CHEMICAL BONDING

IONIC AND METALLIC BONDING – CHAPTER 7

SECTION 7.1 - IONS

- OBJECTIVES:
  - <u>Determine</u> the number of ***valence electrons*** in an atom of a representative element.
  - <u>Explain</u> how the octet rule applies to atoms of metallic and nonmetallic elements.
  - <u>Describe</u> how **cations** form.
  - <u>Explain</u> how **anions** form.

VALENCE ELECTRONS ARE…?

- The electrons responsible for the chemical properties of atoms, and are those in the **outer** energy level.
- Valence electrons - The ***s*** and ***p*** electrons in the outer energy level
  - the highest occupied energy level
- Core electrons – are those in the energy levels below.

KEEPING TRACK OF ELECTRONS

- Atoms in the same column…
  1) Have the same outer electron configuration.
  2) Have the same valence electrons.
- The number of valence electrons are easily determined. It is the group number for a representative element
- Group 2A: Be, Mg, Ca, etc.
  - have 2 valence electrons

ELECTRON DOT DIAGRAMS ARE…

- A way of showing & keeping track of valence electrons.
- How to write them?
- Write the symbol - it represents the nucleus and inner (core) electrons
- Put one dot for each valence electron (**8 maximum**)
- They don't pair up until they have to (Hund's rule)

The Electron Dot diagram for Nitrogen

- Nitrogen has 5 valence electrons to show.
- First we write the symbol.
- Then add 1 electron at a time to each side.
- Now they are forced to pair up.
  - We have now written the electron dot diagram for Nitrogen.

The Octet Rule

- In Chapter 6, we learned that noble gases are unreactive in chemical reactions
- In 1916, Gilbert Lewis used this fact to explain why atoms form certain kinds of ions and molecules
- The Octet Rule: in forming compounds, atoms tend to achieve a noble gas configuration; 8 in the outer level is stable
  - Each noble gas (except He, which has 2) has 8 electrons in the outer level

FORMATION OF CATIONS

- Metals *lose* electrons to attain a noble gas configuration.
- They make positive ions (**cations**)
- If we look at the electron configuration, it makes sense to lose electrons:
- Na **$1s^2 2s^2 2p^6 3s^1$** 1 valence electron
- Na^{1+} **$1s^2 2s^2 2p^6$** This is a noble gas configuration with 8 electrons in the outer level.

ELECTRON DOTS FOR CATIONS

- Metals will have few valence electrons (usually 3 or less); calcium has only 2 valence electrons

ELECTRON DOTS FOR CATIONS

- Metals will have few valence electrons
- Metals will *<u>lose the valence electrons</u>*

ELECTRON DOTS FOR CATIONS

- Metals will have few valence electrons
- Metals will *lose the valence electrons*
- Forming positive ions

Ca^{2+}

This is named the "calcium ion".

NO DOTS are now shown for the cation.

ELECTRON DOTS FOR CATIONS

- Let's do Scandium, #21
- The electron configuration is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$
- Thus, it can lose $2e^-$ (making it 2+), or lose $3e^-$ (making 3+)

- Sc • = Sc^{2+}
  Scandium (II) ion
- Sc • = Sc^{3+}
  •
  Scandium (III) ion

ELECTRON DOTS FOR CATIONS

- Let's do Silver, element #47
- *Predicted* configuration is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 \underline{5s^2 4d^9}$
- *Actual* configuration is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 \underline{5s^1 4d^{10}}$

Ag ● = Ag^{1+} (can't lose any more, charges of 3+ or greater are uncommon)

