

Experiment 5: Chemical Reactions**Part A: Precipitation and acid-base reactions**

(This part of the experiment was adapted from CC-BY Torres & González-Urbina
Experiment: Precipitation and Acid-Base Reactions)

Purpose

The goal of this experiment is to perform a set of simple acid-base and precipitation reactions in aqueous solutions. For the precipitation reactions you will use the solubility rules to identify the solid and aqueous products of the reaction. For the acid-base reactions, you will identify the acidic/basic characteristic of each reactant chemical.

Chemicals

Type A Solutions of	NaCl	NaBr	Na ₂ SO ₄	KCl
Type B Solutions of	Ba(NO ₃) ₂ ,	AgNO ₃	<i>(Barium nitrate is toxic!!! Use in the hood.)</i>	
Type C Solutions of	HCl	CH ₃ COOH		
Type D Solutions of	NaOH	Na ₂ CO ₃		

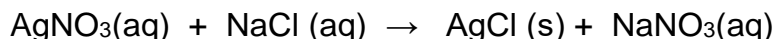
Equipment

Red and blue litmus paper

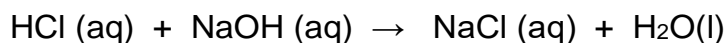
4 small test tubes (You will clean and reuse these test tubes during this experiment.)

Background

Many chemical reactions take place in aqueous solution, and most of these reactions involve ions. Let's consider as an example what happens when mixing a colorless solution of silver nitrate (AgNO₃) with a colorless solution of sodium chloride (NaCl). The solution of silver nitrate contains Ag⁺ cations and NO₃¹⁻ anions, whereas the solution of sodium chloride contains Na⁺ cations and Cl⁻ anions. When we mix these two aqueous solutions, a white precipitate (AgCl) forms immediately due to the ion exchange process.



Acid-base reactions are aqueous reaction also. Acids and bases react by means of a neutralization reaction. An example would be:



This experiment addresses these two important types of chemical reactions.

Precipitation reactions

Some ionic compounds are soluble in water whereas others are not. In a precipitation reaction, two strong-electrolyte solutions are mixed to produce an insoluble solid called precipitate.

Solubility Guidelines:

Ions that form soluble compounds (aq)..... except when combined with	
Group I ions (Na^+ , Li^+ , K^+ , etc)	no exceptions
Ammonium (NH_4^+)	no exceptions
Nitrate (NO_3^-)	no exceptions
Acetate (CH_3COO^-)	no exceptions
Hydrogen carbonate (HCO_3^-)	no exceptions
Chlorate (ClO_3^-)	no exceptions
Halides (F^- , Cl^- , Br^-)	Pb^{2+} , Ag^+ and Hg_2^{2+}
Sulfate (SO_4^{2-})	Ag^+ , Ca^{2+} , Sr^{2+} , Ba^{2+} , Hg_2^{2+} and Pb^{2+}

Ions that form insoluble compounds (s).....except when combined with....	
Carbonate (CO_3^{2-})	group I ions (Na^+ , Li^+ , etc) or (NH_4^+)
Chromate (CrO_4^{2-})	group I ions (Na^+ , Li^+ , etc) or Ca^{2+} , Mg^{2+} or (NH_4^+)
Phosphate (PO_4^{3-})	group I ions (Na^+ , Li^+ , etc) or (NH_4^+)
Sulfide (S^{2-})	group I ions (Na^+ , Li^+ , etc) or (NH_4^+)
Hydroxide (OH^-)	group I ions (Na^+ , Li^+ , etc) or Ca^{2+} , Mg^{2+} , Sr^{2+} or (NH_4^+)

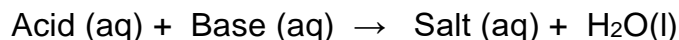
Acids and Bases

Acids are chemicals that produce hydrogen ions (H^+) in water. Bases produce hydroxide ions (OH^-) that accept hydrogen ions. H^+ and OH^- combine to form water. Acids and bases change the color of certain chemicals called indicators, and litmus is a well-known acid-base indicator. Acids and bases can be classified as strong or weak according to the extent to which they ionize/dissociate in solution. A strong acid is completely ionized in solution, whereas a weak acid is only slightly ionized. The same can be applied to bases.

