EXPERIMENT 3:

IDENTIFICATION OF A COMPOUND BY CHEMICAL PROPERTIES

LAB OF GENERAL CHEMISTRY 1, CHEM 0303105

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Goals:

- To identify a compound based on its chemical properties.
- To design a systematic procedure for determining the presence of a particular compound in aqueous solution

INTRODUCTION

-Qualitative Analysis Experiments (تجارب التحليل النوعي) are designed to identify a specific ion by taking advantage of its **unique chemical and physical properties in a mixture through a systematic method of analyses (طريقة منهجية للتحليل).**

-In this experiment, you will **observe chemical reactions** that are characteristic of various compounds under controlled conditions.

-After collecting and organizing your data, you will be given an **unknown compound**; a compound that you have previously investigated. The interpretations of the collected data will assist you in identifying your compound.

Reaction between solid Na and Chlorine gas:

$$Na(s) + Cl_2(g) \rightarrow NaCl\ (s)$$

- **Sodium** is an extremely reactive metal (soft, silvery-white, shiny) that dulls almost instantly upon exposure to air.

- **Chlorine** is a greenish yellow gas with a pungent odor. It is highly reactive and poisonous (used in the WW1 in chemical war)

- The compound formed by sodium and chlorine is **WHITE TABLE SALT**, useful to your health.

- In general, the properties of the new products (compounds) are different from those of the original reactants (substances).

Chemical properties

- **Chemical properties** are characteristics that can be measured or observed only when the identity (هوية) of the substance is changed (undergoes a chemical reaction or change).

- This involve the interaction of a substance with another to form new substance(s).

- These changes based on its environment and the chemicals present

- They include **reactivity such as reactivity with water, flammability, toxicity, rusting, pH, and explosion of dynamite**

- **Examples** of chemical reactions are color change, precipitate, odor, etc.

Here are some examples of chemical properties:

- **Reactivity (e.g.,** the ability of matter to react chemically with other substances or chemicals**).**
- **Toxicity.**
- **Flammability.**
- **Enthalpy Of Formation.**
- **Heat Of Combustion.**
- **Chemical Stability.**
- **Ability To Rust (rusting)**
- **pH**
- **Reactivity With Water**
- **Creating Gas Bubbles From Chemical Reaction,**
- **Explosion Of Dynamite**
- **Electromotive force (in volts) Coordination Number.**
- **Oxidation States.**

Chemical Properties

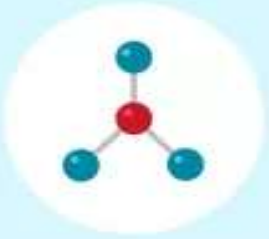
Toxicity

Oxidation States

Heat of Combustion

Chemical Stability

Flammability



Coordination Number

Reactivity

Possible Chemical Bonds

Enthalpy of Formation

ThoughtCo.

What are the observations of chemical reactions ?(ما هي مشاهدات التفاعلات الكيميائية)?.

Chemical changes (rxns) are generally accompanied by one or more of the following observations (evidences or signs):

1. *A gas is evolved, with or without odor.*

2. A precipitate appears (or disappears). The nature of the precipitate is important; it may be crystalline, it may have color, it may merely cloud the solution.

3. Heat may be evolved or absorbed. The reaction vessel becomes warm if the reaction is exothermic or cools if the reaction is endothermic.

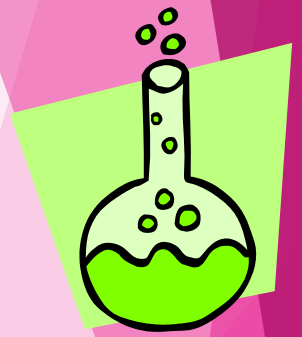
4• A color change occurs. A substance added to the system may cause a color change.

5• A change in odor is detected. The odor of a substance may appear, disappear, or become more intense during the course of a chemical reaction.

