Exp. 2: The 1-2-3 Superconductor $YBa_2Cu_3O_7$ (Text #1)

<u>This Thursday</u>:

- Perform high-temperature, solid-state reaction to prepare $YBa_2Cu_3O_x$

<u>Next Thursday</u>:

- Determine product stoichiometry ("x")
  - *based on lost mass after heating*
  - from an iodometric titration
- Test your product for superconductivity

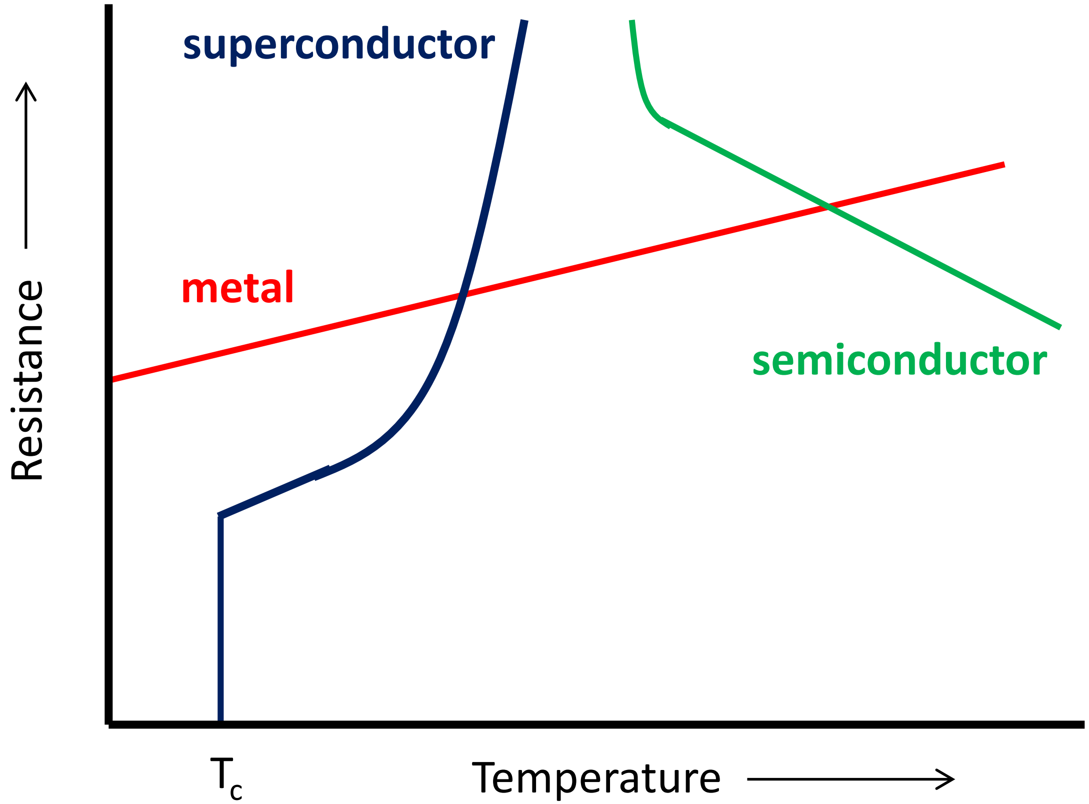
Superconductors

- A material that exhibits zero electrical resistance when cooled below its critical temperature (T_c).
  - This transition to zero resistance is immediate upon reach T_c
  - Because superconductors have zero resistance, current can be maintained in superconducting rings indefinitely

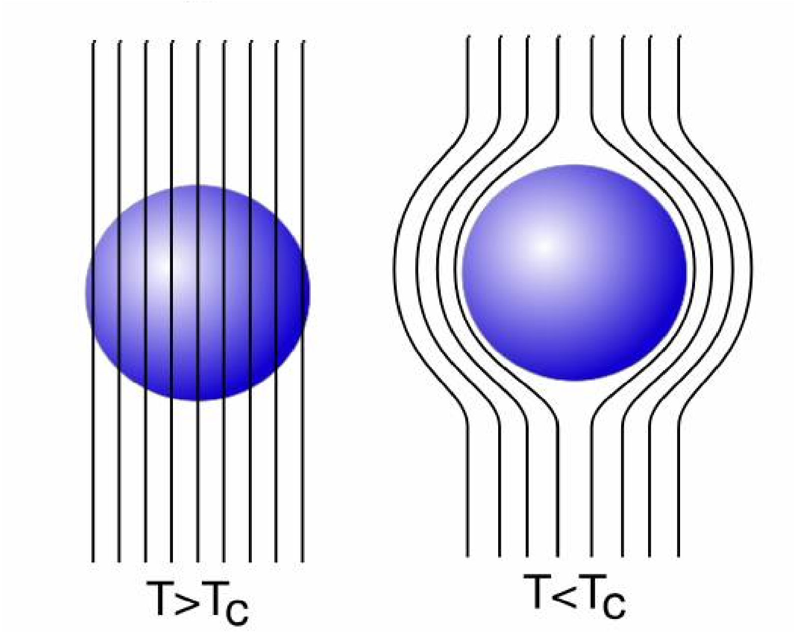
- "High Critical Temperature Superconductors" ($T_c > 77K$) are of particular interest because the low cost refrigerant N_2(L) can be used to maintain the superconducting state.

