Experiment 4

The Periodic Table

Pre-Lab Assignment

Before coming to lab:

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

Periodic trends in reactivity and other physical properties will be determined by qualitative observation. A variety of inorganic compounds, including predictable and unpredictable ionic compounds, binary molecular, acids, and polyatomic ions will be named systematically.

Background

In 1869 Russian chemist Dmitri Mendeleev published the forefather to the modern periodic table in which he arranged the known elements by increasing atomic mass, leaving gaps where he predicted elements not yet discovered would be found. While doing so, Mendeleev noted that elements in close proximity to one another often shared predictable chemical and physical properties, known as periodic trends.

On the periodic table, horizontal rows are known as periods while columns are known as groups or families. Some groups are known by their common names. Group 1A is also known as the Alkali Metals, Group 2A as the Alkaline Earth Metals, Group 7A as the Halogens and Group 8A as the Noble Gases. Main Group elements are designated with an "A" in their group name and are on the edges of the table while transition metals have a "B" and are in the middle. Metals are located on the left of the periodic table and nonmetals on the right, with metalloids straddling the line in between.

When multiple atoms combine, they create a molecule that is held together by chemical bonds. Ionic bonds involve the exchanging of electrons between a metal and a nonmetal. Covalent bonds involve the sharing of electrons between a nonmetal and another nonmetal. The Law of Constant Compositions states that every molecule of a given compound has exactly the same ratio of elements. Thus standardized rules for identifying compounds, called nomenclature, can and has been established.

Ionic Compounds

Ionic compounds are divided into two categories: those with predictable cations with a fixed change, meaning metals from Groups 1A-2A or polyatomic ions, and those with unpredictable cations with a variable charge, meaning transition metals. The format for naming both types of ionic compounds where the anion is monoatomic shown below and on the next page. The underscore (_) indicates a space in the name.

For cations with fixed, predictable charge and a monoatomic anion:

cation element name _ base name of anion element + *ide*

For cations with variable, unpredictable charge and a monoatomic anion:

cation element name(charge) _ base name of anion element *+ ide*

The cation charge is written in Roman Numerals.

Polyatomic ions are groups of atoms that behave as a single unit and carry a shared overall charge. Some common polyatomic ions and their names are included in Table 1 below. They can be substituted for any cation or anion in an ionic compound. Oxyanions (polyatomic ions that include oxygen and carry negative charges) can change the number of oxygens present and thus change their prefix and/or suffix in a predictable pattern while their overall charge is maintained.

per+(anion)+ate **– O** → (anion)+ate **– O** → (anion)+ite **– O** → hypo+(anion)+ite

Table 1: Common Polyatomic Ions

4 oxygens	**3 oxygens**	**2 oxygens**	**1 oxygen**	**0 oxygens**
PO_4^{3-} phosphate	PO_3^{3-} phosphite	PO_2^{3-} hypophosphite		
	CO_3^{2-} carbonate	CO_2^{2-} carbonite	CO^{2-} hypocarbonite	
SO_4^{2-} sulfate	SO_3^{2-} sulfite	SO_2^{2-} hyposulfite		
		CH_3COO^- or $C_2H_3O_2^-$ acetate		
	NO_3^- nitrate	NO_2^- nitrite	NO^- hyponitrite	
ClO_4^- perchlorate	ClO_3^- chlorate	ClO_2^- chlorite	ClO^- hypochlorite	
	BrO_3^- bromate	BrO_2^- bromite	BrO^- hypobromite	
	IO_3^- iodate	IO_2^- iodite	IO^- hypoiodite	
			OH^- hydroxide	
				NH_4^+ ammonium

Binary Molecular Compounds

Binary molecular compounds are named with the most metallic (furthest left and down on the periodic table) listed first with the exception of oxygen, which is always listed last. Since molecular compounds do not contain charges, the exact number of atoms of each element must be explicitly included in the name through the addition of Greek numerical prefixes, as seen in Table 2. The format for naming molecular compounds is shown below. The underscore (_) indicates a space in the name.

prefix*+first element name _ prefix + second element base name + *ide*

**No prefix of "mono-" is used for the first element.*

Table 2: Prefixes for Molecular Compounds

Number	**Prefix**		**Number**	**Prefix**
1	mono-		6	hexa-
2	di-		7	hepta-
3	tri-		8	octa-
4	tetra-		9	nona-
5	penta-		10	deca-

Acids

Acids are molecular compounds that produce H^+ (hydrogen ion) when dissolved in aqueous solution. They contain charges and their name is dependent on the suffix of the anion included. The format for naming acids is shown below. The underscore (_) indicates a space in the name.

For "-ide": | *hydro* + anion base name + *ic* _ acid |

For "-ite": | anion base name + *ous* _ acid |

For "-ate": | anion base name + *ic* _ acid |

Example Exercise: Naming Compounds

Name the following: (1) $CaCl_2$, (2) AuO, (3) P_2O_4, and (4) $HClO_2$.

(1) $CaCl_2$ is an ionic compound with a predictable cation (Ca is in Group 2A, +2).
- **calcium chloride**

(2) AuO is an ionic compound with an unpredictable cation (Au is a transition metal). O is in Group 6A so –2, thus Au must be +2 to balance its charge
- **gold(II) oxide**

(3) P_2O_4 is a molecular compound (both nonmetals)
- **diphosphorous tetroxide**

(4) $HClO_2$ is an acid with an anion that has an "-ite" suffix (ClO_2^- = chlorite)
- **chlorous acid**

Procedure

Part I: Metals with Water

Instructor Demonstration: Your laboratory instructor will demonstrate the reaction of sodium metal in water. Note your observations on your Data Sheet.

> Caution! These reactions may be vigorous and produce flammable $H_2(g)$!