Strong Acids	Strong Bases
HCl, HBr, HI	NaOH, KOH
$HClO_4$, $HClO_3$	$Sr(OH)_2$, $Ba(OH)_2$
H_2SO_4	Na_2O , BaO
Weak Acids	Weak Bases
HF, CH_3COOH , H_2SO_3	NH_3

Acid-Base Neutralization Reactions

A neutralization reaction between a strong acid and a strong base yields a salt and water:



Litmus paper

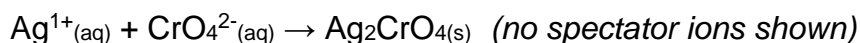
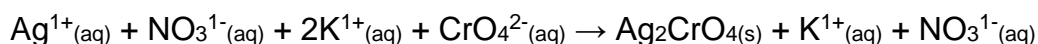
Litmus paper is a quick test to identify whether a solution is acidic or basic. There are two variants for litmus paper; red litmus paper and blue litmus paper. Blue litmus paper turns pink under acidic conditions whereas red litmus paper turns blue under basic conditions. Regardless of which litmus you start with, remember that ***bases turn litmus blue and acids turn litmus red.***

	Red litmus paper	Blue litmus paper
Acidic solution	Red	Red
Basic solution	Blue	Blue

Ionic and Net ionic equations

The ionic equation for a precipitation reaction or acid base reaction shows all the species as they actually exist in solution. Because dissolved ionic compounds exist as separate aqueous ions, the ions should be shown separately. Some of these ions appear the same as both reactants and products. This means that they play no role in the reaction: they are spectator ions. In the ionic equation, you can simplify the chemical equation by canceling the spectators out on each side of the arrow; this produces the net ionic equation.

The ionic and net ionic equations for the reaction between aqueous solutions of silver nitrate (AgNO_3) and potassium chromate (K_2CrO_4) to give a precipitate of silver chromate (Ag_2CrO_4) and a solution of potassium nitrate (KNO_3) are:

**Summary Checklist of Chemical Reactions for Part A, Steps 1-6:**

	NaCl	NaBr	Na ₂ SO ₄	KCl
Ba(NO ₃) ₂	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt
AgNO ₃	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt

***Do not put your observations on this paper. Your observations go in your notebook worksheet.

Summary Checklist of Chemical Reactions for Part A, Steps 7-9:

	NaOH	Na ₂ CO ₃	HCl	CH ₃ COOH
Red Litmus	color	color	color	color
Blue Litmus	color	color	color	color

***Do not put your observations on this paper. Your observations go in your notebook worksheet.

Summary Checklist of Chemical Reactions for Part A, Steps 10-12:

	NaOH	Na ₂ CO ₃
HCl	Heat?	Gas or heat?
CH ₃ COOH	Heat?	Gas or heat?

***Do not put your observations on this paper. Your observations go in your notebook worksheet. These reactions do take place, even if you don't feel heat or see gas formation.

Procedure

Precipitation reactions

- 1) Arrange in the following order the set of reactants Type A:
NaCl (aq) NaBr (aq) Na₂SO₄(aq) KCl (aq)
- 2) Arrange in the following order the set of reactants Type B:
Ba(NO₃)₂(aq) AgNO₃(aq)
- 3) Use reactant Type A NaCl (aq) and add 10 drops to a set of two test tubes. Each tube should have now 10 drops of NaCl.
- 4) Use reactant Type B Ba(NO₃)₂(aq). Add 10 drops to the first test tube containing the NaCl. Write down your observation:
Indicate soluble as (aq) for aqueous or insoluble as (s) for solid.
- 5) Use reactant Type B AgNO₃(aq). Add 10 drops to the second test tube containing the NaCl. Write down your observation:
Indicate soluble as (aq) for aqueous or insoluble as (s) for solid.
- 6) Repeat steps 3 – 5 for each of the other Type A reactants, in the following order:
NaBr Na₂SO₄ KCl

Acid Base Neutralization Reactions

- 7) Arrange in the following order the set of reactants Type C: NaOH (aq) Na₂CO₃(aq)
- 8) Arrange in the following order the set of reactants Type D: HCl (aq) CH₃COOH (aq)
- 9) For each chemical in Type C and Type D, put one drop of solution on a piece of red litmus paper. Then put one drop of each solution on a piece of blue litmus paper. Record all of your observations and identify each chemical as an acid or base.
- 10) Use reactant Type C NaOH (aq) and add 10 drops to a set of two test tubes. Each tube will have now 10 drops of a NaOH.
- 11) Use reactant Type D HCl. Add 10 drops to the first test tube containing the NaOH. Observe if you feel any heat generated. Sometimes the acid and base concentrations are too low to feel heat. However, a reaction has still taken place.
- 12) Repeat steps 10 – 11 for each of the remaining combinations:
NaOH with CH₃COOH Na₂CO₃ with HCl Na₂CO₃ with CH₃COOH

References

- (1) Fetzer-Gislason, P. R.D.W. S., Lab Experiments in Introductory Chemistry; Freeman: 2003.
- (2) Murov, S., Experiments in General Chemistry; Cengage: 2013.
- (3) Ebbing, R. W.D. D., Experiments in General Chemistry; Houghton Mifflin Harcourt Publishing Company: 2004.