6. No sign at all, since the reactants and products are colorless and soluble in the solution

Possible Observations chemical reactions : a gas is evolved

❖ **A gas is evolved**. This evolution may be quite rapid or it may be a "fizzing" sound (caution: never try to smell the reaction mixture directly. There is a way to do this in the lab)



g (gas without odor)

go (gas with odor)

e.g., Calcium carbonate react with hydrogen chloride to produce calcium chloride, carbon dioxide and water.

$CaCO_{3\,(s)} + 2\,HCl_{\,(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{\,(l)} + CO_{2\,(g)}$

Ammonium chloride + sodium hydroxide

$NaOH_{\,(aq)} + NH_4Cl_{\,(aq)} \rightarrow NaCl_{\,(aq)} + NH_{3\,(g)} + H_2O_{\,(l)}$

NH_3 has strong and shocking odor which is easily noticeable.

Possible Observations from chemical reactions: A precipitate appears (or disappears).

- **A precipitate (ppt) appears (or disappears).** The nature of the precipitate is important; it may be crystalline, it may have color, it may merely cloud the solution.

appears

e.g: Silver nitrate and sodium chloride

$NaCl_{(aq)} + AgNO_{3\,(aq)} \rightarrow AgCl_{(s)} + Na(NO_3)_{(aq)}$

disappears

e.g: Calcium carbonate react with hydrogen chloride to produce calcium chloride, carbon dioxide and water.

$CaCO_{3\,(s)} + 2\,HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

Precipitate: ppt-gr (granules), ppt-M (milky), ppt-p (powder), ppt-c (cloudy)

Other examples

Example 1.

$KI_{(aq)} + AgNO_{3\,(aq)} \rightarrow AgI_{(s)} + KNO_{3\,(aq)}$, yellow precipitate of AgI,

see appendix G. Water Solubility of Inorganic Salts, the solubility rules are useful for predicting the solubility of inorganic precipitates.

Example 2.

$Cu(NO_3)_{2(aq)} + Na_2CO_{3\,(aq)} \rightarrow CuCO_{3\,(s)} + NaNO_{3\,(aq)}$, **blue** precipitate of $CuCO_3$

see **Appendix G** for predicting the solubility of inorganic precipitates.

Notice that all reactants and products are colorless except for that of the precipitate in each chemical equation.

Appendix G. Water Solubility Of Inorganic Salts

Water-Soluble Salts

1. All salts of the chloride ion, Cl^-, bromide ion, Br^-, and iodide ion, I^-, are soluble *except* those of Ag^+, Hg_2^{2+}, Pb^{2+}, Cu^+, and Tl^+. BiI_3 and SnI_4 are insoluble. $PbCl_2$ is three to five times more soluble in hot water than in cold water.
2. All salts of the acetate ion, $CH_3CO_2^-$, nitrate ion, NO_3^-, chlorate ion, ClO_3^-, perchlorate ion, ClO_4^-, and permanganate ion, MnO_4^-, are soluble.
3. All common salts of the Group 1A cations and ammonium ion, NH_4^+, are soluble.
4. All common salts of the sulfate ion, SO_4^{2-}, are soluble *except* those of Ba^{2+}, Sr^{2+}, Pb^{2+}, and Hg^{2+}.
5. All Group 1A and 2A salts of the bicarbonate ion, HCO_3^-, are soluble.
6. *Most* salts of the fluorosilicate ion, SiF_6^{2-}, thiocyanate ion, SCN^-, and thiosulfate ion, $S_2O_3^{2-}$, are soluble. *Exceptions* are the Ba^{2+} and Group 1A fluorosilicates, the Ag^+, Hg_2^{2+}, and Pb^{2+} thiocyanates, and the Ag^+ and Pb^{2+} thiosulfates.

