The Material World:
Periodic Table, Bonding and Nomenclature

3. Families of the Periodic Table

Some of these include:

A. Alkali Metals
B. Alkaline Earth Metals
C. Halogens
D. Noble Gases

Definition of a Family: a group of elements with similar chemical and (often) physical properties. These groups are found in vertical columns in the periodic table, and note that these patterns emerge by listing the elements in order of atomic number. (This is sometimes referred to as the ***Periodic Law***.)

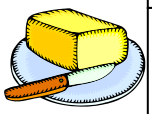
A ***The Alkali Metals*** Alkali is derived from an Arabic word *alqaliy*, meaning ashes of saltwort. Soon you'll understand the connection.

1. **Physical Properties**

a) Do they have a common appearance?_____

b) Are they conductors of electricity?_____

c) What can you generalize about their melting points?_____



2. **Chemical Properties**

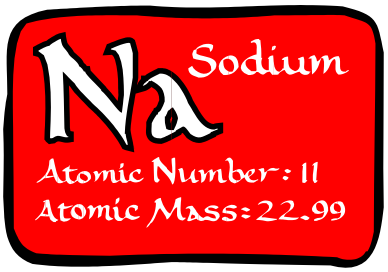
a) Outline the electron arrangement for the first three members of the family.

$_{3}$**Li**
$_{11}$**Na**
$_{19}$**K**
$_{37}$**Rb**
$_{55}$**Cs**
$_{87}$**Fr**

b) How many electrons do you think each alkali metal typically loses? Why? (Compare the force of attraction between the alkali nucleus and an electron in a distant shell with what's going on in a neighboring element with one less proton.)

c) What common ion is formed by alkali metals?_____

d) Sodium is found in oceans, neurons and in minerals but always in the Na^{+1} form. Na would destroy living cells and cause explosive reactions in the ocean. To make neutral sodium, we pass electricity through molten NaCl, thus forcing Na^{+1} to take back its electron.



What do you infer from the above?

e) *Specific Reactions of the Alkali Metals*

The members of this family react vigorously with acids, water, oxygen and halogens. The reaction with water generates hydrogen gas and a base.

<u>Examples of Chemical Equations</u>

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B ***The Alkaline Earth Metals*** They are called alkaline because like alkali metals, they also react with water to form bases, but the bases are like mud or earth in that they do not dissolve well in water.

1. **Physical Properties**

If the alkali metal family members are like butter, the alkaline family is like dry-cheese. What do we mean by that?

$_{4}$**Be**
$_{12}$**Mg**
$_{20}$**Ca**
$_{38}$**Sr**
$_{56}$**Ba**
$_{88}$**Ra**

2. **Chemical Properties**

a) Give a Bohr-Rutherford diagram for the first three members of the family:

b) How many electrons do you think each alkaline earth metal typically loses? Why?

c) What common ion is formed by alkaline earth metals?_____

d) The calcium that's in your bones or in limestone as part of caves, atolls or marble is in the Ca^{+2} form, usually bound to CO_3^{-2}. Neutral calcium, if mistakenly put in calcium supplements (God forbid!), would severely burn your mouth and esophagus because Ca reacts with water.

<u>Explain</u>.

e) *Specific Reactions of the Alkaline Earth Metals*

React with acids, water, oxygen and halogens, but not always as violently as alkali metals. The reaction with water also generates hydrogen gas and a base.

Examples of Chemical Equations

Exercises

1. List all six alkali metals, the so-called group IA elements.

2. Why do we have to store alkali metals in oil? Why can't we keep them in an "empty" jar?

3. Give three reasons why it would be a really bad idea to make umbrella tips out of alkali metals.

4. What family loves to react with alkali metals?

5. Given: $2\ Na + H_2 \rightarrow 2\ NaH$

   Write an equation for the reaction between potassium and hydrogen.

6. Is it easy to form Na^{+2}? Why or why not?

7. List all 6 alkaline earths, the so-called group IIA elements.

8. From physical properties alone, how can you tell alkali metals apart from alkaline earths? List at least two ways.

9. a. What common ion is formed by alkaline earths?
   b. Why does this happen?

