Ch. 4 NOTES ~ Formation of Compounds

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics.*

I. Periodic Table Review – layout of the groups and periods, staircase, seven diatomic molecules, protons and electrons

II. Valence Electron Review

A. **Valence electrons**—the *electrons in the highest energy level* of at atom ("highest shell" or highest n)

1) tells *how many are available for bonding*
2) tells *how many e- will be gained or lost in forming ions*

B. Review electron dot diagrams (Lewis structures)

GROUP #:	VALENCE # out of 8:	USUALLY, WHEN FORMING IONS:
Group IA (1)	1	loses 1
Group IIA (2)	2	loses 2
Group IIIA (13)	3	loses 3
Group IVA (14)	4	can lose, gain, or share
Group VA (15)	5	gains 3
Group VIA (16)	6	gains 2
Group VIIA (17)	7	gains 1
Group VIIIA (18)	8	does not form ions

III. Atoms and Ions

A. *atomic neutrality: atoms are neutral (net charge of zero) # protons = # electrons*

B. **ion**—*a charged atom(s) or a charged group of atoms*

1) formed by gain or loss of electrons
2) **cation**— *a positive ion formed by losing electrons*
3) **anion**— *a negative ion formed by gaining electrons*
   a) *common ending is —IDE* (chloride, bromide, iodide...)
   b) *ions of Group VIIA*, the halogens, are called *halide ions*

CP AN **Cations Positive, Anions Negative** "Cat People Are Nice"
YOU CAN'T LOSE OR GAIN PROTONS TO FORM AN ION !

4) an ion has different properties than its element (Na atom vs. Na^+ ion)
5) **isoelectronic**—having the same number of electrons
   - the reason why an atom loses or gains electrons is to be isoelectronic with the closest Noble Gas.

C. ionic charges (oxidation numbers) of the groups

Charge Chant Song:
" +1, +2, +3, mixed, -3, -2, -1, 0 …
+2 in the middle, unless they tell you otherwise"

(Note – you can write charges with the sign before or after the number. The norm is to use the sign after the number, but the song sounded better with the order reversed. In textbooks, you will

not see the number 1 used with a charge. Only + or - will be shown for 1+ or 1-.)

Group number:	IA 1	IIA 2	IIIA 13	IVA 14	VA* 15	VIA* 16	VIIA* 17	VIIIA 18
Main ionic charge:	**1+**	**2+**	**3+**	**M**	**3-**	**2-**	**1-**	**none**

M most of the Group IVA don't usually form ions; when they do, there are mixed charges possible
* when applicable

C. examples…

E1) Aluminum loses three electrons when its ion is formed. Show what happens with "before and after" electron dot diagrams. The aluminum ion is isoelectronic with which Noble gas?

→ →

13 p^+
13 e^- (3 valence)

13 p^+
10 e^- (loses three to empty the original valence)
isoelectronic with Ne

E2) Chlorine gains one electron when its ion is formed. Show what happens with "before and after" electron dot diagrams. The chloride ion is isoelectronic with which Noble gas?

→ →

17 p+
17 e- (7 valence)

17 p+
18 e- (gains one to fill the valence)
isoelectronic with Ar

IV. 4.1 Notes: The Variety of Compounds

** properties of individual elements may differ from their ions
** properties of individual elements may differ from the compounds they can form

NAME	SYMBOL	PHYSICAL STATE at room temp.	PROPERTIES
SODIUM vs. CHLORINE vs. SODIUM CHLORIDE			
sodium	Na	solid	1) metal 2) silver-white 3) soft 4) reacts violently with H_2O and O_2
chlorine	Cl_2	gas	1) nonmetal 2) greenish 3) poisonous

			4) stinging odor 5) disinfectant
sodium chloride	NaCl	solid	1) white crystals 2) soluble in water 3) important to cells 4) stable
CARBON vs. OXYGEN vs. CARBON DIOXIDE			
carbon	C	solid	1) nonmetal 2) brown to black 3) main ingredient of charcoal and coal 4) burns at high temperatures 5) main component of organic chemicals
oxygen	O_2	gas	1) nonmetal 2) colorless 3) odorless 4) vital to living organisms
carbon dioxide	CO_2	gas	1) colorless 2) odorless 3) stable 4) dissolves in water
HYDROGEN vs. OXYGEN vs. WATER			
hydrogen	H_2	gas	1) nonmetal 2) flammable 3) colorless
oxygen	O_2	gas	1) nonmetal 2) colorless 3) odorless 4) vital to living organisms
water	H_2O	liquid	1) colorless 2) odorless 3) stable 4) vital to living organisms

