Name: ____

Chemistry 117 Laboratory
University of Massachusetts Boston

FIVE UNLABELED BOTTLES

LEARNING GOALS

1. Become familiar with applying the solubility rules to predict whether a precipitate forms.
2. Become familiar with other common reactions that involve the evolution of gases as a product.
3. Become adept at writing net ionic equations.
4. Obtain exposure to deductive reasoning as a scientific approach.

INTRODUCTION

Salts are ionic compounds held together by strong ionic bonds. Some salts are soluble in water and some are insoluble in water. If a salt is soluble in water, it dissociates into solvated cations and anions, which implies that the ion-dipole interactions between the ions and the polar water molecules supply a solvation energy that is greater than the strength of the ionic bonds holding the structure of the salt in place. On the other hand, if a salt is insoluble in water, it implies that the ion-dipole interactions between the ions and the water molecules are not strong enough to overcome the strength of the ionic bonds holding the structure of the salt in place. Salts that are insoluble in water are often relatively soluble in acid. Whether a salt is soluble or not in water can be predicted using the solubility rules.

Solubility Rules

1. All compounds of the ammonium ion (NH_4^+), and of Alkali metal (Group IA) cations, are soluble.
2. All nitrates (NO_3^-) and acetates (ethanoates) are soluble.
3. All chlorides (Cl^-), bromides (Br^-) and iodides (I^-) are soluble **EXCEPT** those of silver, lead and mercury(I).
4. All sulphates (SO_4^{2-}) are soluble **EXCEPT** those of lead, mercury(I), barium, strontium and calcium (silver is slightly soluble).
5. All carbonates (CO_3^-), sulfites (SO_3^{2-}) and phosphates (PO_4^{3-}) are insoluble **EXCEPT** those of ammonium (NH_4^+) and Alkali metal (Group IA) cations.
6. All hydroxides (OH^-) are insoluble **EXCEPT** those of ammonium (NH_4^+), barium (Ba^{2+}) and alkali metal (Group I) cations.
7. All sulfides (S^-) are insoluble **EXCEPT** those of ammonium (NH_4^+), Alkali metal (Group I) cations and Alkali earth metal (Group II) cations.
8. All oxides (O^{2-}) are insoluble **EXCEPT** those of calcium (Ca^{2+}, barium (Ba^{2+}) and Alkali metal (Group I) cations; these soluble ones actually react with the water to form hydroxides (hydrolyse).

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When solutions that contain different soluble salts are mixed, the anion of one salt may form a precipitate with the cation of the other salt. The solubility rules can be used to predict whether or not a precipitate forms. For example, if a dilute (0.1 M) solution of NaCl is mixed with a dilute solution of $AgNO_3$, a precipitate forms. Both NaCl and $AgNO_3$ are soluble salts, thus Na^+, Cl^-, Ag^+ and NO_3^- are floating around in solution the instance these solutions are mixed. NaCl is a soluble salt (rule 1: all alkali metal salts are soluble). $AgNO_3$ is soluble (Rule 2: all nitrates are soluble). Will something precipitate? What are the possibilities? Well, it could be $NaNO_3$ or AgCl. However, $NaNO_3$ is a soluble salt by both rules 1 and 2. AgCl must be the precipitate, just as rule 3 predicts. This type of a reaction is often referred to as double replacement reaction because the anions and cations of both salts switch partners.

$NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$

Try to predict the products of the following reactions using the solubility rules.

$AgNO_3$ and $CuCl_2$

$Ba(NO_3)_2$ and $CuSO_4$

KCl and $Ba(NO_3)_2$

$ZnCl_2$ and NaOH

HCl and NaOH

CaS and $Pb(NO_3)_2$

When acids react with carbonates, sulfides and sulfites, gas evolves (CO_2 for the carbonates, H_2S for sulfides and SO_2 for sulfites).
For example,

$$HCl_{(aq)} + NaHCO_{3(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$
$$2HCl_{(aq)} + NaS_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2S_{(g)}$$
$$2HCl_{(aq)} + Na_2SO_{3(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + SO_{2(g)}$$

These are special acid/base reactions. Many acid/base reactions do not involve the evolution of a gas, but yield only a soluble salt and water, such as the reaction between $HCl_{(aq)}$ and $NaOH_{(aq)}$, which produces $NaCl_{(aq)}$ and water.