ELECTRON DOTS FOR CATIONS

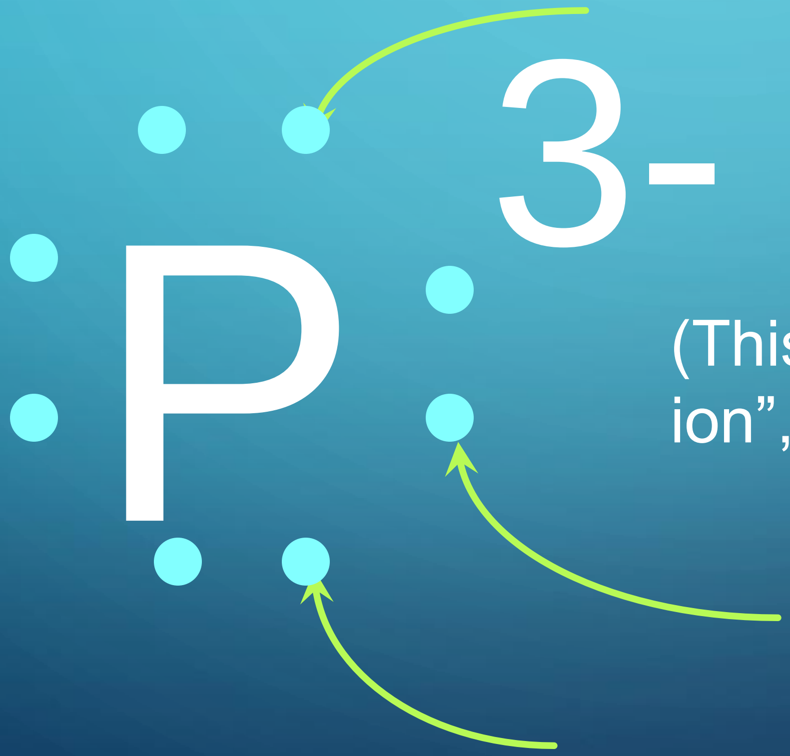
- Silver did the best job it could, but it did not achieve a ***true*** Noble Gas configuration
- Instead, it is called a **"pseudo-noble gas configuration"**

ELECTRON CONFIGURATIONS: ANIONS

- Nonmetals **gain** electrons to attain noble gas configuration.
- They make negative ions (**anions**)
- **S** = **$1s^2 2s^2 2p^6 3s^2 3p^4$** = 6 valence electrons
- **S^{2-}** = **$1s^2 2s^2 2p^6 3s^2 3p^6$** = noble gas configuration.
- ***Halide ions*** are ions from chlorine or other halogens that gain electrons

ELECTRON DOTS FOR ANIONS

- Nonmetals will have many valence electrons (usually 5 or more)
- They will *gain* electrons to fill outer shell.



(This is called the "phosphide ion", and *should show* dots)

STABLE ELECTRON CONFIGURATIONS

- All atoms react to try and achieve a noble gas configuration.
- Noble gases have 2 s and 6 p electrons.
- 8 valence electrons = already stable!
- This is the *octet rule* (8 in the outer level is particularly stable).

SECTION 7.2 IONIC BONDS AND IONIC COMPOUNDS

- OBJECTIVES:
  - Explain the electrical charge of an ionic compound.
  - Describe three properties of ionic compounds.

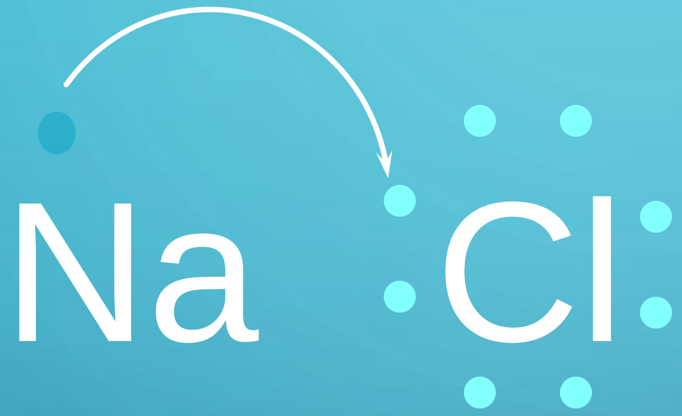
IONIC BONDING

- Anions and cations are held together by *opposite charges* (+ and -)
- Ionic compounds are called **salts**.
- Simplest ratio of elements in an ionic compound is called the formula unit.
- The bond is formed through the transfer of electrons (lose and gain)
- Electrons are transferred to achieve noble gas configuration.

IONIC COMPOUNDS

1) Also called SALTS
2) Made from: a CATION with an ANION (or literally from a *metal* combining with a *nonmetal*)

IONIC BONDING



The metal (sodium) tends to lose its one electron from the outer level.

The nonmetal (chlorine) needs to gain one more to fill its outer level, and will accept the one electron that sodium is going to lose.

IONIC BONDING

Note: Remember that NO DOTS are now shown for the cation!

IONIC BONDING

Lets do an example by combining calcium and phosphorus:

- <u>All the electrons must be accounted for</u>, and **each** atom will have a noble gas configuration (which is stable).

