Chapter 7 Solution Chemistry

7.1 The Nature of Solutions

Warm Up (p. 364) and Quick Check (p. 365)

	Pure substance	Mixture
Car exhaust		√
Tap water		√ solution
Carbon dioxide	√	
Freshly squeezed orange juice		√
Stainless steel		√ solution
tea		√ solution
diamond	√	
Cigarette smoke		√

Practice Problems – Converting Between Units of Solubility (p. 366)

1. $\text{solubility} = \dfrac{2.4 \times 10^{-5}\ \cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \dfrac{147.6\ \text{g}}{1\ \cancel{\text{mol}}} \times \dfrac{1\ \cancel{\text{L}}}{1000\ \text{mL}} = 3.5 \times 10^{-6}\ \text{g/mL}$
2. $\text{solubility} = \dfrac{1.4 \times 10^{-6}\ \cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \dfrac{462.6\ \text{g}}{1\ \cancel{\text{mol}}} \times \dfrac{1\ \cancel{\text{L}}}{1000\ \text{mL}} = 6.5 \times 10^{-7}\ \text{g/mL}$
3. $\text{molar solubility} = \dfrac{9.3 \times 10^{-4}\ \cancel{\text{g}}}{500\ \cancel{\text{mL}}} \times \dfrac{1\ \text{mol}}{143\ 4\ \cancel{\text{g}}} \times \dfrac{1000\ \cancel{\text{mL}}}{1\ \text{L}} = 1.3 \times 10^{-5}\ \text{g/mL}$
4. $\text{mass} = \dfrac{2.6 \times 10^{-3}\ \cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \dfrac{413.3\ \text{g}}{1\ \cancel{\text{mol}}} \times \dfrac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times 250\ \cancel{\text{mL}} = 0.27\ \text{g}$

Quick Check (p. 367)

1. An anion is a negative ion. A cation is a postive ion.
2. Alkali ions, H^+ and NH_4^+ compounds are always soluble.
3. Nitrate compounds are always soluble.
4. Phosphate, carbonate and sulphite have low solubility.

Practice Problems- Predicting the Relative Solubility of Salts in Water (p. 368)

1. NaCl – soluble
2. $CaCO_3$ – low solubility
3. $CuCl_2$ – soluble
4. $Al_2(SO_4)_3$ – soluble
5. BaS – soluble
6. Zinc sulphite – low solubility
7. Ammonium hydroxide – soluble
8. Cesium phosphate – soluble
9. Copper(I) chloride – low solubility
10. Chromium(III) nitrate – soluble

7.1 Activity (p. 369)
Results and Discussion

1. NaNO3
2. No. At 0° C, $KClO_3$ has the lowest solubility. At 90° C, $Ce_2(SO_4)_3$ has the lowest solubility.
3. Increases
4. $Ce_2(SO_4)_3$

7.1 Review Questions

1. Define homogeneous, heterogeneous, pure substance, and mixture. Give an example for each.
Homogeneous – is uniform throughout and exists in one phase. Ie. Alcohol and water
Heterogeneous – is not uniform throughout. Ie. Oil and vinegar
Pure substance – contains only one type of particle (atom or molecule). Ie. Gold or water
Mixture – contains 2 or more components. Ie. Salt water

2. Classify the following as a pure substance or a mixture. If it is a mixture, then state whether or not it is a solution.
(a) distilled water – pure substance
(b) 9 carat gold – mixture - solution
(c) gasoline – mixture - solution
(d) wood – mixture – not a solution
(e) bronze – mixture - solution
(f) chocolate chip ice cream – mixture – not a solution
(g) coffee – mixture - solution
(h) coal – pure substance

3. Complete the following sentences using the terms solute, solvent, miscible, and immiscible. A solution is composed of a solute and solvent. The solvent is the substance that makes up the larger part of the solution. If two components can be mixed in any proportions to make a homogeneous mixture, they are miscible.

4. Give an example of two substances that are immiscible when mixed. Describe what you would see if you mixed them together.
Paint thinner and water are immiscible. You would see 2 layers of liquid that did not mix.

5. When the solubility of a substance is given, what information must be specified?
The amount of solute in a specified volume of solution at a particular temperature.

6. The molar solubility of lead(II) bromide is 2.6×10^{-3} M. What is its solubility in g/ml?

$$\text{solubility} = \frac{2.6 \times 10^{-3}\ \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{367\ \text{g}}{1\ \cancel{\text{mol}}} \times \frac{1\ \cancel{\text{L}}}{1000\ \text{mL}} = 9.5 \times 10^{-4}\ \text{g/mL}$$

7. A saturated solution contains 0.0015g CaC_2O_4 dissolved in 250 mL solution. What is the molar solubility of CaC_2O_4?

$$\text{Solubility} = \frac{0.0015\ \cancel{\text{g}}}{250\ \cancel{\text{mL}}} \times \frac{1\ \text{mol}}{128.1\ \cancel{\text{g}}} \times \frac{1000\ \cancel{\text{mL}}}{1\ \text{L}} = 4.7 \times 10^{-5}\ \text{M}$$

8. The molar solubility of $AgIO_3$ is 1.8×10^{-4} M. Express its solubility in g $AgIO_3$ /mL water. Assume that the volume of solvent = volume of solution.