Effects of Temperature on Electrical Resistance

High resistance = poor current = poor conductivity

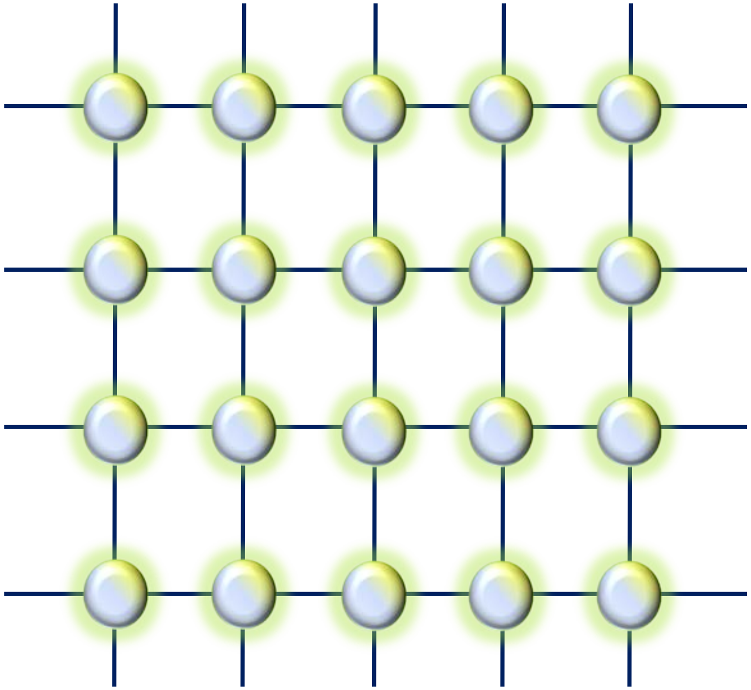


Meissner Effect

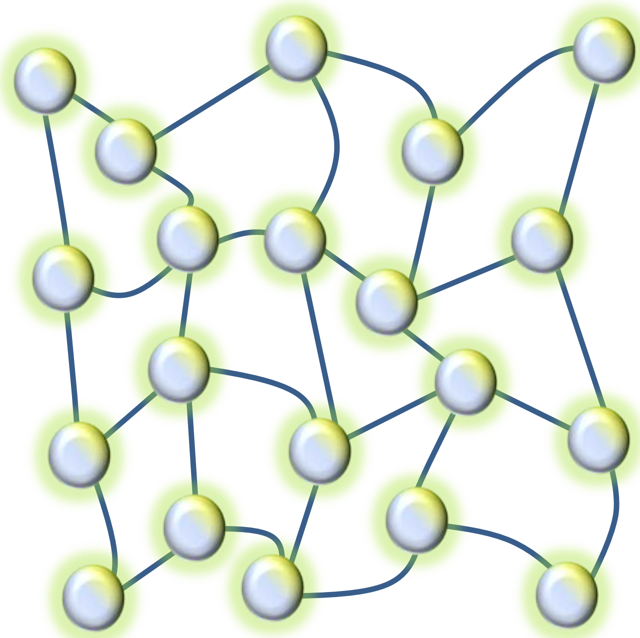


Phonons

Absolute Zero

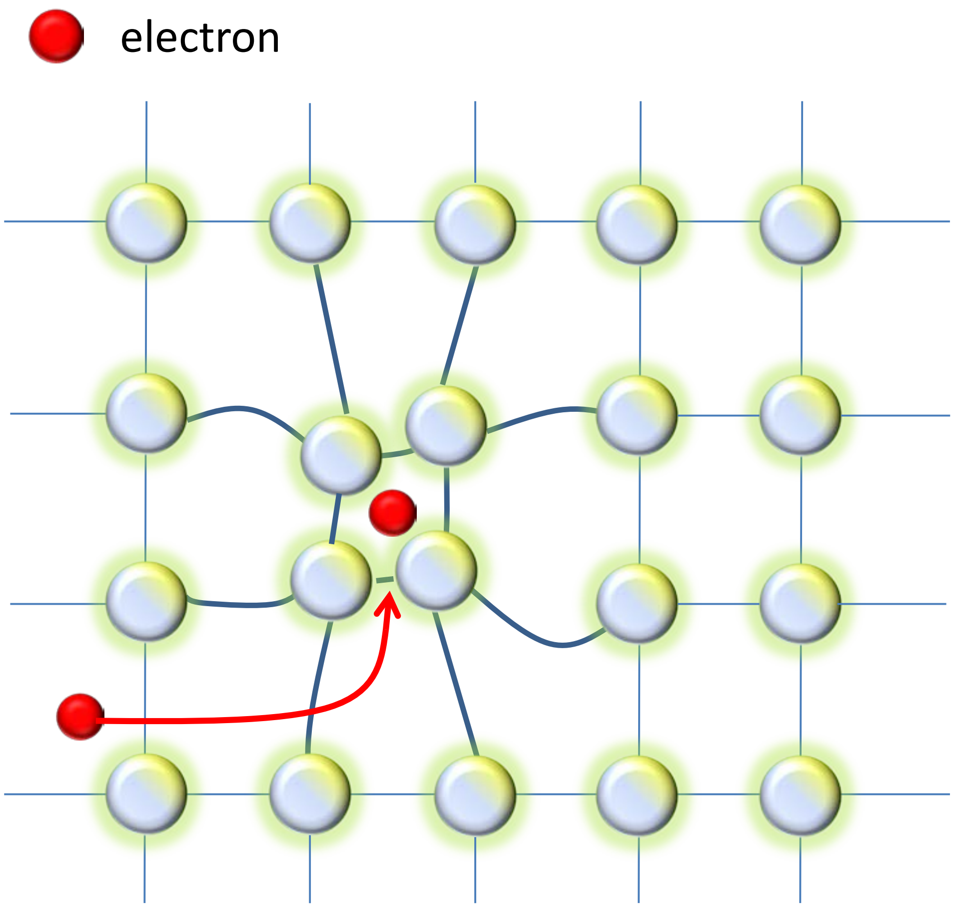


High Temperature



- High temperature results in the creation of high energy **phonons**, packets of vibrational energy
- Phonons create distortion. Electrons migrating through a lattice collide with moving atoms, causing a loss of momentum, and thus, conductivity.

Cooper Pairs



- Cooper pairs are more mobile than individual electrons because the distortion caused by the first electron will attract back the 2nd should it be scattered out of its path.

- Thus, formation of Cooper Pairs leads to superconductivity.

- Higher temperatures increase the scattering effect due to oscillation of lattice atoms, causes Cooper Pairs to separate, raising the resistance.

$YBa_2Cu_3O_7$

- Type II Superconductor
  - Made from an alloy, as opposed to a pure metal

- Superconductivity is observed at $T \geq 92$ K

- Structure is that of a "defect perovskite"
  - Similar to the standard perovskite structure (ABO_3) but some atoms are missing