IONIC BONDING

IONIC BONDING

Ca^{2+}

Ionic Bonding

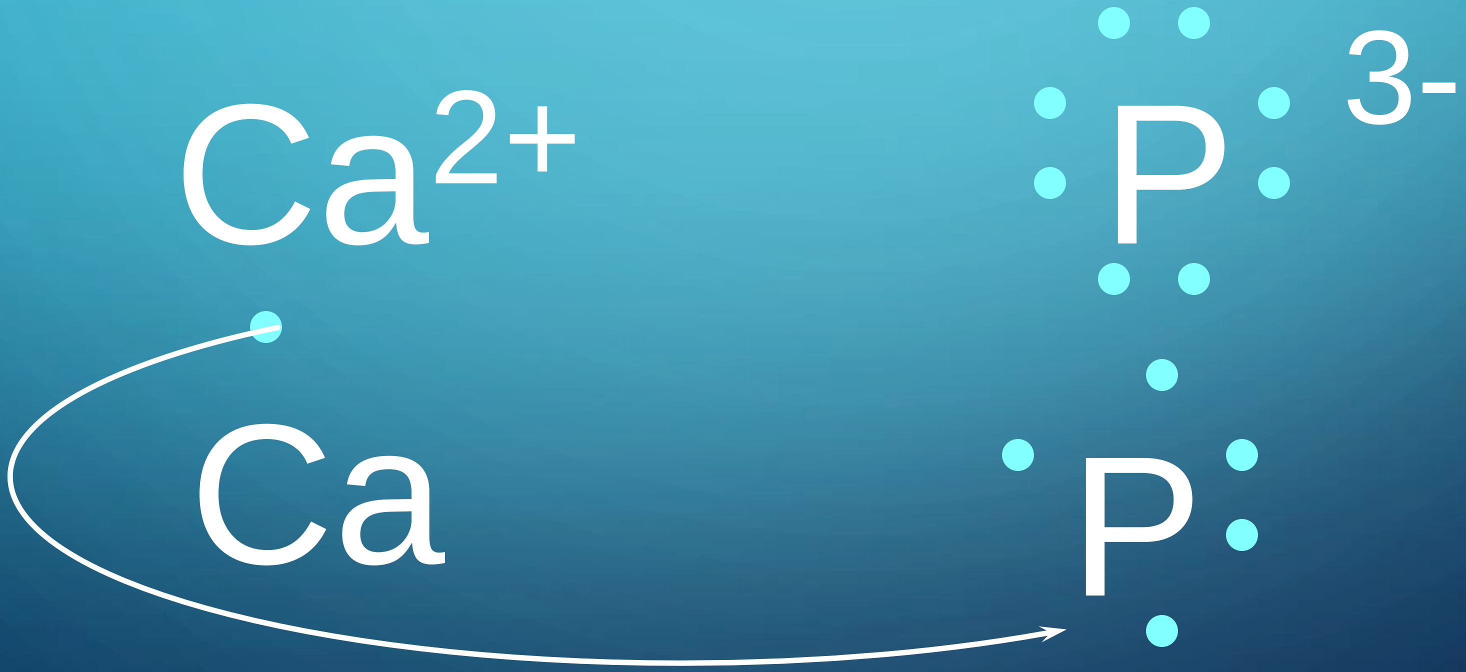
Ionic Bonding

Ca^{2+}

P^{3-}

Ca

Ionic Bonding



Ionic Bonding

Ca^{2+} P^{3-}

Ca^{2+} P

Ionic Bonding

Ca

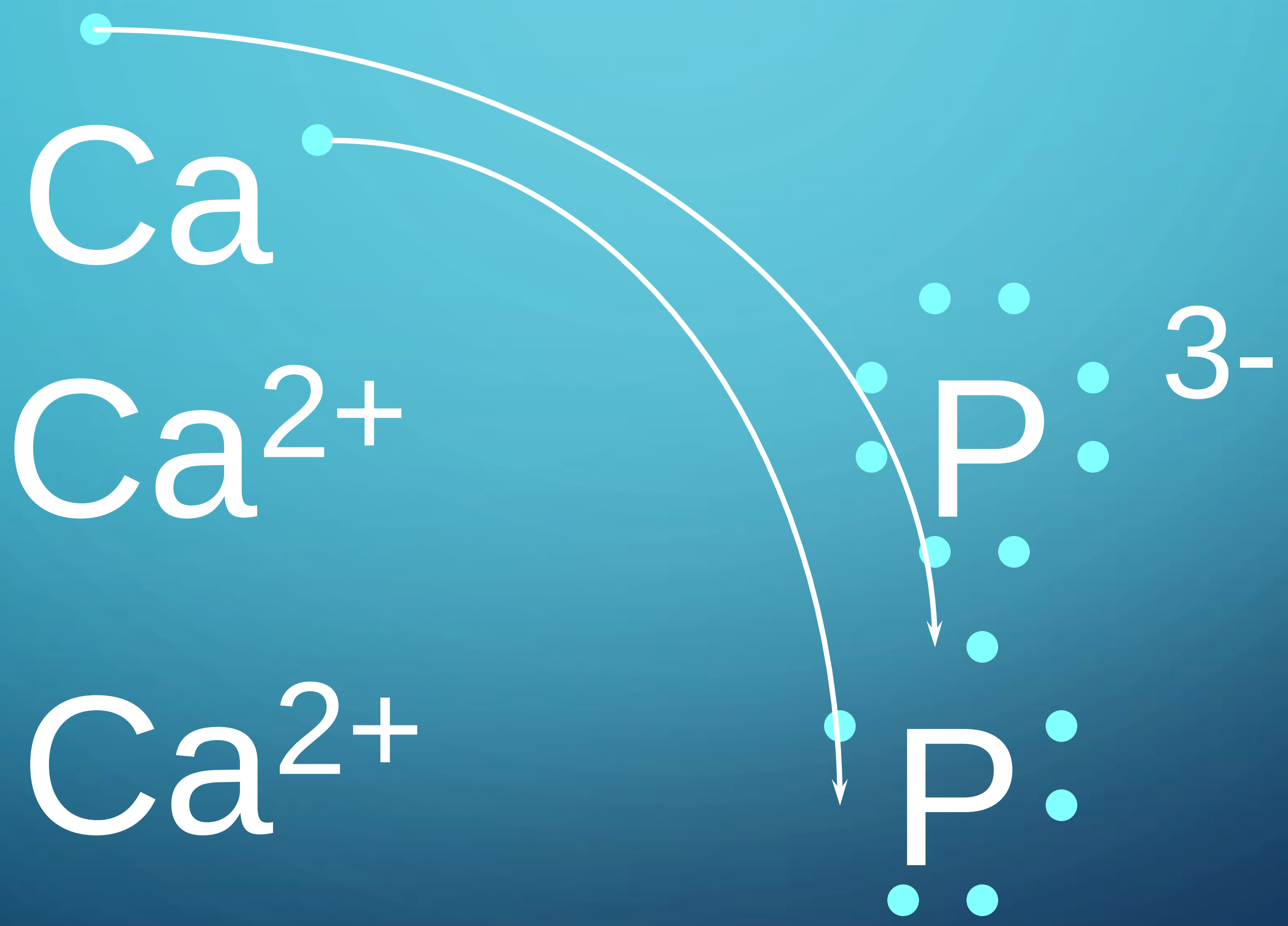
Ca^{2+}

P^{3-}

Ca^{2+}

P

Ionic Bonding



Ionic Bonding

Ca^{2+}

Ca^{2+} $:\ddot{\underset{\cdot\cdot}{P}}:^{3-}$

Ca^{2+} $:\ddot{\underset{\cdot\cdot}{P}}:^{3-}$

Ionic Bonding

$= Ca_3P_2$ ← Formula Unit

This is a **chemical formula**, which shows the kinds and numbers of atoms in the smallest representative particle of the substance.

For an ionic compound, the smallest representative particle is called a:
Formula Unit

PROPERTIES OF IONIC COMPOUNDS

1. Crystalline solids - a regular repeating arrangement of ions in the solid: Fig. 7.9, page 197
   - Ions are strongly bonded together.
   - Structure is rigid.
2. High melting points

- Coordination number- number of ions of opposite charge surrounding it

DO THEY CONDUCT?