$$\text{solubility} = \frac{1.8 \times 10^{-4}\ \cancel{\text{mol}}}{\cancel{\text{L}}} \times \frac{282.8\ \text{g}}{1\ \cancel{\text{mol}}} \times \frac{1\ \cancel{\text{L}}}{1000\ \text{mL}} = 5.1 \times 10^{-5}\ \text{g/mL}$$

9. What does the term aqueous mean?
Dissolved in water

10. Using Table 7.1.1, list three salts containing the sulphide anion that would have a low solubility in water at 25°C.
Many possible answers. For example: FeS, CuS and ZnS

11. Using Table 7.1.1, list three salts containing the anion carbonate that would be soluble at 25°C.
Many possible answers. For example: Na_2CO_3, $(NH_4)_2CO_3$, K_2CO_3

12. List the cations in a salt that are soluble when paired with any anion.
H^+, NH_4^+, Li^+, Na^+ , K^+ , Rb^+ Cs^+ , Fr^+ ,

13. Classify each of the following compounds as soluble or low solubility according to Table 7.1.1.
(a) H_2SO_4 soluble
(b) MgS soluble
(c) $(NH_4)_2SO_3$ soluble
(d) RbOH soluble
(e) $PbSO_4$ low solubility
(f) $CuBr_2$ soluble
(g) $Zn(NO_3)_2$ soluble
(h) $FeSO_4$ soluble

14. A student dissolves 0.53g of $LiCH_3COO$ in water at 25°C to make 100 mL of solution. Is the solution formed saturated or unsaturated? Justify your answer with calculations and by referring to Table 7.1.1.

$$[LiCH_3COO] = \frac{0.53\cancel{\text{g}}}{100\ \cancel{\text{mL}}} \times \frac{1\ \text{mol}}{65.9\ \cancel{\text{g}}} \times \frac{1000\ \cancel{\text{mL}}}{1\text{L}} = 0.080\ \text{M.}$$

According to the solubility table, alkali ions are soluble with all anions. Soluble means a solubility of greater than 0.1M. This solution is unsaturated.

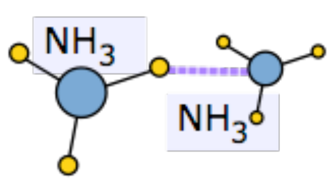
Section 7.2

Warm Up

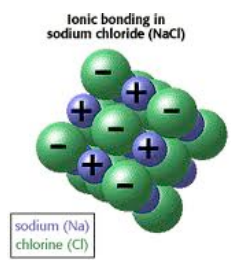
Substance	**Intermolecular Forces Present**
Example: H_2O	hydrogen bonding, dipole-dipole, dispersion forces
I_2	Dispersion forces
HF	hydrogen bonding, dipole-dipole, dispersion forces
PCl_3	Dispersion forces
CH_3CH_2OH	dipole-dipole, dispersion forces

p. 3 Quick check

1. The NaCl has positive and negative ions, and the water has positive and negative dipoles. The positive sodium ion is attracted to the negative dipole on the oxygen atom of the water molecule. The negative chloride ion is attracted to the positive dipole on the hydrogen atom of the water molecule.
2. Water molecules are attracted to each other by hydrogen bonds. The iodine molecules cannot overcome that attraction between water molecules to get between them.
3. No, NaCl is ionic and oil is non-polar covalent. They are not "like".
4. ammonia: NaCl



dipole-dipole force



ionic bonds

p. 6 Quick Check

1. Yes – ammonia is polar and so is water. They are "like".
2. No. Ethanol is polar and hexane is non-polar. They are not "like".
3. CH_3OH is more soluble in water. Water is polar so it will be attracted to the polar end on CH_3OH. C_2H_6 is non-polar so is not "like" water.
4. The large non-polar part of octanol is not able to get between water molecules and overcome the attraction that each water molecule has for another water molecule. Larger alcohols are almost insoluble in water.

p. 7 Quick Check

1. Yes – iodine is also non-polar covalent. Like dissolves like.
2. Mothballs are non-polar so they will dissolve better in paint thinner which is also non-polar.
3. The solid iodine will dissolve in the paint thinner layer only. It will become pink while the water layer remains clear and colorless.

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4. The water molecules are attracted to each other through hydrogen bonds. The CCl_4 molecules are not able to overcome this attraction and get between the water molecules. Water is polar and CCl_4 is non-polar. They are not "like".

7.2 Activity: Determining the Bond Type of a Solute

Results and Discussion
1. What types of intermolecular forces exist in water? In tetrachloroethene?
Water contains hydrogen bonds and dipole-dipole bonds. Tetrachloroethene is non-polar covalent so only contains dispersion forces.

2. State the two possible bond types or intramolecular bonds present in the solute.
The stain must be polar covalent or ionic.

3. Explain why the stain did not dissolve in tetrachloroethene.
The stain is polar or ionic and tetrachloroethene is non-polar. They are not "like".

4. Explain why you cannot narrow down the solute bond type to just one type.
Because both ionic and polar compounds dissolve in polar covalent solvents.

5. Compare your answers to those of another group. How do they compare?

7.2 Review Questions
1. Explain the phrase "like dissolves like" in your own words.
Solutes that have a similar type of intermolecular forces as a solvent will dissolve.
2. Is ethanol hydrophilic or hydrophobic? Explain using a diagram.
Hydrophilic

3. Is $Br_2(l)$ more soluble in $CS_2(l)$ or $NH_3(l)$? Explain.
Br_2 is non-polar so is more soluble in CS_2 which is also non-polar. NH_3 is polar so is not "like" Br_2.