    - Copper ions occupy the A sits
    - Both Ba^{2+} and Y^{3+} occupy the B sites
    - The ratio is not 1:1:3 because some oxygen atoms are missing
      - Coordination numbers of 8 for Y, 10 for Ba, and either 4 or 5 for Cu
    - Orthorhombic

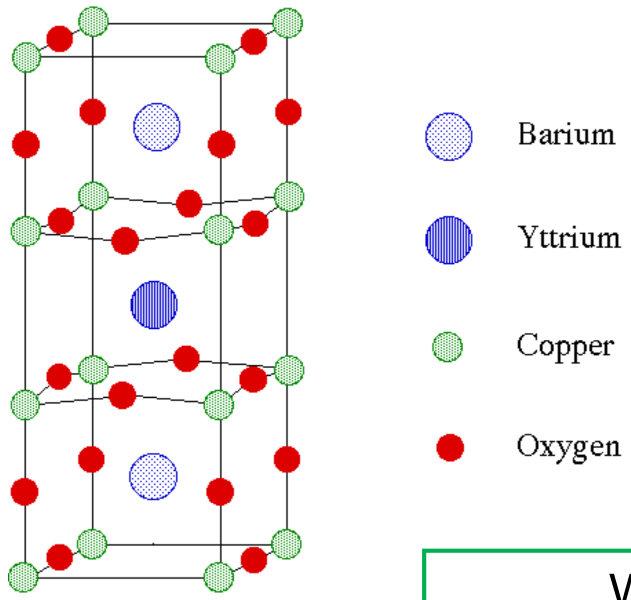
Stoichiometry of $YBa_2Cu_3O_x$: Determining *x*

$$\tfrac{1}{2}\, Y_2O_{3\,(s)} + 2\, BaCO_{3\,(s)} + 3\, CuO_{(s)} \rightarrow YBa_2Cu_3O_{x\,(s)} + 2\, CO_{2\,(g)}$$

What value of 'x' is expected from stoichiometry? 6.5

Desired for superconductivity? 7

Unit cells of $YBa_2Cu_3O_x$ and $CaTiO_3$



What would $CaTiO_3$ (Perovskite) look like?

http://imr.chem.binghamton.edu/labs/super/superc.html

Synthesis of $YBa_2Cu_3O_7$

- Solid state reactions are slow!
  - Atoms in crystals do not diffuse readily
  - At very high temperatures, the atoms can be forced to migrate quickly enough to form new bonds on a reasonable time scale

- Synthesis will be carried out at 900 C in the tube furnace under flowing O_2.
  - Why is O_2 required?

- Accuracy is very important. If the metals are not present in a 1:2:3 ratio, or if the materials are not well mixed, the product will NOT be superconductive.