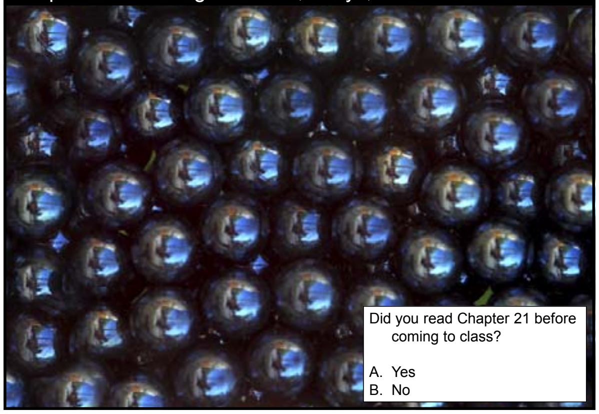
Chapter 21: Bonding in Metals, Alloys, and Semiconductors

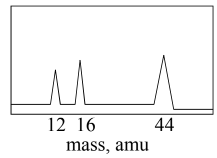


Did you read Chapter 21 before coming to class?

A. Yes
B. No

Review: A mass spectrograph analyzes substances. This display could be for what substance?

a) Mg
b) S
c) MgF_2
d) CO
e) CO_2

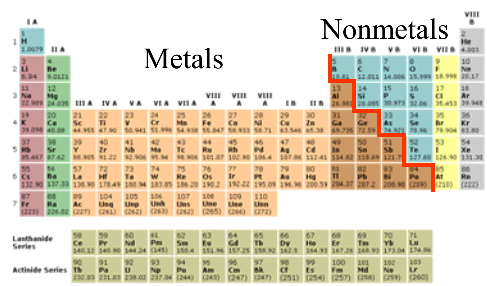


Why do we need to use a match to explode the balloon?

A. Products of combustion of the match catalyze reaction of $H_2 + O_2$
B. Heat from the match provides the required energy of activation
C. We need the match to pop the balloon and expose the H_2 to the O_2
D. Matches contain small amounts of palladium (Pd)

Basic Categories

- The elements divide nicely into two categories, *metals* and *nonmetals*.



The three main types of bonds

1. Metal—Metal: "metallic bond"
   - **Alloys**. Characteristics are like a pure metal
2. Metal—Nonmetal: "Ionic bond"
   - **Salts**. Crystalline in form. Often toxic.
3. Nonmetal—Nonmetal: "Covalent bond"
   - **Gases, Organic Compounds**. Characteristics are like pure nonmetals.

How does melting temperature relate to the strength of bonds?

- Temperature at which change of state takes place reflects the strength of forces holding matter together: high temperature changes reflect strong forces

Metals melt at high temperatures.

	MELTING TEMPERATURE BC	BOILING TEMPERATURE BC (under 1 atm pressure)	State At Room Temperature
Helium	doesn't form solid except under high pressure!	-269	Gas
Hydrogen	-259	-253	Gas
Neon	-249	-246	Gas
Nitrogen	-210	-196	Gas
Water	0	100	Liquid
Ethanol	-117	78.5	Liquid
Table salt	801	1413	Solid
Copper	1083	2567	Solid
Gold	1065	2807	Solid

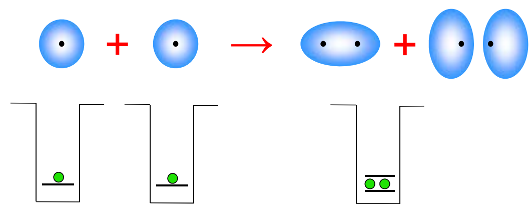
Metals are dense.

	DENSITY g / cm^3		
	Solid	Liquid	Gas
Helium		0.122	0.00018
Hydrogen	0.078	0.071	0.0001
Neon	1.54	1.21	0.00082
Nitrogen	1.09	0.81	0.0013
Water	0.90 (0°C)	1.00	0.0006
Ethanol	1.3	0.80	0.0020
Table salt	2.2	Not available	Not available
Copper	8.9	Not available	Not available
Gold	19.3	Not available	Not available

What other properties do metals have?

- Classified as network solids
- Generally have:
  - High Melting T
  - High Boiling T
  - High Density
- Conduct both heat and electricity
- Malleable – flatten into thin sheets
- Opaque – can't see through even thin sheets
- Reflective (Metallic Luster) – shiny

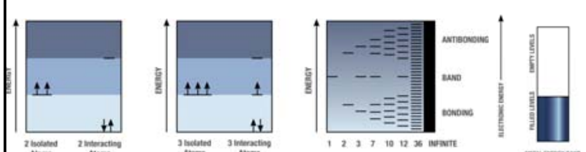
When molecular orbitals form, the total number of orbitals stays the same.



The two ground state atomic orbitals

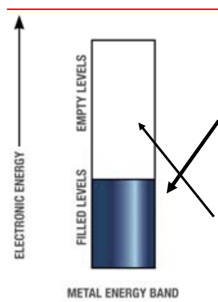
Result in two new molecular orbitals

When you get enough atoms together, the resulting orbitals are very close in energy, and we think of them as energy bands.



