AP Chemistry By Satellite
Laboratory Manual
Instructor's Edition

EXPERIMENT 9: SOLUBILITIES

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Reagents

CHEMICAL	Quantity	CHEMICAL	Quantity
ammonium chloride	0.50 g	potassium nitrate	0.50 g
ammonium nitrate	0.50 g	silver nitrate	0.50 g
barium nitrate	0.50 g	sodium acetate trihydrate	0.50 g
barium sulfate	0.50 g	sodium bromide	0.50 g
calcium nitrate tetrahydrate	0.50 g	sodium carbonate	0.50 g
copper (II) carbonate	0.50 g	sodium chloride	0.50 g
copper (II) nitrate trihydrate	0.50 g	sodium hydroxide	0.50 g
lead (II) nitrate	0.50 g	sodium nitrate	0.50 g
potassium chloride*	0.10 g	sodium sulfate	0.50 g
		deionized water	~100 mL

Solids should be provided to students in vials with microspatula caps. Wrap the vial containing silver nitrate with electricians tape to protect it from light. All samples should be crushed into small crystals before placing into vials. Remember, the crystals must fit into the wells of the 96–well plate.

Deionized water may have to be used for preparing solutions and dissolving solids in this experiment. The concentration of chloride ion in deionized water may be enough to cause precipitation of silver chloride.

*These solids are used only in the preparation of the unknown.

A labeled waste container is needed for the following reagents;

barium nitrate
barium sulfate
cupric carbonate
cupric nitrate
lead nitrate
silver nitrate

Unknown Preparation

Unknowns should be provided to the students in groups of four 13 x 100 mm test tubes. The group of tubes should be labeled with an identification number and a list of all the ions found in the group. All solutions used should be 0.1M. Approximately 5 mL of each unknown should be sufficient for identification.

Suggested unknown combinations:

	Test Tubes				
Unk. #	A	B	C	D	List of ions
1	Na_2SO_4	$AgNO_3$	NaCl	$Cu(NO_3)_2$	Na^+,Ag^+,Cu^{2+},SO_4^{2-},NO_3^-,Cl^-
2	$Cu(NO_3)_2$	$Pb(NO_3)_2$	Na_2CO_3	NaCl	Cu^{2+},Pb^{2+},Na^+,NO_3^-,CO_3^{2-},Cl^-
3	$Ba(NO_3)_2$	$AgNO_3$	$Cu(NO_3)_2$	NaOH	Ba^{2+},Ag^+,Cu^{2+},Na^+,NO_3^-,OH^-
4	$AgNO_3$	NaOH	Na_2SO_4	Na_2CO_3	Ag^+,Na^+,NO_3^-,OH^-,SO_4^{2-},CO_3^{2-}
5	KCl	$Pb(NO_3)_2$	$Cu(NO_3)_2$	$AgNO_3$	K^+,Pb^{2+},Cu^{2+},Ag^+,Cl^-,NO_3^-
6	$Ba(NO_3)_2$	KCl	$Pb(NO_3)_2$	$AgNO_3$	Ba^{2+},K^+,Pb^{2+},Ag^+,NO_3^-,Cl^-

Solution Preparation:

Use values from the table below to prepare the solutions of the salts needed in this experiment. (See Appendix I & III. for more detail.) Multiply both weight and volume columns by the number of students in the class to determine the total mass of salt required and to obtain the total amount of solution required.

The table gives amounts needed to prepare 5 mL (one unknown sample) of each solution. Multiply the mass of the salt and the volume of solution by the number of students to receive that unknown to determine the total amounts you will need. It is also suggested that you prepare 25 to 50% more solution than your calculated value so that extra unknown is available for students having difficulties.

Salt	Conc. of salt	Weight of salt	Vol. of solution
$Ba(NO_3)_2$ (barium nitrate)	0.1 M	0.131 g	5 mL
$Cu(NO_3)_2 \cdot 3H_2O$ (copper(II) nitrate)	0.1 M	0.121 g	5 mL
$Pb(NO_3)_2$ (lead(II) nitrate)	0.1 M	0.166 g	5 mL
KCl (potassium chloride)	0.1 M	0.037 g	5 mL
$AgNO_3$ (silver nitrate)	0.1 M	0.085 g	5 mL
Na_2CO_3 (sodium carbonate)	0.1 M	0.053 g	5 mL
NaCl (sodium chloride)	0.1 M	0.029 g	5 mL
NaOH (sodium hydroxide)	0.1 M	0.020 g	5 mL
Na_2SO_4 (sodium sulfate)	0.1 M	0.077 g	5 mL

Equipment

EQUIPMENT	**Quantity**
plate, 96-well	2
dropper	1
beaker, 50 mL	1
microstirrer	1

For information on obtaining well plates, microscale stirrers, and a block of bottles with micro-spatulas attached to the cap, see Appendix VI.

