EXPERIMENT E5

Precipitation and Water Purity

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(Most photos VC211 previous labs/Hamade)

(Modified version of University of Michigan General Chemistry Laboratory Manual[1])

I. AFTER-LAB REPORT (ALR) INSTRUCTIONS FOR EXPERIMENT E5

This is a group experiment but each student must submit the entire individual report by the end of the experiment E5, however data analysis and discussions can be shared among the group members. You must adhere to all safety rules.

<u>So prepare all the following report sections entirely ahead of time. At end of experiment you must collect all below sections and give to instructor before leaving the lab.</u>

1. Type cover page (format same as instructed before).
2. Study ahead of lab (using references, internet and library resources) section IV. PRE-LAB ASSIGNMENTS as instructed and follow section V. GENERAL INSTRUCTIONS.
3. Copy or type from this document and from references a brief description (no more than 1 page total) of (sections II, II & references at end of this document): objectives, introduction, background, and theory. To help you with this, you may use your own typed summary of the quoted references and the additional references at the end of the report (do not include the additional references in your report). Again no more than one page for this section.
4. Ahead of time, read & follow instructions of experimental procedures in sections VI.
5. Copy/paste/type the procedures given in section VI (your choice to copy as is, no need to handwrite). Leave some spaces as needed to handwrite your data and notes.
6. There are no PLE or PLQ for this experiment, however, you must copy/paste/type (as is the entire section VII. REPORTS OF RESULTS) to include the following portions that appear before the additional references at the end of this document. **Leave enough space to handwrite yours/team answers during and immediately after the experiment is completed: (ignore all faded text sections that are identified as "skip this part")**
    a. Pre-Laboratory Report: Answer the questions ahead of lab.
    b. Team Report: All parts 1 through 5
    c. Team Assessment Form
    d. Laboratory Discussion Team / Presentation Grading Form
    e. Laboratory Discussion
    f. Grading (must include in report for instructor to complete or you get no grade)

SUMMARY OF E5 ALR REPORT (include cover page)

I. AFTER-LAB REPORT (ALR) INSTRUCTIONS FOR EXPERIMENT E5
II. OBJECTIVES
III. INTRODUCTION & BACKGROUND
IV. PRE-LAB ASSIGNMENT
V. GENERAL INSTRUCTIONS
VI. EXPERIMENTAL PROCEDURES (ignore all faded text sections that are identified as "skip this part")

PART 1. ***What is a Precipitate?***
a. Information
b. Procedure

PART 2.A. Is Precipitation Predictable

a. Information
b. Notes to the Procedure
c. Procedure
d. Data Analysis
e. Optional Points to Consider (**skip this part**)

PART 2.B. ***Can I Identify it?*** **(skip this part)**

PART 3. ***Concentration and Precipitation***

a. Information
b. Notes to the Procedure
c. Procedure
d. Additional Information
e. E. Data Analysis: Use Table 3, Table 4 & Table 5 to record your results
f. Extensions **(skip this part)**
g. Optional Points to Consider **(skip this part)**

PART 4. ***Solvent Pollution & Precipitation***

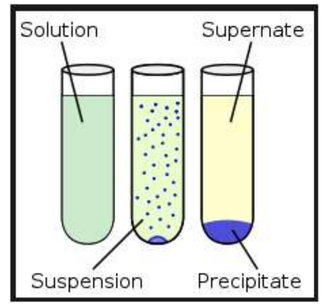
a. Information
b. Notes to the Procedure
c. Procedure
d. Data Analysis
e. Optional Points to Consider (**skip this part)**

PART 5. Can I purify it? (skip this part)

VII. REPORTS OF RESULTS
Pre-Laboratory Report
Team Report: Parts 1-5
Team Assessment Form: Instructor may have different evaluation form
Grading (skip this page)

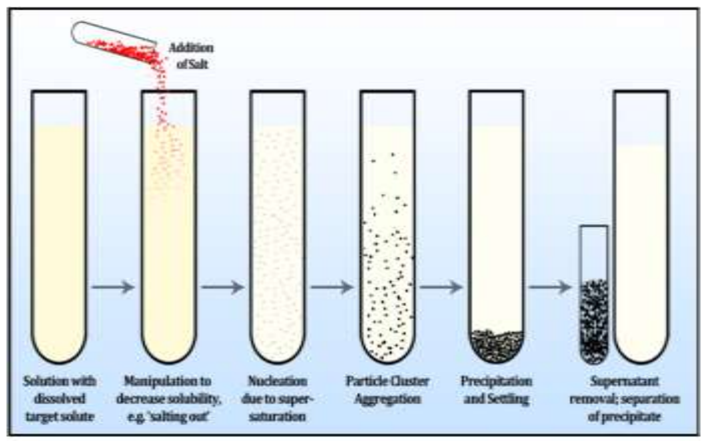
REFERENCES

II. OBJECTIVES



- Become familiar with the logic and experimental tests used to determine precipitate identity.
- Investigate links between precipitation and ion characteristics.
- Determine if some minimum ion concentration is required for precipitation.
- Compare the impact of water and solvents other than water on water purity and precipitation.
- Design experiments to identify unknown ions in a sample of water.

III. INTRODUCTION & BACKGROUND



Waterborne chemicals pose a threat to the safety and purity of water supplies. Soluble forms of many of the heavy metals (such as copper, mercury, and lead ions) are toxic. Soluble forms of the alkaline earth metals (such as calcium and magnesium ions) cause water hardness of the most common manifestations of water hardness is the insoluble scum formed in the presence of soap. Soluble calcium ions in the water and stearate ions in soap can react to form insoluble calcium stearate. The solid formed when the dissolved ions come together is the "precipitate". The dumping of liquids other than water may cause additional insoluble scum to form.

Your task is to determine by experiment the answer to questions about water purity and precipitation. For example, is precipitation a predictable event? You will also design experiments to identify or remove undesirable contaminants (ions) from water by precipitation.

IV. PRE-LAB ASSIGNMENT

Study the following references and some of the references duplicated at the end of this document for E5:

1. University of Michigan laboratory manual: Konigsberg Kerner & Penner-Hahn, Hayden McNeil; Hands on Chemistry Laboratory Manual, 1st Ed., Jeffrey A. Paradis, Kristen Spotz, McGraw Hill Higher Education Press, 2006 (Experiment 6- Precipitation and water Purity pages 49-73, Appendix C.1 Precipitation and Solubility pages 185-188, and Appendix A.3 Filtration page 167).
2. VC210 textbook: Chemistry-The Central Science (Theodore L. Brown; H. Eugene LeMay, Jr.; Bruce E.Bursten), Pearson International edition (Pearson Prentice-Hall, Inc.), 12th edition 2012, ISBN 9780321696724 (Chapter 15 Tab le 4.1 page 121 and Chapter 17 pages 722-739). Topics:

solubility guidelines for common ionic compounds in water, solubility equilibria, factors that affect solubility, precipitation & separation of ions, & qualitative analysis of metallic elements.

V. GENERAL INSTRUCTIONS

"Make sure you take photos of your favorite lab work for use in your final PPT presentation assigned by your TA about one of the experiments E1-E5. TA will examine your data immediately after the experiment and no need to record your data on his/her typical datasheet"

This is a group experiment where each student shares data with his members of the group & groups share data with each other as instructed below for each part of the experiment. At the end of the experiment you must turn in individual reports immediately before leaving the laboratory or you will get -0- points for this experiment.

1. **You should follow safety rules, regulations and the guidelines on chemical waste disposals. Protect yourself, your neighbor & the environment.**
2. At start of lab after my lecture, TA will walk around the groups, collect E4 reports, examine the pre-lab reports of E5 as directed in section I, and then each group give brief few minutes discussion of last week experiment.
3. Immediately as soon as you finish your experiment, each group will gather one after the other in front of the TA and discuss your results and conclusions of today's experiment.
4. After that, you must start cleaning your entire work bench areas, including disposing waste in proper containers and wash glassware with soap & water using brush.
5. Then after that the instructor will inspect your cleaned area and if he satisfied he will tell you to proceed discussing the results with your teams and prepare the final team report so you can give that to the TA before leaving the lab.

