CHAPTER 4 – REACTIONS IN AQUEOUS SOLUTION

Section 4.1 – General Properties of Aqueous Solutions

(a) Do you agree or disagree with the statement below? Justify your answer.

If a solid dissolves completely into water, it is classified as an electrolyte.

(b) Modify the statement above so that it is more accurate with respect to the definition of an electrolyte.

(c) Write equations for what happens when each of the following substances is dissolved into water. Water is not listed as a reactant in any of the equations below. Water is just the solvent. Some of these substances will dissociate into ions when they dissolve in water, and some of them won't dissociate. Use the symbol (*aq*) to represent a species that is aqueous.

(i) $MgCl_2(s) \longrightarrow$

(ii) $CH_3OH(l) \longrightarrow$

(iii) $KOH(s) \longrightarrow$

(iv) $(NH_4)_2SO_4(s) \longrightarrow$

(v) $C_6H_{12}O_6(s) \longrightarrow$

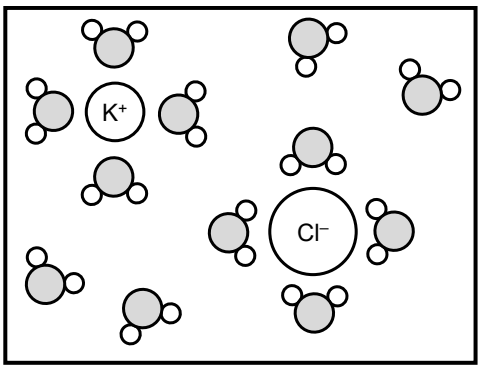
(vi) $HCl(aq) \longrightarrow$

(vii) $Al(NO_3)_3(s) \longrightarrow$

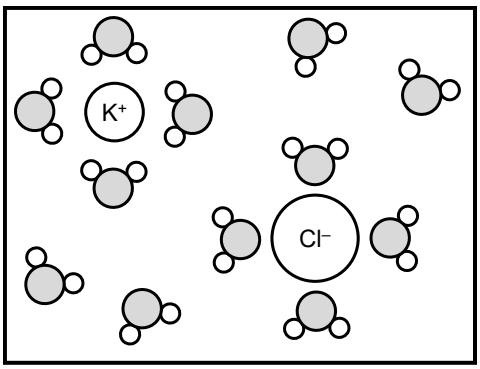
(viii) $CH_3CH_2OH(l) \longrightarrow$

(d) Which of these diagrams best represents a solution of potassium chloride?

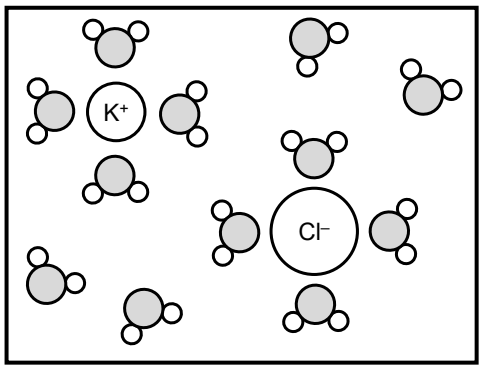
(A)



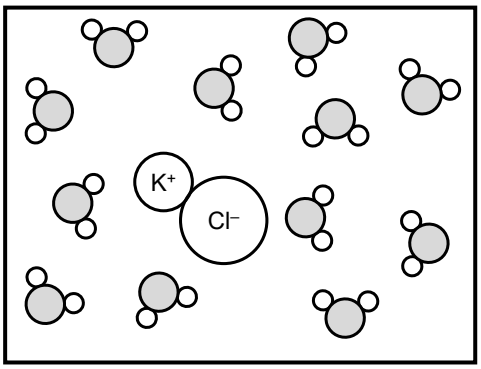
(B)



(C)



(D)



Section 4.2 – Precipitation Reactions

(a) Write a definition of the word precipitate (noun).

(b) Refer to Table 4.1 on p. 121. For each compound, write its chemical formula and indicate if it should be soluble or insoluble in water.
(Note: Zinc and cadmium form ions with a charge of +2)

Name	Chemical Formula	Soluble or Insoluble?	Name	Chemical Formula	Soluble or Insoluble?
zinc nitrate			calcium phosphate		
cadmium sulfide			lead(II) bromide		
lead(II) acetate			barium hydroxide		
ammonium carbonate			sodium sulfate		
silver chloride			nickel(II) hydroxide		

(c) Write the **molecular equation** for the double replacement reaction that occurs when solutions of sodium carbonate and magnesium sulfate are mixed together.