Useful Experimental Comments

Experiment Scheduling

This experiment will require approximately 3-4 hours to complete.

Students should complete **Part I** by the end of the first laboratory period. The solutions prepared in the first lab period are to be used in completing **Part II** during the second portion of the experiment. **Part III**, the unknown, can be completed during the third laboratory hour. If solutions from **Part I** are not saved and have to be regenerated in **Part II**, the experiment will take longer to complete.

College Board Recommendations: This experiment is not one specifically recommended by the College Board for AP Chemistry students. However, the experience gained in descriptive chemistry and writing chemical reactions should prove valuable on the AP Exam.

Microscale techniques similar to those used in Experiment 6,"Conductivity" will be used in this experiment. Students should use that laboratory report as a reference to assist in the completion of this experiment.

PART I: Solubility of Some Selected Salts:

The students will measure the solubility of a group of ionic compounds (Table I) by adding small amounts of the solid to water and recording their observations. While the list of compounds in Table I includes 7 different anions and 10 different cations, it does not include a large number of combinations. The second part of the experiment will have the students develop a more complete list of the solubility of all anions and cations. Students will also extend their understanding of ionic and net ionic equations.

You need to remind the students to use small amounts of the solid in the wells; a few crystals are sufficient. If too much solid is used, it will be difficult to distinguish between a small amount of the solid dissolving and none of the solid dissolving. Some of the solids will dissolve at a slower rate than others. Caution your students to allow time for the solids to dissolve so as not to reach an incorrect conclusion regarding the solubility of the compound. Students should be reminded to clean the microstirrers carefully between uses. It is very important that the students are organized and careful about recording their observations when using the 96–well plate.

Students must save those solutions containing soluble salts for use in part II of the experiment. Covering the well plates with the plastic lids and/or wrapping them in plastic wrap will minimize evaporation of the solutions.

Table II (Solubility Information) should be completed as each observation is made. Students are encouraged to complete the ionization equation as they measure the solubility. During the data collection, check students' observations and entries in Table II.

The generalizations which the students are expected to make are not particularly sophisticated. Conclusions after the limited samples of compounds from Table I may appear rather cumbersome or uninformative to some of your students. Suggest to the students who point this out that following more extensive testing it may be possible to make broader generalizations about the solubility behavior of particular ions.

PART II: Solubility of Other Salts

Check the well plates at the beginning of the next laboratory period and add deionized water to those wells where the water level has dropped. The wells must be nearly full to provide enough solution for the second part of the experiment.

The second section is quite different from the first and some of your students may find it rather difficult. Students are faced with the question of determining the solubility of a salt, $NaNO_3$, by inference. In order to reach a conclusion, students are expected to select two compounds from Table I and then mix solutions of the two compounds. The choice of which two compounds to mix must be made carefully as one of the products must be known to be soluble and the other product must be $NaNO_3$. If two compounds are selected such that the known compound is insoluble, it will be difficult (at the student's current level of understanding) to tell experimentally whether $NaNO_3$ did not also precipitate. If some of your students have a difficult time figuring out the combination you might consider the following approach;

> Suggest to the student an equation of the following form is required;
>
> $$\_\_\_\_\_ + \_\_\_\_\_ \rightarrow \_\_\_\_\_ + NaNO_3$$
>
> Ask the student where the Na^+ and the NO_3^- must come from on the reactant side of the equation. Clearly one of the reactants must contain Na^+ and the other NO_3^-. Then re–write the equation:
>
> $$Na^+\_\_\_ + \_\_\_NO_3^- \rightarrow \_\_\_\_\_ + NaNO_3$$
>
> Now the student must select a salt from Table I which contains Na^+ and a salt which contains NO_3^- such that the other combination of ions is a soluble salt also in Table I.

A second example is included to further drive home the thought process. The point of these two exercises is to show the students the logic which is needed to complete the second part of the experiment, the expansion of the solubility information.