VI. EXPERIMENTAL PROCEDURES

Copy/paste/type your own merged version of experimental procedures given in the following entire section. Section VI has instructions on which procedures to follow or skip. Leave some spaces as needed to handwrite your data and notes. To eliminate confusions just follow procedure in section VI instead of previously used University of Michigan laboratory manual.

PART 1. *What is a Precipitate?*

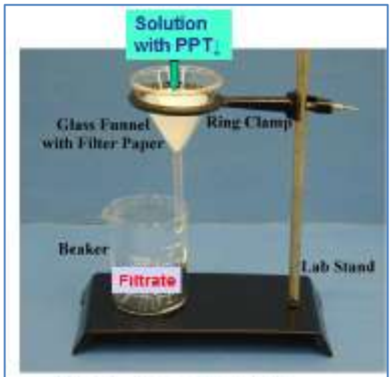
Your goal is to design experiments and use your logic to determine precipitate identity.

a. Information (see reference Chapter 4, Table 4.1, page 121 of VC210 textbook)
Potassium (K^+), sodium (Na^+) and nitrate (NO_3^-) ions are highly soluble (see references).

b. Procedure

Each 2 students in a group must test 1 sample once, so each group will test 2 samples (once each).

CAUTION
Do not dump any of the reagents down the sink.
Discard the waste in an appropriate waste container.
Do not allow the solutions to come in contact with your skin.



Crimp one edge of the filter for better sealing

1. Obtain 5ml of 0.1M copper sulfate, $CuSO_4$, and 5mL of 0.1M barium chloride, $BaCl_2$. Record the appearance of each solution.
2. Combine each solution into one small beaker. Record your observations. Label and save the mixture for later use.
3. Assuming that the reaction involves the coming together of ions in solution, what ions could have combined to form the precipitate?
4. Separate the reaction mixture by filtration (see demo figures on the right and also see end of experiment). Record the observable properties of the filtrate. What conclusions can be drawn from your data regarding the filtrate product species?
5. Write a chemical equation which represents the reaction and is supported by your data

PART 2.A. *Is Precipitation Predictable?*

In this experiment you will be asked if precipitation of a salt is a predictable event? For example, is precipitation of a salt predictable from structural characteristics of its cation such as its charge or ionic radius and/or from the position of its element in the periodic table? If you determine that, tendency to precipitate and cation structure is linked, you should be able to correctly make precipitation predictions about untested salt samples. You should also be able to identify an unknown salt based on its precipitation behavior.

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a. Information

When a salt dissolves, the partial positive and negative charges of water molecules provide a substitute for the charges (ions) in the solid salt. The negative poles of some water molecules attract the positive ions (cations) while the positive poles of some water molecules attract the negative ions (anions) in the solid salt (see figure on the right). This water-ion attraction cloaks each ion on the surface of the crystal with water molecules, and the ions are pulled into the water phase. The independent ions, now sheathed in water molecules, are free to move about in the water.

In a precipitation reaction, the process is reversed. Thus dissolving and precipitation are opposing processes. The more soluble a salt is, the less likely it will precipitate. Similarly, a salt that readily precipitates must not be very soluble.

Teams are to gather information about the solubility and precipitation behavior of a group of cations (Group I or II below -instructor assigned). In order to ensure that you are looking at cation (and not anion) effects every team will use the nitrate salts of all of the varying cations

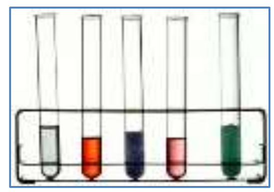
Cation Groups (0.1M nitrate salts): Skip Hg^{2+} & Cd^{2+}, then use Mn^{2+} instead of Li^{+} as shown in Table 1 later.

I	Na^{+}	Ba^{2+}	Mg^{2+}	Co^{2+}	Ni^{2+}	Cu^{2+}	Hg^{2+}	Al^{3+}	Pb^{2+}
II	K^{+}	Li^{+}	Ca^{2+}	Sr^{2+}	Cr^{3+}	Fe^{3+}	Zn^{2+}	Ag^{+}	Cd^{2+}

Anion Groups (0.1M sodium salts)

In order to ensure that you are looking at anion (and not cation) effects every team will use sodium salts of tested anions.

b. Notes to the Procedure



<u>Very much the same as c. Procedure except as following:</u>

a. Each group will test precipitation of either cations (I) or cations (II) **<u>but not both</u>** (procedure says both). Either cations (I) or (II) tested with all the **<u>6 anions</u>** as shown by the procedure. Groups must alternate using either cations (I) or (II) but share the results with the other group (but not the rest of the groups). For example Group #1 may select cations (I) to test, then Group #2 must select cations (II). Both Groups must accumulate and share the observation data for cations (I) & (II) and make it part of their discussions, but no need to tabulate the other group data on their report. So each group will submit their own experimental results for either cations (I) or cations (II) but not both.

b. The procedure shows 9 cations for (I) or (II). For safety reasons you will test 8 cations of (I) or 8 cations of (II), omitting Hg^{2+} & Cd^{2+} from all parts of the experiment. Also Li^{+} is replaced with Mn^{2+}. Each cation in (I) or (II) is to be **<u>tested once</u>**. So each student in a group should test ***two different cations*** to precipitate, a total of **8 cations per group**.

c. Students must prepare master table reflecting the instructions, share the results within the group and within the next group. You must show on your own table the precipitate color if any, solution color & write no precipitate (**<u>no ppt</u>**) if there is none for specific samples (see Ag^{+} example in Table 2). The procedure has the list of the cations and anions to be tested and has an example (omitting Hg^{2+} & Cd^{2+} and replacing Li^{+} with Mn^{2+} from all parts of the entire experiment).

d. **<u>Steps 1 thru 7</u>** remain the same as the procedure. However, in **<u>Step 4</u>,** you will not need to use a disposable pipet because the solution agents are housed in bottles that have an eye dropper-like-lid ready to drop the agents (**<u>only use 2 drops from each tested agent bottle per tested sample)</u>**. In **<u>Step 6</u>**, avoid repeating test results unless results are erroneous and the instructor authorizes you to do so and to minimize chemical waste. Work diligently.

e. Complete the *__Data Analysis__* __1 & 2__ but skip the *__Optional Points to Consider__* section.

__Tabl1: CATION GROUPS TO PRECIPITATE__ **(0.10 M nitrate salts for each cation).**

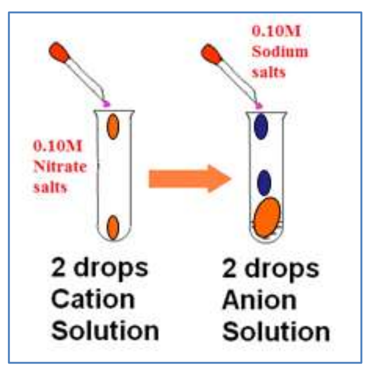
GROUP I	Na^+	Ba^{2+}	Mg^{2+}	Co^{2+}	Ni^{2+}	Cu^{2+}	Al^{3+}	Pb^{2+}
GROUP II	K^+	Mn^{2+}	Ca^{2+}	Sr^{2+}	Cr^{3+}	Fe^{3+}	Zn^{2+}	Ag^+

__Table 2: ANION GROUPS PRECIPITATING* (PPT) REAGENTS__**: (0.10 M sodium salts for each anion). Select cations group I or group II but not both, then add your observations on the table according to instructions & using group II example for Ag^+ (caution: colors may not be as shown). Compare your results with the other group I/II. Clear means no precipitate (ppt).**