10. List three natural sources of alkaline earth metals.

11. Given: $MgO + H_2O \rightarrow Mg(OH)_2$.

    Write an equation to represent the reaction between CaO and water.

12. a. Which of the following is the most difficult to form? Mg^{+1}, Mg^{+2} or Mg^{+3}?
    b. Why?

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C ***The Halogens*** < *hals* is ancient Greek for sea. Because these family members form salts upon reacting with metals, and since the sea is rich in salt, we call them halogens.

The halogens make up the second last column on the right hand side of the periodic table.

$_{9}$**F**
$_{17}$**Cl**
$_{35}$**Br**
$_{53}$**I**
$_{85}$**At**
Not discovered

1. **Physical Properties**

All halogens are nonmetals. At room temperature F_2 and Cl_2 are pale green and greenish yellow gases, respectively. Bromine is red-brown liquid with a foul smell, while iodine is a blue-black solid. Astatine is unstable, and so we do not know its physical properties.

a. Based on the above which halogen has the highest boiling point?
b. Can you guess which one has the lowest?

c. As mentioned, the halogens are part of a group of elements classified as non-metals. Are they good conductors of heat and electricity?

2. Chemical Properties

a. What is the electronic configuration (shell diagram) of each halogen?

$_{9}$ F

$_{17}$Cl

$_{35}$Br

$_{53}$I

^{85}At

b. Based on these configurations, what do you expect the common ion for halogens to be? Why?

c. *Specific Chemical Reactions of Halogens*

1. Halogens react with metals.

Examples

2. They react with hydrogen gas according to the following general equation:

$X_2 + H_2 \rightarrow 2\ HX$

Examples

3. They react with water according to the following general equation:

$X_2 + H_2O \rightarrow HX + HOX$

Examples

4. They form diatomic molecules. $X + X \rightarrow X_2$

Examples

Why does this happen? In forming such molecules, halogens *share* electrons and each halogen atom in the diatomic molecule pulls on the electron from its partner. Consider for example two atoms of F:

C *The Noble Gases (formerly known as Inert Gases)*

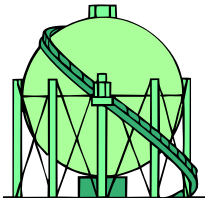
The noble gases make up the last column on the right hand side of the periodic table.

1. **Physical Properties**

All noble gases are poor conductors of heat and electricity. They are all gases at room temperature.

2. **Chemical Properties**

a. They do *not* react with metals or with oxygen.



*Why?*_____

$_{2}$**He**
$_{10}$**Ne**
$_{18}$**Ar**
$_{36}$**Kr**
$_{54}$**Xe**
$_{86}$**Rn**

b.

- Even the most reactive member of the family has only been known to react with powerful electron muggers like F_2 and PtF_6.
- No compounds of He and Ne exist.

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Exercises

1. List the halogens.

2. List 3 physical properties of the halogens

3. What do halogens react with? List at least three examples.

4. Given:

   $X_2 + H_2 \rightarrow 2\ HX$

   Write an equation for the reaction between iodine and hydrogen.

5. What family of the periodic table includes all three states of matter at room temperature?

6. Why do halogens form the -1 ion? Why diatomic molecules?

7. How do you distinguish between silver and sodium if both are stored in oil, and you are not allowed to open their glass jars?

8. Could you find a piece of pure sodium if you visited the right national park? Pure calcium? Explain.

9. After years of sitting in a half-empty bottle, some Ca flakes don't react as vigorously as they once did. What could have happened?