Atomic orbitals on many, many identical atoms interact to form a continuous set of closely spaced levels. The new orbitals are molecular orbitals.

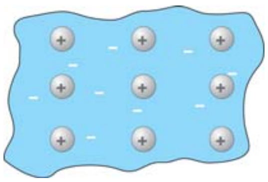
Many molecular orbitals closely spaced in energy give rise to a band of energies



- Metals have few valence electrons compared to number of orbitals
- Electrons want to be in low energy states – "filled" levels
- Levels still exist (and easily available) even when there are no electrons in them – "empty" levels

What do molecular orbitals look like in a metal?

- Molecular orbitals extend essentially through the entire piece of metal
- Lots of energy levels for electrons
- Small amounts of energy can move electrons between orbitals
- Electrons not tightly attached to any particular atom – "Sea of Electons"



The energy band with mobile electrons explains all metallic properties!

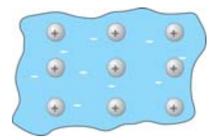
Properties arising from Energy Band Structure with mobile electrons

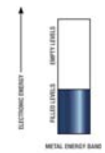
High melting temperatures – nuclei surrounded by electron sea melting requires the breaking of strong attractive interactions

Electrical conductivity – mobile charge carriers are the electrons

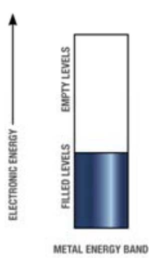
Thermal conductivity – electrons can absorb/give up heat easily; transport it away because of electron mobility

Malleability – electrons serve as lubricant, allowing layers of nuclei to slide past one another





The Opacity, Luster, and Reflectivity of metals are tied to the existence of many available energy levels.

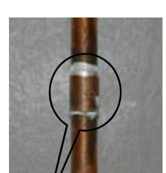


Alloys result when two or more elemental metals are combined to make a new metal

- Examples:
  - Copper + Zinc → Brass
  - Copper + Tin → Bronze
  - Gold + Nickel (± Palladium, Zinc) → White Gold
  - Iron + Carbon → Steel
  - Iron + Chromium (± others) → Stainless Steel
- Because all metal atoms have:
  - Few valence electrons
  - Low ionization energies

How do the properties of alloys differ from pure metals?

- Alloys not as good conductors of electricity and heat
- Alloys often melt at a lower temperature
- Alloys may be less malleable than pure metals



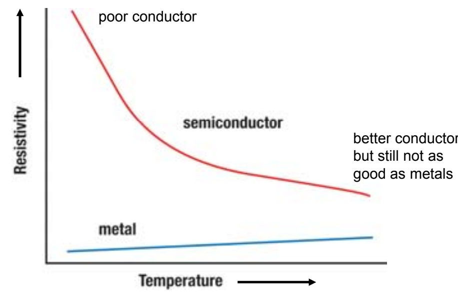
low-melting solder used to hold copper pipe together is an alloy

The amount of carbon in steel determines how brittle it is.

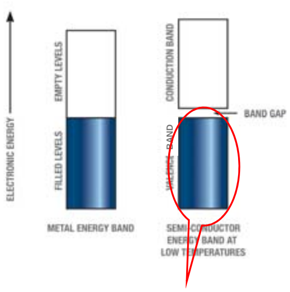
What is a Semi-conductor?

- Not quite metals or non-metals
  - Higher ionization energies and more valence electrons give rise to change in the energy level structure
- Have some properties of metals
  - Conduct electricity under certain conditions
  - Solids with high melting points
- Widely used in computers and other electronic devices
  - Particularly, Si and Ge

Why do semiconductors and metals behave differently at T increases?



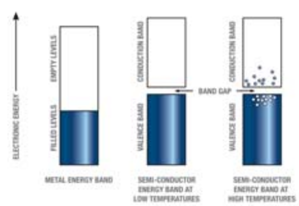
Semiconductors have Energy Band Split in Two. There are no orbitals with the energies in the gap



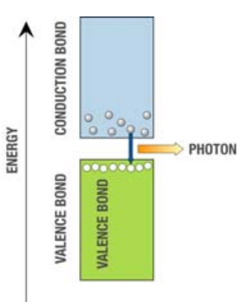
Band filled – no electrical conductivity possible at low temperatures

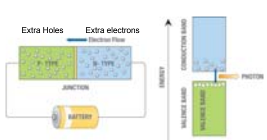
High temperature conductivity of semiconductors

- Conductivity requires mobile electrons with empty energy Levels
- At high temperature, some electrons get kicked "upstairs" (above the band gap) and gain access to empty levels.
- This also creates "holes" down below that behave like positive charges.
- We can also create holes and conduction band electrons by "doping" the semiconductor (e.g. Phosphorus adds an electron, Aluminum adds a hole)



Light Emitting Diodes





Photon color emitted by diode
Is related to energy of band gap

Band gap size vs. Temperature

- As the temperature changes, the orbital energies shift and the size of the band gap changes.
- Does the band gap get smaller or larger when you cool a LED?