CATION GROUP I 2drops	CATION GROUP II 2drops	REF 2drops	Cl^- 2drops	CrO_4^{2-} 2drops	I^- 2drops	$C_2O_4^{2-}$ 2drops	S^{2-} 2dro ps	SO_4^{2-} 2drops	SPCTR GROUP I	SPCTR GROUP II
Na^+	K^+	clear								
Ba^{2+}	Mn^{2+}	clear								
Mg^{2+}	Ca^{2+}	clear								
Co^{2+}	Sr^{2+}	clear								
Ni^{2+}	Cr^{3+}	clear								
Cu^{2+}	Fe^{3+}	clear								
Al^{3+}	Zn^{2+}	clear								
Pb^{2+}	Ag^+	clear	White ppt↓	Brown ppt↓	Yellow ppt↓	White ppt↓	Black ppt↓	White ppt↓		

*precipitation reagents are 0.10 M sodium salts of the anion.

c. Procedure



1. Record a hypothesis regarding the question "is precipitation predictable?" Make sure your hypothesis is precise and relates precipitation to some cation characteristic. For example,

   Your hypothesis might include "the [greater/less] the__ [characteristic of a cation that can be determined from the position of its element in the periodic table], the greater it's tendency to precipitate".

   If your hypothesis is correct which four of your nine assigned cations are less likely to precipitate?

2. **Use Table 2 above** to record your results (or if you want you may prepare a page sized table (8.5 x 11") that includes seven columns (one reference column for your assigned cations. and one column for each precipitating reagent), and nine blank rows. Make a copy of your form.)

3. Identify the spectator ions (cation and anion) that are common to all your assigned (cation and anion) group reagents.
4. Place your data table on a flat surface and cover it with a clean plastic sheet (a heavy plastic sheet such as an overhead transparency works well).

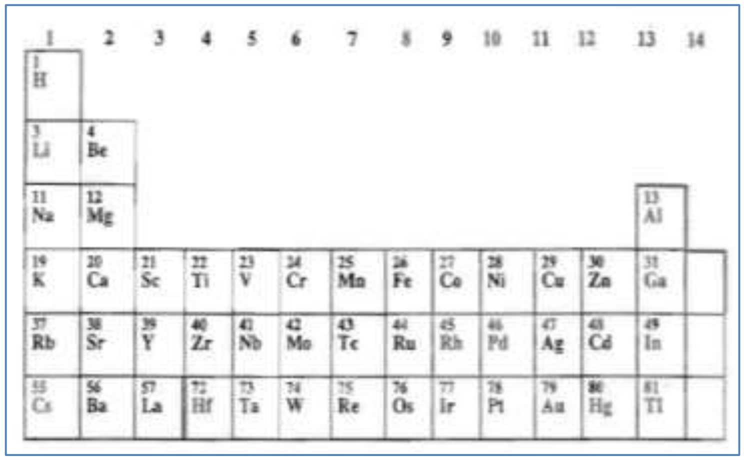
CAUTION
Do not dump any of the reagents down the sink!
Discard the waste in an appropriate waste container!
Do not allow the solutions to come in contact with your skin! Wear gloves!
(Silver ion, Ag^+, will discolor your skin. Some ions are toxic).

Add two drops of your first cation solution (Cation Group I: start with 0.1M sodium nitrate, $NaNO_3$ or Cation Group II: start with 0.1M potassium nitrate, KNO_3, as assigned) to each column of the first cation row. Do the same for the other rows, substituting the appropriate cation solution.

5. Do not add any precipitating reagent to the first column (REF 2 drops: reference column). To each cation solution in the second column add two drops of 0.1M sodium chloride, NaCl. Add 2 drops of one of the other 5 precipitating reagents to each cation solution in the appropriate column. Do not touch the tip of the eye dropper to the cation drops or you will contaminate the precipitating agent!
6. Repeat any tests until you reach a team consensus. Record your observations (above table). Has a precipitate (ppt.) formed? Indicate "ppt↓", "none" or "unsure". Record the ppt. color. Do not discard your data table! Save your data table to refer to while conducting **Part I.B**.
7. Optional: Enter your team's data into the class data base (use a computer if available). Obtain a copy of the summarized class data and record your analysis of the data (see directives below).

d. Data analysis

1. Obtain the class data. Compare the tendency to precipitate of cations from elements in families 1, 2, and 12 of the periodic Table. Enter the class data results into the periodic table below.



Is there an observable pattern in the data? Take care to consider that the number of reported tests for each cation or number of tested cations per family may not be the same

2. Does the class data validate or dispute your recorded hypothesis regarding precipitation? Why?

e. Optional Points to Consider (skip this part)

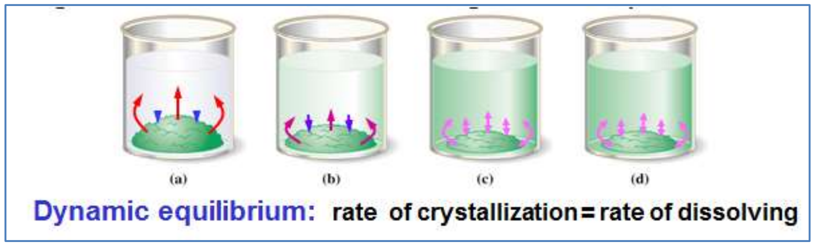
1. Is there a relationship between color of the salt solutions and placement of the ion's element in the periodic Table? (You might begin by marking all elements with colored cations.)
2. Is there a relationship between color and tendency to precipitate? Compare the solubility of colored and colorless ions.
3. Compare anion solubility. Is it possible to create a generalized rule for the solubility behavior of anions? For example, "all sulfates are soluble except__."
4. How do the solubility of the alkaline earth (family IIA) compounds compare? (Organize the class data graphically.) Imagine that you have a sample containing mixture of alkaline earth cations. Is it possible to separate the individual ions by selective precipitation? How?
5. Is there a relationship between cation solubility and structural features sure as ionic radius and/or cation charge?

PART 2.B. *Can I Identify it?* (skip this part)

Skip this Part 2B because most of the cations are already to be tested in the previous steps. Your task is to use your results and the combined results of all teams from **Part 2A** to design an experiment to identify cations in solution based on precipitation observations. You will be given a sample of well water. it contains one of the following ions: Pb^{2+}. Ba^{2+}, K^{+}, Hg^{2+}, AL^{3+}, Cu^{2+}, Ca^{2+}, or Sr^{2+}. Devise a way to use the precipitating agents tested in this experiment (Part 2A) to determine which ion is present record your procedure and results.

PART 3. ***Concentration and Precipitation*.**

Your task is to investigate precipitation of ions at varying concentrations. Is there some minimum concentration of ions required for precipitation? Can toxic ions be completely removed from water by precipitation?

