ mol } NH_4Cl$

$$M_{NH_4Cl} = \frac{0.0935\text{ mol } NH_4Cl}{0.5000\text{ L}} = 0.187\ M$$

$NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$; $M_{NH_4^+} = M_{Cl^-} = 0.187\ M$

d. $1.00\text{ g } K_3PO_4 \times \frac{1\text{ mol } K_3PO_4}{212.27\text{ g}} = 4.71 \times 10^{-3}\text{ mol } K_3PO_4$

$$M_{K_3PO_4} = \frac{4.71 \times 10^{-3}\text{ mol}}{0.2500\text{ L}} = 0.0188\ M$$

$K_3PO_4(s) \rightarrow 3\ K^+(aq) + PO_4^{3-}(aq)$; $M_{K^+} = 3(0.0188) = 0.0564\ M$; $M_{PO_4^{3-}} = 0.0188\ M$

33. Molar mass of NaOH = 22.99 + 16.00 + 1.008 = 40.00 g/mol

$$\text{Mass NaOH} = 0.2500\ \text{L} \times \frac{0.400\ \text{mol NaOH}}{\text{L}} \times \frac{40.00\ \text{g NaOH}}{\text{mol NaOH}} = 4.00\ \text{g NaOH}$$

34. $$10.\ \text{g AgNO}_3 \times \frac{1\ \text{mol AgNO}_3}{169.9\ \text{g}} \times \frac{1\ \text{L}}{0.25\ \text{mol AgNO}_3} = 0.24\ \text{L} = 240\ \text{mL}$$

35. a. $$2.00\ \text{L} \times \frac{0.250\ \text{mol NaOH}}{} \times \frac{40.00\ \text{g NaOH}}{} = 20.0\ \text{g NaOH}$$