Table III is completed by observing the results of mixing solutions obtained in **Part I**. If the solutions saved from **Part I** have evaporated, they can be regenerated by adding deionized water to the wells. The wells will need to be nearly full in order to have enough solution to complete **Part II**.

Table IV should be used to summarize the observations for the solubility of the salts. This information should then be summarized in as few statements as possible . All ionic and net ionic equations should also be written for the tests which are completed.

Be careful to recognize that some of the compounds are slightly soluble. Depending on the amount of reactants mixed students may have different observations. This is likely to occur for silver sulfate, Ag_2SO_4, and lead chloride, $PbCl_2$.

PART III: Identifying Solutions of Unknown Salts

Each student is expected to identify an unknown to provide them with the opportunity to test their understanding of solubility and precipitation concepts. Provide students with unknowns in 4-13 x 100 mm test tubes filled with solutions described in the preparation section. Along with the four test tubes the students should be given a list of all the cations and anions which are present. At least one ion in each test tube will be identifiable. If the counter ion can not be identified on the basis of solubility, the students are expected to make a logical guess as to its identity. Two sheets are provided in the laboratory: one to record experiments and observations and the second to list and justify conclusions about the identity of the ions in the test tubes.

EXPERIMENT 9: SOLUBILITIES

Pre-lab Questions:

Answer these questions before coming to class. They introduce you to several important ideas that you will use in this experiment. You must turn-in this exercise before you will be allowed to begin the experiment. Be sure to bring a calculator and paper to laboratory.

1. Define solubility.

   Solubility is a measure of the amount of solute that will dissolve in water. Substances are qualitatively classed as soluble, slightly soluble or insoluble in water.

2. Define precipitation.

   Precipitation is the process of forming an insoluble solid in solution.

3. Write the balanced molecular equation, the complete ionic equation, and the net ionic equation for the reaction of $Na_2CO_3(aq)$ with $AgNO_3(aq)$.

$$\mathbf{Na_2CO_3}(aq) + \mathbf{2\ AgNO_3}(aq) \rightarrow \mathbf{Ag_2CO_3}(s) + \mathbf{2\ NaNO_3^-}(aq)$$

$$\mathbf{2Na^+}(aq) + \mathbf{CO_3^{2-}}(aq) + \mathbf{2Ag^+}(aq) + \mathbf{2NO_3^-}(aq) \rightarrow \mathbf{Ag_2CO_3}(s) + \mathbf{2Na^+}(aq) + \mathbf{2NO_3^-}(aq)$$

$$\mathbf{2Ag^+}(aq) + \mathbf{CO_3^{2-}}(aq) \rightarrow \mathbf{Ag_2CO_3}(s)$$

EXPERIMENT 9: SOLUBILITIES

EQUIPMENT:
96-well plate........................... 2
50 mL beaker.......................... 1
dropper................................. 1
microstirrer 1

PART I: Solubility of Some Selected Salts

Table I. contains a list of salts whose solubilities are to be determined in this experiment.

Table I. Solid Salts

Na_2SO_4	$NaCl$
Na_2CO_3	$NaOH$
$NaC_2H_3O_2$	$NaBr$
NH_4NO_3	NH_4Cl
$Cu(NO_3)_2$	$CuCO_3$
$Ba(NO_3)_2$	$BaSO_4$
KNO_3	
$Ca(NO_3)_2$	
$Pb(NO_3)_2$	
$AgNO_3$	

All of these solid salts are available in the laboratory. Each of the bottles containing the salts has a microspatula inserted into the stopper which is to be used for dispensing. **Do not mix spatulas at any time.** Contamination will result.

Complete Table II by writing the formula (column 2) for each salt and noting the color (column 3) of each of the compounds. Solubilities (column 4) can be determined by placing a *few crystals* into the bottom of a well in the 96–well plate. Carefully label each well (column 1), identifying the salt contained in the solution. As you transfer the salts to the well be careful not to spill the solid in adjacent wells. Fill the wells with deionized water using a dropper, leaving just enough room to stir the mixture. Do not overfill the wells. Use a microstirrer to carefully mix the contents of each well. Be sure to carefully clean the microstirrer between uses! Some solids may dissolve faster than others. Be sure to perform your tests carefully so that you can be confident your observations are correct. <u>You must save the solutions formed for later parts of the experiment.</u> For those compounds which are soluble in water, note the color of the solution (column 5) and also identify the ions in the solution (column 6).