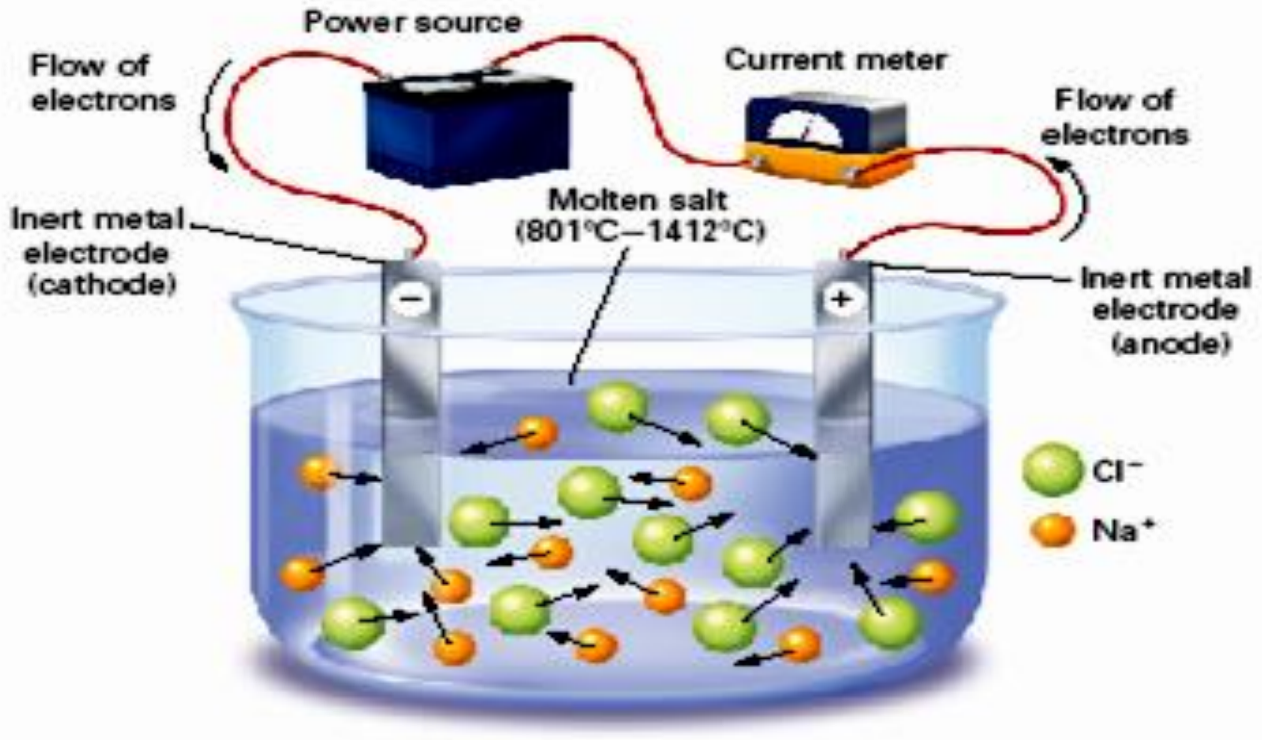
- Conducting electricity means allowing charges to move.
- In a solid, the ions are locked in place.
- Ionic solids are insulators.
- When melted, the ions can move around.

3. Melted ionic compounds conduct.
   - NaCl: must get to about 800 °C.
   - Dissolved in water, they also conduct (free to move in aqueous solutions)

81

Figure 7.11 Electrical Conductivity of Molten Sodium Chloride - Page 198

The ions are free to move when they are **molten** (or in **aqueous solution**), and thus they are able to conduct the electric current.



SECTION 7.3
BONDING IN METALS

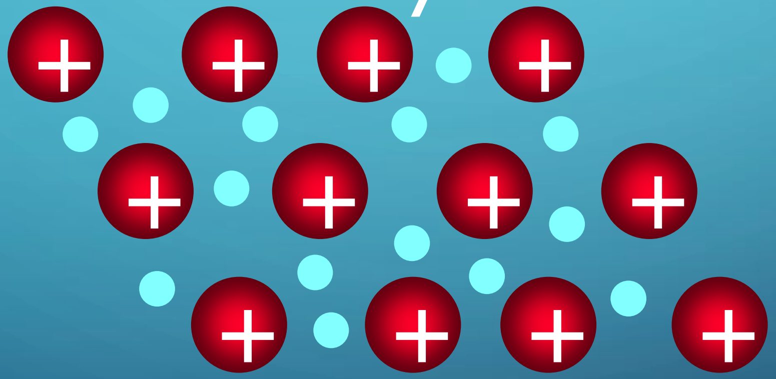
- OBJECTIVES:
  - Model the valence electrons of metal atoms.
  - Describe the arrangement of atoms in a metal.
  - Explain the importance of alloys.

METALLIC BONDS ARE…

- How metal atoms are held together in the solid.
- Metals hold on to their valence electrons **very weakly**.
- Think of them as positive ions (cations) floating in a sea of electrons: Fig. 7.12, p.201

SEA OF ELECTRONS

- Electrons are free to move through the solid.
- Metals conduct electricity.