10. What do neon and helium react with?

11. Would it be dangerous to light a match in a room containing 5% argon?

12. What is more likely poisonous? Xenon? Or fluorine? Explain.

13. What am I? Use your knowledge of the periodic table and the periodic table itself to identify the element being described.

a. I am the alkaline earth metal with the least number of protons.___
b. Out of all the alkali metals, I have the most energy levels (shells) filled.___
c. I'm an alkali metal that loses an electron to Cl to produce the kind of salt added to fries.___
d. My valence number is 2, and I'm bigger than Ba.___
e. My most common ion is +2, and I burn with a white dazzling light.___
f. I'm the most common halogen in the ocean.____

g. I have 8 more protons than oxygen.___
h. I am not He but I am an inert (noble) gas smaller than Ar.__
i. The smallest atom of my family, I am a gas that refuses to burn or react with anything.___
j. I am a shiny solid halogen that is mixed with alcohol to form an antiseptic.___
k. When my oxide is added to water, you get limewater.____
l. I am the only metalloid in group IIIA (boron's family).____
m. I am the smallest of two nonmetals in group VA.____
n. I am the most reactive metal in the second period (We don't mean the second period of a hockey game. A period 2 element has electrons in the first two energy levels).__
o. I am the most reactive nonmetal in the third period.___
p. I am the most reactive halogen.____
q. I am the most reactive alkali metal.___
r. When neutral I have 18 electrons.____
s. With a charge of +2, I have 18 electrons.___
t. With a charge of –1, I have 36 electrons.___
u. With a charge of +3, I end up with 10 electrons.___
v. I am a gas in the same column as the alkali metals, but I don't belong with them.___
w. I am the only alkali metal named after a country.___
x. Although I am not P, in his family I am the worst conductor of electricity.___
y. I am the only member of group IIIA who is *not* malleable.____
z. People who are xenophobic are afraid of strangers. I am the noble gas named after strangers.___
zz. Among the alkali metals I am the member with the most energy levels.___

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4. Bonding

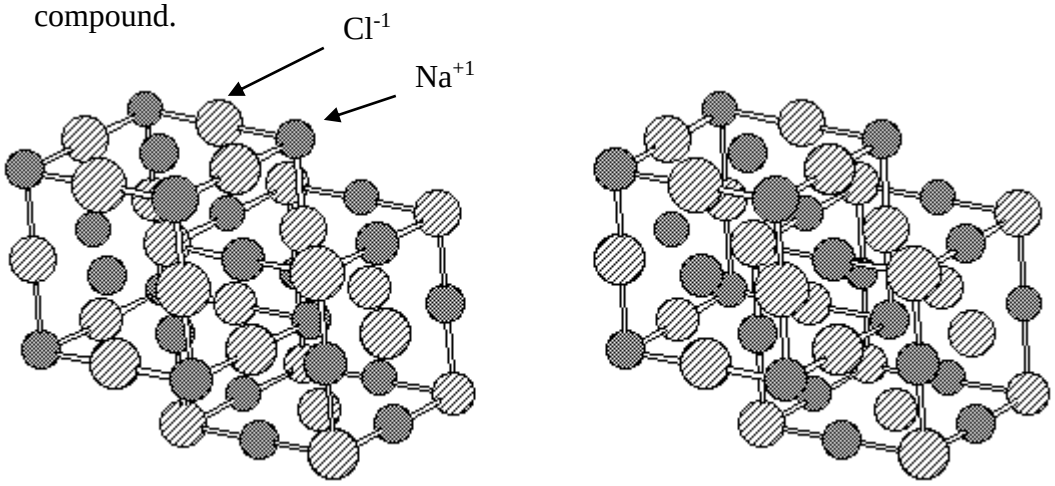
A. *Ionic Bonding Between a Metal and a Non Metal*

When a metal reacts with a nonmetal, electrons are transferred from the metal to the nonmetal, creating a positive ion and a negative ion. The compound, usually a crystalline salt, is known as an ionic compound. The attraction between the metal positive ions and the nonmetal negative ion is called an ***ionic bond***.

Examples In the reaction between sodium and chlorine, represent each ***valence*** electron (last shell electron) with a dot, and then use arrows to show the transfer of electrons.

Reaction:
Product:
Formula:

NaCl, like most ionic compounds, does not actually exist as a separate molecule. Each Na^{+1} ion attracts Cl^{-1} ions all around itself while the Cl^{-1} ions attract Na^{+1} ions all around themselves. What results is a geometric arrangement of ions and at the macro level we see a compound.