(d) Write the **complete ionic equation** for the equation you wrote in part (c).

(e) What are the **spectator ions** from the equation you wrote in part (d)?

(f) Write the **net ionic equation** for the equation you wrote in part (d).

(g) Will a precipitate form when solutions of barium nitrate and potassium hydroxide are mixed together? If yes, write the net ionic equation for this reaction. If no, explain why a precipitate does not form.

(h) Consider what would happen when each pair of aqueous solutions are mixed together.
If a precipitate is formed, write the chemical formula of the precipitate.
If no precipitate is formed, write "no reaction"

Chemicals that are mixed together	**Formula of Precipitate**
zinc nitrate + magnesium sulfate	
silver nitrate + potassium carbonate	
calcium hydroxide + copper(II) chloride	
lithium sulfate + barium bromide	
sodium acetate + potassium phosphate	
lead(II) nitrate + sodium bromide	
sodium phosphate + nickel(II) chloride	

(i) There were five reactions from part (h) that produced a precipitate.
Write balanced net ionic equations for these five reactions.

Section 4.3 – Acids, Bases, and Neutralization Reactions

(a) Acids are substances that ionize in aqueous solution to form _____ ions. Acids are often called proton _____.

(b) Write two examples of monoprotic acids in the table below.

Chemical Name	Chemical Formula

(c) Write one example of a diprotic acid in the table below.

Chemical Name	Chemical Formula

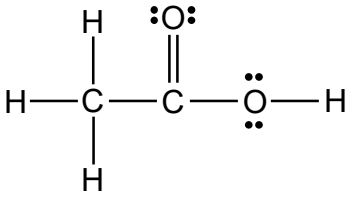
(d) When a single arrow is used in an ionization reaction, we say that the substance that ionizes is a _____ electrolyte. On the other hand, if double arrows in opposite directions are used, we say that the substance that ionizes is a _____ electrolyte.

(e) Write the equations for the 1st and 2nd ionizations of sulfuric acid. Use a single arrow or double arrows as necessary.

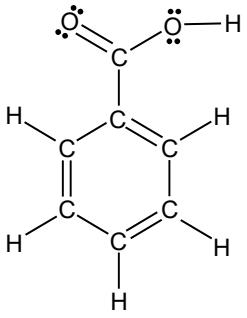
1st ionization

2nd ionization

(f) Circle the hydrogen that is ionized when each of these acids dissolves in water.



acetic acid
(vinegar)



benzoic acid

(g) Bases are substances that _____ H^+ ions. When bases dissolve in water, they produce _____ ions.

(h) Ammonia is a base. Write an equation for what happens when ammonia is added to water. Use a single arrow or double arrows as necessary.

(i) Acids can be defined as strong or weak. Strong acids are 100% ionized in solution. Weak acids are only partially ionized (about 5% or less) in solution. There are seven strong acids that you need to memorize. Circle the seven strong acids from the list below.

H_2SO_4	HNO_2	HF	$HClO_4$	HNO_3
$HClO_3$	H_3PO_4	HCl	H_2CO_3	CH_3COOH
HCN	HBr	H_2S	HClO	HI

Any acid from the list above that you did not circle is classified as a weak acid.

(j) Write the names and formulas of the seven strong acids in the table below.

Chemical Name	Chemical Formula

(k) Strong bases include soluble metal hydroxides, in which the metal is either an alkali metal or one of the heavy alkaline earth metals. Write the formulas for the bases in the table below.

Chemical Name	Chemical Formula
lithium hydroxide	
sodium hydroxide	
potassium hydroxide	
calcium hydroxide	
strontium hydroxide	
barium hydroxide	