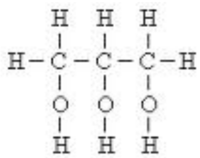
4. Explain why NH_3 is very soluble in water, but NCl_3 is not.
NH3 is polar just like water. NCl_3 is non-polar so will not dissolve in water.

5. When I_2 is added to water, it does not dissolve. However, if I_2 is added to an aqueous solution of KI, it will dissolve. Use the following reaction, and your understanding of intermolecular forces to explain the above observations.
$I_2(s) + I^-(aq) \rightarrow I_3^-(aq)$
I_2 is non-polar so will not dissolve in polar water. If the water contains I^- ions however, the I_2 reacts to form $I_3^-(aq)$ which is ionic. This ion will then be attracted to the positive dipole on the hydrogen atoms on the water molecules.

6. Which is more soluble in water? Explain.

(a) C_4H_{10} or C_3H_6OH C_3H_6OH – it contains a polar end that is attracted to the polar water molecules
(b) $MgCl_2$ or toluene (C_7H_8) $MgCl_2$ is ionic so will dissolve better in water. Toluene is non-polar.

7. Glycerin is a common solvent and is found in many skin care products. A student mixed 10 mL of water, 10 mL of glycerin and 10 mL of carbon tetrachloride together. A small amount of $CuCl_2$ was added to the mixture. Explain what you would see.

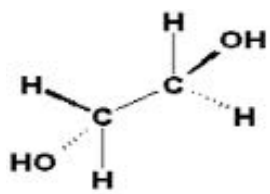


BCch11-7.2-16-glycerin

Glycerin

The glycerin and water would mix together but the carbon tetrachloride would remain as a separate layer. The $CuCl_2$ would dissolve into the water/glycerin layer and would color that layer blue.

8. Ethylene glycol is commonly used as antifreeze. In which solvent would antifreeze be most soluble?

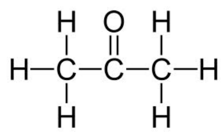


BCch11-7.2-17-ethylglyc

Ethylene glycol

(a) water or paint thinner (a non-polar covalent solvent)
water. Water and ethylene glycol are both polar.
(b) ammonia or carbon tetrachloride
ammonia. Ammonia and ethylene glycol are both polar.
(c) hexene (C_6H_{12}) or glycerin (a polar covalent solvent)
glycerin. Glycerin and ethylene glycol are both polar.

9. List the intermolecular forces present between the following solutes and solvents:
(a) CsCl in H_2O
CsCl is ionic. Water contains hydrogen bonds, dipole-dipole bonds and dispersion forces.
(b) CH_3OH in glycerin
CH_3OH is polar and contains hydrogen bonds, dipole-dipole forces and dispersion forces.
Glycerin is polar and contains hydrogen bonds, dipole-dipole forces and dispersion forces.
(c) N_2 in C_8H_{18}
N_2 contains only dispersion forces as does C_8H_{18}
(d) acetone in ammonia



BCch11-7.2-18-acetone

Acetone

Acetone contains dipole-dipole forces and dispersion forces. Ammonia contains hydrogen bonds, dipole-dipole forces and dispersion forces.

Section 7.3

Warm Up:

1. For a strong cup of coffee, you would use a large amount of coffee for a given volume of water.
2. To dilute the coffee, you would add more water or milk.
3. No, you have not changed the amount of caffeine in the coffee because you have not added any more coffee. You have simply increased the volume of solution.

Practice Problems – Dilution Calculations

1. $[NaOH] = \frac{0.100 \text{ mol}}{1 \cancel{L}} \times \frac{0.0500 \cancel{L}}{0.0800 \text{ L}} = 0.0625 \text{ M}$
2. $[H_2SO_4] = \frac{1.5 \text{ mol}}{1 \cancel{L}} \times \frac{0.0350 \cancel{L}}{0.0500 \text{ L}} = 1.1 \text{ M}$
3. $[Ca(NO_3)_2]$ original solution $= \frac{0.25 \cancel{g}}{0.100 \text{ L}} \times \frac{1 \text{ mol}}{164.1 \cancel{g}} = 0.015 \text{ M}$
   $[Ca(NO_3)_2]$ diluted solution $= \frac{0.015 \text{ mol}}{1 \cancel{L}} \times \frac{0.0500 \cancel{L}}{0.0750 \text{ L}} = 0.010 \text{ M}$
4. $[K_2CrO_4] = \frac{0.40 \text{ mol}}{1 \cancel{L}} \times \frac{0.0180 \cancel{L}}{0.0380 \text{ L}} = 0.19 \text{ M}$

Quick Check

Write balanced dissociation equations for each salt when it is dissolved in water.

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

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

3. potassium chromate $K_2CrO_4 \text{ (aq)} \rightarrow 2\ K^+\text{(aq)} + CrO_4^{2-}\text{(aq)}$

4. zinc phosphate $Zn_3(PO_4)_2 \text{ (aq)} \rightarrow 3\ Zn^{2+}\text{(aq)} + 2\ PO_4^{3-}\text{(aq)}$

Quick Check

Calculate the concentration of all ions in each of the following. Begin by writing the balanced dissociation equation for each.

