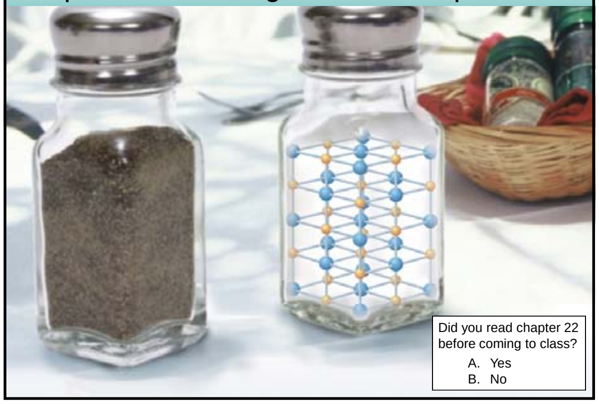
Chapter 22: Bonding in Ionic Compounds



Did you read chapter 22 before coming to class?

A. Yes
B. No

Review: Which color light emitting diode (LED) has the largest band gap?

a) Red
b) Yellow
c) Green
d) Blue

Compare and Contrast: Ionic Compounds vs Metals

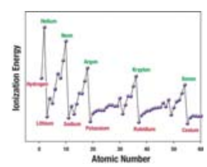
- Network Solids
- High melting T's
- Brittle solids
- Don't conduct heat and electricity in solid
- Often colorless and usually transparent in big chunks (White when powdered)

- Network Solids
- High melting T's
- Malleable
- Good conductors of heat and electricity in solid
- Opaque

- Explanation: Many closely spaced energy levels with mobile electrons

Metals vs Non-Metals

- Metals
  - Large atoms
  - Few valence electrons
  - Low ionization energies
- Non-metals
  - Small atoms
  - Many valence electrons
  - High ionization energies

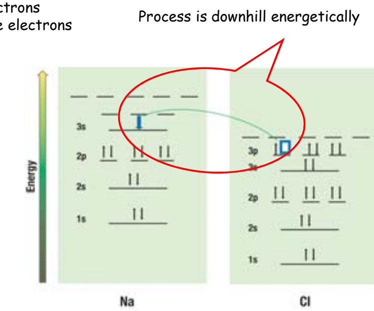


Why do metals and non-metals react?
Principles of reactivity:
materials react to lower energy and increase entropy of universe

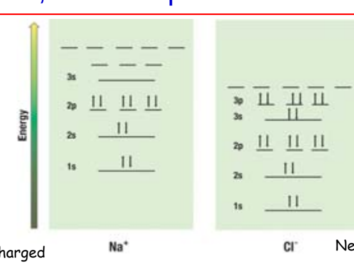
How can energy be lowered?

Metals lose valence electrons
Non-metals gain valence electrons

Process is downhill energetically



When electrons are moved from one atom to another, ions are produced



Positively charged Sodium ions (11 protons, 10 electrons)

Na^+

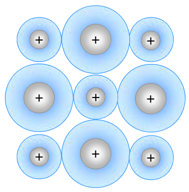
Cl^-

Negatively charged Chloride ions 35 protons, 36 electrons

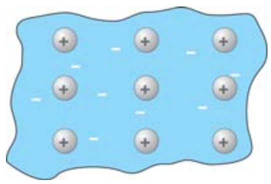
Electrons "belong" to individual ions; they are not shared among ions as was the case in metals.

Electron location and mobility is much lower in an ionic substance than in a metal

Ionic Crystal



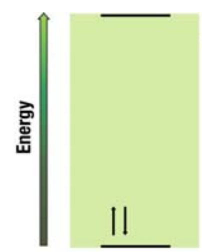
Metal



Electrons – fixed; localized on individual nucleus

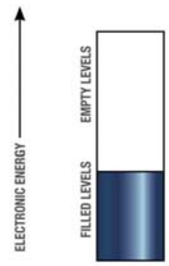
Sea of Electrons – mobile; electron density is spread out over many nuclei

Energy levels in an ionic crystal have relatively large spacing (rather than the nearly continuous spacing in metals)



IONIC COMPOUND ENERGY LEVELS

few levels, spaced very far apart

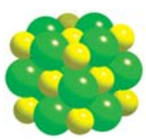


METAL ENERGY BAND

many closely spaced levels spread out over many nuclei

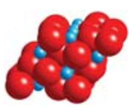
Examples of Ionic Compounds

NaCl



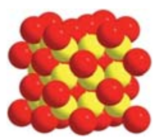
Ions: same charges and similar sizes

Al_2O_3



Ions: different charges and sizes

Na_2O



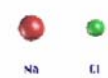
Ions: similar sizes, but different charges

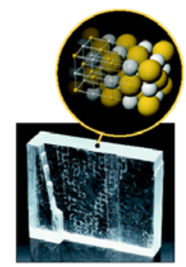
Describe the structure of each compound: Do ions of one type cluster together?
What type of ion immediately surrounds a given ion?
How do the answers to these two questions relate to the electric force law?

What prediction could you make about the arrangement of ions in any ionic compound?

Formation of a salt crystal

- $2Na + Cl_2 = 2NaCl$





What about entropy change?

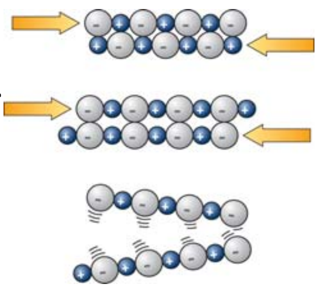
What about entropy change?