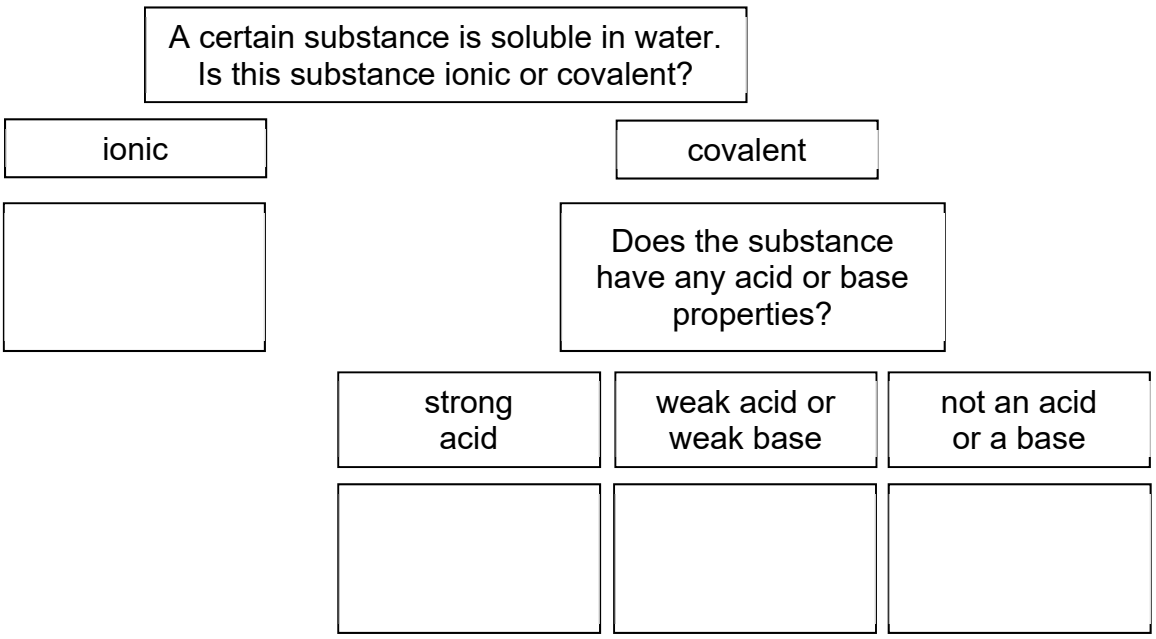
(l) Other examples of weak bases (besides ammonia) include compounds known as **amines**. An amine is a derivative of ammonia in which one or more hydrogen atoms have been replaced by carbon atoms. When an amine reacts with water, the lone pair on the nitrogen atom bonds with one of the hydrogen atoms from water. The result is the formation of a cation and the hydroxide ion. Write an equation for what happens when each of these amines is added to water. Use a double arrows to indicate that amines are weak bases.

methylamine, CH_3NH_2

dimethylamine, $(CH_3)_2NH$

trimethylamine, $(CH_3)_3N$

(m) Use the information in Table 4.3 to fill in the boxes below with the terms strong electrolyte, weak electrolyte, or nonelectrolyte.



(n) Classify each of the following substances as a strong, weak, or nonelectrolyte.

HNO_2	CH_3OCH_3	$Ba(OH)_2$	$C_6H_{12}O_6$
HBr	CH_3COOH	$CH_3CH_2NH_2$	$C_3H_8O_3$ (glycerol)
CH_3CH_2OH	NH_3	KNO_3	$NaC_2H_3O_2$

strong electrolyte	weak electrolyte	nonelectrolyte

(o) When solutions of an acid and a base are mixed together, a _____ reaction occurs. In general, the reaction between an acid and a metal hydroxide produces _____ and a _____.

(p) The following section presents a variety of neutralization reactions. For each of the following reactions, write the balanced **molecular equation**, the **complete ionic equation**, and the **net ionic equation**. You do not have to write phases of matter, as (*s*), (*l*), (*g*) or (*aq*).

Note: When writing the complete ionic equation, strong acids or soluble ionic compounds should be broken up into ions. Substances that are insoluble, pure solids, pure liquids, or weak electrolytes should not be broken up into ions.

Strong Acid + Strong Base

hydrochloric acid + sodium hydroxide

Molecular Equation:

Complete Ionic Equation:

Net Ionic Equation:

nitric acid + calcium hydroxide

Molecular Equation:

Complete Ionic Equation:

Net Ionic Equation:

Weak Acid + Strong Base

acetic acid + potassium hydroxide

Molecular Equation:

Complete Ionic Equation:

Net Ionic Equation:

nitrous acid + barium hydroxide

Molecular Equation:

Complete Ionic Equation:

Net Ionic Equation:

Strong Acid + Weak Base

hydrobromic acid + ammonia

Molecular Equation:

Complete Ionic Equation:

Net Ionic Equation:

chloric acid + methylamine

Molecular Equation:

Complete Ionic Equation:

Net Ionic Equation:

Weak Acid + Weak Base

hydrofluoric acid + ammonia

Molecular Equation:

Complete Ionic Equation:

Net Ionic Equation:

(q) Certain anions can react with acids to produce a gas. Three examples are as follows.