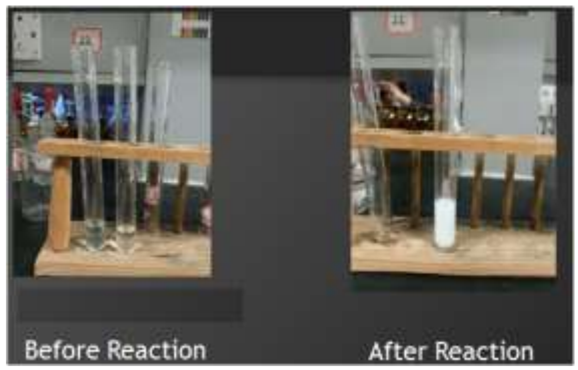


a. Information

Each team is to investigate a specific precipitation reaction (instructor assigned). Varying team results will be shared and the resulting data bank used for analysis of results.

b. Notes to the Procedure

<u>Very much the same as procedure except as following:</u>



Your task is to investigate precipitation of ions at varying concentrations:

> ____***Is there some minimum concentration of ions required for precipitation?***
> ____***Can toxic ions be removed from water by precipitation?***

Use the same instructions as the procedure except with few minor changes that the instructor has to approve your plan of work before starting the experiment. Four students/group need to design their own concentrations of select solutions that are shown by the first column of Table 3 below (Reactions # I through # VI (six reactions)). Then follow the instructor's clarifications of the manual instructions briefly described below:

a. Each group must select only three types of reactions from the left column of Table 3 and carry on the experiment using the corresponding reactants shown by the rows of Table 3.
b. Each reaction will be tested mostly with three or two different concentrations of reactants as directed by your instructor and according to the lab inventory availability of the reagents. Typically you will start reactions using 1 M reactants then dilute down reactants to 0.1 M & 0.01 M concentrations.
c. The TA's will instruct you how to work together and approve the design of your own select reactions. A group will end up doing either 8 or 9 different reaction trials, depending on dilution limits, so each student will do at least 2 different reactions. Each group designs the reactants to differ by composition and by concentrations. Here groups should alternate reactions and compare results with each other.
d. For many of the reagents you may have to dilute with de-ionized water to reduce (vary) concentrations using your skills ($C_1xV_1 = C_2\ xV_2$). Stock reagents are mostly available a

1M solutions or 0.1M, check with the instructor for availability but each group must test 8 samples.

e. Add only 2 drops of each the reactants for each of the reactions and do not waste chemicals.

f. Table 4 and Table 5 may be used as an example to design your own reactions as described above. Report your observations of the reactions to your instructor and complete your report information as instructed by the lab manual.

g. The instructor will guide you through next sections: ***c. Procedure*** (steps 1-3), ***d. Additional Information*** (steps 4&5), ***e. Data Analysis*** (steps 6 & 7). **Skip:** ***f. Extensions*** (8-10), and **Skip:** ***g. Optional Points to Consider*** (steps 11&12).

h. ***Be diligent to safe chemicals & time. Do not repeat trials without the permission of instructor.***

> **CAUTION: Do not dump any of the reagents down the sink! Discard the waste in an appropriate waste container under the supervision of your instructor! Reduce waste by working diligently and do not repeat experimental trials without the approval of the instructor. Do not allow solutions to come in contact with your skin! Wear gloves & goggles! (Silver ion, Ag^+, will color your skin. Some ions are TOXIC).**

TABLE 3: Team reactions (some reactants are different than those used in the UM lab manual because of the availability of inventory).

REACTION #	REACTANT #1	REACTANT #2
I	$Pb(NO_3)_2$	KI
II	$Pb(NO_3)_2$	NaOH
III	$AgNO_3$	KI
IV	$ZnSO_4$	NaOH
V	$CaCl_2$	$K_2C_2O_4$
VI	$CaCl_2$	NaOH

TABLE 4: Example of reactions that may be selected by a particular group of your class, say Group # 5.

REACTION #	REACTANT #1	REACTANT #2	OBSERVATIONS
II-1	0.10M $Pb(NO_3)_2$	0.10M NaOH	
II-2	0.10M $Pb(NO_3)_2$	1.0M NaOH	
II-3	0.01M $Pb(NO_3)_2$	0.01M NaOH	
IV-1	0.10M $ZnSO_4$	0.10M NaOH	
IV-2	0.10M $ZnSO_4$	1.0M NaOH	
IV-3	0.01M $ZnSO_4$	0.01M NaOH	
V-1	0.10M $CaCl_2$	0.10M $K_2C_2O_4$	
V-2	0.01M $CaCl_2$	0.01M $K_2C_2O_4$	

TABLE 5: Another example of alternative reactions that may be selected by next group of your class.

REACTION #	REACTANT #1	REACTANT #2	OBSERVATIONS
I-1	0.10M $Pb(NO_3)_2$	1.0M KI	
I-2	0.10M $Pb(NO_3)_2$	0.10M KI	
I-3	0.01M $Pb(NO_3)_2$	0.01M KI	
III-1	0.10M $AgNO_3$	1.0M KI	
III-2	0.10M $AgNO_3$	0.10M KI	
III-3	0.01M $AgNO_3$	0.01M KI	
VI-1	0.10M $CaCl_2$	0.10M NaOH	
VI-2	0.01M $CaCl_2$	0.01M NaOH	

CAUTION

Do not dump any of the reagents down the sink!

Discard the waste in an appropriate waste container!

Do not allow solutions to come in contact with your skin!

c. Procedure

1. In a small test tube add 10 drops of reactant #1 to reactant #2 (both reactants at 0.10M). Shake well. Record the amount of precipitate as "lots", "slight", "none, or "unsure". Identify the reacting ions and products. Label and save the precipitated mixture.
2. Discuss and record your team's hypothesis about concentration and precipitation. What do you expect to observe as you repeat the reaction at higher and lower ion concentrations?
3. Repeat the reaction using both reactants at equal concentrations above and below 0.10M. Record a team consensus about the amount of ppt as "lots", "slight", "none", or "unsure". Label and save any precipitated mixture.

d. Additional Information

If < 0.10M reagent is not available, dilute the 0.10M sample. (for example, 2 drops of 0.10M reagent + 18 drops of distilled water = 0.010M)

If > 0.10M reagent is not available, add a few crystals of the solid to its 0.10M reagent.

4. **(skip this part)** Filter any precipitated mixture from steps 1, 3, or 4 and collect the filtrate (the clear liquid passing through the filter). Divide the filtrate into two portions. (Note: if additional filtrate is needed you may repeat a reaction using proportionately larger volumes of each reagent.) To one filtrate portions add a few crystals of any of the reactant #1

chemical. To the other portion add 1 to 5 drops of 0.1M Na_2S. (Note: sulfide salts of most transition and heavy metal ions are insoluble) does a precipitate form? Does the filtrate appear to contain unprecipitated ions?

5. Enter your team's data into the class database (use a computer if available). Obtain a copy of the summarized class data and conduct an analysis of the data (see directives below).

e. Data analysis: Use Table 3, Table 4 & Table 5 to record your results

6. Obtain the class data do you observe patterns in the data regarding concentration effects and precipitation? For example, does precipitation of all salts occur within the same concentration values? Does the amount of precipitate increase or decrease with increase in concentration? Are all ions removed from solution upon precipitation?
7. Does the data support or contradict your hypothesis regarding concentration and precipitation? Explain your reasoning.

f. Extensions (skip this part)

8. What will you observe if the reactants are not equal in concentration? specifically, what will happen to the amount of precipitate formed, if the amount of reactant 2 is at a concentration greater than 1.0m while reactant #1 remains at 0.1M concentration?
9. Does the order of addition of reactants effect the results? for example, add
   5 drops of 0.1M $Pb(NO_3)_2$ to 5 drops of 1M NaOH→?
   5 drops of 1M NaOH to 5 drops of 0.1M $Pb(NO_3)_2$ →?
10. Add 3mL of water to the middle of beaker or petri dish so a pool is formed in the center. Simultaneously place crystals (or drops) of each reactant at opposite sides of the pool. Do not move, shake or stir the contents. Observe for several minutes. Now repeat the procedure except wait several minutes before adding the second reactant. Compare the results.

g. Optional Points to Consider (skip this part)

11. Is there a minimum concentration of ions required for precipitation?
12. You need to remove an "undesirable ion" from solution. Is it possible to completely remove the ion from solution by precipitation and filtration? Does the identity and concentration o' the precipitating agent matter?

PART 4. *Solvent Pollution & Precipitation*

A drum containing a solvent other than water is accidentally dumped into a pond of water containing dissolve salts. What, if anything, will happen? In inquiry you will compare the solubility and precipitation of salts in different solvents (water, acetone and, hexane).

a. Information

Water is polar; Acetone (CH_3COCH_3) is moderately polar; hexane (C_6H_{14}) is nonpolar.
Your team should investigate the same reactants assigned in **Part 3**.