Water-Insoluble Salts

1. All common salts of the fluoride ion, F^-, are insoluble *except* those of Ag^+, NH_4^+, and Group 1A cations.
2. In general, all common salts of the carbonate ion, CO_3^{2-}, phosphate ion, PO_4^{3-}, borate ion, BO_3^{3-}, arsenate ion, AsO_4^{3-}, arsenite ion, AsO_3^{3-}, cyanide ion, CN^-, ferricyanide ion, $[Fe(CN)_6]^{3-}$, ferrocyanide ion, $[Fe(CN)_6]^{4-}$, oxalate ion, $C_2O_4^{2-}$, and the sulfite ion, SO_3^{2-}, are insoluble, *except* those of NH_4^+ and the Group 1A cations.
3. All common salts of the oxide ion, O^{2-}, and the hydroxide ion, OH^-, are insoluble *except* those of the Group 1A cations, Ba^{2+}, Sr^{2+}, and NH_4^+. $Ca(OH)_2$ is slightly soluble. Soluble oxides produce the corresponding hydroxides in water.
4. All common salts of the sulfide ion, S^{2-}, are insoluble *except* those of NH_4^+ and the cations that are isoelectronic with a noble gas (e.g., the Group 1A cations, the Group 2A cations, Al^{3+}, etc.).
5. Most common salts of the chromate ion, CrO_4^{2-}, are insoluble *except* those of NH_4^+, Ca^{2+}, Cu^{2+}, Mg^{2+}, and the Group 1A cations.
6. All common salts of the silicate ion, SiO_3^{2-}, are insoluble *except* those of the Group 1A cations.

Table G.1 Summary of the Solubility of Salts

Anion	Soluble Salts with These Cations	"Insoluble" Salts with These Cations
acetate, $CH_3CO_2^-$	most cations	none
arsenate, AsO_4^{3-}	NH_4^+, Group 1A (except Li^+)	most cations
arsenite, AsO_3^{3-}	NH_4^+, Group 1A (except Li^+)	most cations
borate, BO_3^{3-}	NH_4^+, Group 1A (except Li^+)	most cations
bromide, Br^-	most cations	Ag^+, Hg_2^{2+}, Pb^{2+}, Cu^+, Tl^+
carbonate, CO_3^{2-}	NH_4^+, Group 1A (except Li^+)	most cations
chlorate, ClO_3^-	most cations	none
chloride, Cl^-	most cations	Ag^+, Hg_2^{2+}, Pb^{2+}, Cu^+, Tl^+
chromate, CrO_4^{2-}	NH_4^+, Ca^{2+}, Cu^{2+}, Mg^{2+}, Group 1A	most cations
cyanide, CN^-	NH_4^+, Group 1A (except Li^+)	most cations
ferricyanide, $[Fe(CN)_6]^{3-}$	NH_4^+, Group 1A (except Li^+)	most cations
ferrocyanide, $[Fe(CN)_6]^{4-}$	NH_4^+, Group 1A (except Li^+)	most cations
fluoride, F^-	Ag^+, NH_4^+, Group 1A	most cations
fluorosilicate, SiF_6^{2-}	most cations	Ba^{2+}, Group 1A
hydroxide, OH^-	NH_4^+, Sr^{2+}, Ba^{2+}, Group 1A	most cations
iodide, I^-	most cations	Ag^+, Hg_2^{2+}, Pb^{2+}, Cu^+, Tl^+, Br^{3+}, Sn^{4+}
nitrate, NO_3^-	most cations	none
nitrite, NO_2^-	most cations	none
oxalate, $C_2O_4^{2-}$	NH_4^+, Group 1A (except Li^+)	most cations
oxide, O^{2-}	NH_4^+, Sr^{2+}, Ba^{2+}, Group 1A	most cations
perchlorate, ClO_4^-	most cations	none
permanganate, MnO_4^-	most cations	none
phosphate, PO_4^{3-}	NH_4^+, Group 1A (except Li^+)	most cations
silicate, SiO_3^{2-}	Group 1A	most cations
sulfate, SO_4^{2-}	most cations	Sr^{2+}, Ba^{2+}, Pb^{2+}, Hg^{2+}
sulfide, S^{2-}	NH_4^+, Groups 1A and 2A	most cations
sulfite, SO_3^{2-}	NH_4^+, Group 1A (except Li^+)	most cations
thiocyanate, SCN^-	most cations	Ag^+, Hg_2^{2+}, Pb^{2+}
thiosulfate, $S_2O_3^{2-}$	most cations	Ag^+, Pb^{2+}