Predict the products of the following reaction

$HNO_{3(aq)}$ and $Na_2CO_{3(aq)}$

$HNO_{3(aq)}$ and $K_2S_{(aq)}$

$HClO_{4(aq)}$ and $Li_2SO_{3(aq)}$

$H_2SO_{4(aq)}$ and $NaOH_{(aq)}$
(HINT: this is an acid/base reaction that does not produce gas)

Net Ionic Equation

The true nature of a soluble salt in water is solvated cations and anions evenly dispersed throughout the solution. Very little interaction occurs between the cations and anions because the strength of the solvation by the surrounding water molecules is very strong (ion-dipole interactions). Therefore, $NaCl_{(aq)}$ is perhaps more accurately written as $Na^+_{(aq)} + Cl^-_{(aq)}$. If reactions are presented with the soluble ions written separately, it is called the *ionic equation*. Ions that are present as both reactants and products do not actually participate in the reaction and they are called spectator ions. If these species are removed from the ionic equation, it is called the *net ionic equation*.

For example,

Overall reaction: $NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$
Ionic equation: $Na^+_{(aq)} + Cl^-_{(aq)} + Ag^+_{(aq)} + NO_3^-{}_{(aq)} \rightarrow Na^+_{(aq)} + NO_3^-{}_{(aq)} + AgCl_{(s)}$
Net ionic equation: $\cancel{Na^+_{(aq)}} + Cl^-_{(aq)} + Ag^+_{(aq)} + \cancel{NO_3^-{}_{(aq)}} \rightarrow \cancel{Na^+_{(aq)}} + \cancel{NO_3^-{}_{(aq)}} + AgCl_{(s)}$
$Cl^-_{(aq)} + Ag^+_{(aq)} \rightarrow AgCl_{(s)}$

For practice, try writing the net ionic equation for each of the reactions on pg 2. *On the prelab quiz, you will be asked to select the correct net ionic equation for one of these eight reactions.*

The Challenge

In the experiment you are confronted with a set of reagent bottles without labels. Each bottle contains an aqueous solution of a single ionic compound. Although we do not know the contents of any particular bottle, we do remember the list of five compounds. You are asked to identify the compound in each bottle. You must gather clues by mixing small samples from pairs of bottles and examining the mixture for evidence of a chemical reaction. Most of the chemical reactions will either form a precipitate or evolve gas. The colors of the solution may also provide clues. You must use the solubility rules and the examples of gas evolution given above as a guide to help you correctly identify the contents of each bottle.

PROCEDURE

You are asked to solve the puzzle of the five unlabeled bottles twice, for two separate sets which are denoted I and II. Each such set is a separate experiment and separate data sheets are provided. Do not mix any solution from Set I with one from Set II. The list of five compounds is given on the data sheet.

Within each set, the bottles are identified as A, B, C, D and E. The data sheet has spaces where you can write your observations of the color of each solution and any evidence of chemical reaction that you see when mixing samples from a pair of bottles. Rinse a test tube with water and then mix a few drops of solution from a pair of bottles. Swirl the contents, wait a few seconds for the reaction to occur and note your observation on the data sheet. If you observe no evidence of a reaction, write “see nothing” in the box.

After finishing all ten pairs from one set, compare your observations with your predictions of expected reactions and solve the puzzle of naming the compounds in A, B, C, D and E. Write your answers at the bottom of the sheet. Then go back and write a net ionic equation in each box in which a chemical reaction occurs. Understand that there may be pairs of compounds which react without forming a precipitate or gaseous product. You must write the net ionic reactions for these also.