You will need 5-6 crystals of each assigned reactant
You will need about 4ml (80 drops) of each sol vent

b. Notes to the Procedure

Very much the same as procedure except as following:

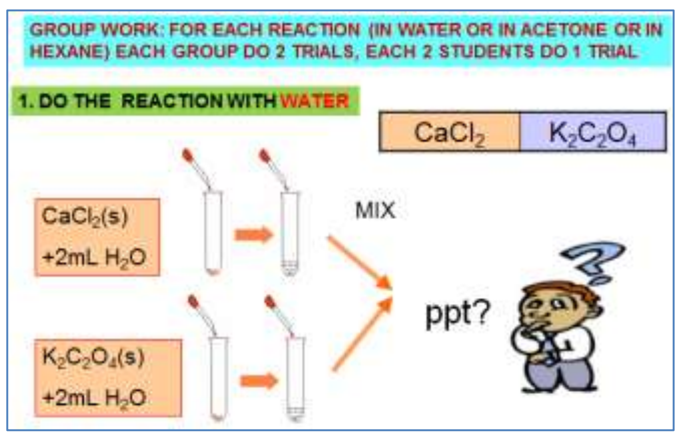
Follow the instructor's directions that he will guide you through the procedure shown in the procedure next, and he may ask you to skip some steps (SKIP STEP 9). Group work: for each reaction (in water or in acetone or in hexane) each group tests the solubility of two solids separately ($CaCl_2$ & $K_2C_2O_4$), where each two students of the group test one solid while the other two students test the other alternative solid. Complete Table 6 for each group results.

TABLE 6: *Solids Solubility in Polar & Non-Polar Solvents (total 6 samples to test)*

Solid Type	Ionized Water	Acetone	Hexane
I.$CaCl_2$			
II.$K_2C_2O_4$ (potassium oxalate)			
Supernatant (I + II)			

c. Procedure

1. Record your hypothesis regarding effect of varying solvent polarity on solubility and precipitation of salts. If your hypothesis is correct what will you observe? For example, will precipitation occur in all solvents? Will the amount of precipitate differ?
2. Test and compare the solubility of your assigned salt reactants in water, acetone, and hexane.



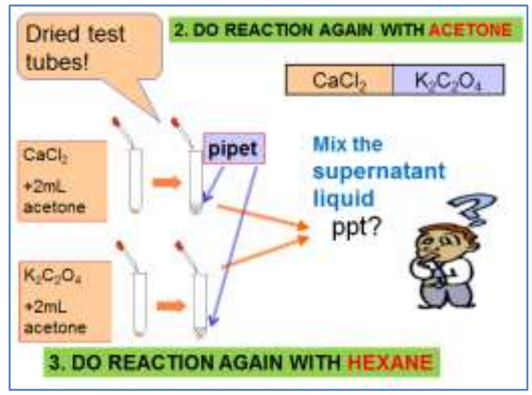
CAUTION
Acetone and hexane are volatile!
Do not inhale acetone or hexane keep the samples closed or use a hood!
Do not dump acetone or hexane down the sink!
Discard the acetone or hexane in an appropriate (organic) waste container!

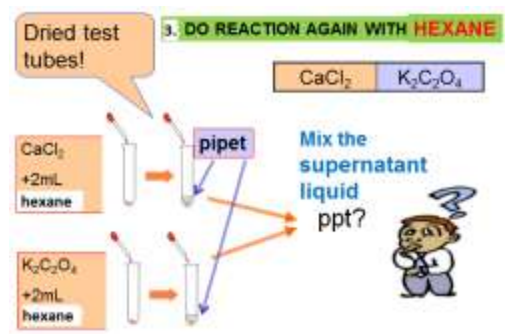
Add a few crystals of reactant #1 to each of three separate dry test tubes labeled water, acetone or hexane. Add= 2.0mL (40 drops) of water or acetone or hexane to the crystals.

Mix vigorously. Record your observations. Are the crystals “insoluble”, “slightly soluble” or “soluble” in each testing solvent? Save the labeled samples for later use.

Repeat the tests with reactant #2. Save the labeled samples for later use.

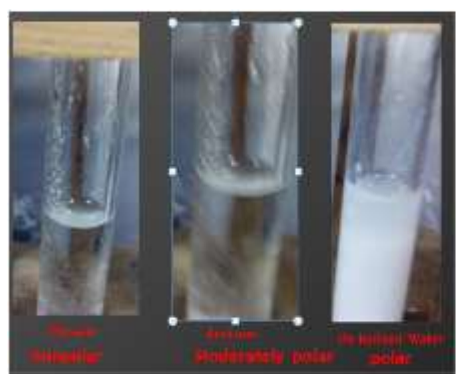
3. Separate any undissolved solid from the solvent solution (containing dissolved crystal). For example, pipet or decant off the supernatant liquid (the clear solution above any undissolved solid) into clean and dry test tubes or containers (labeled to identify the contents).
4. Test and compare the effect of solvent environment on precipitation. Combine the clear liquids of reactant #1 and #2 from the same solvent mixture (e.g. water with water or acetone with acetone or hexane with hexane). Does precipitation occur? How much? Record "lots", "slight", "none", or "unsure", repeat any tests until you reach a consensus.
5. Do your team results show any pattern between precipitation (step 4 above) and solubility (step 3) of the salts in a given solvent
6. Enter your team's data into the class database (use a computer if available). obtain a copy of the summarized class data and conduct an analysis of the data (see directives below)





d. Data Analysis

7. Are any visible patterns in the class data regarding effect of solvent polarity on solubility and precipitation of salts? Record any data patterns and give specific examples.
8. Does the class data confirm or deny your recorded hypothesis? How do you know?



e. Optional Points to Consider (skip this part)

9. The concentration of NaCl in Utahs' great salt lake is = 6M. If a drum containing acetone accidentally spills into the lake is it likely that some NaCl will precipitate? Information: the solubility of NaCl = 35.7g/100cc (0°c) or 39.lg/100cc (100°C).

PART 5. Can I purify it? (skip this part)

Your task is to use your acquired knowledge and skills to design an experiment to selectively remove ions from solution by precipitation and filtration. Each group will do 2 samples where each 2 students will do 1 sample (once each). Follow the instructor's directions that he will guide you through the following procedure: The water effluent from a plant contains a mixture of Cu^{2+}, Fe^{3+}, and Na^{+} ions. You are to design a method for maximizing removal of Cu^{2+} ions from the mixture. You may use any of the reagents (precipitating agents or solvents) tested in this experiment and/or filtration. Note: if you are successful the blue color of $Cu^{2+}(aq)$ will fade. The presence of copper (II) ions can be checked quantitatively. The sample's absorbance can be read at $\lambda_{optimum}$ (λ 650) using a spectrophotometer (Appendix A4). A reading of zero indicates removal of the Cu^{2+} ions.

Collect all your results as instructed on the first page of this experiment and complete your final lab report by adding and answering the next section VII. Then hand deliver the report to your instructor. No reports will be accepted after the end of this lab session.
Prepare all needed tables and report format ahead of the lab session so you can be ready to enter & share collected data.

NOW CONTINUE TO FINISH ALL THE NEXT SECTION VII. REPORTS OF RESULTS

VII. REPORTS OF RESULTS

Students must print/copy/type/paste this entire section (as is) and then handwrite the <u>answers that only relevant to your experiment</u> while ignoring the other questions that are not relevant to the E5. Provide additional spaces as needed. The last "Grade" sheet is for the instructor to complete but you must print the form for him and include within this section

Pre-Laboratory Report

1. Name:____________________Team#:__________________Date:__________Section:____________

2. when a solution of silver fluoride, 0.1M AgF, is mixed with a solution of barium acetate, 0.1M $Ba(C_2H_3O_2)_2$ a precipitate forms:

$$AgF + Ba(C_2H_3O_2)_2 \rightarrow \text{precipitate}$$

   A. In order to identify the precipitating ions you conduct some experimental tests.

      1) you substitute a solution of 0.1M sodium acetate, $NaC_2H_3O_2$, for the $Ba(C_2H_3O_2)_2$ solution and mix it with 0.1M AgF

$$AgF + NaC_2H_3O_2 \rightarrow ?$$

What is the purpose of this test?