1. 3.0 M $Zn(NO_3)_2$: $Zn(NO_3)_2(aq) \rightarrow Zn^{2+}(aq) + 2\ NO_3^-(aq)$
3.0M 3.0 M 6.0 M

2. 0.50M Na_2CO_3 : $Na_2CO_3(aq) \rightarrow 2\ Na^+(aq) + CO_3^{2-}(aq)$
0.050M 1.0M 0.50 M

3. 1.5 M ammonium oxalate: $(NH_4)_2C_2O_4(aq) \rightarrow 2\ NH_4^+(aq) + C_2O_4^{2-}(aq)$
1.5M 3.0 M 6.0 M

4. 3.2×10^{-3} M calcium phosphate : $Ca_3(PO_4)_2(aq) \rightarrow 3\ Ca^{2+}(aq) + 2\ PO_4^{3-}(aq)$
3.2×10^{-3} M 9.6×10^{-3} M 6.4×10^{-3} M

Practice Problems — Calculating the Concentrations of Ions in Solution

1. $[HNO_3] = \frac{0.20\ mol}{1\ \cancel{L}} \times \frac{0.035\ \cancel{L}}{0.1100\ L} = 0.0636\ M$

$[Al(NO_3)_3] = \frac{0.15\ mol}{1\ \cancel{L}} \times \frac{0.075\ \cancel{L}}{0.1100\ L} = 0.102\ M$

$HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
0.0636 M 0.0636 M 0.0636 M

$Al(NO_3)_3(aq) \rightarrow Al^{3+}(aq) + 3\ NO_3^-(aq)$
0.102 M 0.102 M 0.306 M

$[H^+] = 0.064$ M
$[NO_3^-] = 0.0636$ M + 0.306 M = 0.37 M
$[Al^{3+}] = 0.10$ M

2. $[H_2SO_4] = \frac{0.85\ mol}{1\ \cancel{L}} \times \frac{0.0226\ \cancel{L}}{0.0580\ L} = 0.33\ M$

$[Na_2SO_4] = \frac{1.3\ mol}{1\ \cancel{L}} \times \frac{0.0354\ \cancel{L}}{0.0580\ L} = 0.79\ M$

$H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
0.33 M 0.66 M 0.33 M

$Na_2SO_4(aq) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq)$
0.79 M 1.6 M 0.79 M

$[Na^+] = 1.6$ M
$[SO_4^{2-}] = 0.33$ M + 0.79 M = 1.1 M
$[H^+] = 0.66$ M

3. $[K_3PO_4] = \dfrac{0.10\ \text{mol}}{1\ \cancel{\text{L}}} \times \dfrac{0.0500\ \cancel{\text{L}}}{0.0900\ \text{L}} = 0.0556\ \text{M}$

$[K_2C_2O_4] = \dfrac{0.20\ \text{mol}}{1\ \cancel{\text{L}}} \times \dfrac{0.0400\ \cancel{\text{L}}}{0.0900\ \text{L}} = 0.0889\ \text{M}$

$$\begin{array}{llll} K_3PO_4\ (aq) \rightarrow & 3K^+(aq) & + & PO_4^{3-}(aq) \\ 0.0556\ \text{M} & 0.167\ \text{M} & & 0.0556\ \text{M} \end{array}$$

$$\begin{array}{llll} K_2C_2O_4\ (aq) \rightarrow & 2K^+(aq) & + & C_2O_4^{2-}(aq) \\ 0.0889\ \text{M} & 0.178\ \text{M} & & 0.0889\ \text{M} \end{array}$$

$[PO_4^{3-}] = 0.056\ \text{M}$
$[K^+] = 0.167\ \text{M} + 0.178\ \text{M} = 0.34\ \text{M}$
$[C_2O_4^{2-}] = 0.089\ \text{M}$

4. $[(NH_4)_3PO_4] = \dfrac{2.3 \times 10^{-3}\ \text{mol}}{1\ \cancel{\text{L}}} \times \dfrac{0.1000\ \cancel{\text{L}}}{0.1400\ \text{L}} = 1.6 \times 10^{-3}\ \text{M}$

$[(NH_4)_2S] = \dfrac{4.5 \times 10^{-2}\ \text{mol}}{1\ \cancel{\text{L}}} \times \dfrac{0.0400\ \cancel{\text{L}}}{0.1400\ \text{L}} = 1.3 \times 10^{-2}\ \text{M}$

$$\begin{array}{llll} (NH_4)_3PO_4\ (aq) \rightarrow & 3\ NH_4^+(aq) & + & PO_4^{3-}(aq) \\ 1.6 \times 10^{-3}\ \text{M} & 4.8 \times 10^{-3}\ \text{M} & & 1.6 \times 10^{-3}\ \text{M} \end{array}$$

$$\begin{array}{llll} (NH_4)_2S\ (aq) \rightarrow & 2\ NH_4^+(aq) & + & S^{2-}(aq) \\ 1.3 \times 10^{-2}\ \text{M} & 2.6 \times 10^{-2}\ \text{M} & & 1.3 \times 10^{-2}\ \text{M} \end{array}$$

$[PO_4^{3-}] = 1.6 \times 10^{-3}\ \text{M}$
$[NH_4^+] = 4.8 \times 10^{-3}\ \text{M} + 2.6 \times 10^{-2}\ \text{M} = 3.1 \times 10^{-2}\ \text{M}$
$[S^{2-}] = 1.3 \times 10^{-2}\ \text{M}$

Quick Check

1. How can you tell from a substance's formula if it is ionic or molecular? Give two examples of an ionic compound.
Ionic Compounds contain a metal ion (or ammonium ion) and a negative ion. An example of anionic compound is NaCl or NH_4NO_3. A molecular compound contains only non-metals.