Table II. Solubility Information

Well #	Compound	Color of solid	Solubility in water	Color of solution	Identify ions in solution
	$NaCl$	**white**	**yes**	**colorless**	**Na^+, Cl^-**
	$NaOH$	**white**	**yes**	**colorless**	**Na^+, OH^-**
	$NaBr$	**white**	**yes**	**colorless**	**Na^+, Br^-**
	Na_2SO_4	**white**	**yes**	**colorless**	**Na^+, SO_4^{2-}**
	Na_2CO_3	**white**	**yes**	**colorless**	**Na^+, CO_3^{2-}**
	$NaC_2H_3O_2$	**white**	**yes**	**colorless**	**Na^+, $C_2H_3O_2^-$**
	NH_4Cl	**white**	**yes**	**colorless**	**NH_4^+, Cl^-**
	NH_4NO_3	**white**	**yes**	**colorless**	**NH_4^+, NO_3^-**
	KNO_3	**white**	**yes**	**colorless**	**K^+, NO_3^-**
	$CuCO_3$	**green**	**no**		
	$Cu(NO_3)_2$	**blue**	**yes**	**blue**	**Cu^{2+}, NO_3^-**
	$Ca(NO_3)_2$	**white**	**yes**	**colorless**	**Ca^{2+}, NO_3^-**
	$Ba(NO_3)_2$	**white**	**yes**	**colorless**	**Ba^{2+}, NO_3^-**
	$Pb(NO_3)_2$	**white**	**yes**	**colorless**	**Pb^{2+}, NO_3^-**
	$AgNO_3$	**grey**	**yes**	**colorless**	**Ag^+, NO_3^-**
	$BaSO_4$	**white**	**no**		

For ionic compounds we can write equations which reflect solubility behavior. If the compound is soluble, the equation is written as:

$$\mathbf{MX}_{(s)} \xrightarrow{\mathbf{H_2O}(l)} \mathbf{M^+}(aq) + \mathbf{X^-}(aq)$$

The equation reads as follows: when the solid ionic compound MX is added to water, it dissolves forming the aqueous ions M^+ and X^-. The presence or absence of ions can be determined by conductivity. If the compound is insoluble in water the equation can be written:

$$\mathbf{MY}_{(s)} \xrightarrow{\mathbf{H_2O}(l)} \textbf{WND (will not dissolve)}$$

Write the solubility equations for the compounds listed in Table I using the approach described above and the experimental data from Table II.

Equations 1 – 16

$$Na_2SO_4(s) \xrightarrow{H_2O(l)} 2Na^+(aq) + SO_4^{2-}(aq)$$

$$Na_2CO_3(s) \xrightarrow{H_2O(l)} 2Na^+(aq) + CO_3^{2-}(aq)$$

$$NaC_2H_3O_2(s) \xrightarrow{H_2O(l)} Na^+(aq) + C_2H_3O_2^-(aq)$$

$$NaCl(s) \xrightarrow{H_2O(l)} Na^+(aq) + Cl^-(aq)$$

$$NaOH(s) \xrightarrow{H_2O(l)} Na^+(aq) + OH^-(aq)$$

$$NaBr(s) \xrightarrow{H_2O(l)} Na^+(aq) + Br^-(aq)$$

$$NH_4Cl(s) \xrightarrow{H_2O(l)} NH_4^+(aq) + Cl^-(aq)$$

$$NH_4NO_3(s) \xrightarrow{H_2O(l)} NH_4^+(aq) + NO_3^-(aq)$$

$$KNO_3(s) \xrightarrow{H_2O(l)} K^+(aq) + NO_3^-(aq)$$

$$CuCO_3(s) \xrightarrow{H_2O(l)} \text{WND}$$

$$Cu(NO_3)_2(s) \xrightarrow{H_2O(l)} Cu^{2+}(aq) + 2NO_3^-(aq)$$

$$Ca(NO_3)_2(s) \xrightarrow{H_2O(l)} Ca^{2+}(aq) + 2NO_3^-(aq)$$

$$Ba(NO_3)_2(s) \xrightarrow{H_2O(l)} Ba^{2+}(aq) + 2NO_3^-(aq)$$

$$Pb(NO_3)_2(s) \xrightarrow{H_2O(l)} Pb^{2+}(aq) + 2NO_3^-(aq)$$

$$AgNO_3(s) \xrightarrow{H_2O(l)} Ag^+(aq) + NO_3^-(aq)$$

$$BaSO_4(s) \xrightarrow{H_2O(l)} \text{WND}$$

Study the list of ions identified in column 6 of Table II. Do you see any patterns of solubility behavior in compounds containing identical cations or anions? Summarize the solubility behavior of each ion below.