Cations	Soluble Salts with These Anions	"Insoluble" Salts with These Anions
ammonium, NH_4^+	most anions	no common anions
Group 1A	most anions	no common anions

Other Possible Observations

- **Heat may be evolved (exo) or absorbed (endo)**. The reaction vessel becomes warm if the reaction is exothermic or cools if the reaction is endothermic.

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e.g., acid-base reactions

$$NaOH_{aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + heat$$

- **A color change occurs**. A substance added to the system may cause a color change.

e.g., $KI_{(aq)} + AgNO_{3\,(aq)} \rightarrow$ **AgI (s)** + $KNO_{3\,(aq)}$, yellow precipitate of AgI,

e.g., bromine + alkene (or alkyne), redox reactions

- **pH change**

Experimental Procedure

- The chemical properties of the following compounds, dissolved in water, are investigated in this experiment: $NaCl$, Na_2CO_3, Na_2SO_4, NH_4Cl, $BaCl_2$, $ZnSO_4$

- The following **TEST REAGENTS (كواشف الاختبار)** are used to identify and characterize these compounds: $AgNO_3$, $NaOH$, H_2SO_4, and $Ba(NO_3)_2$

- A series of tests for the chemical properties of **known compounds** in aqueous solutions (1 mL) are conducted with test reagents (5-10 drops) in test clean tubes.

- A similar series of tests are conducted on an **unknown compounds**. In each case, an unknown compound is identified on the basis of the chemical properties observed.
- Notice that **reagent** is a solid chemical or solution having known concentration of analyte

In this experiment,

- you will **observe chemical reactions** that are characteristic of various compounds under controlled conditions.
- After collecting and organizing your data, you will be given an **unknown compound**, a compound that you have previously investigated its chemical properties. The interpretations of the collected data will assist you in identifying your unknown compound.

Test reagent	NaCl	Na_2CO_3	Na_2SO_4	NH_4Cl	$BaCl_2$	$ZnSO_4$	unknown
$AgNO_3$	P, AgCl	P, Ag_2CO_3					
NaOH	NR	NR		go, NH_3		P, $Zn(OH)_2$	
H_2SO_4	NR	g, CO_2					
$Ba(NO_3)_2$	NR	P, $BaCO_3$		NR		P, $BaSO_4$	

Record your observation (as p—precipitate + color; c—cloudy + color ; nr—no reaction; g—gas, no odor; go—gas, odor) in the reaction matrix of the report sheet and write down the possible chemical reaction in each case.