      2) What do the test results bellow tell you about the AgF + $Ba(C_2H_3O_2)_2$ reaction?

$$AgF + Ba(NO_3)_2 \rightarrow \text{precipitate*}$$

* The precipitate that forms is identical in properties to that formed in the AgF + $Ba(C_2H_3O_2)_2$ reaction.

      3) Which reference blank test (indicated below) did you to directly test the hypothesis that silver ions are critical to precipitate formation?

Circle the reference blank lest reagent combination that could be used to directly verify if precipitate formation involves silver ions.

AgF + $Ba(NO_3)_2$ NaF + $Ba(C_2H_3O_2)_2$ AgF + $KC_2H_3O_2$

3. Prepare a data table for **Part 2.A** (of the experimental) on an 8 1/2× 11 sheet of paper an make a copy to place under the plastic sheet. Note: your instructor will assign you to one cation group to study in lab. In the meantime leave the cation column blank.

4. Record a precise hypothesis and expected observations for Part 2a for suggestions regarding formulating a hypothesis.

Team Report: Entire team collaborate & hand write discussions in provide spaces

Must be submitted in team leader ALR report, then on your individual report write across the pages of the Team Report "SEE TEAM LEADER REPORT name of leader xxxxx". This saves time in copying same information

Name:____________________Team#:______________Date:__________Section:___________

Part I. What is the precipitate?

Observations of reactants and product mixture

$CuSO_4$	$BaCl_2$	Product Mixture

Possible reacting ions:

Experimental tests to identify reacting ions

Filtrate observations

Analysis and Conclusion

Identity of reacting ions:

Proposed products and properties listed in CRC Handbook or from any available data source:

Chemical equation based on data:

Part 2. Precipitation Studies

Part 2.A. Is precipitation predictable?

Team hypothesis and expected observations:
Four cations least likely to precipitate:
Spectator ions (cation and anion) common to all assigned reactions?

Team Observations

PRECIPITATING REAGENTS*						
CATION REF	Cl^-	CrO^{2-}_4	I^-	$C_2O^{2-}_4$	S^{2-}	SO_4^{2-}

*precipitating reagents are 0.1M sodium salts of the anion.

Data Analysis (Class Data)

Attach a copy of the class data your team used for the purpose of data analysis.

Compare the solubility or tendency to precipitate of the cations with elements in families 1, 2, and 12 in the periodic table. Is there an observable pattern? Record your analysis below. **Be sure to refer to the attached class data to support any conclusion.**

Note: the number of reported tests for varying cations may not be the same. The comparative percentage of precipitates (out of total tests) per cation is more valid than number of precipitates reported. Also note that the number of tested cations per family may not be the same.

<u>Precipitation vs Cation family (1 vs. 2 vs 12)</u>

<u>Part 2.B. Can I identify it?</u> Unknown sample # _________

<u>Part 3. Water Purity and Concentration Studies</u>

Assigned reactants: # 1______ #2___________

Observations of reactants and products

Reaction #1	Reactant #2	Precipitate (“Lots”, “Slight”, “none”, “Unsure”)
Identity of reacting ions		Identity of Participate

Team Hypothesis and expected observations:

Experimental tests and observations:

Precipitate yield* vs Concentration Reactants

= and <0.1M	= and at 0.1M	= and >0.1M

*Record (“lots”.”slight”.”none”,”unsure”)

Filtrate observations (skip this part)

Filtrate	Filtrate+Crystals	Filtrate+0.1M Na_2S
Skip this part	**Skip this part**	**Skip this part**

Analysis of team results

1. What do your team results indicate about concentration and precipitation?
2. Does the filtrate contain unprecipitated reactant ions? How do you know?

Analysis of Class Data

1. What results are shown in the class data? Use the class data to give specific examples of any patterns.
2. Does the class data validate your hypothesis? Explain.

Part 4. Solvent Pollution and Precipitation

Team hypothesis and expected observations:

Assigned Reactants: Reactant #1= ______ Reactant #2 =______

Team Observations:

Solubility and Precipitation of Reactants in Solvents of Varying Polarity

Solvent	Solubility Reactant #1	Solubility Reactant #2	Precipitate (“Lots”, “Slight”, “none”, “Unsure”)
H_2O			
Acetone CH_3COCH_3			
Hexane C_6H_{14}			

Data Analysis (class data)

1. Record any patterns shown in the class data regarding effect of solvent polarity on solubility and precipitation of salts. Give specific examples referring to the class data.
2. Does the class data validate or refute your team hypothesis? Explain your reasoning.

Part 5. Can I purify it? SKIP THIS PART

Unknown sample # ___________

Laboratory Discussion

1. Is it possible to predict if a precipitate will be white or a color other than while bas on the position of the cation's element in the periodic table? Organize the class data (**Part 2A**) in a graph to answer this question.

   Based on your answer predict the compound within each pair that is a color other hall white: nickel sulfate or lead sulfate; cobalt oxalate or strontium oxalate?

2. Is there a relationship between precipitation and ion charge? For example, what generalizations can be made about the solubility of ionic compounds, if both the cation and anion are singly or multiply charged? Organize the class data (**Part 2A**) in a graph to answer this question.

   Based on your answer select the compound within each pair that is less soluble in water: iron (III) chloride, $FeCl_3$, or iron oxide, Fe_2O_3; sodium oxalate. $Na_2C_2O_4$, or calcium oxalate, CaC_2O_4

3. Is it possible 10 predict cation solubility based on the position of its element in the periodic table? For example, compare precipitation of family 1, 2, and 12 cations. Organize the class data (**Part 2A**) in a graph to answer this question.

   Based on your answer select the compound within each pair that is less soluble in water: nickel bromide, $NiBr_2$ or platinum bromide, $PtBr_2$; zinc iodate, $Zn(IO_3)_2$, or mercury iodate. $Hg(IO_3)_2$

4. Examine the relationship, if any, between concentration and the amount of precipitate. Organize the class data (**Part 3**) in the form of a histogram (if time permits during the lab session). For example, compare the amount of hydroxide precipitates of varying cations at the different concentrations. It is a scientific fact that calcium hydroxide is more soluble than zinc hydroxide which is more soluble than lead hydroxide. Does the class data support or refute these scientific facts?

   You are to remove Hg^{2+} ions from a contaminated body of water by precipitation and filtration will it be possible to completely remove all Hg^{2+} ions will a particular precipitating agent remove more Hg^{2+} ions than another.

5. What is the relationship, if any, between salt solubility, precipitation, and solvent polarity? Organize the class data from **Part 4 (**table or graph) to answer this question.

6. **Skip this part:** If a drum of acetone accidentally spills into Utahs' Great Salt Lake is it likely that NaCl will precipitate? The concentration of NaCl in the Great Salt Lake is = 6M. The CRC Handbook reports the solubility of NaCl =35.7g/100cm^3 at 0°C and 37.1 g/100cm^3 at 100°C.

Team Assessment Form: Instructor may have different evaluation form

Team name:_________________ lab section: _________________

Team#:_____________________ date:_______________________

Determine and record the percent contribution of each team member to the experiment.

Your name: percent contribution:

_____________________ __________________

Other team names: percent contribution:

_____________________ __________________

_____________________ __________________

_____________________ __________________

Describe your contributions to the completion of the experiment and the team report and discussion presentation. **Return this form to your instructor.**

Laboratory Discussion Team Presentation Grading Form: SKIP THIS PART

Team number:__________________ Date__________________ Section: ___________________

Team members:____

During the post-lab discussion period at the conclusion of the experiment, each team will be asked to present their answer to one of the post-lab discussion questions. These presentations will count for a total of 14 points. Points will be assigned by your instructor using the same criteria used in prior discussions (does the groups' answer utilize the class data?, is the data organized in a helpful manner?, is the answer logical based on the class data?, is the group's answer clearly communicated?, is the group's presentation well organized and effective?) and student input.