1. Obtain one small piece of calcium and one small piece of magnesium. Store these on a plastic weigh boat until use.
2. Fill a 250 mL beaker approximately half full of tap water. Find a watchglass that will fit on top of the beaker and set it aside.
3. Carefully put the piece of calcium into the beaker of water and immediately cover the top with the watchglass. Observe any changes that take place and record your observations in your data sheet.
4. After the reaction has completed, dispose of the beaker's contents in the specified waste container and refill the beaker halfway with tap water.
5. Carefully put the piece of magnesium into the beaker of water and immediately cover the top with the watchglass. Observe any changes that take place and record your observations in your data sheet.
6. After the reaction has completed, dispose of the beaker's contents in the specified waste container.
7. Summarize your observations about their reaction with water into a periodic trend for the three metals observed: sodium, magnesium, and calcium.

Part II: Observations of Elements

1. Take observations of the elements listed and complete the table on your data sheet.

Part III: Nomenclature of Compounds

1. Use the IUPAC naming rules outlined in the Background section to write the name or formula for each compound in Part III of the data sheet. Common names and jumbled formulas will not be accepted. Spelling counts!

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Experiment 4—Data Sheet

Name: _____

Part I: Metals with Water

1. Sodium with water Observations:

2. Calcium with water Observations:

3. Magnesium with water Observations:

4. Summarize metals' reactivity with water

Part II: Observations of Elements

Element	Symbol	Metal, Metalloid, or Nonmetal	Description
Aluminum			
Carbon			
Copper			
Iron			
Magnesium			
Nickel			
Nitrogen			
Oxygen			
Phosphorous			
Silicon			
Silver			
Sulfur			
Tin			
Zinc			

Part III: Nomenclature of Compounds

For each formula, identify the compound type, write the formulas for any ions present in the compound, and then write the name for the compound. For compound type, use I for ionic, M for molecular, or A for acid. Use the naming rules outlined in the background reading for this experiment. Spelling counts!

	Formula	Type?	Ions present? (if any)	Name
1.	$NaCl$			
2.	$AgNO_3$			
3.	$Ca(OH)_2$			
4.	Na_2SO_4			
5.	$CdBr_2$			
6.	KNO_2			
7.	$Fe(NO_3)_3$			
8.	$(NH_4)_3PO_4$			
9.	$Mg(HCO_3)_2$			
10.	$(NH_4)_2S$			
11.	$HgCl_2$			
12.	$H_2SO_4(aq)$			
13.	$Cr(BrO_3)_3$			
14.	Cu_2CO_3			
15.	$HCl(aq)$			
16.	CO_2			
17.	Na_2O_2			

	Formula	Type?	Ions present? (if any)	Name
18.	KIO_2			
19.	V_2O_5			
20.	Na_2SO_3			
21.	$Ta(NO_2)_4$			
22.	Ag_2CO_3			
23.	CrF_3			
24.	$Zr(HSO_4)_2$			
25.	$H_2CO_2(aq)$			
26.	$Au(ClO_3)_3$			
27.	$HC_2H_3O_2(aq)$			

For each name, identify the compound type, write the formulas for any ions present in the compound, and then write the formula for the compound. For compound type, use I for ionic, M for molecular, or A for acid. Use the naming rules outlined in the background reading for this experiment. Jumbled formulas will not be accepted!

	Name	**Type?**	**Ions present? (if any)**	**Formula**
1.	barium chloride			
2.	lead(II) iodide			
3.	ammonium hydroxide			
4.	bismuth(III) chloride			
5.	magnesium nitrate			
6.	iron(III) chloride			
7.	calcium bromite			
8.	copper(I) bicarbonate			
9.	silver phosphite			
10.	nickel(II) phosphate			
11.	sodium sulfite			
12.	tin(IV) oxide			
13.	zinc nitrite			
14.	titanium(IV) iodate			
15.	manganese(IV) sulfide			
16.	phosphoric acid			
17.	hypochlorous acid			

	Name	Type?	Ions present? (if any)	Formula
18.	ammonium cyanide			
19.	hydrobromic acid			
20.	barium hydroxide			
21.	carbon tetrachloride			
22.	sulfur dioxide			
23.	carbonic acid			
24.	zinc phosphite			
25.	yttrium (III) oxide			
26.	nitrous acid			
27.	chromium(III) sulfite			
28.	carbon disulfide			

Experiment 4—Post-Lab Assignment

Name: _____

1. Using the trend you observed in Part I, predict and explain whether the following elements would be reactive with water:

   a. Barium, Ba

   b. Aluminum, Al

   c. Argon, Ar

2. Generally, metals are able to conduct electricity while nonmetals do not. What would you expect for metalloids? Explain.

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Experiment 4—Pre-Lab Assignment

Name: _____

1. Consider the element silicon (Si) and its position on the periodic table.

   a. Is it a metal, nonmetal, or metalloid? _____

   b. What group is it in? _____

   c. What period is it in? _____

   d. Is it a main group element or transition metal? _____

   e. When bonded with O, would it form an ionic or covalent compound? _____

2. Consider the element rubidium (Rb) and its position on the periodic table.

   a. Is it a metal, nonmetal, or metalloid? _____

   b. What group is it in? _____

   c. What period is it in? _____

   d. Is it a main group element or transition metal? _____

   e. What charge would it have as an ion? _____

   f. When bonded with O, would it form an ionic or covalent compound? _____

3. For each formula, identify the compound type and then write the name for the compound. For compound type, use I for ionic, M for molecular, or A for acid. Use the naming rules outlined in the background reading for this experiment. Spelling counts!

	Formula	**Type?**	**Name**
a.	$Zn(IO_3)_2$		
b.	$HClO_4$ (aq)		
c.	CO_2		

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