Observations with $AgNO_3$ test reagent

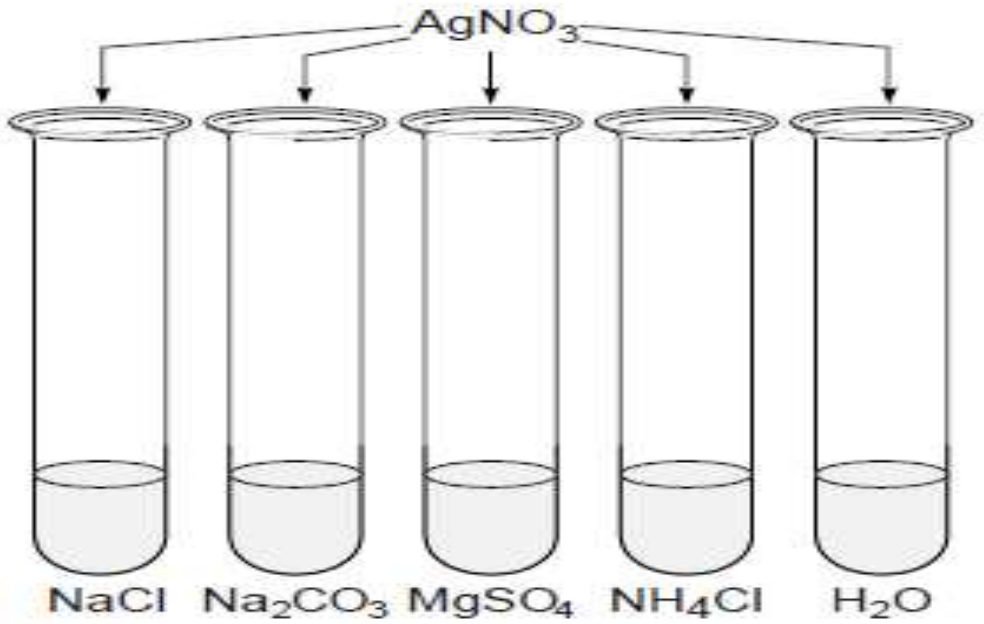

Figure 2.2a Arrangement of test tubes for testing with the silver nitrate reagent.

CLEANUP: Rinse the test tubes with tap water and twice with deionized water.

-No water droplets should adhere to the inner surface of the test tube after cleaning.

- In qualitative analysis, clean glassware are needed to prevent contamination of the testing reagents.

Observations with NaOH and HCl test reagents

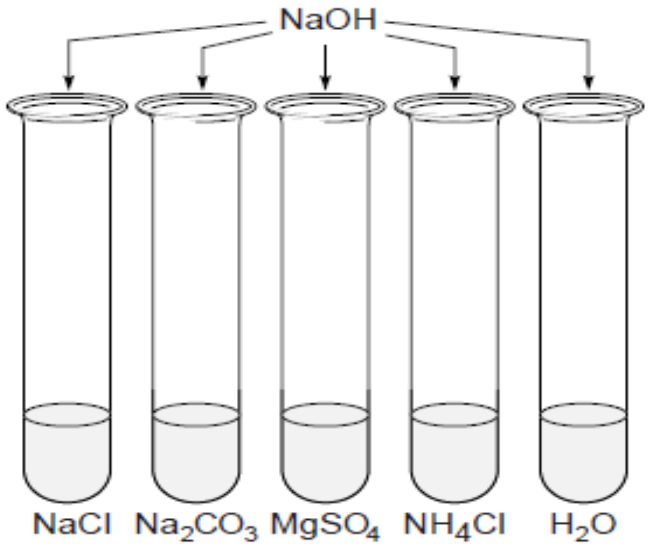

Figure 2.3 Arrangement of test tubes for testing with the sodium hydroxide reagent.

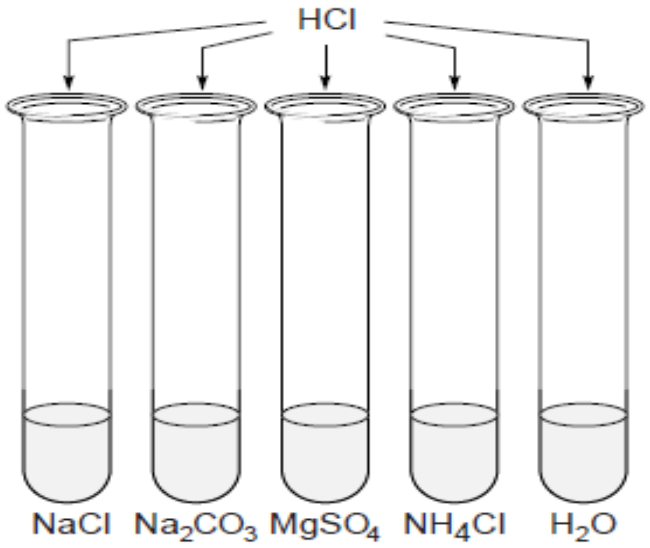

Figure 2.4 Arrangement of test tubes for testing with the hydrochloric acid reagent.