2. Sugar has the formula $C_{12}H_{22}O_{11}$. Will a sugar solution conduct electricity? Explain.
No, sugar is molecular. Ions are required for a solution to conduct electricity.

3. Explain why a 1.0 M solution of HCl will be a stronger electrolyte than a 1.0 M solution of CH_3COOH.
HCl is a strong acid, which means that it will dissociate into ions completely. CH_3COOH is a weak acid so does not dissociate very much into ions.

7.3 Activity: Investigating Electrical Conductivity

In your diagrams, it should be demonstrated that:

- the dimmest light bulbs will be $C_{12}H_{22}O_{11}$ and C_2H_5OH because they are molecular
- only slightly brighter will be NH_3 and CH_3COOH. NH_3 is a weak base so does contain a few ions. CH_3COOH is a weak acid and also contains a few ions.

- The next brightest bulb will be in the HCl. There is a total ion concentration of 1.6M.
- The next brightest bulb will be the NaCl with a total ion concentration of 2.0M.
- The brightest bulb will be in the Na_2CO_3 with a total ion concentration of 2.4M.

Results and Discussion

1. Which solutions were ionic? Covalent?

Ionic = HCl, NaOH and Na_2CO_3. Covalent = $C_{12}H_{22}O_{11}$, C_2H_5OH, CH_3COOH, and NH_3
.

2. For each ionic solution, write a dissociation equation for the solute, and calculate the concentration of each ion present.

$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$
0.8 M 0.8 M 0.8 M
$NaCl(aq) \rightarrow Na^+(aq) + Cl^-(aq)$
1.0 M 1.0 M 1.0 M
$Na_2CO_3(aq) \rightarrow 2\,Na^+(aq) + CO_3^{2-}(aq)$
0.8 M 1.6 M 0.8 M

3. Calculate the total ion concentration of each ionic solution by adding all of the ion concentrations together. Write this value under its corresponding diagram.

In HCl: [ions] = 1.6M
In NaCl: [ions] = 2.0M
In Na_2CO_3 : [ions] = 2.4M

4. Rank the solutions in order from strongest electrolyte to weakest electrolyte. List the nonelectrolytes last. Use an equal sign (=) for solutions that are about equally conductive.

Na_2CO_3 > NaCl > HCl > CH_3COOH = NH_3 > $C_{12}H_{22}O_{11}$ = C_2H_5OH

5. Summarize the rules for determining if a solute will make a solution that is a good electrical conductor.

A good electrical conductor is one that contains ions. The higher the concentration of ions in solution, the greater its conductivity will be.

7.3 Review Questions

1a) $[HCl] = \dfrac{0.55\text{ mol}}{1\,\cancel{L}} \times \dfrac{0.175\,\cancel{L}}{0.200\text{ L}} = 0.48\text{ M}$

b) $[Na_2Cr_2O_7] = \dfrac{0.035\text{ mol}}{1\,\cancel{L}} \times \dfrac{0.0450\,\cancel{L}}{0.1000\text{ L}} = 0.016\text{ M}$

c) $[NaOH] = \dfrac{2.0\text{ mol}}{1\,\cancel{L}} \times \dfrac{0.1000\,\cancel{L}}{0.0750\text{ L}} = 2.7\text{ M}$

2. mol HCl required = $\frac{2.5\text{ mol}}{1\ \cancel{L}} \times 0.2500\cancel{L} = 0.625$ mol HCl

volume of stock solution = $0.625\ \cancel{mol} \times \frac{1\text{ L}}{6.0\ \cancel{mol}} = 0.10$ L

3. When a solute dissolves in a solvent, the solvent molecules surround the solute particles. If the solvent is water, it is called hydration. If the solvent molecules are not water, it is call solvation.

4. A water molecule is polar. The oxygen atom on a water molecule has a negative dipole because the electrons in the bonds are more attracted to the oxygen atom. The negative dipole on the oxygen atom is attracted to the positive charge on the cation.

5. You will have 2 diagrams. Surrounding the K^+ ion, the water molecules are aligned such that the oxygen atoms are closest to the K^+ ion. For the I^- ion, the water molecules are aligned such that the hydrogen atoms are closest.

6.
a) $FeCl_3(aq) \rightarrow Fe^{3+}(aq) + 3Cl^-(aq)$
b) $MnHPO_4(aq) \rightarrow Mn^{2+}(aq) + HPO_4^{2-}(aq)$
c) $Zn(SCN)_2(aq) \rightarrow Zn^{2+}(aq) + 2SCN^-(aq)$
d) $Al_2(Cr_2O_7)_3(aq) \rightarrow 2Al^{3+}(aq) + 3Cr_2O_7^{2-}(aq)$
e) $Ag_2C_2O_4(aq) \rightarrow 2Ag^+(aq) + C_2O_4^{2-}(aq)$
f) $Fe_2(SO_3)_3(aq) \rightarrow 2Fe^{3+}(aq) + 3SO_3^{2-}(aq)$
g) $CrCrO_4(aq) \rightarrow Cr^{2+}(aq) + CrO_4^{2-}(aq)$
h) $NH_4HC_2O_4(aq) \rightarrow NH_4^+(aq) + HC_2O_4^-(aq)$