- $2Na + Cl_2 = 2NaCl$ + lots of heat and light

Heat and light – cause an increase in entropy of the surroundings

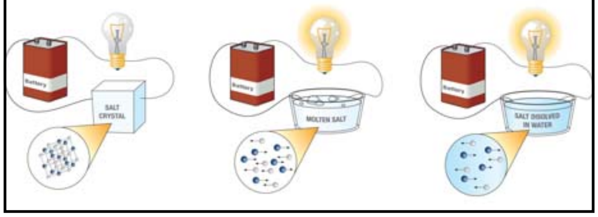
How does the model explain properties of salts (ionic compounds) ?

- High melting and boiling temperatures?
  - Strong attractions between + and – ions
  - Attractive forces act over fairly large atomic distances
- Brittleness?
  - Strong repulsions when ions with like charge come together; material shatters to relieve the stress.



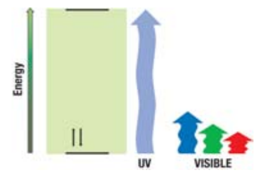
Conductivity

- Don't conduct as a solid. Why?
- Do conduct when molten or dissolved. Why?



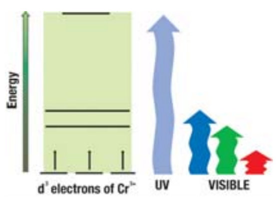
Salts are generally transparent to light

- Why are they transparent?
  - Electron orbitals are localized around individual ions with FEW energy levels



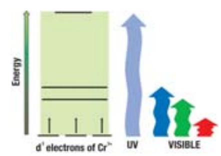
Why are some ionic materials colored?

- Because they contain "transition" metals with more energy levels for electrons
  - Sapphire is a crystalline form of Ol_2O_3
  - Chromium substitutions in the lattice allow blue and green light to be absorbed, resulting in a Ruby.
  - Titanium and Iron substitutions allow green and red light absorption, and give the blue color to what we normally think of as Sapphire

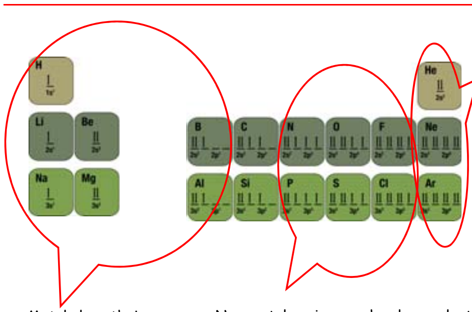


Making a laser

- A ruby laser is possible because of the energy level structure



We can use the periodic table to make predictions of what ions usually form.



Unreactive noble gases don't form ions.

Metals lose their valence electrons.

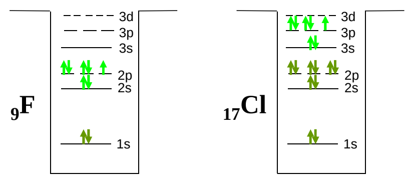
Non-metals gain enough valence electrons to become "noble".

The octet rule

- Atoms will most likely form an ion that has the ns^2np^6 configuration of the closest noble gas atom.
  - Metals take on this configuration by losing electrons
  - Non-metals take on this configuration by gaining electrons

Families

- Chlorine and Fluorine will form the same types of compounds since their valence electrons are the same number and same orbital type.



Beryllium (Be) will most likely form an ion with what charge?

a) -1
b) -2
c) +1
d) +2

What would the chemical formula for magnesium fluoride (a salt of Mg and F) be?

a) MgF
b) Mg_2F
c) MgF_2
d) MgF_3

Ionic compounds are neutral (no net charge). What are the ionic charges in the following compounds?

NaCl	Na^{+1} and Cl^{-1}
KBr	K^{+1} and Br^{-1}
MgF_2	Mg^{+2} and F^{-1}
Al_2O_3	Al^{+3} and O^{-2}

Naming convention for salts

- The metal comes first with its name unchanged
- The nonmetal comes second, with the suffix “ide” appended

Predicting Formulas for Salts

- Find the number of electrons lost by the metals and gained by the non-metals.
- If they are equal, the atoms combine one to one.
- If they are NOT equal, use the number lost/gained for the ***other*** atom’s subscript.
  - Examples

Mg and O	Mg^{2+} & O^{2-} → MgO
P and Ca	P^{3-} & Ca^{2+} → Ca_3P_2
N and Li	N^{3-} & Li^{+} → Li_3N

When Potassium (K) and Chlorine (Cl) combine the resulting formula is

A. KCl
B. K_2Cl
C. KCl_2
D. K_2Cl_3
E. K_3Cl_2

When Aluminum (Al) and Chlorine (Cl) combine the resulting formula is

A. AlCl
B. Al_2Cl
C. $AlCl_2$
D. $AlCl_3$
E. Al_3Cl_2

When Magnesium (Mg) and Sulfur (S) combine the resulting formula is

A. MgS
B. Mg_2S
C. MgS_2
D. Mg_2S_3
E. Mg_3S_2

When Calcium (Ca) and Phosphor (P) combine the resulting formula is

A. CaP
B. Ca_2P
C. CaP_2
D. Ca_2P_3
E. Ca_3P_2

How about carbon?

- Would carbon like to gain or lose electrons?
- It turns out that it likes to share electrons in covalent bonds, which we'll talk about on Monday.