Experiment 2 *Prelaboratory Assignment*

Identification of a Compound: Chemical Properties

Date _____ Lab Sec. _____ Name _____ Desk No. _____

1. Experimental Procedure, Part A. a. What is the criterion for clean glassware?

b. What is the size and volume of a "small, clean test tube?"

2. Experimental Procedure, Part A.2. Describe the technique for testing the odor of a chemical.

3. a. Depending upon the tip of a dropper pipet, there are approximately 20 drops per milliliter of water. What is the approximate volume (in mL) of one drop of an aqueous solution?

b. A micropipet delivers 153 drops of alcohol for each milliliter. Calculate the volume (in mL) of alcohol in each drop.

4. Write a balanced equation for the following observed reactions:

a. Aqueous solutions of sodium hydroxide, NaOH, and sulfuric acid, H_2SO_4, are mixed. The neutralization products are water and one other compound with the evolution of heat.

b. Aqueous solutions of copper(II) nitrate, $Cu(NO_3)_2$, and sodium carbonate, Na_2CO_3, are mixed. A blue precipitate of copper(II) carbonate forms in addition to one other compound.

5. Experimental Procedure, Part A. The substances, NaCl, Na_2CO_3, $MgSO_4$, and NH_4Cl used for test solutions, are all soluble ionic compounds. For each substance indicate the ions present in its respective test solution.

   NaCl: _____

   Na_2CO_3: _____

   $MgSO_4$: _____

   NH_4Cl: _____

6. Three colorless solutions in test tubes, with no labels, are in a test tube rack on the laboratory bench. Lying beside the test tubes are three labels: potassium iodide, KI, silver nitrate, $AgNO_3$, and sodium sulfide, Na_2S. You are to place the labels on the test tubes using only the three solutions present. Here are your tests:

   - A portion of test tube #1 added to a portion of test tube #3 produces a yellow, silver iodide precipitate.
   - A portion of test tube #1 added to a portion of test tube #2 produces a black, silver sulfide precipitate.

   a. Your conclusions are:
      Test Tube 1_____

      Test Tube 2_____

      Test Tube 3_____

   b. Write the balanced equation for the formation of silver iodide, AgI.

   c. Write the balanced equation for the formation of sulfide, Ag_2S.

7. Refer to Appendix G and determine which of following salts are insoluble in

water: $NaNO_3$, $AgCl$, $Mg(OH)_2$, NH_4NO, and Ag_2CO_3

POST LAB QUESTIONS

1. Identify a chemical reagent used in this experiment that can be used to distinguish solid $CaCl_2$(soluble) from solid $CaCO_3$(insoluble). What is the distinguishing observation?

A chemical reagent that we could have used for this experiment to distinguish the two soluble and insoluble solids is HCl. If we mix $CaCl_2$ and HCl the solid will be soluble, no reaction will occur. If we mix HCl and $CaCO_3$ then a reaction will occur, bubbles will form.

2. What test reagent used in this experiment will distinguish a soluble Cl^-salt from a soluble SO_4^{2-}salt? What is the distinguishing observation?

A test reagent that we can use for this experiment to distinguish the soluble Cl^- and the soluble SO_4^{2-}, is $AgNO_3$. If we mix $AgNO_3$ and Cl^- a reaction will occur forming a precipitate. If we mix it with SO_4^{2-} no reaction will occur.