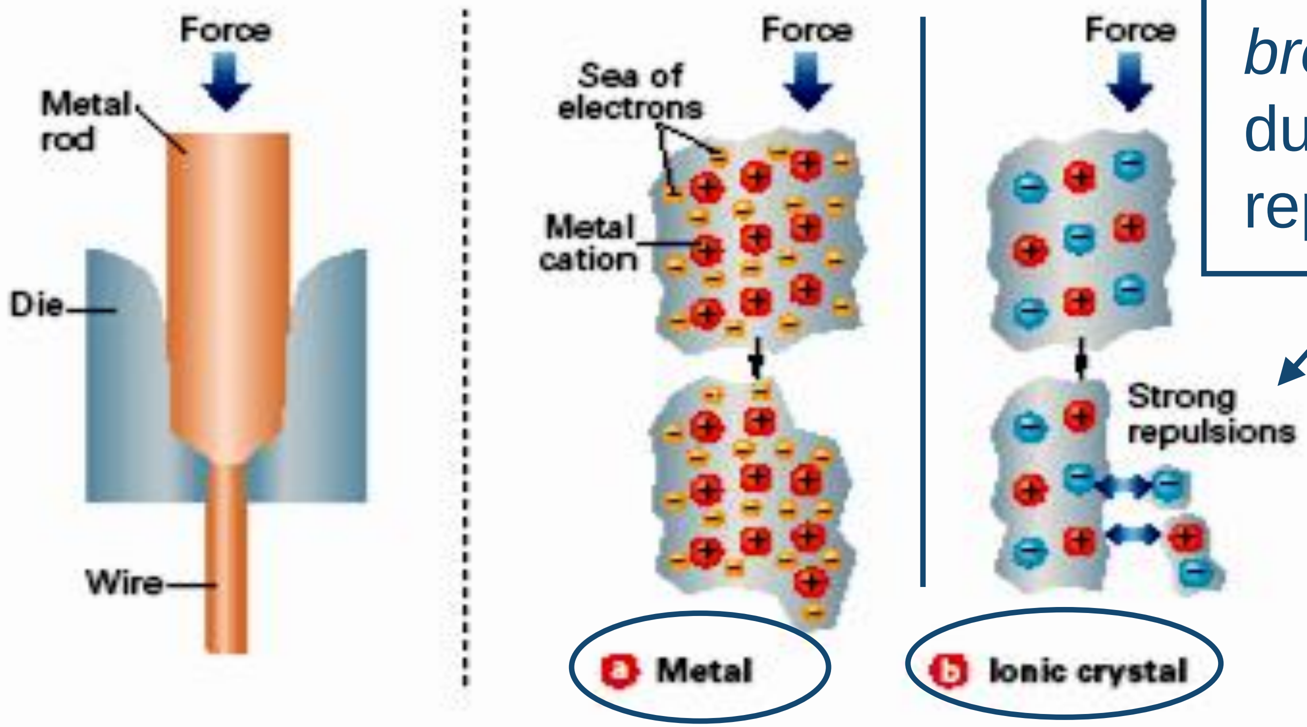
METALS ARE <u>MALLEABLE</u>

- Hammered into shape (bend).
- Also <u>ductile</u> - drawn into wires.
- Both malleability and ductility explained in terms of the ***<u>mobility</u>*** <u>of the valence electrons</u>