Different ionic compounds may have a different geometric pattern. The actual arrangement depends on the size and charge of the ions and on the ratio of positive ions to negative ions.

Examples of other ionic dot structures.

Note that the sum of positive and negative charges in the compound is always zero.

a. Mg and Cl

Reaction:
Product:
Formula:

b. Na and O

Reaction:
Product:
Formula:

c. Al and O

Reaction:
Product:
Formula:

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Exercises

1. (1) Use dot structures to predict the formula of the compound formed when the given elements react.
   (2) Then write a formula for what has been produced.

a. Al and Cl
b. Be and O
c. Na and O
d. Li and F
e. Mg and N
f. Ca and F
g. K and N
h. K and Br
i. Be and F
j. Ca and P

****B.** ***Covalent Bonding Between Non Metals (430 only)***

Non metals do *not* assume a charge when reacting with each other. Instead they share electrons in an attempt to fill their outermost shells. Lewis dot structures use a dot for each valence electron. For the simplest structures, we then try to arrange the dots (without creating any new ones) so that each atom is satisfied. Hydrogen only wants two electrons. Carbon, nitrogen, oxygen, and the halogens want eight electrons (this is known as the *octet rule*).

Three Basic Rules for ***Lewis Dot Structures****:*

1. Each ***valence*** electron is represented by 1 dot.
2. For hydrogen, halogens and second period non-metals, the number of electrons needed to complete a shell is the number of electrons that the atom will have to share when forming a covalent bond.
3. Each atom in the stable compound must be satisfied. Otherwise you'll have an unstable radical.

Element	Shell Diagram	Valence Electrons (number of dots)	Missing Electrons (number of electrons to be shared)
H	**1)**	**1**	**2 - 1 = 1**
C	**2)4**	**4**	**8 - 4 = 4**
N	**2)5**	**5**	**8 - 5 = 3**
O	**2)6**	**6**	**8 - 6 = 2**
Cl	**2)8)7**	**7**	**8 - 7 = 1**

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Examples

1. NH_3 = ammonia. This compound, made from hydrogen and nitrogen, is an important precursor of fertilizers. It is also found in comets and in interstellar space. We have to combine nitrogen with its five valence electrons with three hydrogens, each with 1 valence electron. Since nitrogen needs three more electrons to fill its shell, it will bond to three hydrogens, which will all be satisfied.

Draw a dot structure.

2. C_2H_6O

There are two possibilities here. Two different compounds with the same chemical formula are known as ***isomers***.
This is ethyl alcohol found in beer, wine etc.
But with the same formula but different structure and different chemical properties is dimethyl ether.

Draw 2 different dot structures.

3. $C_{13}NH$ = cyanopolyyne. This molecule has never been successfully synthesized and does not exist on earth. But it's known to exist near a star at distance of 660 light years from earth. *(see Radiation and Radioactivity. Draganic and al. 1990. p 159)*

Draw a dot structure.

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Exercises

1. Draw dot structures for the following: (Careful! Not all compounds are covalent!)

a. F_2

b. C_4H_{10}

c. C_2H_7N

d. K_2S

e. For the reaction between Ca and Cl

f. For the reaction between Li and F

g. C_5H_5N

h. C_6H_6

i. CO_2

j. N_2

k. C_2H_2

l. HBr (don't put in more dots than necessary!)

m. C_5H_{10}

n. N_2H_4

2. Balance the following **and translate them** into word equations.

<u>Example</u>: $H_{2(g)} + N_{2(g)} \rightarrow NH_{3(g)}$

<u>Answer:</u> $3\ H_{2(g)} + N_{2(g)} \rightarrow 2\ NH_{3(g)}$

3 moles of hydrogen gas react with one mole of nitrogen gas to produce 2 moles of nitrogen trihydride (ammonia) gas.