Gen. #1

Ion	**Name**	**Solubility**
Na^+	sodium	all tested salts are soluble (SO_4^{-2}, Cl^-, OH^-, Br^-, CO_3^{2-}, $C_2H_3O_2^-$)
NH_4^+	ammonium	all tested salts are soluble (Cl^-, NO_3^-)
K^+	potassium	all tested salts are soluble (NO_3^-)
Cu^{2+}	copper(II)	NO_3^- salt is soluble
Ca^{2+}	calcium	NO_3^- salt is soluble
Ba^{2+}	barium	NO_3^- salt soluble CO_3^{2-} salt insoluble
Pb^{2+}	lead	NO_3^- salt soluble
Ag^+	silver	NO_3^- salt soluble
SO_4^{2-}	sulfate	Na^+ salt soluble Ba^{2+} salt insoluble

Gen. #1 (continued)

CO_3^{2-}	**carbonate**	**Na^+ salt soluble** **Cu^{2+} salt insoluble**
Cl^-	**chloride**	**Na^+, NH_4^+ salts are soluble**
OH^-	**hydroxide**	**Na^+ salt is soluble**
Br^-	**bromide**	**Na^+ salt is soluble**
$C_2H_3O_2^-$	**acetate**	**Na^+ salt is soluble**
NO_3^-	**nitrate**	**K^+, NH_4^+, Cu^{2+}, Ca^{2+}, Ba^{2+}, Pb^{2+}, Ag^+ salts are soluble**

EXPERIMENT 9: SOLUBILITIES

EQUIPMENT:
96-well plate.......................... 2
50 mL beaker......................... 1
dropper................................ 1
microstirrers.......................... 1

PART II: Solubility of Other Salts

It is possible to expand our observations by mixing pairs of compounds whose solubilities are known (Table I) and observing the solubility behavior of the products.

What experiment would you perform to determine the solubility of sodium nitrate, assuming that the storeroom has no solid $NaNO_3$ available for your use?

Expl. #1

Mix a solution of NH_4NO_3 and NaCl. We already know that NH_4Cl is soluble so if there is a precipitate it will be $NaNO_3$. If there is no precipitate then $NaNO_3$ is soluble.

Check the experiment with your instructor. When he or she approves, perform the experiment. Record your observations on the solubility of $NaNO_3$.

Obs #1

No precipitate is formed, therefore, $NaNO_3$ is soluble.

Do you have sufficient information in your solubility data to predict the solubility of $PbSO_4$? If so, what is your prediction?

Pred. #2

No, there is not enough information to predict whether $PbSO_4$ is soluble or insoluble. Based on past chemical information students may predict that $PbSO_4$ is insoluble.

What experiment would you perform to determine the solubility of $PbSO_4$, assuming the storeroom has no solid $PbSO_4$ available for you to use?

Expl. #2

Mix $Pb(NO_3)_2$ and Na_2SO_4. We know from the previous experiment that $NaNO_3$ is soluble. If a precipitate forms when the two solutions are mixed, it will be $PbSO_4$.

In the following portion of the experiment you will be working with solutions you prepared in the first part of the experiment. If the solutions have evaporated, add a few drops of deionized water to each well. The wells will need to be almost full in order to have enough solution to complete the experiment. Use Table II to locate the needed solutions and a dropper to transfer the needed amounts. Be sure to rinse the dropper thoroughly with deionized water when changing solutions.

TABLE A

Na_2SO_4	Na_2CO_3	$NaC_2H_3O_2$	NaCl	NaOH	NaBr

TABLE B

NH_4NO_3	KNO_3	$Cu(NO_3)_2$	$Ba(NO_3)_2$	$AgNO_3$	$Ca(NO_3)_2$	$Pb(NO_3)_2$

Using a clean 96-well plate, place one drop of a nitrate compound (Table B) in the first six wells of a vertical column in your 96-well plate. For example, the first six vertical wells, C1-H1, would each contain one drop of NH_4NO_3. The second six vertical wells, C2-H2, would each contain one drop KNO_3.