Figure 7.12 - Page 201
Metal Rod Forced Through Die

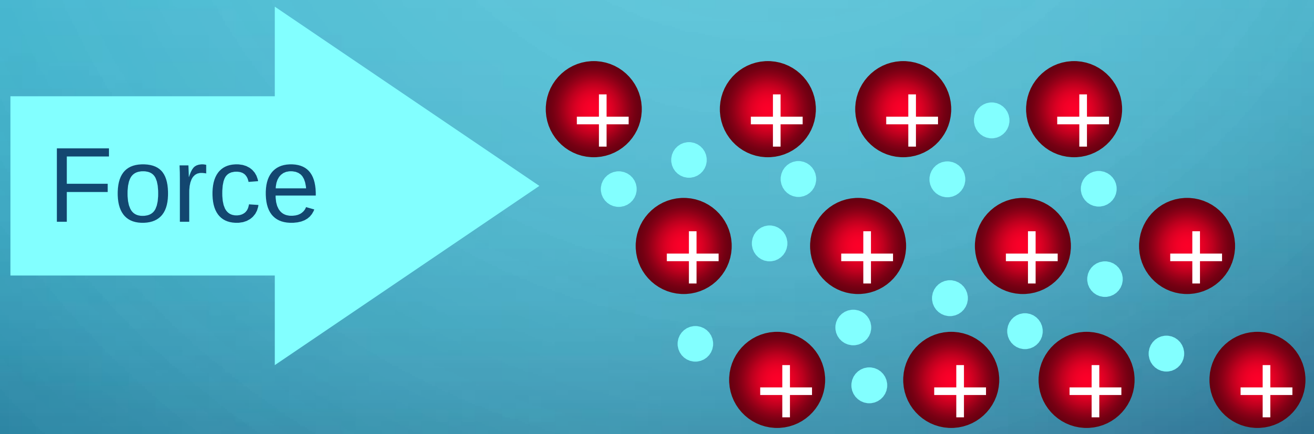
Due to the mobility of the valence electrons, metals have:

1) Ductility and **2) Malleability**



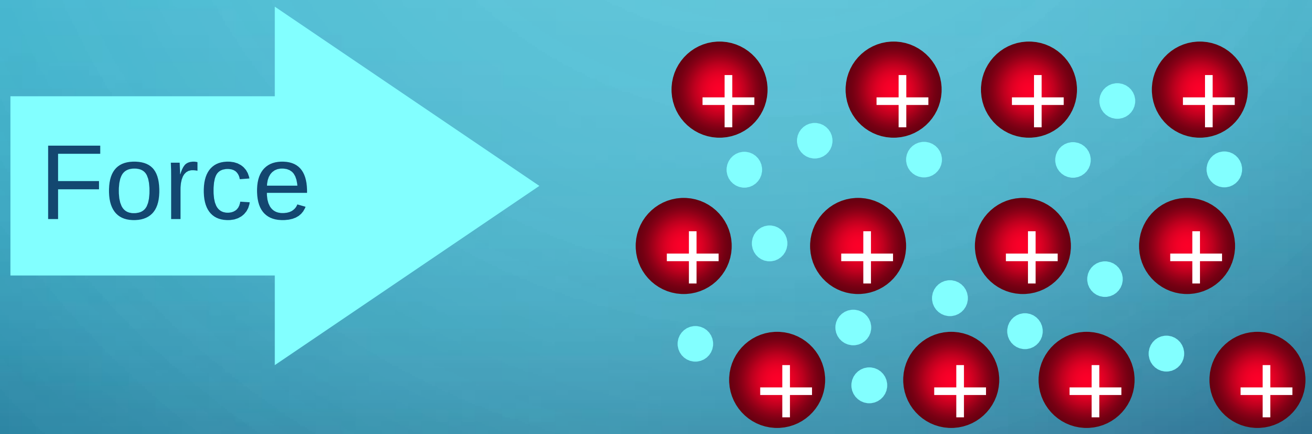
Notice that the **ionic crystal** *breaks* due to ion repulsion!

MALLEABLE

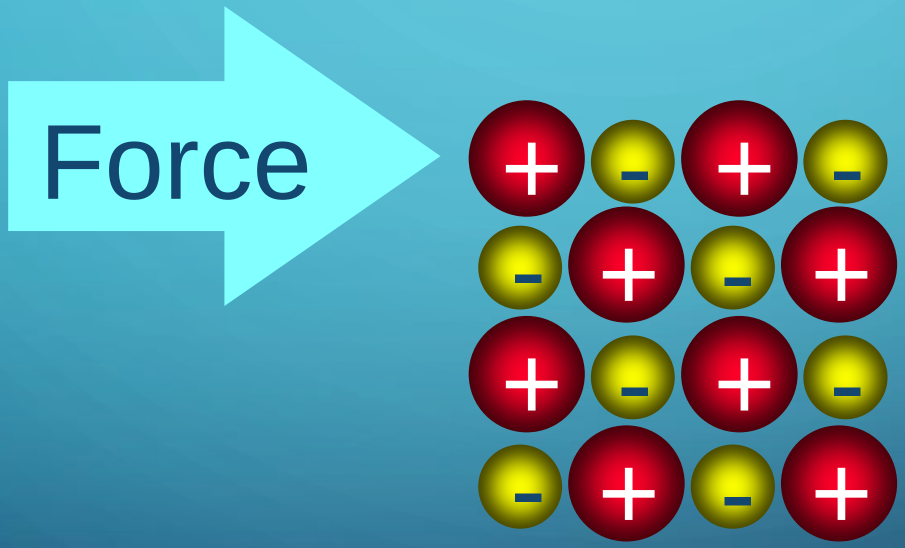


MALLEABLE

- Mobile electrons allow atoms to slide by, sort of like ball bearings in oil.