a. $Mg(s) + O_{2(g)} \rightarrow MgO_{(s)}$

b. $H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$

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

d. $Al_{(s)} + Fe_2O_{3(s)} \rightarrow Al_2O_{3\ (s)} + Fe_{(l)}$

e. $C_{(s)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2(g)}$

3. In #2d, the iron is produced as a liquid. What does that tell you about the energy associated with the reaction?

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5. Periodic Trends

A. Electronegativity

This is a measure of an atom's tendency to pull electrons towards itself while bonded to another atom. In a sense, it is a measure of greediness. The nonmetals, which are close to having a full energy level, are far more electronegative than metals.
Within any period, as atomic number increases, electronegativity increases.
For the nonmetals, *within a family*, electronegativity *decreases* with increasing number. So fluorine, for instance, is the most electronegative halogen; in fact it is the periodic table's most electronegative atom.

B. Atomic Volume or Radius

Within a family, not surprisingly, atomic volume increases with increasing atomic number. But note that across a period (from left to right), atomic volume actually decreases. This is because additional nuclear charge is acting on the same number ofshells.

C. Melting Point and Boiling Points

For alkali metals, both melting points and boiling points decrease with increasing atomic number. So Fr is the lowest-melting alkali metal.
For halogens, the trend reverses itself. Both melting points and boiling points increase with increasing atomic number. Hence at room temperature chlorine is a gas, but bromine is a liquid and astatine and iodine are still solids.

D. Ionization Energy

Ionization energy is the amount of energy needed to remove an electron from an atom in its gaseous state.
With increasing atomic number within a family, ionization energy decreases. Within a period, ionization energy *increases* as one moves from left to right.

<u>In Class Exercise</u>

Draw a small periodic table, and then use arrows to represent all of the trends described in the above text.

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Exercises

1. From each pair, choose the atom that is more willing to lose an electron.

a. Mg He
b. Na Be^{+2}
c. Ca K
d. Ca^{+1} K^{+1}
e. F Rb
f. F Br
g. F^{-1} Rb
h Cl F
i. O^{-2} Mg
j. Mg Al

2. Which alkali metal has the lowest melting point?

3. Which halogen has the highest boiling point?

4. Which halogen has the highest electronegativity value?

5. Pick the element with the largest atomic volume.

a. Li Na K

b. F Cl Br

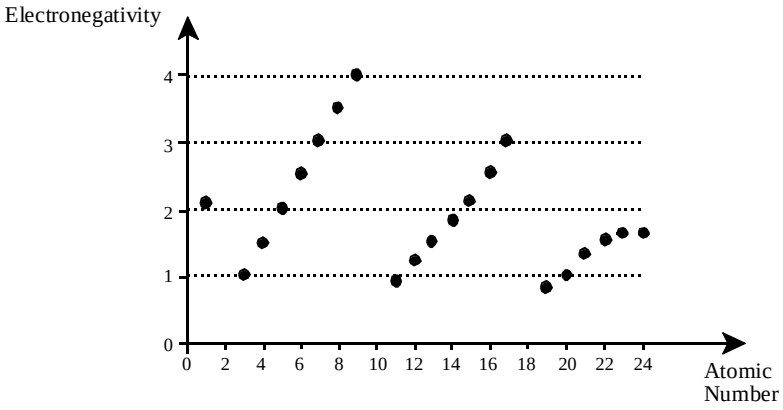
c. Ca K Ba

d. Li Be

e. Na Mg Fr

f. Hf Re Au

6. The following graph shows the change in the electronegativity of certain elements as a function of their atomic numbers.



According to this graph, which of the following statements is TRUE?