7. moles HCl from first solution: $\frac{0.60\text{ mol}}{1\ \cancel{L}} \times 0.2500\ \cancel{L} = 0.15$ mol

moles HCl from second solution = $\frac{1.0\text{ mol}}{1\ \cancel{L}} \times 0.3000\ \cancel{L} = 0.30$ mol

total moles HCl = 0.15 mol + 0.30 mol = 0.45 mol
total volume = 250.0 mL + 300.0 mL = 550.0 mL = 0.5500 L
[HCl] = 0.45 mol / 0.5500 L = 0.82 M

8. a) $CuCl_2(aq) \rightarrow Cu^{2+}(aq) + 2Cl^-(aq)$
0.20 M 0.20 M 0.40 M
b) $Li_2C_2O_4(aq) \rightarrow 2Li^+(aq) + C_2O_4^{2-}(aq)$
1.5 M 3.0 M 1.5 M
c) $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
6.0 M 6.0 M 6.0 M

d) $Mg(MnO_4)_2(aq) \rightarrow Mg^{2+}(aq) + 2\ MnO_4^-(aq)$
1.4×10^{-3} M 1.4×10^{-3} M 2.8×10^{-3} M
e) $[Al(NO_3)_3] = \underline{0.25\text{ mol}} \times \underline{0.0185\ \cancel{L}} = 0.11$ M

$1\ \cancel{L} \quad 0.0409\ L$

$$[Cu(NO_3)_2] = \frac{0.50\ mol}{1\ \cancel{L}} \times \frac{0.0224\ \cancel{L}}{0.0409\ L} = 0.27\ M$$

$Al(NO_3)_3\ (aq) \rightarrow Al^{3+}(aq) + 3NO_3^-(aq)$
0.11 M   0.11 M   0.33 M

$Cu(NO_3)_2\ (aq) \rightarrow Cu^{2+}(aq) + 2NO_3^-(aq)$
0.27 M   0.27 M   0.54 M

$[Al^{3+}] = 0.11$ M
$[NO_3^-] = 0.33$ M + 0.54 M = 0.87 M
$[Cu^{2+}] = 0.27$ M

9. $(NH_4)_2CrO_4\ (aq) \rightarrow 2\ NH_4^+(aq) + CrO_4^{2-}(aq)$
0.60 M   **0.30 M**

10. The NO_3^- ions move to the positive electrode. The K^+ ions move to the negative electrode. This is a strong electrolyte because it contains ions.

11. Strong acids dissociate completely to form ions. They are HCl, HBr, HI, HNO_3, H_2SO_4 and $HClO_4$.

12. Place the conductivity apparatus in each solution. The HNO_3 solution will be a strong conductor because it is ionic. The $C_{12}H_{22}O_{11}$ solution will be a poor conductor because it is molecular.

13. a) strong electrolyte b) non-electrolyte c) weak electrolyte
d) strong electrolyte e) non- electrolyte f) weak electrolyte

14. Disagree. You can have a sugar solution of high concentration, but it is still molecular, and contains no ions. It will not conduct electricity. Strong electrolytes contain many ions.

Section 7.4
Warm Up
There are many different ways to classify these substances. Many students will group according to ionic or molecular. Other students may group as acids, bases, salts and molecular.

Quick Check
1. Balance the following neutralization equation:
$1\ H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow 2\ H_2O(l) + 1\ Na_2SO_4(aq)$
2. Write the balanced equation for the reaction between aluminum hydroxide and hydrobromic acid to form aluminum bromide and water.
$3\ HBr(aq) + Al(OH)_3\ (aq) \rightarrow AlBr_3\ (aq) + 3\ H_2O(l)$

3. Complete and balance the following equation:
$2\ NH_4OH\ +\ H_2SO_4 \rightarrow (NH_4)_2SO_4\ +\ 2\ H_2O\ (l)$
4. Write the formula for the acid and base that will react to give the salt K_2CO_3 and water. Acid = H_2CO_3 and base = KOH

Practice Problems — Simple Titration Calculations

1. $\text{mole NaOH} = \frac{0.30\ \text{mol}}{1\ \cancel{\text{L}}} \times 0.01562\ \cancel{\text{L}} = 4.69 \times 10^{-3}\ \text{mol NaOH}$

   $\text{mole HCl} = 4.69 \times 10^{-3}\ \cancel{\text{mol NaOH}} \times \frac{1\ \text{mol HCl}}{1\ \cancel{\text{mol NaOH}}} = 4.69 \times 10^{-3}\ \text{mol HCl}$

   $[HCl] = \frac{4.69 \times 10^{-3}\ \text{mol HCl}}{0.02500\ \text{L}} = 0.19\ \text{M}$

2. $\text{mole } H_2SO_4 = \frac{0.20\ \text{mol}}{1\ \cancel{\text{L}}} \times 0.02425\ \cancel{\text{L}} = 4.85\ \times 10^{-3}\ \text{mol } H_2SO_4$

   $\text{mole NaOH} = 4.85 \times 10^{-3}\ \cancel{\text{mol } H_2SO_4} \times \frac{2\ \text{mol NaOH}}{1\ \cancel{\text{mol } H_2SO_4}} = 9.70 \times 10^{-3}\ \text{mol NaOH}$

   $[NaOH] = \frac{9.70 \times 10^{-3}\ \text{mol NaOH}}{0.01000\ \text{L}} = 0.97\ \text{M}$

3. $\text{mole } Sr(OH)_2 = \frac{0.015\ \text{mol}}{1\ \cancel{\text{L}}} \times 0.02268\ \cancel{\text{L}} = 3.40 \times 10^{-4}\ \text{mol } Sr(OH)_2$