The sulfide ion (S^{2-}) reacts with acids to produce _____ gas.

The carbonate ion (CO_3^{2-}) or the bicarbonate ion (HCO_3^-) reacts with acids to produce water and _____ gas.

The sulfite ion (SO_3^{2-}) reacts with acid to produce water and _____ gas.

(r) Write the equations for the following reaction that produces a gas.

sodium carbonate + hydrochloric acid

Molecular Equation:	
Complete Ionic Equation:	
Net Ionic Equation:	

Section 4.4 – Oxidation – Reduction Reactions

(a) When an element loses electrons, it becomes (oxidized reduced).

(b) When an atom gains electrons, it becomes (oxidized reduced).

(c) When calcium reacts with oxygen to form calcium oxide,

which element is oxidized in this reaction? _____

which element is reduced in this reaction? _____

(d) When sodium reacts with chlorine to form sodium chloride,

which element is oxidized in this reaction? _____

which element is reduced in this reaction? _____

(e) Fill in the table with the oxidation numbers for each element.

Substance	Oxidation Number	Substance	Oxidation Number
Fe		CO_3^{2-}	C = O =
Zn		CrO_4^{2-}	Cr = O =
O_2		$C_2O_4^{2-}$	C = O =
Al^{3+}		PO_4^{3-}	P = O =
S^{2-}		HCO_3^-	H = C = O =
Ba^{2+}		NH_4^+	N = H =
H_2O	H = O =	N_2H_4	N = H =
H_2O_2	H = O =	NH_2OH	N = H = O =
OF_2	O = F =	NO_2^-	N = O =
NaH	Na = H =	NO_3^-	N = O =
CH_4	C = H =	HCl	H = Cl =
CO_2	C = O =	$HClO_4$	H = Cl = O =
OH^-	O = H =	C_2H_5OH	C = H = O =
ClO_3^-	Cl = O =	H_2SO_3	H = S = O =
NO_3^-	N = O =	H_2SO_4	H = S = O =

$$Mg + 2\,HCl \rightarrow MgCl_2 + H_2$$

(f) In the reaction above, magnesium is (oxidized reduced) from _____ to _____, and hydrogen is (oxidized reduced) from _____ to _____.

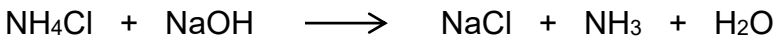
$$PbS + 4\,H_2O_2 \rightarrow PbSO_4 + 4\,H_2O$$

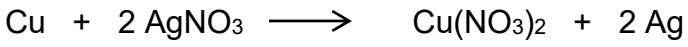
(g) In the reaction above, sulfur is (oxidized reduced) from _____ to _____, and oxygen is (oxidized reduced) from _____ to _____.

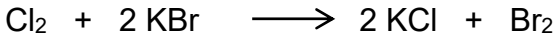
$$FeS + 2\,HNO_3 \rightarrow Fe(NO_3)_2 + H_2S$$

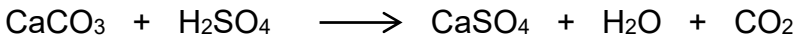
(h) Is the reaction above a redox equation? If so, why? If not, why not?

(i) For each of the following reactions, determine if any elements are being oxidized or reduced. If there is oxidation and reduction, identify the oxidation numbers for the elements that are changing on both sides of the equation.

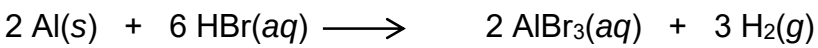


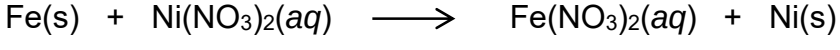






(j) Write the net ionic equation for each reaction





A list of metals arranged in order of decreasing ease of oxidation is called an activity series. The metals at the top of the table are most easily oxidized. The metals at the bottom of the table are very stable. Any metal on the list can be oxidized by the ions of the elements below it. See Table 4.5 on page 136 in your textbook.

(k) For each of the following reactions, use the activity series to determine if a reaction occurs. If a reaction occurs, write the net ionic equation for the reaction.

Tin metal is added to a solution of magnesium nitrate.

Aluminum metal is added to a solution of copper(II) chloride.

Zinc metal is added to a solution of hydrobromic acid.

Platinum metal is added to a solution of hydrochloric acid.