Add one drop of each solution in Table A horizontally across the 96-well plate. For example, put one drop of Na_2SO_4 in C1 through C7 followed by one drop of Na_2CO_3 in wells D1 through D7. Record your results, identifying the formation of a precipitate and/or color changes, if any, in each well.

Complete Table III with the well location and the formulas of the possible products formed. Two of the cells in Table III have been completed as examples.

Table III

	NH_4NO_3	KNO_3	$Cu(NO_3)_2$	$Ba(NO_3)_2$	$AgNO_3$	$Ca(NO_3)_2$	$Pb(NO_3)_2$
Na_2SO_4	$NaNO_3$*(a)* $(NH_4)_2SO_4$ *(aq*	K_2SO_4*(aq)* $NaNO_3$*(aq)*	$CuSO_4$*(aq)* $NaNO_3$*(aq)*	$BaSO_4$*(s)* $NaNO_3$*(aq)*	Ag_2SO_4*(s* $NaNO_3$*(aq)*	$CaSO_4$*(s)* $NaNO_3$*(aq)*	$PbSO_4$*(s)* $NaNO_3$*(aq)*
Na_2CO_3	$(NH_4)_2CO_3$ *(aq)* $NaNO_3$*(aq)*	K_2CO_3*(aq)* $NaNO_3$*(aq)*	$CuCO_3$*(s)* $NaNO_3$*(aq)*	$BaCO_3$*(s)* $NaNO_3$*(aq)*	Ag_2CO_3*(s)* $NaNO_3$*(aq)*	$CaCO_3$*(s)* $NaNO_3$*(aq)*	$PbCO_3$*(s)* $NaNO_3$*(aq)*
$NaC_2H_3O_2$	$NH_4C_2H_3O_2$ $NaNO_3$*(aq)*	$KC_2H_3O_2$ $NaNO_3$*(aq)*	$Cu(C_2H_3O_2)_2$ $NaNO_3$*(aq)*	$Ba(C_2H_3O_2)_2$ $NaNO_3$*(aq)*	$AgC_2H_3O_2$ $NaNO_3$*(aq)*	$Ca(C_2H_3O_2)_2$ $NaNO_3$*(aq)*	$Pb(C_2H_3O_2)_2$ $NaNO_3$*(aq)*
NaCl	NH_4Cl*(aq)* $NaNO_3$*(aq)*	KCl*(aq)* $NaNO_3$*(aq)*	$CuCl_2$*(aq)* $NaNO_3$*(aq)*	$BaCl_2$*(aq)* $NaNO_3$*(aq)*	AgCl*(s)* $NaNO_3$*(aq)*	$CaCl_2$*(aq)* $NaNO_3$*(aq)*	$PbCl_2$*(s)* $NaNO_3$*(aq)*
NaOH	NH_3*(aq)* $NaNO_3$*(aq)*	KOH*(aq)* $NaNO_3$*(aq)*	$Cu(OH)_{2(s)}$ $NaNO_3$*(aq)*	$Ba(OH)_{2}$*(aq)* $NaNO_3$*(aq)*	AgOH*(aq)* $NaNO_3$*(aq)*	$Ca(OH)_2$*(aq)* $NaNO_3$*(aq)*	$Pb(OH)_2$*(s)* $NaNO_3$*(aq)*
NaBr	NH_4Br*(aq)* $NaNO_3$*(aq)*	KBr*(aq)* $NaNO_3$*(aq)*	$CuBr_2$*(aq)* $NaNO_3$*(aq)*	$BaBr_2$*(aq)* $NaNO_3$*(aq)*	AgBr*(s)* $NaNO_3$*(aq)*	$CaBr_2$*(aq)* $NaNO_3$*(aq)*	$PbBr_2$*(s)* $NaNO_3$*(aq)*

Use the information in Tables II and III to complete Table IV. If the compound is insoluble, put an "I" in the cell. If the compound is soluble, put an "S" in the cell. (Note: *Data obtained from Table II.)

