CHAPTER 8

Ionic and Metallic Bonds

Chemical Formulas

Shows the kind of atoms and number of atoms in a compound.

- $MgCl_2$
- NaCl
- $CaCO_3$
- Al_2O_3
- $Ca_3(PO_4)_2$

COUNTING ATOMS

$AlCl_3$ Al: Cl:	$Pb(NO_3)_2$ Pb: N: O:
$Mg(OH)_2$ Mg: O: H:	$C_2H_4O_6(OH)_3$ C: H: O:

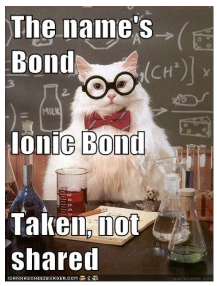
Polyatomic Ions

- Polyatomic ions are tightly bound groups of atoms that behave as a unit and carry a charge.
- *-ite* or *–ate* means oxygen is involved.

Trends in Polyatomic Ions

				Perchlorate
Carbonate	**Nitrate**	**Phosphate**	**Sulfate**	**Chlorate**
	Nitrite	Phosphite	Sulfite	Chlorite
				Hypochlorite

Nitride N^{3-}	**Sulfide** S^{2-}	**Phosphide** P^{3-}	**Chloride** Cl^-
Nitrite NO_2^-	**Sulfite** SO_3^{2-}	**Phosphite** PO_3^{3-}	**Chlorite** ClO_2^-
Nitrate NO_3^-	**Sulfate** SO_4^{2-}	**Phosphate** PO_4^{3-}	**Chlorate** ClO_3^-



8.1 Forming of Chemical Bonds

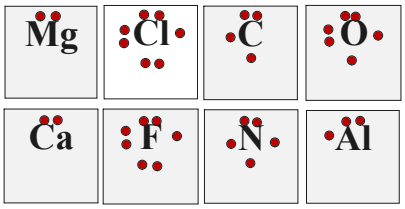
How do compounds exist?

Chemical Bonds: the force that holds two atoms together.

- Forms between a positive ion and a negative ion or between a positive nucleus and a negative electron.
- Valence electrons are involved in the formation of chemical bonds between two atoms.

Electron Dot Structures

Dots represent valence electrons.



Electron Dot Structures

Show valence electrons as dots.

-Paired + unpaired electrons

The inner electrons and the atomic nuclei are represented by the symbol for the element being considered.

DOT Structures

Al: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
S: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
Ca: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
P: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

Reactivity & the Stable Octet

- Octet = 8 valence electrons, just like Noble gases
  - > 8 valence electrons makes an atom stable and unreactive
  - > Have high ionization energies and low Electronegativity
- Elements tend to react to acquire the stable electron configuration of a noble gas.

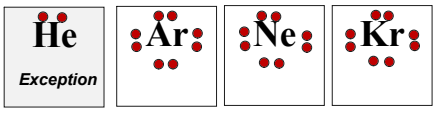
Noble Gas Configuration

Atoms want this to be stable!!

- Na: unstable
- Na^+: noble gas configuration
- O: unstable
- O^{2-}: noble gas configuration

Electron dot structures

Here are the noble gases.



Unstable atoms must gain or loseelectrons to attain this dot structure.

Octet Rule

Eight valence electrons makes an atom stable.

3 ways to satisfy octet rule:

- **Lose electrons** ***(metals)***
- **Gain Electrons** ***(nonmetals)***
- **Share electrons** ***(nonmetals)***

Exceptions to the Octet Rule: **H, He, Li, Be, B**

- ***Why are thee exceptions?***

Formation of Positive Ions

A positively charged ion is called a cation.

Ionization Energy: energy required to remove an electron

Metallic elements lose valence electrons to complete the octet in the next lowest energy level. *(Lose an energy level)*

Maximum charge is usually 4^+.