4.2 Notes: *How elements form compounds*

V. **Octet Rule**

A. *reactivity of atoms is based on achieving a complete octet (8/8)*

B. *atoms in compounds tend to have a stable* **Noble Gas configuration**

C. *exceptions* to the Octet Rule

1) atoms of *transition metals*

2) they achieve a **pseudo-Noble Gas configuration**

3) examples: Ag^+, Cu^+, Au^+, Cd^{2+}, Hg^{2+}

VI. Ways to achieve a stable outer energy level

A. *transferring of electrons* = **ionic bond**

B. *sharing of electrons* = **covalent bond**

VII. Formation of **Ionic Compounds** *(electron transfer)*

A. **ionic bond**—*a chemical attraction between positive ions (cation) and a negative ion (anion)*

1) *cation is the metal*

2) *anion is the nonmetal*

B. *total of positive charges = total of negative charges*

C. **Noble Gas configurations** of both ions are achieved

D. *electronegativity differences are large*

1) the cation is not electronegative ("not greedy" or electropositive) and will let its electron(s) be taken

2) the anion is more electronegative ("greedy") and will take the electron(s)

E. **formula unit**— the *lowest whole-number ratio of ions* in an ionic compound

1) do not use the term "molecule" to describe an ionic compound

2) ionic compounds occur in *repeating units in their crystals*

F. *crystalline solids*—a structure containing *3-D repeating patterns* of formula units

1) crystals are arranged in a *positive-negative alternating setup*:

```
Na+ Cl-  Na+ Cl-  Na+ Cl-  Na+  Cl-  Na+ Cl-  Na+ Cl-
Cl-  Na+ Cl-  Na+ Cl-  Na+  Cl-  Na+ Cl-  Na+ Cl-  Na+
Na+ Cl-  Na+ Cl-  Na+ Cl-  Na+  Cl-  Na+ Cl-  Na+ Cl-
Cl-  Na+ Cl-  Na+ Cl-  Na+  Cl-  Na+ Cl-  Na+ Cl-  Na+
Na+ Cl-  Na+ Cl-  Na+ Cl-  Na+  Cl-  Na+ Cl-  Na+ Cl-
Cl-  Na+ Cl-  Na+ Cl-  Na+  Cl-  Na+ Cl-  Na+ Cl-  Na+
```

2) examples of crystal shapes: SC, BCC, FCC, HCP…

3) setup is called a **crystal lattice** which is hard and brittle

4) *salt—any ionic compound,* not just sodium chloride

VIII. Cations and Anions in ionic compounds

A. formation of **cations**

1) the **octet rule** applies

2) example

E3) Francium has one valence electron (87 total e^-). It is easier for it to lose the valence electron than it is to gain seven more to complete the "shell." It forms a 1+ ion, exposing a previously filled shell.

$$Fr \rightarrow Fr^+ + e^-$$

The francium ion is isoelectronic with radon (86 e^-), but it still has a nucleus with 87 protons, keeping it an ion of Fr instead of changing it into an atom of Rn.

B. formation of **anions**

3) the **octet rule** applies

4) *common ending is —IDE* (chloride, sulfide, oxide...)

5) example

E4) Selenium has six valence electrons (34 total e^-). It only needs two more to achieve a complete octet. It forms a 2- ion and has the configuration of krypton (36 e^-).

Se + 2 e^- → Se^{2-}

The selenide ion is isoelectronic with krypton (36 e-), but it still has a nucleus with 34 protons, keeping it an ion of Se instead of changing it into an atom of Kr.

IX. Electron Dot Diagrams for Ionic Compounds

A. make sure the compound is composed of metals and nonmetals

B. draw the dot diagrams of the cations and anions, using different colors if possible or open circles and closed circles for electrons from the different ions

- (Remember that all electrons are alike, but you should show which ones came from which ions in the transfer.)