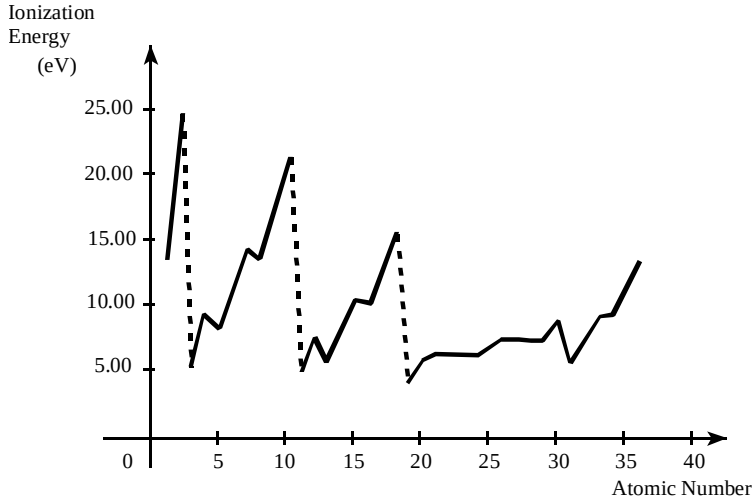
A) In Period 2, electronegativity increases as the atomic number increases.

B) In Period 2, electronegativity decreases as the atomic number increases.

C) In Period 2, electronegativity does not change as the atomic number increases.

D) In Period 2, electronegativity decreases and then increases as the atomic number increases.

7. The following graph shows the ionization energies of certain elements as a function of their atomic numbers.



Which is CORRECT?

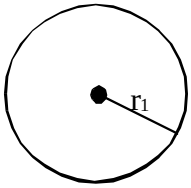
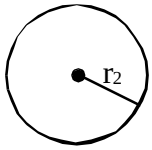
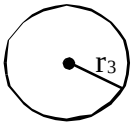
A) Within a period, the ionization energy usually increases as the atomic number increases.

B) Within a period, the ionization energy usually decreases as the atomic number increases.

C) In general, the ionization energy of the elements in Period 3 is greater than the ionization energy of the elements in Period 2.

D) The ionization energy of the elements in Period 4 varies regularly when the atomic number increases regularly.

8. The atomic size of an element is an example of a **periodic property**.
The atomic size of the four elements below can be illustrated by using the atomic radius of each of these elements.

Atom of element 1	Atom of element 2	Atom of element 3	Atom of element 4
			
r_1 : 0.205 nm	r_2 : 0.140 nm	r_3 : 0.117 nm	r_4 : 0.091 nm

In which of the following periodic tables are these elements correctly placed?

A)

H			
	1		
	2		
	3		
	4		

C)

H			
1	2	3	4

B)

4			
	3		
		2	
			1

D)

H			
4	3	2	1

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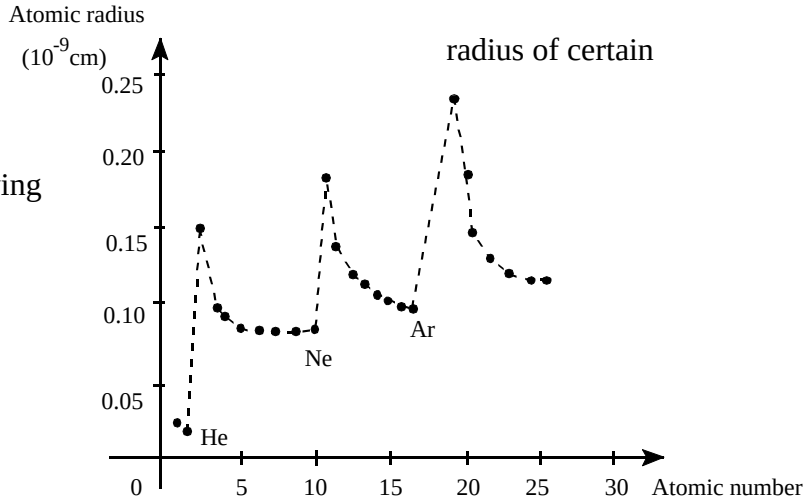
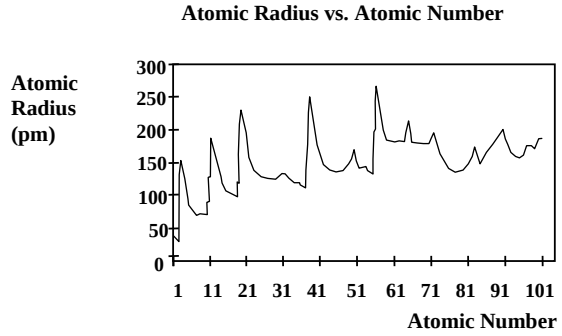
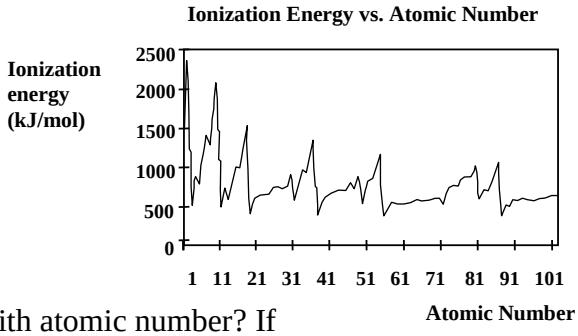
9. The graph below illustrates the atomic radius of certain elements as a function of their atomic numbers.