Part B: The Scientific Method

This experiment was adapted from Torres & González-Urbina, CUNY, The Scientific Method.

Purpose

The goal of this experiment is to understand how the scientific method works. In order to do this, you will make observations, look for patterns and come up with a hypothesis in order to identify an unknown compound. You will do this by comparing the chemical reactions of the unknown compound with a set of known compounds. Observe changes that indicate a chemical reaction has occurred, such as gas evolution, the formation of a precipitate, a change of color, or the generation of heat.

Chemicals

Caution: Solutions of barium are toxic.

Known compounds: $\text{NaCl}_{(aq)}$ $\text{NaI}_{(aq)}$ $\text{Na}_2\text{CO}_{3(aq)}$ $\text{Na}_2\text{HPO}_{4(aq)}$ $\text{Na}_2\text{SO}_{4(aq)}$,

Reagents: $\text{Ba}(\text{NO}_3)_{2(aq)}$ $\text{AgNO}_{3(aq)}$ thymol blue

Unknown compound $_{(aq)}$

$\text{NH}_{3(aq)}$, which is also written as $\text{NH}_4\text{OH}_{(aq)}$

Equipment

Six test tubes (you will clean and reuse these test tubes during this experiment)

Background The scientific method is a sequence of logical steps.

The first step is to collect data by making observations and/or measurements of a sample. The next step consists of looking for patterns and trends in the data. When a pattern is observed, scientists develop a hypothesis, that is, a feasible explanation of the observations. After formulating a hypothesis, scientists think of experiments to test the hypothesis. If the results of repeated experiments support the hypothesis, scientists formulate a theory that explains the observations.

This experiment was adapted from the literature [1, 2].

Summary Checklist of Chemical Reactions for Part B:

Reagents to add to Test Tubes	Known Chemicals and Unknown in the Test Tubes (6 test tubes)					
	NaCl	NaI	Na_2CO_3	Na_2HPO_4	Na_2SO_4	Unknown
$\text{Ba}(\text{NO}_3)_2$	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt
AgNO_3	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt	ppt or no ppt
thymol blue	color	color	color	color	color	color

***Do not put your observations on this paper. Your observations go in your notebook worksheet.

Procedure

1) Obtain the unknown compound solution, the known compound solutions, and the reagent solutions.

Testing for a barium precipitate

2) Using 6 test tubes, add 10 drops of solution to each test tube. Each test tube should have a different known compound solution, and the last test tube has the unknown solution.

Add 2 drops of ammonia (NH_3) solution to each test tube and mix. (NH_3 will not be part of the chemical equation.)

3) Add five drops of the $\text{Ba}(\text{NO}_3)_2$ solution to each of the test tubes. Shake gently to obtain homogeneity. Examine each test tube carefully and look at the results. Record your observations: precipitate or no precipitate.

4) Discard the solutions from the test tubes into the waste container. Wash the test tubes, and rinse them with distilled water. You will reuse these test tubes for the following steps.

Testing for a silver precipitate

5) Using the cleaned 6 test tubes, add 10 drops of solution to each test tube. Each test tube should have a different known compound solution, and the last test tube has the unknown solution.

6) Add five drops of the silver nitrate AgNO_3 solution to each test tube. Record your observations: precipitate or no precipitate.

7) Discard the solutions from the test tubes into the waste container. Wash the test tubes, and rinse them with distilled water. You will reuse these test tubes for the following steps.

Testing with thymol blue

8) Using the cleaned 6 test tubes, add 10 drops of a different known solution and the unknown solution to each test tube.

9) Add five drops of the thymol blue solution to each test tube. Shake each test tube gently before recording your observations: write down the colors of the resulting solutions.

10) Discard the solutions from the test tubes into the right waste container. Wash the test tubes, and dispose of them in the broken glass container.

Identifying the unknown compound

11) The unknown is one of these compounds:

NaCl NaI Na₂CO₃ Na₂HPO₄ Na₂SO₄

You should be able to identify your unknown compound by matching its chemical reactions with those of one of the known compounds. Explain your logic when you identify your unknown.

References

- (1) Ebbing, R. W.D. D., Experiments in General Chemistry; Houghton Mifflin Harcourt Publishing Company: 2004.
- (2) Beran, J. A., Laboratory manual for principles of general chemistry; John Wiley and Sons: 2010.