C. all ions should be stable

1) all cation dot diagrams show no dots
2) all anion dot diagrams show a complete octet
3) all charges will balance out to zero

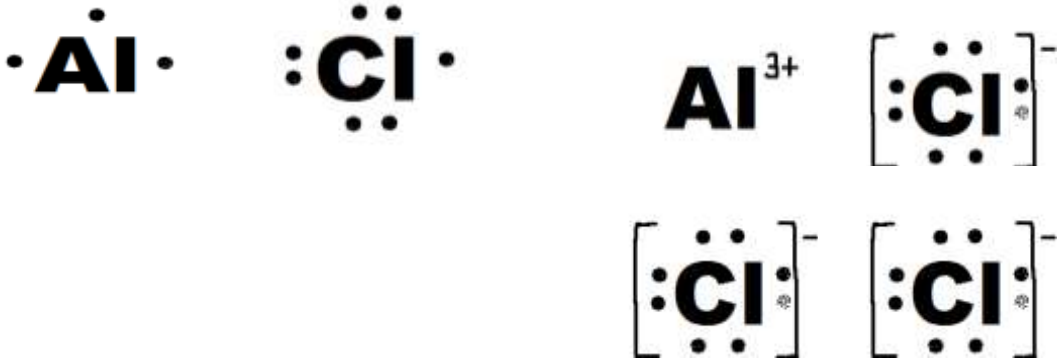
D. examples

1) sodium chloride, NaCl

sodium atom chlorine atom → → sodium ion chloride ion

CATION CHARGE TOTAL = 1+
ANION CHARGE TOTAL = 1-
NET CHARGE = 0

2) aluminum chloride, $AlCl_3$



aluminum atom chlorine atom → → aluminum ion chloride ions

(three chlorines are needed to balance the charges)

CATION CHARGE TOTAL = 3+
ANION CHARGE TOTAL = 3 x (1-) = 3-
NET CHARGE = 0

X. Formation of **Covalent Compounds** *(electron sharing)*

** *For the purposes of this course, compounds classified as covalent are composed of all nonmetals* **

A. **single covalent bond**—a *sharing* of electrons between two atoms
   1) consists of *one electron from each partner*
   2) *weaker than an ionic bond*
   3) smaller difference in electronegativity between the bonding partners
   4) bonding will occur to achieve a Noble Gas valence configuration

B. **structural formula**—set of symbols showing the *arrangement* and *bonding patterns* of atoms

C. **molecule**—a covalent compound existing as *defined molecules, not formula units*

XI. Multiple Covalent Bonds: Double and Triple Bonds

A. **double covalent bond**—sharing *two pairs* of electrons

B. **triple covalent bond**—sharing *three pairs* of electrons

XII. Electron Dot Diagrams for Covalent Compounds

A. make sure the compound is composed of all nonmetals
B. remember the octet rule (no lone electron dots when finished)
C. draw each electron dot diagram using the "A" group numbers
D. make the compound by combining the individual structures, sharing electrons
E. examples
   1) single bonds

single boron atom with three fluorines → boron trifluoride

   2) double bonds

single O atom single O atom → diatomic oxygen molecule

   3) triple bonds

2 nitrogen atoms → diatomic nitrogen molecule

ON YOUR OWN…

E5) Draw the electron dot dirgram for Cl_2.

E6) Draw the electron dot diagram for SF_2.

XIII. Coordinate Covalent Bonds

A. **<u>coordinate covalent bond</u>**—a covalent bond consisting of *two electrons donated by a single atom*

3) achieves stable configurations
4) behaves as a normal covalent bond
5) shown by a long arrow

B. example

ammonia **hydrogen ion** → **OR** **ammonium ion**

XIV. Comparison of ionic and molecular compounds

Table: Comparison of characteristics

	Molecular compounds	***Ionic compounds***
Particles	*Molecules*	*Formula units* made of ions (cations & anions)
Elements	Nonmetals	Metals & nonmetals
Conductivity	Low "nonelectrolytes"	High (when molten or in aqueous solution) "*electrolytes*"
State at room temp.	Solid, liquid, or gas	Solid
Type of Bond	Polar or nonpolar *covalent*	*Ionic*
Misc.	Covalent compounds	*Salts*