What are the two trends illustrated by the following graph?



10. Based on the graphs below, in general terms what happens to the atomic radius and ionization energy as the atomic number increases across a given period?





13. Do the atomic masses grow steadily and consistently with atomic number? If not list as many exceptions as you could find.

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6. Naming compounds (Nomenclature) and Polyatomics

Outline

A. Ionic Compounds

a.	From Formula to Name:	monoatomic ions and some polyatomics
b.	From Name to Formula:	monoatomic and more polyatomics
c.	Transition Metal Compounds*:	Roman numerals at their best (not part of program)

B. Covalent Compounds

a.	From Formula to Name:	prefixes galore!
b.	From Name to Formula	

A. Ionic compounds

a. **From Formula to Name**: monoatomic ions and some polyatomics

Reminder: How do you recognize an ionic compound from its formula?

Rules: (1) the metal's name remains the same.
(2) use the 'ide' suffix for the non-metal.

Examples
a. $NaCl$
b. KI
c. Li_2O
d. Ca_3P_2
e. $MgCl_2$

Some Polyatomics

(a polyatomic ion has more than one type of atom within the same ion. The charge belongs to the entire group!)

OH^{-1}	hydroxide	found in many bases
NO_3^{-1}	nitrate	found in fertilizer
SO_4^{-2}	sulphate	found in pigments and medicine
PO_4^{-3}	phosphate	found in fertilizer and some soaps

Examples Name the following:

f. $NaOH$

g. Na_2O

h. K_3PO_4

i. K_3P

j. CaS

k. $CaSO_4$

l. K_3N

m. KNO_3

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Exercise

1. Name the following

a. CaO
b. $Be(OH)_2$
c. K_2SO_4
d. $NaBr$
e. Rb_2O
f. Li_3PO_4
g. $Mg(NO_3)_2$
h. Al_2O_3
i. BeS
j. KI
k. Ca_3N_2
l. Rb_2SO_4
m. SrF_2
n. Na_2S
o. Li_3P
p. Na_2CO_3
q. MgH_2
r. KOH
s. Na_2Se
t. MgI_2

b. **From Name to Formula: monoatomics and more polyatomics**

Method:

1. Look up the charges for each ion.
2. Figure out how many of each kind are needed so that the total charge is zero.

Examples Write a formula for the following:

a. Sodium oxide
b. Potassium chloride
c. Magnesium phosphide

More Polyatomics

CO_3^{-2}	carbonate	found in limestone
ClO_3^{-1}	chlorate	found in bleach
NH_4^{+1}	ammonium	found in smelling salts
HCO_3^{-1}	hydrogen carbonate	found in baking soda