Use this sheet to assign a grade between 0 -5 for each team except for your own team. Grades should be based on the effectiveness of the overall presentation:

0	1	2	3	4	5
unsatisfactory	poor	fair	good	very good	excellent

Consider if the team's presentation is well organized and effective (is the problem clarified and the process used to determine the answer clear and logical)? Are the team's conclusions understandable and useable (e.g. could you answer an exam question related to the investigation?

Question	Points	Comments
1		
2		
3		
4		
5		
6		

HOW TO SUBMIT E5 ALR REPORT?

1. **Teams to meet in assigned areas under the supervision of the TA. You are not allowed to leave until E5 is completed, glassware and lab areas clean to original or better condition, discuss entire data and report with the TA and then submit your completed individual reports.**
2. **Each student must submit individual report**
3. **Omit all sections that said in procedure "Omit" or faded text, such as Part 5, or when data is not available such as CRC Handbook , data bank base on compute (not available). But you must clearly mark across entire section of that part the word "OMIT".**
4. **The group report part is to be completed by the group and submitted to the group leader report. While the remaining members of the group will write across that page of their own team report "SEE TEAM LEADER REPORT & give his name xxxx". This way you save time in duplicating the Team Report data.**

Grading: SKIP THIS PAGE

Make sure you include this form with your report for the instructor to complete

Name:____________________Team#:_____________Date:__________Section:___________

	Possible	Points Earned
pre-lab (5 pts)		
A. Was completed correctly and turned in Laboratory*	**A.5**	___________
*student must be present and perform experiment to receive points.		
B. Part 1. Observations recorded (l pt) and reasonable conclusions (based on tests) are stated (3 pts)	**B.4**	___________
C. Part 2. Observations recorded (1 pt); a reasonable hypothesis is recorded where identified cations conform to hypothesis (1 pt): spectator ions are identified (1 pt); reasonable conclusions (class data referred to) are stated regarding cation solubility and position in the periodic table (3 pts); hypothesis is re-examined (l pt)	**C.7**	___________
D. Part 3. Observations recorded (l pt); a reasonable hypothesis is recorded (l pt); reasonable conclusions (based on team and class data) are stated regarding concentration vs. precipitation(4 pts)		
OR Part 4. Observations recorded (1 pt); hypothesis is reasonable(l pt); reasonable conclusions (class data is used and referred to) are given regarding solubility, ppt. and solvent polarity (4 pts)	**D.6**	___________
E. Part 5A. Observations recorded (l pt); the ion is correctly identified using an appropriate scheme (3 pts).	**E.4**	___________
lab discussion (14 pts)		
F. Team presentation	**F.14**	___________
Total	40	___________

REFERENCES

1. University of Michigan laboratory manual: Konigsberg Kerner & Penner-Hahn, Hayden McNeil; Hands on Chemistry Laboratory Manual, 1st Ed., Jeffrey A. Paradis, Kristen Spotz, McGraw Hill Higher Education Press, 2006 (Experiment 6- Precipitation and water Purity pages 49-73, Appendix C.1 Precipitation and Solubility pages 185-188, and Appendix A.3 Filtration page 167).

2. VC210 textbook: Chemistry-The Central Science (Theodore L. Brown; H. Eugene LeMay, Jr.; Bruce E.Bursten), Pearson International edition (Pearson Prentice-Hall, Inc.), 12th edition 2012, ISBN 9780321696724 (Chapter 4 Tab le 4.1 page 121 and Chapter 17 pages 722-739). Topics: solubility guidelines for common ionic compounds in water, solubility equilibria, factors that affect solubility, precipitation & separation of ions, & qualitative analysis of metallic elements.

3. **ADDITIONAL REFERENCES**

THE FOLLOWING PAGES ARE FOR FOR YOUR REVIEW ONLY AND NO NEED TO COPY/PRINT INTO YOUR LAB REPORT. HOWEVER, YOU ARE ENCOURAGED TO REFER TO AND DISCUSS BRIEFELY IN YOUR REPORT.

A. VC210 textbook: Chemistry-The Central Science (Theodore L. Brown; H. Eugene LeMay, Jr.; Bruce E.Bursten), Pearson International edition (Pearson Prentice-Hall, Inc.), 12th edition 2012, ISBN 9780321696724 (Chapter 4 Tab le 4.1 page 121)

TABLE 4.1 • Solubility Guidelines for Common Ionic Compounds in Water

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	CH_3COO^-	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Insoluble Ionic Compounds		**Important Exceptions**
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of NH_4^+, the alkali metal cations, Ca^{2+}, Sr^{2+}, and Ba^{2+}

B. University of Michigan laboratory manual: Konigsberg Kerner & Penner-Hahn, Hayden McNeil; Hands on Chemistry Laboratory Manual, 1st Ed., Jeffrey A. Paradis, Kristen Spotz, McGraw Hill Higher Education Press, 2006 (Experiment 6- Precipitation and water Purity pages 49-73, Appendix C.1 Precipitation and Solubility pages 185-188, and Appendix A.3 Filtration page 167).

A. 3 FILTRATION

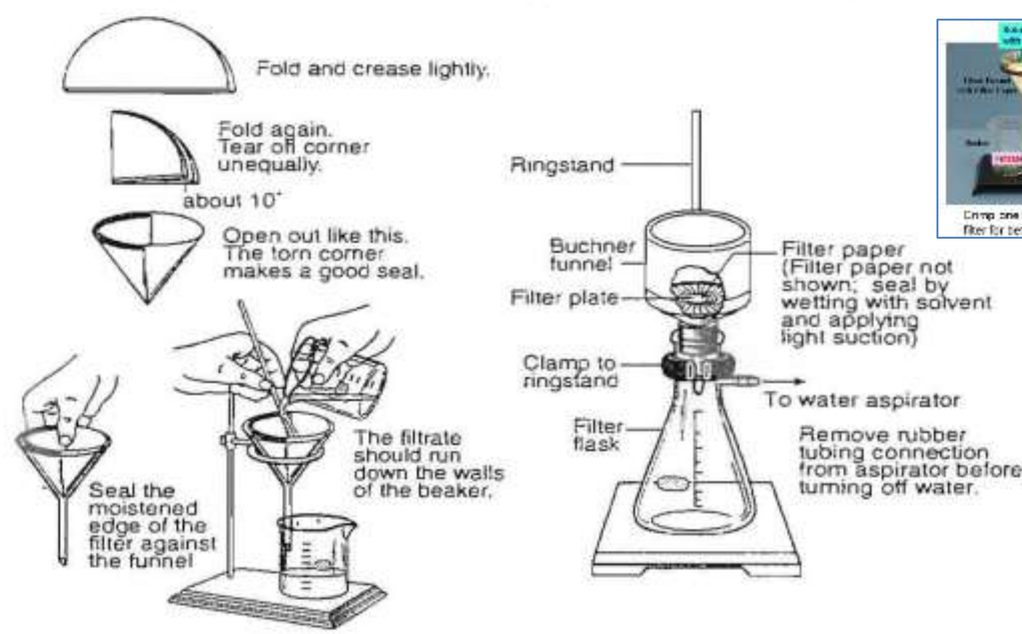
A common laboratory procedure is the separation of a solid from a liquid by filtration. In the laboratory you will choose between two methods of filtration. *Gravity filtration* is a rather slow process carried out with simple equipment. *Suction filtration* requires a water pump and special glassware, but once set up, it proceeds rapidly.