General increase

Successive Ionization Energies for Period 3 Elements

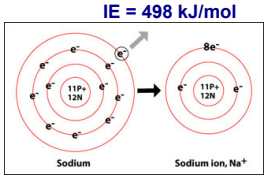
Element	IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7
Na	498	4560	6910	9540	13 400	16 600	20 100
Mg	736	1445	7730	10 600	13 600	18 000	21 700
Al	577	1815	2740	11 600	15 000	18 310	23 290
Si	787	1575	3220	4350	16 100	19 800	23 800
P	1063	1890	2905	4950	6270	21 200	25 400
S	1000	2260	3375	4565	6950	8490	27 000
Cl	1255	2295	3850	5160	6560	9360	11 000
Ar	1519	2665	3945	5770	7230	8780	12 000

General decrease

Positive Ions

Na + ionization Energy → Na^+ + 1 electron

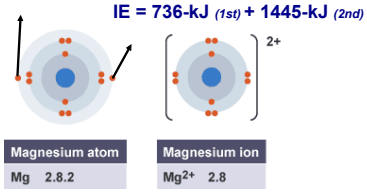
IE = 498 kJ/mol



Positive Ions

Mg + ionization Energy → Mg $^{2+}$ + 2 electron

IE = 736-kJ *(1st)* + 1445-kJ *(2nd)*



Formation of Negative Ions

A negatively charged ion is called an anion.

Electronegativity: ability of an atom to attract electrons

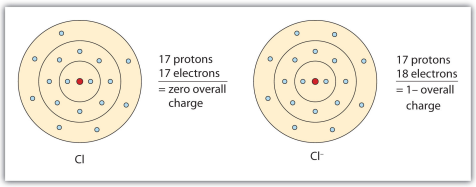
Nonmetallic elements gain electrons or share electrons with other nonmetallic elements to achieve a complete octet.

Maximum charge is usually 3-.

Always have an ***-ide*** ending when naming.

Negative Ions

Chlorine + 1 electron → Cl^- + energy



Halide Ions

- Halogens in group 7A gain one electron.
- Negative 1 charge.
- Cl^-, F^-, I^-, Br^-
- **Notice the -ide ending of the word Halide...**

↳ gain electrons

Which completes the octet in the next lowest energy level?

- P
- Mg
- I
- S

Which of the following has a noble gas configuraton?

- Na^-
- N^{2-}
- Ca^{2+}
- Br^{3+}

Pseudo-Noble Gas Configurations

Relatively stable arrangement formed by Group B elements

Unlike group 2A elements, if Transition metals lose their 2 valence electrons, their d orbitals may or may not be full.

Transition metals can Never attain a noble gas configuration.

Pseudo-Stable

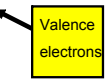
- Some ions do not have noble-gas electron configurations- - - these are exceptions to the octet rule.
- Ex.) Silver, copper, gold, cadmium, mercury, zinc
- Pseudo stable: 18 valence electrons

Pseudo-Stable Elements

- **Zn: [Ne] $3s^2$ $3p^6$ $4s^2$ $3d^{10}$**
  > ***Unstable (2 valence electrons)***
- **Zn^{2+}: [Ne] $3s^2$ $3p^6$ $3d^{10}$**
  > ***Pseudo-Stable (18 valence electrons)***

Example of Pseudo Stable

- **Cd: $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^6$ $5s^2$ $4d^{10}$**



- **Cd^{2+}: $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^6$ $4d^{10}$**

Transition Metals

- Form cations only, however, the charges may vary in some atoms.
- **Multi-Valent Metals**: can have 2 or more ionic charges
  > Copper can lose 1 or 2 electrons. (Cu^+ or Cu^{2+})
  > Iron can lose 2 or 3 electrons. (Fe^{2+} or Fe^{3+})
- See periodic table with charges.

Pseudo-Stable

- **When transition metals lose valence electrons and have 10 electrons in the outer d sublevel. (18 Valence electrons)**
- **Transition metals can lose 1 or 2 valence electrons to achieve this.**

Which is Pseudo-Stable?

- Cu: [Ne] $3s^2\ 3p^6\ 4s^2\ 3d^9$
- Cu^{2+}: [Ne] $3s^2\ 3p^6\ 3d^9$
- Cu: [Ne] $3s^2\ 3p^6\ 4s^1\ 3d^{10}$
- Cu^{+}: [Ne] $3s^2\ 3p^6\ 3d^{10}$

Which is Pseudo-Stable?

- Ag: [Kr] $5s^2\ 4d^9$
- Ag^{2+}: [Kr] $4d^9$
- Ag: [Kr] $5s^1\ 4d^{10}$
- Ag^{+}: [Kr] $4d^{10}$

4s 3d

Fe: [Ar] $\underline{4s^2}\,3d^6$ 

Fe^{2+}: [Ar] $\underline{4s^0}\,3d^6$ 

Fe^{3+}: [Ar] $\underline{4s^0}\,3d^5$ 

Ni: [Ar] $\underline{4s^2}\ 3d^8$ 

Ni $^{2+}$: [Ar] $\underline{4s}\ 3d^8$ 

- Is the neutral version stable?
- Is the charged version pseudo stable?

Cu: [Ar] $\underline{4s^2}\,3d^9$ 

Cu^{2+}: [Ar] $\underline{4s}\ 3d^9$ 

- In this version of Copper, its neutral version ended in $\underline{4s^2}3d^9$, so it has 2 valence electrons.
- Is the charged version pseudo stable?

Cu: [Ar] $\underline{4s^1}3d^{10}$ 

Cu^{+}: [Ar] $\underline{4s}\,3d^{10}$ 

- In this version of Copper, its neutral version ended in $4s^13d^{10}$, so it lost it's 1 valence electron.
- Is the charged version pseudo stable?

Au: [Xe] $6s^2$ $5d^9$

Au^{2+}: [Xe] $6s$ $5d^9$

How many valence electrons are inthe neutral version?
Is the charged version stable?

Au: [Xe] $6s^1 5d^{10}$

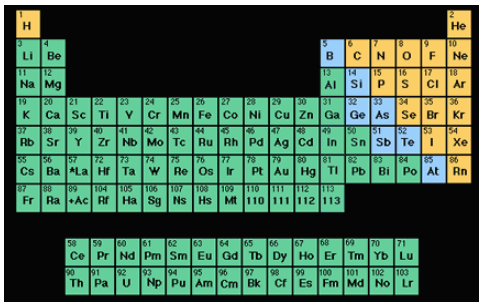
Au^{+}: [Xe] $6s$ $5d^{10}$

How many valence electrons are in the neutral version?
Is the charged version stable?

Co: [Ar] $4s^2 3d^7$

Co $^{2+}$: [Ar] $4s^0 3d^7$

Is the neutral version stable?
Is the charged version pseudo stable?



8.2 Formation of Ionic Bonds

The forces of attraction that bind oppositely charged ions together are called ionic bonds.

Metals (cations) bond to a nonmetal (anions)

- Also called **salts**.

The Formation of Compounds

Compounds are formed when two or more atoms bond together.

Atoms form compounds to satisfy the octet rule.

Atoms in compounds usually have a noble gas configuration.

Elemental vs. Chemical Compounds F_2 vs. NaCl

Binary Ionic Compound: two types of atoms $BaCl_2$

$CaSO_4$ is not a Binary Ionic Compound

Electrically Neutral Compounds

- Ionic compounds are **electrically neutral** groups of ions joined by electrostatic forces
- Total positive charge of the cations must equal the total negative charge of the anions.
- **Net charge** of all ionic compounds equals zero!

Electrons lost = electrons gained

Ratio of Ionic Bonds

NaCl = 1:1 ratio
$MgCl_2$ = 1:2 ratio
Al_2O_3 = 2:3 ratio

This ratio never changes for a specific ionic compound

Must also be lowest whole number ratio

Formula Unit

- **Simplified version of an ionic compound.**
- **Lowest whole number ratio of ions in an ionic compound.**

- **Na_2Cl_2 is NaCl**
- **Al_4O_6 is Al_2O_3**

Rules for Writing Formulas and naming them

Monatomic Ions: a single atom with a positive or negative charge

Cation (rules): listed first in a formula

Anion (rules): listed last with an *-ide* ending

Polyatomic vs. Monoatomic

- Must be named differently!!!!
- Monoatomic anions always end with –ide.
- Polyatomic anions end with -ide, -ite, or -ate.
- Always look for a polyatomic ion when naming compounds.

b

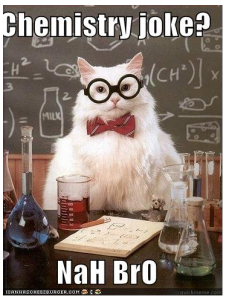
Balancing Charge | Magnesium + Iodide | Chemical Formula

Balancing Charge | Barium + Nitrogen | Chemical Formula

Ca^{2+}	N^{3-}
Total Positive Charge	**Total Negative Charge**

Fill in the Chart

Element	Valence Electrons	Ionic Charge	Element	Valence Eelctrons	Ionic Charge	Chemical Formula
Calcium			Oxygen			
Aluminum			Chlorine			
Magnesium			Phosphorus			
Sodium			Nitrogen			
Sulfur			Iron			



Compounds with Polyatomic Ions

- **Ionic compounds containing three or more different elements**
- **Parentheses used as needed**

Polyatomic Ions in Compounds

Keep the polyatomic ion together

Only look at the charges!

- SO_4^{2-}
- PO_3^{3-}
- NO_3^-

Al^{3+}	NO_3^-
Total Positive Charge	**Total Negative Charge**

Ca^{2+}	PO_4^{3-}
Total Positive Charge	**Total Negative Charge**

Polyatomic Ions in Compounds

	Ionic Charge		Ionic Charge	Chemical Formula
Sodium		Sulfate		
Aluminum		Nitrate		
Ammonium		Sulfur		
Magnesium		Phosphate		

Properties of Ionic Compounds

- Metals bonded to Non-Metals
- Most are crystalline solids.
- Arranged in repeating 3-D pattern
- High Melting points
- Conductors of electricity *Metals have mobile electrons*
- Also called SALTS...

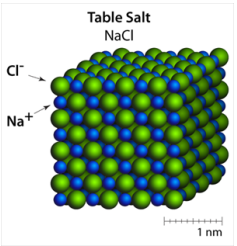
Crystal Formation

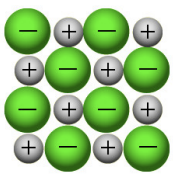
During formation of an ionic compound, the positive and negative ions are packed into a repeating pattern that balances the force of attraction between ions.

Remember, anions repel each other and cations repel each other, but anions and cations attract.

Large number of cations and anions exist together.

Pattern of Ionic Compounds



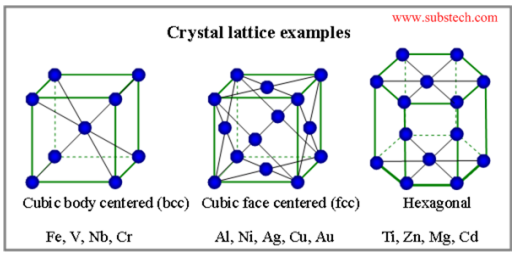


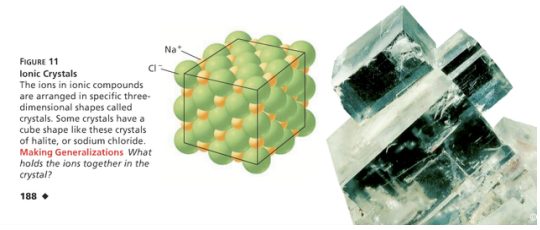
Crystal Lattice

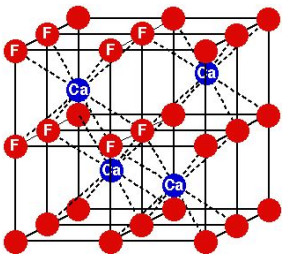
A 3-dimensional geometric arrangement of particles.

Each cation is surrounded by anions and each anion surrounded by cations.

The shape of ionic crystals depends on the ratio of ions bonded to each other.







Properties of Ionic Crystals

Melting point, boiling point, and hardness of a crystal depend on how strongly the ions are attracted to each other.

Ionic bonds are relatively strong, so a large amount of energy is required to break them apart.

Lattice Energy: the energy required to separate 1 mole of ions in an ionic compound.

Properties of Ionic Crystals

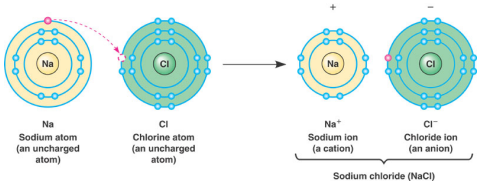
Solid state: ionic compounds do not conduct electric current.

Liquid State: When ionic compounds are melted

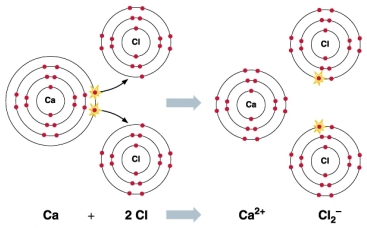
Electrolytes: Ionic compounds that conduct electric current when dissolved in water. *(Aqueous solution)*

- *Aqueous Solution= dissolved in water*

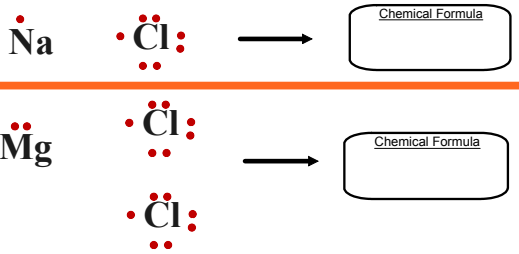
Forming Ionic Compounds



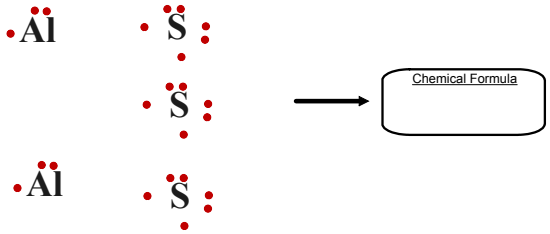
Forming Ionic Compounds



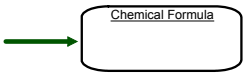
Transfer of Electrons forming Ionic Compounds



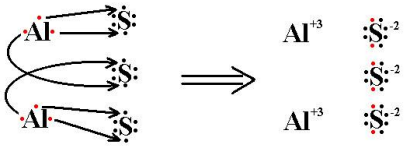
Transfer of Electrons forming Ionic Compounds



Show the Transfer of electrons between nitrogen and calcium, then write the chemical formula.



Forming Ionic Compounds



Chemical Formula	Cation	Anion	Balancing Charge
NiF_2			
$CrSO_4$			
$NaNO_2$			
$Co(ClO_3)_3$			
$(NH_4)_3PO_4$			
Fe_2O_3			
FeO			

8.4 Metallic Bonds and Properties

What is holding metal atoms together?

- The valence electrons in metal atoms resemble a sea of electrons because the outer energyl levels overlap
- They are mobile... Low ENC ↑ Low electronegativity

- Delocalized Electrons: drift freely within a metal.
- Good electrical conductors

Properties of Metals

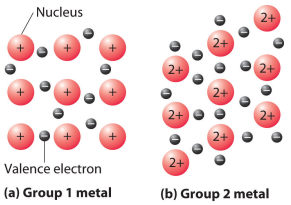
Melting Point Varies, although it is usually high.

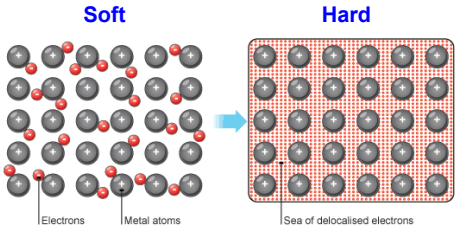
Good conductors of electricity due to delocalized electrons.

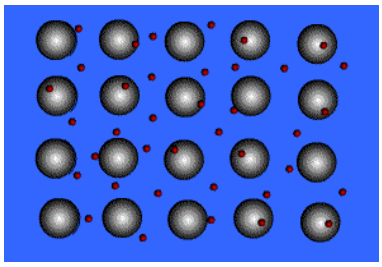
More delocalized electrons increases strength:
Alkali metals are softer than transition metals.

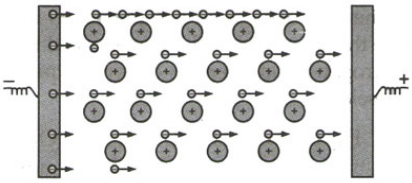
Due to sea of mobile electrons.
- Ductile: drawn into wires
- Malleable: hammered into shapes

More valence electrons fill in the gaps





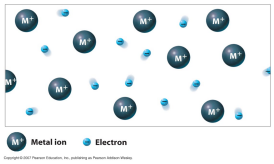


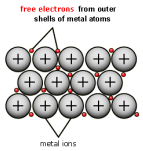


Electrical conductivity in metal crystals

What holds metal atoms together?

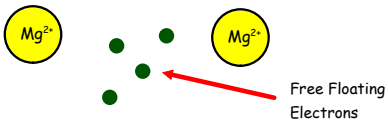
- Metallic Bonds
- Attraction metal atoms have for free floating electrons.





Metallic Bonds

- Metallic bonds consist ofthe attraction of the free-floating valence electrons for the positively charged metal ions.



Alloys

- Alloys are mixtures of elements with metallic properties.
- Composed of two or more elements, at least one of which is a metal. Usually have atoms of similar size.
- Their properties are often superior to those of their Component elements, which is why they are used in the world.

Common Alloys

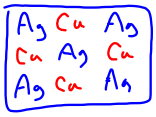
Alloy	Composition	Properties	Uses
Brass	Copper, zinc	Does not corrode easily; looks like gold	Coins, musical instruments
Stainless steel	Iron, chromium, nickel, carbon	Resistant to corrosion, strong	Cutlery, utensils
Solder	Tin, lead	Low melting point	For joining metals
Pewter	Tin, antimony, copper	Bright, shiny, looks like silver	Decorative ornaments

Gold Purity by Karat Count	
Karat Measure	Gold Purity
24 karat	100% pure gold
22 karat	91.7% gold + 8.3% other metal(s)
18 karat	75% gold + 25% other metal(s)
14 karat	58% gold + 42% other metal(s)
10 karat	42% gold + 58% other metal(s)

Substitutional Alloys

When an atom of similar size replaces another atom within a crystal.

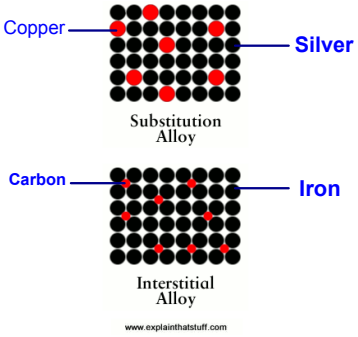
- In sterling silver, copper replaces silver.



InterstitialAlloys

When small holes in a metallic crystal are filled with smaller atoms that fill in the empty space. *(sand in a bucket of gravel)*

- Carbon Steel (Iron and Carbon)
  - > Iron is malleable due to the holes its crystal, carbon fills in those holes making it stronger.



Chapter 8 Test - 100 Points

5 Matching: vocabulary

45 Multiple Choice: *(Example questions...)*

- Which of the following will bond with _____?
- What is important about the noble gases?
- How many valence electrons are in _____?
- Count the atoms in the following compound.
- What is the chemical formula for _____?
- What is the charge of the ions in _____?
- Which ion is pseudo stable?
- What is the electron configuration for a lithium ion?
- What is the net charge of an ionic compound?
- How many electrons are lost total in _____?
- What is the name of the following compound?

Lab 8.2: The Formation of a Salt

1. **What was the purpose of the Lab?**
2. **What were the materials used? *(not from the lab manual)***
3. **Write the chemical equation and explain what occurred during the reaction.**
4. **Write the procedure you followed. *(in your own words)***
5. **Draw the Data Table with data from the lab.**
6. **Answer the 4 Data & Observation Questions**
7. **Answer the 4 Analyze & Conclude Questions**