   $\text{mole } HNO_3 = 3.40 \times 10^{-4}\ \cancel{\text{mol } Sr(OH)_2} \times \frac{2\ \text{mol NaOH}}{1\ \cancel{\text{mol } Sr(OH)_2}} = 6.80 \times 10^{-4}\ \text{mol } HNO_3$

   $[HNO_3] = \frac{6.80 \times 10^{-4}\ \text{mol } HNO_3}{0.00500\ \text{L}} = 0.14\ \text{M}$

4. $\text{mole NaOH} = \frac{0.12\ \text{mol}}{1\ \cancel{\text{L}}} \times 0.01000\ \cancel{\text{L}} = 1.2 \times 10^{-3}\ \text{mol NaOH}$

   $\text{mol } H_2C_2O_4 = 1.2 \times 10^{-3}\ \cancel{\text{mol NaOH}} \times \frac{1\ \text{mol } H_2C_2O_4}{2\ \cancel{\text{mol NaOH}}} = 6.0 \times 10^{-4}\ \text{mol}$

   $\text{volume } H_2C_2O_4 = 6.0 \times 10^{-4}\ \cancel{\text{mol } H_2C_2O_4} \times \frac{1\ \text{L}}{0.50\ \cancel{\text{mol } H_2C_2O_4}} = 1.2 \times 10^{-3}\ \text{L}$

Quick Check

1. How is a pipette is different than a burette? A pipette is used to deliver a specific volume of solution. The solution is suctioned up into the pipette. A burette is used to gradually add a volume of solution. It has a valve that dispenses solution.
2. What solution goes into the burette? Usually the standardized solution.
3. Which piece of glassware is the indicator added to? The Erlenmeyer flask.
4. What is "equivalent" at the equivalence point? Moles of H^+ and moles of OH^-.

7.4 Activity: Titrating CH_3COOH with NaOH

Results and Discussion

1. $CH_3COOH + NaOH \rightarrow NaCH_3COO + H_2O$
2. Colourless

3. When a small amount of NaOH is added, it is neutralized by the CH_3COOH. There is an excess of CH_3COOH so the indicator remains colourless.
4. 12.30 mL – 0.50 mL = 11.80 mL
5. At the endpoint the indicator changes colour because the CH_3COOH has been completely neutralized by the added NaOH and there is now an excess of NaOH in the flask.
6. Trial #1: 12.31 mL – 0.50 mL = 11.81 mL
   Trial #2: 23.75 mL – 12.31 mL = 11.44 mL
   Trial #3: 35.22 mL – 23.70 mL = 11.52 mL
   Average volume NaOH = (11.44 mL + 11.52 mL) / 2 = 11.48 mL
7. mol NaOH = $\frac{0.15 \text{ mol}}{1 \cancel{\text{L}}} \times 0.01148 \cancel{\text{L}} = 1.72 \times 10^{-3}$ mol NaOH
8. mol CH_3COOH = $1.72 \times 10^{-3} \cancel{\text{mol NaOH}} \times \frac{1 \text{ mol } CH_3COOH}{1 \cancel{\text{mol NaOH}}} = 1.72 \times 10^{-3}$ mol
9. $[CH_3COOH] = \frac{1.72 \times 10^{-3} \text{ mol } CH_3COOH}{0.0100 \text{ L}} = 0.17$ M

Review Questions

1. Acid begins with H or ends in –COOH. Ex. HCl or CH_3COOH. A base contains hydroxide. An example is NaOH.
2. (a) $HI + LiOH \rightarrow LiI + H_2O$
   (b) $Ca(OH)_2 + 2\ HNO_3 \rightarrow Ca(NO_3)_2 + 2\ H_2O$
   (c) $CH_3COOH + NH_4OH \rightarrow NH_4CH_3COO + H_2O$
   (d) $H_2SO_4 + 2\ KOH \rightarrow K_2SO_4 + 2\ H_2O$

3. In the diagram, the $H_2C_2O_4$ is in the burette, and the NaOH is in the flask. A pipette is used to measure out a specific volume of NaOH into the Erlenmeyer flask.
The solution will be pink at the beginning of the titration because the Erlenmeyer contains the base NaOH. At the endpoint, the solution will be colourless when all of the NaOH has been neutralized.

4. Standardized – a solution whose concentration is known.
Equivalence point – the point in the titration where moles H+ = moles OH-.
Endpoint – the point in the titration where the indicator changes colour.

5. A student titrated 10.00 mL HCl with 0.050 M $Sr(OH)_2$. The table below shows the data collected. Calculate the [HCl].