Table IV. Solubility Summary

	Na^+	NH_4^+	K^+	Cu^{2+}	Ba^{2+}	Ag^+	Ca^{2+}	Pb^{2+}
SO_4^{2-}	**S** *	**S**	**S**	**S**	**I**	**I**	**I**	**I**
CO_3^{2-}	**S** *	**S**	**S**	**I**	**I**	**I**	**I**	**I**
$C_2H_3O_2^-$	**S** *	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Cl^-	**S** *	**S** *	**S**	**S**	**S**	**I**	**S**	**I**
OH^-	**S** *	**S**	**S**	**I**	**S**	**S**	**S**	**I**
Br^-	**S** *	**S**	**S**	**S**	**S**	**I**	**S**	**I**
NO_3^-	**S**	**S** *	**S** *	**S** *	**S** *	**S** *	**S** *	**S** *

Summarize the experimental data contained in Table IV in as few statements as possible.

The response should be essentially the same as Gen. 1, but with more observations, the student should feel more confident in extending generalizations.

Ion	Name	Solubility
Na^+	sodium	all tested salts are soluble
NH_4^+	ammonium	all tested salts are soluble
K^+	potassium	all tested salts are soluble
Cu^{2+}	copper(II)	CO_3^{2-} and OH^- are insoluble, all others tested are soluble
Ca^{2+}	calcium	SO_4^{2-}, OH^- and Co_3^{2-} are insoluble, all others tested are soluble
Ba^{2+}	barium	SO_4^{2-} and CO_3^{2-} are insoluble, all others tested are soluble
Pb^{2+}	lead	NO_3^- and $C_2H_30_2^-$ salts are soluble, all others tested are insoluble
Ag^+	silver	NO_3^-, $C_2H_3O_2^-$, and OH^- salts soluble all others tested are insoluble
SO_4^{2-}	sulfate	Na^+, K^+, Cu^{2+} and NH_4^+ salts are soluble, all others tested are insoluble
CO_3^{2-}	carbonate	Na^+, K^+, and NH_4^+ salts are soluble, all others tested are insoluble
Cl^-	chloride	Ag^+ and Pb^{2+} salts are insoluble, all others tested are soluble.
OH^-	hydroxide	Cu^{2+} and Pb^{2+} salts are insoluble, all others tested are soluble.
Br^-	bromide	Ag^+ and Pb^{2+} salts are insoluble, all others tested are soluble.
$C_2H_3O_2^-$	acetate	all tested salts are soluble
NO_3^-	nitrate	all tested salts are soluble

EXPERIMENT 9: SOLUBILITIES

EQUIPMENT:
96-well plate.......................... 2
50 mL beaker......................... 1
dropper................................ 1
microstirrer 1

PART III: Identifying Solutions of Unknown Salts

You will now try to solve a problem based on the chemical experience you have accumulated to this point. You will be given 4 test tubes which will contain aqueous solutions of substances used in this experiment. You will also be given a list of the ions that are contained in the 4 test tubes. Your assignment is to determine which ions are in each test tube. Note that a given ion may be present in more than one test tube. Remember that if you identify a cation in a test tube there must be a corresponding anion present. You should be able to definitely identify at least one ion in each test tube. If you are unable to identify the counter ion you should make a logical guess. Be sure to differentiate between proof and guesses. You must justify each conclusion in writing!

You may test the unknowns by combining them with any of the substances used previously in this experiment. Use a clean 96-well plate and dropper to perform any needed tests. After receiving your test tubes with the list of ions or molecules, it may be a good idea to review those portions of your previous laboratory work that relates to those ions.

Record *all* experiments you perform on your unknown solutions, note important observations and record any conclusions you make as a result of the experiment. Be careful and accurate when you perform your experiments and when you record your observations and conclusions. Your instructor *must* be able to follow your logic when reading your observations and conclusions.

It is your responsibility to record the unknown number of the set of test tubes given to you. Not only is the number important for correctly grading your results, but in the event you require more unknown to complete all tests you will need the correct number in order to receive more of the same unknown.

Experiments and Observations

UNKNOWN # _________

Answers will vary. Students should perform experiments on each test tube appropriate to identify the ions on their lists.

Conclusions and Explanations

UNKNOWN # __________

A: _________ B: _________ C: _________ D: _________

Students should identify the ions in each test tube and justify those identifications with the experimental observations recorded on the previous page. Grading should be based both on the accuracy of the identifications and on the logic of the explanations.

Post-lab Questions:

The answers to the following problems should accompany your laboratory report.