Your report for this experiment consists of the two data sheets with all the blanks filled in.
Name ________________________________ Lab Section ____________________________

Five Unlabeled Bottles
Set I

Fill out the work sheet bellow and use it as a guide to decipher your unknowns. Using the solubility chart as a guide, draw an arrow connecting the cations of one salt that will form a precipitate with the anion from another salt.

compound	compound name	Cation formula	Connect reacting ions	anion formula
$CuSO_4$				
$Ba(NO_3)_2$				
$CuCl_2$				Cl^-
$AgNO_3$		Ag^+	→	
KCl				

Summarize what you expect to see after mixing all ten possible pairs of solutions. If you expect to see a reaction, write what you expect to see (precipitate, gas evolution, color change, ect.) If you do not expect a reaction to occur, write "no rxn".

$CuSO_4$, $Ba(NO_3)_2$			
$CuSO_4$, $CuCl_2$	$Ba(NO_3)_2$, $CuCl_2$		
$CuSO_4$, $AgNO_3$	$Ba(NO_3)_2$, $AgNO_3$	$CuCl_2$, $AgNO_3$	
$CuSO_4$, KCl	$Ba(NO_3)_2$, KCl	$CuCl_2$, KCl	$AgNO_3$, KCl

How many of the reactions do you expect to form precipitates?
How many of the reactions do you expect to evolve gas?
How many other reactions do you expect to occur?
How many reactions in total do you expect to occur?

Five unlabeled bottles.

OBSERVATIONS

Mix the unknown solutions A-E according to the chart below and record your observations. If there is a chemical reaction, write the net ionic equation.

A,B			
A,C	B,C		
A,D	B,D	C,D	
A,E	B,E	C,E	D,E

Record the color of the initial solutions for unknowns A-E as either colorless or blue:

A______________ B______________ C______________ D______________ E______________

Identify the unknown solutions:

A______________ B______________ C______________ D______________ E______________

Name ________________________________ Lab Section ___________________________

Five Unlabeled Bottles ***Set II***

Fill out the work sheet bellow and use it as a guide to decipher your unknowns. Using the solubility chart as a guide, draw an arrow connecting the cations of one salt that will form a precipitate with the anion from another salt.

compound	compound name	Cation formula	Connect reacting ions	anion formula
$ZnCl_2$				
KOH				
HCl				
Na_2CO_3				
LiBr				

Summarize what you expect to see after mixing all ten possible pairs of solutions. If you expect to see a reaction, write what you expect to see (precipitate, gas evolution, color change, ect.) If you do not expect a reaction to occur, write "no rxn".

$ZnCl_2$, KOH			
$ZnCl_2$, HCl	KOH, HCl		
$ZnCl_2$, Na_2CO_3	KOH, Na_2CO_3	HCl, Na_2CO_3	
$ZnCl_2$, LiBr	KOH, LiBr	HCl, LiBr	Na_2CO_3, LiBr

How many of the reactions do you expect to form precipitates?

How many of the reactions do you expect to evolve gas?

How many other reactions do you expect to occur?

How many reactions in total do you expect to occur?

Five unlabeled bottles.

OBSERVATIONS

Mix the unknown solutions A-E according to the chart below and record your observations. If there is a chemical reaction, write the net ionic equation.

A,B			
A,C	B,C		
A,D	B,D	C,D	
A,E	B,E	C,E	D,E

Record the color of the initial solutions for unknowns A-E as either colorless or blue:

A______________ B______________ C______________ D______________ E______________

Identify the unknown solutions:

A______________ B______________ C______________ D______________ E______________

Five unlabeled bottles.

Lab Report:

There will be no abstract required for this experiment. Your lab report will consist of your data sheets (pg 5-8) and a summary of your identifications. The data sheet is worth 30 points.

The Summary: Identify each of the unknown solution in Part 1 and 2 and describe how you came to these conclusions based on your experimental observations. (There are 10 unknowns, all together so you will receive 1 point for the correct identification of each unknown solution and 2 points each for the correct explanation of how you were able to use your experimental observations to deduce the identification of the unknown).