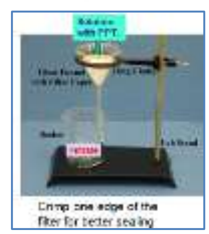
How to Gravity filter

1. Set up the equipment. Fold the filter paper as shown. Place it in the funnel and moisten it with distilled water or the solvent in use to seal it against the funnel.
2. Decant (pour off) most of the supernatant solution (the clear liquid above the solid) into the funnel. Using a glass rod, pour the precipitate into the funnel as shown.
3. Wash the precipitate with small amounts of solvent to get rid of trace impurities.
4. Dry the precipitate by leaving it in the open or putting it in an oven at a suitable temperature.

How to Filter with a Buchner Funnel

1. Set up the equipment and clamp the filter flask to the ringstand.
2. Place the filter paper in the funnel, and moisten it with water or the solvent to be used.
3. Turn the vacuum on. While the vacuum is on, pour into the funnel the solution to be filtered.
4. Wash the precipitate with a small amount of solvent. Allow the solid to dry by drawing air through the funnel.
5. Remove the precipitate from the filter by lifting one edge of the filter paper with a spatula.





Gravity Filtration

Suction Filtration

APPENDIX C

CHEMICAL REACTIVITY

C.1 PRECIPITATION AND SOLUBILITY

Precipitation reactions are a common type of reaction involving ions in solution that react to form a solid. An ion is an electrically charged atom or radical. Ionic compounds contain a positive ion (for example, Na^+, Pb^{2+}) and a negative ion (for example, Cl^-, NO_3^-). Compounds containing a positive ion other than hydrogen and a nonmetal other than oxygen or OH^- (hydroxide) are called *salts*. Salts are solids at room temperature. Their melting and boiling points are higher than those of molecular solids due to the large amount of energy required to overcome the attractive forces between oppositely charged ions. Although salts are difficult to melt, many can be dissolved easily in water. When a salt crystal dissolves, it does not simply come apart into ions. Rather, the associated ions comprising the crystal are separated (*dissociated*) by the molecules of the water into which it is dissolved.

Breakup of a salt crystal by water

The electron pairs are shared unequally between the hydrogen and oxygen atoms in water molecules. The O end of the molecule attracts the shared electron pair more strongly than the H. The O end of the molecule is therefore negative with respect to the H end. Such a separation of charge creates an electric *dipole*. The partial positive and negative charges on water molecules provide a substitute for the positive and negative charges in the salt crystal:

Each positively charged ion is surrounded by water molecules with their negatively charged oxygens turned toward it, and each negatively charged ion is surrounded by water molecules with their positively charged hydrogens turned toward it. The ions are said to be*hydrated* by water. The hydrated aqueous state is represented by placing (aq) as a subscript next to the ionic symbol -- for example, $K^+_{(aq)}$ or $Cl^-_{(aq)}$. Once you dissolve the salt, it is completely ionized.

Solubility

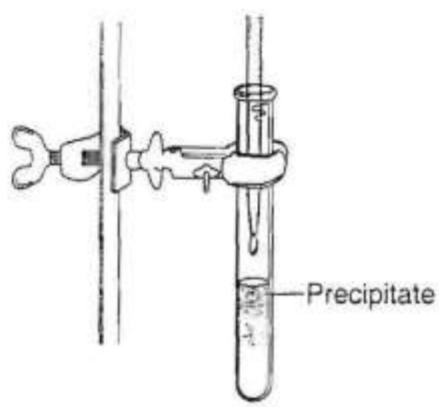
Solubility is defined as the amount (g or mol) of *solute* (substance you are dissolving) that will dissolve in a given quantity (volume) of solvent at a specific temperature and pressure to give a *saturated* solution. Saturated solutions contain so much dissolved substance that no more can be dissolved. For example, the *CRC Handbook* lists the solubility of table salt, NaCl, as 35.70g/100mL water at 20°C. Since the mass of a mole of NaCl = 58.44g, a saturated solution of NaCl is 6.11M or the solubility is 6.11mol/L at 20°C. This means that it is impossible to prepare an aqueous solution (solution where the solvent is water) of NaCl that is greater than 6.11M in concentration at a temperature of 20°C.

The solubilities of ionic salts vary tremendously. The solubility of HgS is 10^{-26}mol/L at 20°C in water. The low solubility of HgS implies that interionic forces are greater than the force of attraction between the charged ions and the water molecules.

The solubility of substances are dependent on temperature and the nature of the solvent. For example, the CRC Handbook indicates that the solubility of NaCl in water is 35.70g/100mL water at 20°C and 39.12g/100mL at 100°C. NaCl is only slightly soluble in alcohol and is insoluble in benzene.

Precipitation

If solutions of two different salts are mixed, all of the different ions are free to interact in the resulting solution. Even though all of the ions were soluble in the two initial solutions, new ion combinations may result in an insoluble *precipitate* when the solutions are mixed. A precipitate is a solid formed in solution by a reaction. These are sometimes called methathesis



reactions, from a Greek word meaning "interchange." Ions exchange partners to achieve more favorable electrostatic interactions. For example, if you mix solutions of silver nitrate and potassium chloride, you obtain a precipitate of insoluble silver chloride:

$$AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$$

Silver chloride, AgCl, is highly insoluble and therefore very few Ag^+ and Cl^- ions remain in solution. If the solution is evaporated (after removing the AgCl) crystals of KNO_3 are produced with a negligible amount of AgCl. The ionic equation makes it easier to understand the mechanism of reaction:

$$Ag^+_{(aq)} + NO_3^-{}_{(aq)} + K^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)} + K^+_{(aq)} + NO_3^-{}_{(aq)}$$

where the letters in parentheses describe the physical state of each species (s, solid; g, gas; l, liquid; aq, aqueous solution).

A *net* ionic equation includes only the ions undergoing change. Because K^+ and NO_3^- appear on both sides of the equation in the same form, they can be canceled. Thus, the net ionic equation for the reaction is $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

A common error in writing ionic equations is to ionize a salt into two or more parts that do not balance with the original. Thus, you might incorrectly ionize $CaCl_2$ into $Ca^{2+} + Cl_2$ rather than $Ca^{2+} + 2Cl^-$. Splitting a salt must produce positive and negative charges in equal amounts.

Precipitate Identification

In order to identify the products of a reaction, scientists use experimental tests, knowledge, other information (e.g., from the CRC Handbook.), and logic. For example, if you mix equal volumes of 0.1M mercuric nitrate and potassium iodide, you observe:

$Hg(NO_3)_2$	+	$2KI$	$\rightarrow$	**? precipitate forms**
clear and colorless		*clear and colorless*		*orange-red solid*

Knowledge and Logic:

Recognize that each dissolved salt is ionized:

$$Hg^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2K^+_{(aq)} + 2I^-_{(aq)} \rightarrow \text{? precipitate}$$

Recognize that the product must contain both anions and cations and therefore,

$Hg^{2+}_{(aq)}\ K^+_{(aq)}$ **does not** form the precipitate
$NO_3^-{}_{(aq)} + I^-_{(aq)}$ **does not** form the precipitate

and thus the possible combinations are $Hg(NO_3)_2$, KI, HgI_2, KNO_3

Recognize that the product cannot be the reactant. Therefore the only possible products are

HgI_2 and KNO_3.

Experimental Tests and Observations:

Experiment Test: KNO_3 + KI → no precipitate

The above test results indicate that $Hg^{2+}_{(aq)}$ must be present for the precipitate to form.

Experiment Test: $Hg(NO_3)_2$ + KNO_3 → no precipitate

The test results indicate that $I^-_{(aq)}$ must be present for the precipitate to form..

Additional Information and Conclusion:

The *CRC Handbook* indicates that HgI_2 is orange-red. K^+ and NO_3^- ions are both colorless. If the precipitate is KNO_3 it should be white rather than orange-red. The precipitate must be HgI_2 and therefore the reaction must be, $Hg(NO_3)_2 + 2KI \rightarrow HgI_{2(s)} + 2KNO_3$