Molarity of $Sr(OH)_2$ = 0.050 M	**Trial #1**	**Trial #2**	**Trial #3**
Initial burette reading (mL)	0.00	16.05	32.93
Final burette reading (mL)	16.05	32.93	49.68
Volume of $Sr(OH)_2$ added (mL)	16.05	16.88	16.75
Average volume $Sr(OH)_2$ (mL)	16.82		

mole $Sr(OH)_2$ = $\frac{0.050 \text{ mol}}{} \times 0.01682 \cancel{\text{L}} = 8.41 \times 10^{-4}$ mol $Sr(OH)_2$

$$\text{mole HCl} = 8.41 \times 10^{-4}\ \cancel{\text{mol Sr(OH)}_2} \times \frac{2\ \text{mol HCl}}{1\ \cancel{\text{mol Sr(OH)}_2}} = 1.68 \times 10^{-3}\ \text{mol HCl}$$

$$[\text{HCl}] = \frac{1.68 \times 10^{-3}\ \text{mol HCl}}{0.01000\ \text{L}} = 0.17\text{M}$$

6. $\text{mol } H_2CO_3 = 0.20\ \text{mol} \times 0.02500\ \text{L} = 0.0050\ \text{mol } H_2CO_3$

$$\text{mol NaOH} = 0.0050\ \cancel{\text{mol } H_2CO_3} \times \frac{2\ \text{mol NaOH}}{1\ \cancel{\text{mol } H_2CO_3}} = 0.010\ \text{mol NaOH}$$

$$\text{volume NaOH} = 0.010\ \cancel{\text{mol NaOH}} \times \frac{1\ \text{L}}{0.50\ \cancel{\text{mol NaOH}}} = 0.020\ \text{L NaOH}$$

7. $\text{mole NaOH} = \frac{0.50\ \text{mol}}{1\cancel{\text{L}}} \times 0.01820\ \cancel{\text{L}} = 9.1 \times 10^{-3}\ \text{mol NaOH}$

$$\text{mole } CH_3COOH = 9.1 \times 10^{-3}\ \cancel{\text{mol NaOH}} \times \frac{1\ \text{mol HCl}}{1\ \cancel{\text{mol NaOH}}} = 9.1 \times 10^{-3}\ \text{mol } CH_3COOH$$

$$[CH_3COOH] = \frac{9.1 \times 10^{-3}\ \text{mol } CH_3COOH}{0.01000\ \text{L}} = 0.91\ \text{M}$$

8. $[H_2C_2O_4] = \frac{0.18\ \cancel{\text{g}}}{0.25000\ \text{L}} \times \frac{1\ \text{mol}}{126\ \cancel{\text{g}}} = 5.7 \times 10^{-3}\ \text{M}$

$$\text{mol } H_2C_2O_4 = \frac{5.7 \times 10^{-3}\ \text{mol}}{1\ \cancel{\text{L}}} \times 0.02500\ \cancel{\text{L}} = 1.4 \times 10^{-4}\ \text{mol } H_2C_2O_4$$

$$\text{mol NaOH} = 1.4 \times 10^{-4}\ \cancel{\text{mol } H_2C_2O_4} \times \frac{2\ \text{mol NaOH}}{1\ \cancel{\text{mol } H_2C_2O_4}} = 2.9 \times 10^{-4}\ \text{mol NaOH}$$

$$[\text{NaOH}] = \frac{2.9 \times 10^{-4}\ \text{mol}}{0.01525\ \text{L}} = 1.9 \times 10^{-2}\ \text{M}$$

9. $\text{mol NaOH} = \frac{0.10\ \text{mol}}{1\cancel{\text{L}}} \times 0.01830\ \cancel{\text{L}} = 1.83 \times 10^{-3}\ \text{mol NaOH}$

$$\text{mol } C_9H_8O_4 = 1.83 \times 10^{-3}\ \cancel{\text{mol NaOH}} \times \frac{1\ \text{mol } C_9H_8O_4}{1\ \cancel{\text{mol NaOH}}} = 1.83 \times 10^{-3}\ \text{mol } C_9H_8O_4$$

$$\text{mass } C_9H_8O_4 = 1.83 \times 10^{-3}\ \cancel{\text{mol } C_9H_8O_4} \times \frac{180\ \text{g}}{1\ \cancel{\text{mol } C_9H_8O_4}} = 0.329\ \text{g}$$

$\%\ C_9H_8O_4 = 0.329\ \text{g} / 0.50\ \text{g} \times 100\% = 66\%$

10. $\text{mol HCl} = \frac{0.10\ \text{mol}}{1\ \cancel{\text{L}}} \times 0.00725\ \cancel{\text{L}} = 7.25 \times 10^{-4}\ \text{mol HCl}$

$$\text{mol Ca(OH)}_2 = 7.25 \times 10^{-4}\ \text{mol HCl} \times \frac{1\ \text{mol Ca(OH)}_2}{2\ \cancel{\text{mol HCl}}} = 3.63 \times 10^{-4}\ \text{mol Ca(OH)}_2$$

$$\text{mass Ca(OH)}_2 = 3.63 \times 10^{-4}\ \cancel{\text{mol Ca(OH)}_2} \times \underline{74.1\ \text{g}} = 0.027\ \text{g}$$

$1\ \cancel{\text{mol } Ca(OH)_2}$

11. Volume NaOH added:
trial 1 = 15.25 mL
trial 2 = 15.22 mL
trial 3 = 15.40 mL
average volume = (15.25 + 15.22) / 2 = 15.24 mL NaOH

$$\text{mol NaOH} = \frac{0.100 \text{ mol}}{1\ \cancel{\text{L}}} \times 0.01524\ \cancel{\text{L}} = 1.52 \times 10^{-3} \text{ mol NaOH}$$

$$\text{mol HA} = 1.52 \times 10^{-3}\ \cancel{\text{mol NaOH}} \times \frac{1 \text{ mol HA}}{1\ \cancel{\text{mol NaOH}}} = 1.52 \times 10^{-3} \text{ mol HA}$$

$$\text{molar mass HA} = 0.1915 \text{ g} / 1.52 \times 10^{-3} \text{ mol HA} = 126 \text{ g/mol}$$