Examples Write a formula for…

d. sodium hydrogen carbonate

e. magnesium chloride

f. magnesium chlorate

g. sodium nitrate

h. ammonium chloride

i. ammonium carbonate

j. potassium carbonate

k. aluminium sulphate

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Exercises

1. Write formulas for the following; show all work.

a. sodium bromide
b. magnesium phosphide
c. calcium phosphate
d. magnesium chloride
e. beryllium carbonate
f. strontium nitride
g. barium nitrate
h. potassium nitride
i. sodium chlorate
j. sodium fluoride
k. lithium hydroxide
l. calcium hydroxide
m. calcium sulfide
n. calcium hydride
o. ammonium bromide
p. ammonium hydroxide
q. potassium hydrogen carbonate
r. aluminium chloride
s. aluminium iodide
t. gallium nitride
u. aluminium sulphide
v. hydrogen carbonate
w. lithium sulphate

Covalent Compounds

Reminder: How do you recognize a covalent compound?

a. From formula to name

The following prefixes must be used to name covalent compounds:

PREFIX	NUMBER OF ATOMS
mono(do not use at the beginning of name)	1
di	2
tri	3
tetra	4
penta	5
hexa	6

- Also use the ***ide*** suffix, but only at the end of the name.

Examples

1. Name the following:

a. CO_2

b. H_2O

c. N_2O_4

d. P_2O_5

e. Na_2O (careful!)

f. CCl_4

2. Write formulas

a. carbon monoxide

b. dihydrogen dioxide

c. nitrogen dioxide

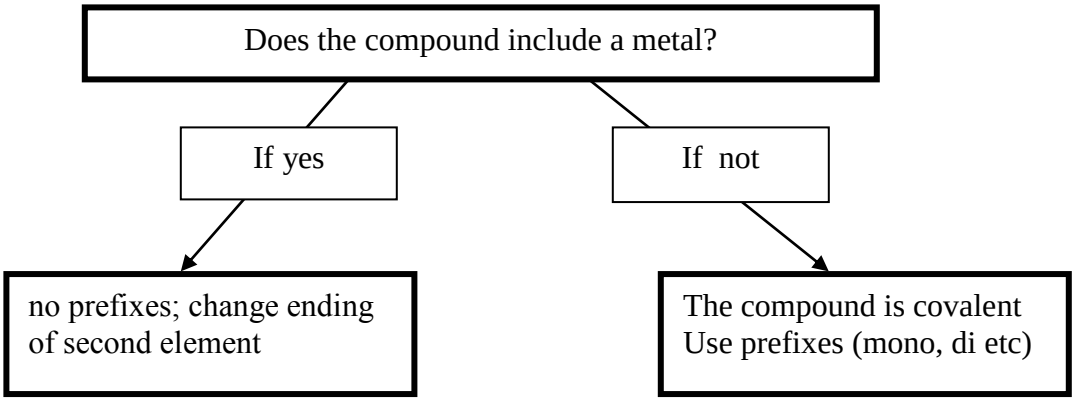
d. potassium oxide (careful!)

e. carbon tetrabromide

The Material World:
Periodic Table, Bonding and Nomenclature

Summary:

Ionic Compound	no prefixes; change ending of second element
Covalent Compounds	Use Prefixes; change ending of second element



The Material World:
Periodic Table, Bonding and Nomenclature

Exercises

1. Name the following covalent compounds.

a. SiO_2
b. CS_2
c. NO
d. PCl_3
e. PF_5

2. First figure out if the compound is covalent or ionic. Then name it appropriately.

a. PCl_5
b. KBr
c. $CuSO_4$
d. PI_3
e. K_2CO_3
f. NH_4I

3. Write formulas for the following:

a. magnesium phosphate
b. lithium hydrogen carbonate
c. diphosphorus pentoxide
d. silicon tetrachloride
e. calcium hydroxide
f. sodium fluoride
g. nitrogen trifluoride

4. The scum-producing reaction between soap and Ca^{2+} can be represented by:

$$Ca^{2+} + 2\ NaC_{17}H_{35}CO_2 \rightarrow Ca(C_{17}H_{35}CO_2)_2 + 2\ Na^+$$

From the above formulas, determine the charge of the stearate ($C_{17}H_{35}CO_2$) polyatomic ion.

(Hint: the charges have to add up to zero)