3. Predict what would be observed (and why) from an aqueous mixture for each of the following (all substances are water soluble).

a. Potassium carbonate and hydrochloric acid

By mixing the two we get potassium chloride. CO_2 and water will also be present but no precipitate will form.

b. Zinc chloride and silver nitrate

By mixing zinc chloride and silver nitrate we will get zinc nitrate and silver chloride. The silver chloride will form a precipitate because it is not soluble in water.

c. Magnesium chloride and sodium hydroxide

By mixing magnesium chloride and sodium hydroxide, we would get magnesium hydroxide and sodium chloride. Since magnesium hydroxide is insoluble it will produce a precipitate.

d. Ammonium nitrate and sodium hydroxide

By mixing ammonium nitrate and sodium hydroxide we get sodium nitrate, ammonia, and water. No precipitate would form in this situation because they are all soluble.

4. Three colorless solutions in the test tubes, with no labels, are in a test tube rack on the lab bench. Lying beside the test tubes are three labels: 0.10 M Na_2CO_3, 0.10 M HCl, and 0.10 M KOH. You are to place the labels on the test tubes using only the three solutions present. Here are your tests:

- **A few drops of the solution from the test tube 1 added to a similar volume of the solution in the test tube 2 produces no visible reaction but the solution becomes warm.**
- **A few drops of the solution from the test tube 1 added to a similar volume of the solution in test tube 3 produces carbon dioxide gas.**
- **Identify the labels for test tubes 1,2, and 3.**

Test tube 1: 0.10 M HCl
Test tube 2: 0.10 M KOH
Test tube 3: 0.10 M Na_2CO_3

5. Three colorless solutions in test tubes, with no labels, are in the test tube rack on the lab bench. Lying beside the test tubes are three labels: silver nitrate, $AgNO_3$; hydrochloric acid, HCl; and sodium carbonate, Na_2CO_3. You are to place the labels on the test tubes using only the three solutions present. Here is your analysis prodedure:

- **A portion of test tube 1 added to a portion of test tube 2 produces CO_2.**
- **A portion of test tube 2 added to a portion of test tube 3 produces a white silver carbonate precipitate.**

a. On the basis of your observations, how would you label the three test tubes?

Test tube 1: HCl
Test tube 2: Na_2CO_3
Test tube 3: $AgNO_3$

b. What would you expect to happen if a portion of test tube 1 is added to a portion of test tube 3?

If we mixed a portion of test tube 1 and test tube 3 then we would get AgCl,
this will form a precipitate because it is insoluble.

6. For individual solutions of the cations Ag^+, Ba^{2+}, Mg^{2+}, and Cu^{2+}, the following experimental observations were collected:

	$NH_3(aq)$	$HCl(aq)$	$H_2SO_4(aq)$
Ag^+	No change	White ppt.	No change
Ba^{2+}	No change	No change	White ppt.
Mg^{2+}	White ppt.	No change	No change
Cu^{2+}	Blue ppt/ dark blue solm. with excess	No change	No change

From these experimental observations,

a. Identify a reagent that distinguishes the chemical properties of Ag^+ and Mg^{2+}. What is the distinguishing observation?

The reagent that distinguishes the chemical properties would be HCl because this forms a precipitate with Ag+ forming AgCl. If we mix it with Mg^{2+} then we get $MgCl_2$.

b. Identify a reagent that distinguish the chemical properties of the HCl and the H_2SO_4. What is the distinguishing observation?

The reagent that distinguishes the chemical properties would be Ag+, when it reacts with HCl we get AgCl which forms a precipitate. If mixed with H_2SO_4 no precipitate forms because it is soluble.

c. Identify a reagent that distinguishes the chemical properties of Ba^{2+} and Cu^{2+}. What is the distinguishing observation?

The reagent that distinguishes the chemical properties would be NH_3, when it reacts with Cu^{2+} we see a blue solution form due to its reaction with ammonia. When Ba^{2+} is mixed with NH_3 a reaction will not occur because it is soluble.

d. Identify a reagent that distinguishes the chemical properties of Cu^{2+} and Mg^{2+}. What is the distinguishing observation?

The reagent that distinguishes the chemical properties would be NH_3, when we react it with Cu^{2+} we get a deep-blue solution but it forms a white precipitate with Mg^{2+} .