1. Distinguish between the terms slightly soluble and weak electrolyte. (Refer to Conductivity Lab, Exp. #6.)

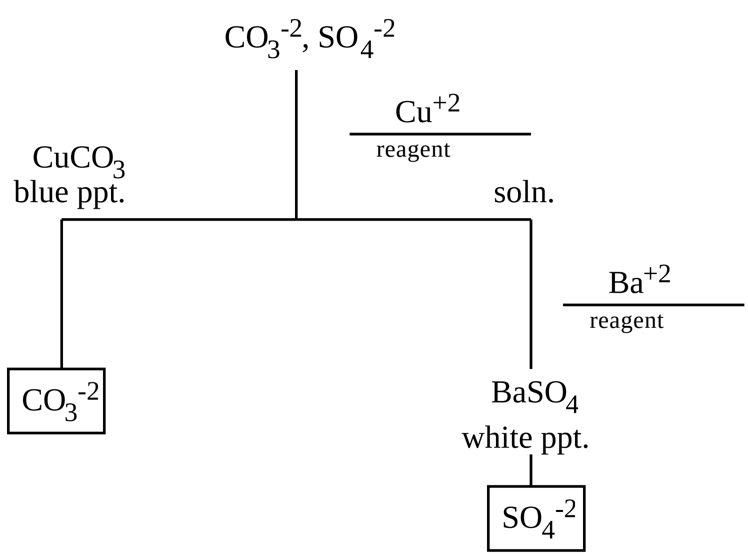
   A substance which is slightly soluble dissolves in water to a small extent, usually defined as between 0.01g/100 mL and 0.1g/100mL. A substance that is slightly soluble could be a strong electrolyte, weak electrolyte or a nonelectrolyte. A weak electrolyte is a substance which has a low electrical conductivity is water. The low electrical conductivity is a result of a low concentration of ions in solution. A weak electrolyte can be completely soluble in water, such as acetic acid.

2. What is the difference between separation and identification of substances?

   Separation is the act or process of isolating components of a mixture in a pure or reasonably pure form. Identification is the act of determining the exact chemical nature of the substance by comparing to known behavior.

3. A sample solution may contain either, both or neither of the following ions: CO_3^{2-} and SO_4^{2-}. Explain how you could determine the identity of the ions in the solution using the solubility data you collected in the experiment. Your answer may consist of a flow chart or a written explanation.

   Add $Cu(NO_3)_2$ solution to the solution. If a blue precipitate forms, CO_3^{2-} is present in the solution. If no precipitate forms, CO_3^{2-} is not present. To a sample of the liquid remaining after the first test, add $Ba(NO_3)_2$ solution. It a white precipitate forms, SO_4^{2-} is present in the solution. If no precipitate forms SO_4^{2-} is not present.



INSTRUCTOR EVALUATION
EXPERIMENT 9: SOLUBILITY

NAME: ____________________
SCHOOL: ____________________

Please complete the form as soon as possible after your students have completed the laboratory. Include any comments you have on each section of the experiment. If the answer to any question is “no” please note the specific problems or difficulties encountered. Attach extra sheets if necessary. At the end of the semester, return all forms to **Dr. John Gelder, Department of Chemistry, Oklahoma State University, Stillwater, OK 74078**. Your comments and suggestions are very important in helping to correct errors and improve the overall quality of this manual.

1. How much time was required to complete the experiment? _______ hours
   Briefly describe those sections of the experiment which were completed during each laboratory period. (Note: You may include Part numbers or page numers for simplicity.)

	NO	YES
2. Was the pre-lab exercise ...		
A. ...completed by the students?	_____	_____
B. ... adequate introduction to the ideas introduced in the experiment?	_____	_____

Comments:

	NO	YES
3. Were the laboratory instructions ...		
A. ...understood by the students with little or no assistance from you?	_____	_____
B. ...leading to the collection of necessary data?	_____	_____
C. ...resulting in data with acceptable experimental error?	_____	_____

Comments:

	NO	YES
4. Were the questions and calculations included in the experiment ...		
A. ...completed by most students?	_____	_____
B. ...relevant to the experiment?	_____	_____

Comments:

	NO	YES
5. Were the post-lab problems ...		
A. ...completed by most students?	_____	_____
B. ...relevant to the experiment?	_____	_____
C. ...sufficient to illustrate the overall goals of the experiment?	_____	_____

Comments:

	NO	YES
6. Was the experiment as a whole ...		
A. ...interesting to the students?	_____	_____
B. ...relevant to the course work?	_____	_____
C. ...written at an appropriate level of difficulty?	_____	_____

Comments: