CHEM 115
Ionic & Molecular Bonding

Lecture 21
Prof. Sevian

Agenda

- Review ionic vs. molecular
- What characterizes ionic bonding?
- What characterizes covalent bonding?
- The gray area between ionic and molecular and why compounds can't always be clearly categorized as ionic or molecular
- The Lewis structure model for predicting bonding arrangements in molecular compounds
- Group problem

- Final Exam has been scheduled for:
  - Wednesday, May 21
  - 8:00-11:00AM
  - Snowden Auditorium (W-1-88)

Please let me know by Friday, April 25, if you have any conflicts with other course's final exams

Convert monthly bills over to automated electronic bills instead of bills mailed to you.

Periods vs. Groups

Comparing two elements in the same period:

- Use Z_{eff} argument
- Same number of complete shells, so size (radius) of cores is the same
- Different charges in nucleus, but same number of core electrons, leads to different core charge
- Different numbers of electrons in valence
- Arguments are usually based on Q_+ (core charge) and Q_- (valence charge) being different while distance between core and valence (r) is nearly the same

Comparing two elements in the same group:

- Use # of shells argument
- Different number of complete shells, so size (radius) of cores is different
- Core charges are the same because valence electrons same
- Arguments are usually based on distance between core and valence (r) being different while Q_+ and Q_- are the same

Electron affinity

The energy associated with adding an electron to an atom

1A	2A	3A	4A	5A	6A	7A	8A
H −73							He > 0
Li −60	Be > 0	B −27	C −122	N > 0	O −141	F −328	Ne > 0
Na −53	Mg > 0	Al −43	Si −134	P −72	S −200	Cl −349	Ar > 0
K −48	Ca −2	Ga −30	Ge −119	As −78	Se −195	Br −325	Kr > 0
Rb −47	Sr −5	In −30	Sn −107	Sb −103	Te −190	I −295	Xe > 0

- Electron affinities in kJ/mol
- The more negative the electron affinity, the more exothermic. Therefore, the greater attraction the atom has for the electron to be added.
- Trend: As you go from left to right across a row, the electron affinity generally ________

The big picture: The pattern of a Coulomb's law argument

1. Usually comparing one set of circumstances to a second set, to explain why one measure is larger or smaller than another
   - Neon atom vs. sodium atom with atomic radius
   - $MgCl_2$ vs. $CaCl_2$ with energy required to break the ionic bonds
2. For each set of circumstances, determine what the relevant attraction is between a Q_- and a Q_+
   - Attraction between outermost electron (-) and effective core charge (+) will affect atomic radius
   - Attraction between negatively charged ion (Cl^-) and positively charged ion (Mg^{2+} or Ca^{2+}) will determine strength of ionic bond
3. For each set of circumstances, determine what the distance of separation is between the + and – charges
   - Number of shells (periods)
   - Number of shells on + ion plus number of shells on – ion
4. Usually one variable, distance or (Q_+ and Q_-), can be considered constant while the other one varies. The one that varies is responsible for the difference in the measure
   - Neon has Q+=+8 while sodium has Q+=+1. Neon has 2 shells while sodium has 3 shells. Both differences lead to sodium's outermost electron being further away and less tightly bound.
   - Both attractions are a +2 ion with a -1 ion. Cl^- ion has same radius, but Mg^{2+} ion is smaller than Ca^{2+} ion, so separation distance between Q+ and Q- is smaller in $MgCl_2$, therefore harder to break the ionic bond.

Spend a few more hours every week doing something that requires no electricity or gas.

Map of Chapter 8

- What holds ions together
  - Predicting qualitative trends
- What holds molecules together
  - Predicting enthalpy of reaction from bond energies
- Ionic vs. covalent character of bonds: polarity and electronegativity model
- Lewis structure model
  - Simple structures (octet rule), with single and multiple bonds
  - Resonance structures
  - More complicated structures (breaking the octet rule)
  - Formal charges
- Bond strength and length
  - Using Lewis structures to predict
  - Using Hess's law and bond enthalpies

Ionic vs. Molecular (what you already know)

1. Ionic bonding
    - Occurs between ions
    - Ions are particles that are charged
        - Atoms that have gained or lost electron(s)
        - Polyatomic ions
    - In solid state, ions are arranged in regular, repeating, alternating + and - lattice structure
    - Strong attractions between + and -, and lattice structure in which every ion surrounded by many ions of opposite charge, make it difficult (energetically) to change solid to liquid
    - As a result, all ionically bonded materials are solids at room temperature and have very high melting points

Plant a tree

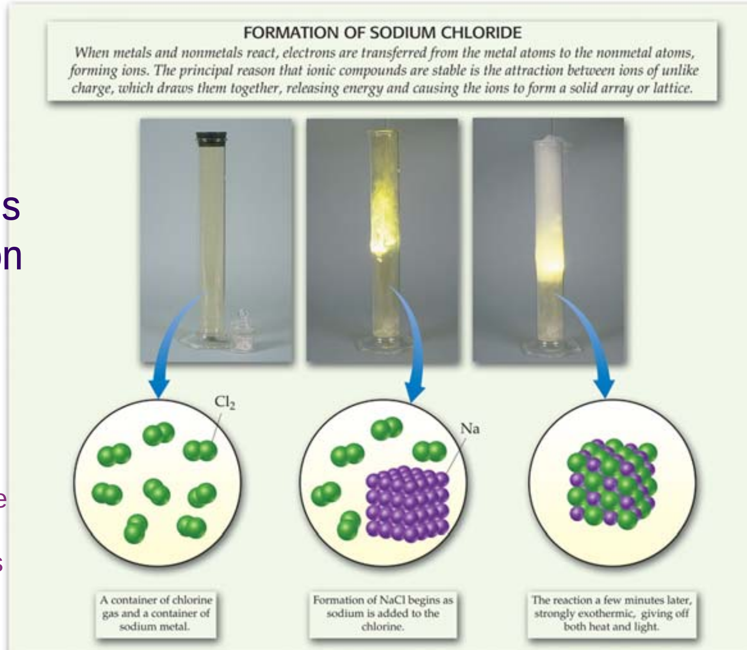
Remove your name from mailing lists to reduce the amount of junk mail you receive.

Ionic vs. Molecular (review)

2. Covalent bonding
    - Occurs between neutral atoms within individual molecules (neutral atoms are not charged)
    - Forces of attraction that hold atoms together inside of molecules result from attractions of each atom’s nucleus (+) toward neighboring atom’s electrons (-) as well as its own electrons (also -)
    - Only valence electrons of atoms interact with valence electrons of other atoms
    - Covalent means ‘shared valence’ electrons
    - When covalently bonded molecules are in solid state, the molecules are arranged in regular, repeating lattice structures. The forces of attraction that hold together molecules in the solid state are weaker than ionic (full + and – monopoles) because inter-molecular forces are between polarized molecules (dipoles) or polarizable molecules $\Rightarrow$ lower melting points.

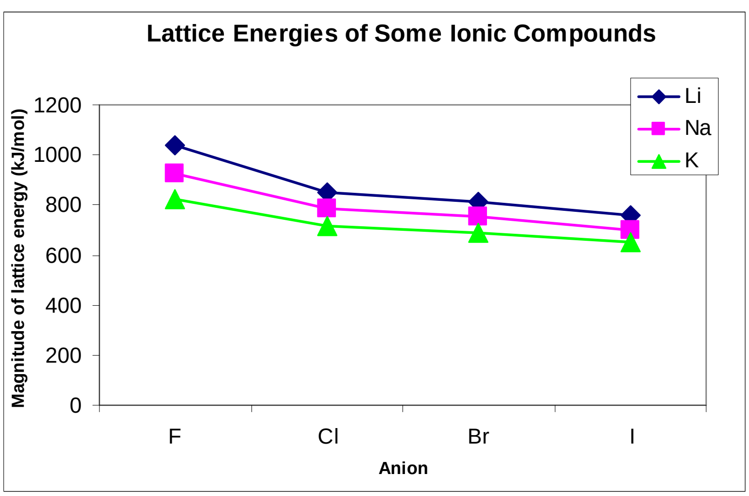
Lattice energy in ionic compounds is formation energy

Equal and opposite to energy required to break apart the lattice into separated ions



Unplug power transformers (chargers) when they are not in use.

Period and Group Trends in Lattice Energy



Data from textbook p. 305

Qualitative trends (comparisons) in strength of ionic bonding

- Recall that Coulomb's law predicts that force of attraction between two oppositely charged objects depends on magnitudes of charges (direct) and on distance that separates them (inverse squared)

- Comparing the lattice energies of two ionic compounds depends on two factors:
  - Compare magnitudes of ionic charges (Q_+ and Q_-) over the same separation distance (r)
  - Compare separation distance (r) if the same ionic charges (Q_+ and Q_-)
  - (Both factors can work in the same direction)
  - (If factors work in opposing directions, you need to know more quantitative information to make a prediction)

Eat less meat

Bond polarity

- Electronegativity model
- But first, it's easier to talk about bonds in molecular compounds when we can say something about what those bonds are made of
- Remember, bonds in molecular compounds are called covalent (co=share, valent=made of valence electrons)
- Generally, covalent bonds occur between nonmetals

Reduce standby electricity trickles. Plug seldom used appliances into a power strip and keep the power strip off except when you're using an appliance.

Lewis Dot Structure Model

Valence number of an atom is the quantity of valence electrons

- Periods 1, 2, 3 have only *s* and *p* electrons in valence shell
- Period 3 and higher: *d*-orbitals are available and can play role in valence shell
- Count only the *s* and *p* electrons in the valence shell to make Lewis dot structures

Convention dictates “Hund’s rule” applies to filling the four locations that dots can occupy around a Lewis dot structure for an atom

(This is the Z_{eff} model in different clothing/vocabulary)

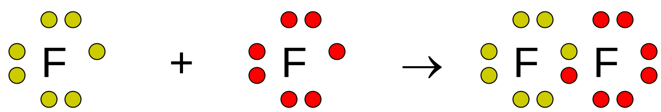
H +1C, -1V							He +2C, -2V
Li +1C, -1V	Be +2C, -2V	B +3C, -3V	C +4C, -4V	N +5C, -5V	O +6C, -6V	F +7C, -7V	Ne +8C, -8V
Na +1C, -1V	Mg +2C, -2V	Al +3C, -3V	Si	P	S	Cl	Ar +8C, -8V

As it warms up this summer, use air conditioning less often and open your windows to a breeze instead.

Lewis Dot Structure Model

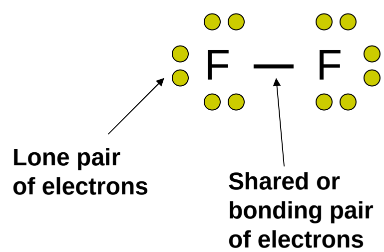
- Powerful model for predicting molecular shapes
- Assists in answering questions:
  - Why do bonds between atoms within a molecule have specific angles?
  - Why are molecular geometries complicated (3-dimensional) and not flat (2-dimensional)?
  - Why are attractive forces between some molecules stronger/weaker than between other molecules?
  - How is structure related to lots of other chemical and physical properties of covalently bonded materials?
- Theory behind Lewis dot structures is that valence electrons are distributed as either
  - Pairs of electrons that are shared by two atoms (shared pairs)
  - Pairs of electrons that belong to a single atom (unshared, or lone pairs)

Lewis Structures of Simplest Molecules



or

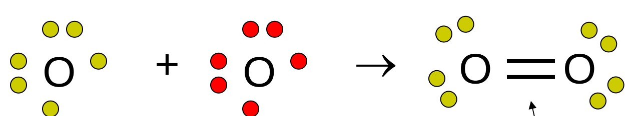
There is no difference between one electron and another. When a molecule is formed, the electrons have no allegiance to their original atoms.



Octet Rule

A noble gas configuration (8 valence electrons) is stable. Atoms tend to form molecules or polyatomic ions in such a way that each atom is surrounded by 8 electrons (an octet).

➢ *There are lots of exceptions. They are interesting and we will study them. But first let's master the simplest rules.*



Conservation of electrons:

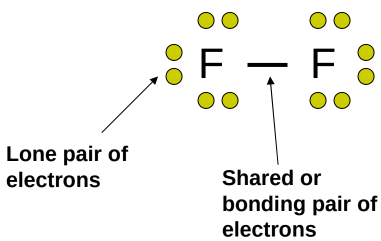
How many electrons on left?

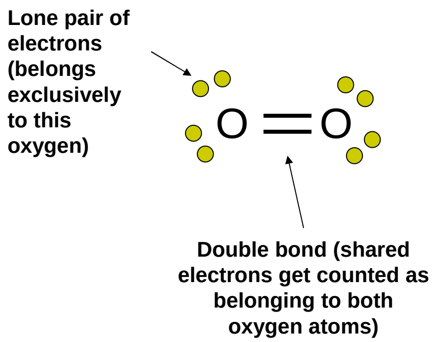
How many electrons on right?

Double bond

Lewis Dot Structure Model

- Theory of Lewis dot structures is that valence electrons are distributed as either
  - Pairs of electrons that are shared by two atoms (shared pairs)
  - Pairs of electrons that belong to a single atom (unshared, or lone pairs)





Think – Pair – Share

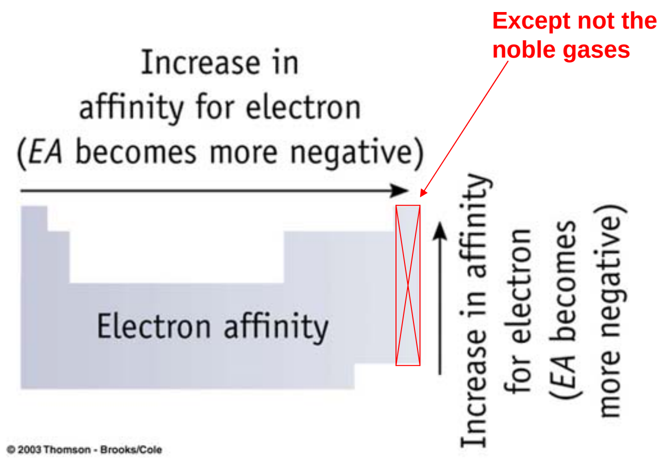
Draw the Lewis structures of the following molecules. Don't forget to show all the valence electrons: both the bonding electrons and the lone pairs. (It might help to check your work by conservation of valence electrons.)

1) N_2
2) CH_4
3) CH_3Cl
4) NH_3
5) H_2CO

The next time a light bulb burns out, replace it with a fluorescent bulb.

Reminder: Electron Affinity

Electron affinity measures how much an atom "likes" electrons



Building Lewis Structures

1. Determine central atom (atom with lowest electron affinity because electron density will spread as far as possible, given the opportunity)
2. Count total number of valence electrons in molecule
3. Arrange atoms around central atom
4. Start with single bonds
5. Place remaining valence electrons
6. Move electrons to form octets, making double or triple bonds where necessary

Check: Make sure you have conservation of electrons

Hang laundry to air dry instead of using a dryer.

Buy fresh local produce instead of industrially produced imported.

Practicing the Steps (example 1)

Draw the Lewis structure for ammonium (NH_4^+)

1. N is central because H atoms can only bond once
2. Total valence electrons
   - 5 on N
   - 1 on each H gives 4 more
   - Ion has +1 charge, meaning one electron is removed
   - Total = 5 + 4 – 1 = 8

The rest of the steps:

Practicing the Steps (example 2)

Draw the Lewis structure for the nitrate ion (NO_3^-)

1. N is central because it has the least electron affinity
2. Total valence electrons
   - 5 on N
   - 6 on each of three O atoms gives 18 more
   - Ion has -1 charge, meaning one electron is added
   - Total = 5 + 18 + 1 = 24

The rest of the steps:

Take the T more often instead of driving