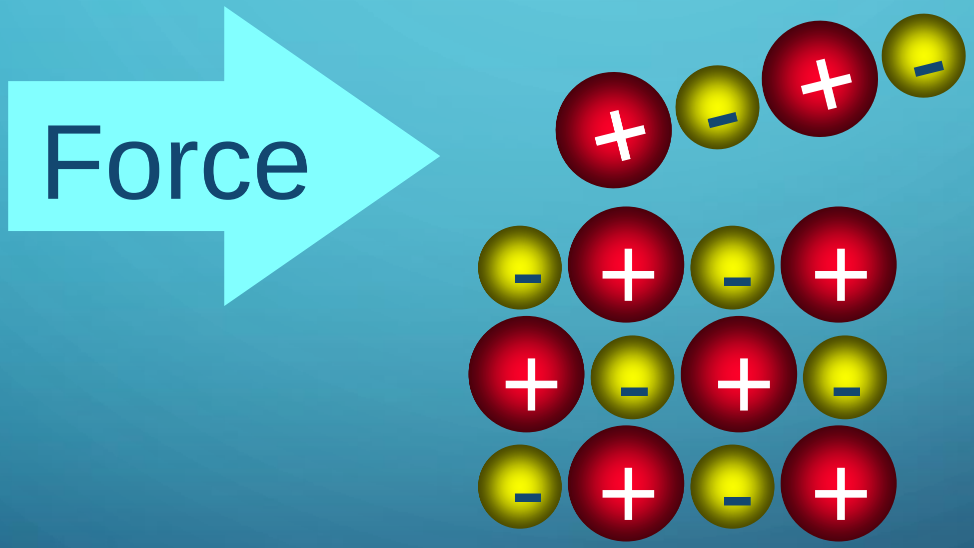


IONIC SOLIDS ARE BRITTLE



IONIC SOLIDS ARE BRITTLE

- <u>Strong Repulsion</u> breaks a crystal apart, due to similar ions being next to each other.



CRYSTALLINE STRUCTURE OF METAL

- If made of *one kind of atom*, metals are among the simplest crystals; very compact & orderly
- Note Fig. 7.14, p.202 for types:

<u>1. Body-centered cubic:</u>

  - every atom (except those on the surface) has 8 neighbors
  - Na, K, Fe, Cr, W

CRYSTALLINE STRUCTURE OF METAL

2. Face-centered cubic:

- every atom has 12 neighbors
- Cu, Ag, Au, Al, Pb

3. Hexagonal close-packed

- every atom also has 12 neighbors
- different pattern due to hexagonal
- Mg, Zn, Cd

ALLOYS

- We use lots of metals every day, but few are pure metals
- Alloys are mixtures of 2 or more elements, at least 1 is a metal
- made by melting a mixture of the ingredients, then cooling
- **Brass**: an alloy of Cu and Zn
- Bronze: Cu and Sn

WHY USE ALLOYS?

- Properties are often *superior* to the pure element
- Sterling silver (92.5% Ag, 7.5% Cu) is harder and more durable than pure Ag, but still soft enough to make jewelry and tableware
- Steels are very important alloys
    - corrosion resistant, ductility, hardness, toughness, cost

MORE ABOUT ALLOYS…

- Table 7.3, p.203 – lists a few alloys
- Types? a) substitutional alloy- the atoms in the components are about the same size
- b) interstitial alloy- the atomic sizes quite different; smaller atoms fit into the spaces between larger
- "Amalgam"- dental use, contains Hg

End of Chapter 7

QUESTIONS FOR PRACTICE

- Practice Problems Page 193 #1, 2; 7.1 Section Assessment #3 – 11
- Practice Problems Page 196#12, 13; 7.2 Section Assessment #15, 16, 18, 19, 20, 22
- 7.3 Section Assessment #24, 26, 27

QUESTIONS FOR REVIEW

- Page 207 – 210 #30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 52, 53, 55, 56, 58, 59, 61, 62, 63, 65, 67, 76, 80, 87, 88, 89, 94, 97, 101
- Additional worksheets may also be given