Physical Properties of Matter

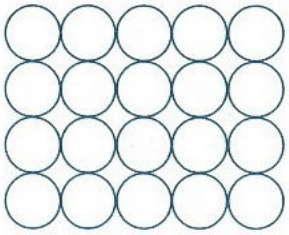
States of Matter

- Solid
- Liquid
- Gas
- Plasma

- Bose-Einstein condensate
  - Not naturally occurring

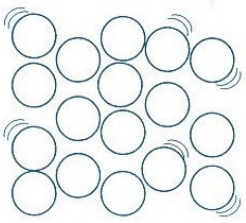
Solid

- Definite shape
- Definite volume
- Usually very dense
- Not easily compressed



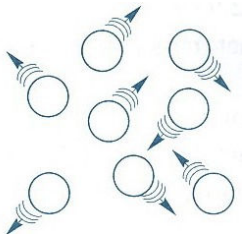
Liquid

- No fixed shape
- Definite volume
- Usually less dense that a solid
- Not easily compressed



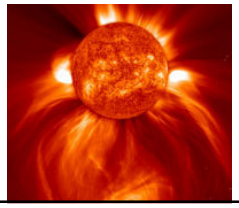
Gas

- No fixed shape
- No fixed volume
- Usually much less dense than solids or liquids
- Easily compressed



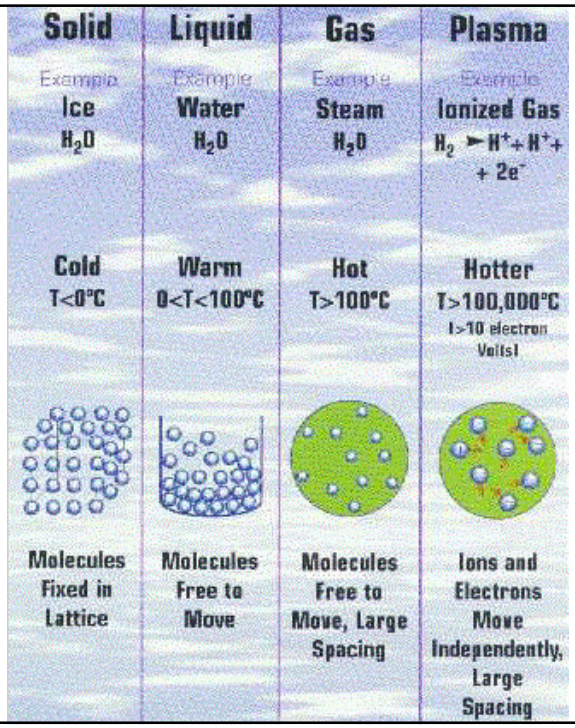
Plasma

- Plasma consists of a collection of free-moving electrons and ions
- Due to its unstable nature, the only way to have large amounts of plasma is at temperatures over $1x10^{8}$ ^{o}C
- Plasmas make up over 99% of the visible universe



Bose-Einstein Condensate

- "Condensates" are extremely low-temperature fluids which contain properties and exhibit behaviors that are currently not completely understood
- Bose-Einstein condensation is an exotic quantum phenomenon that was observed in dilute atomic gases for the first time in 1995, and is now the subject of intense theoretical and experimental study



Kinetic Molecular Theory

- Ludwig Boltzmann & James Maxwell (1860)
- Proposed a model to explain the properties of gases
- Describes the behavior of gases in terms of particles in motion
- The model makes several assumptions about the size, motion, and energy of gas particles

Particle Size

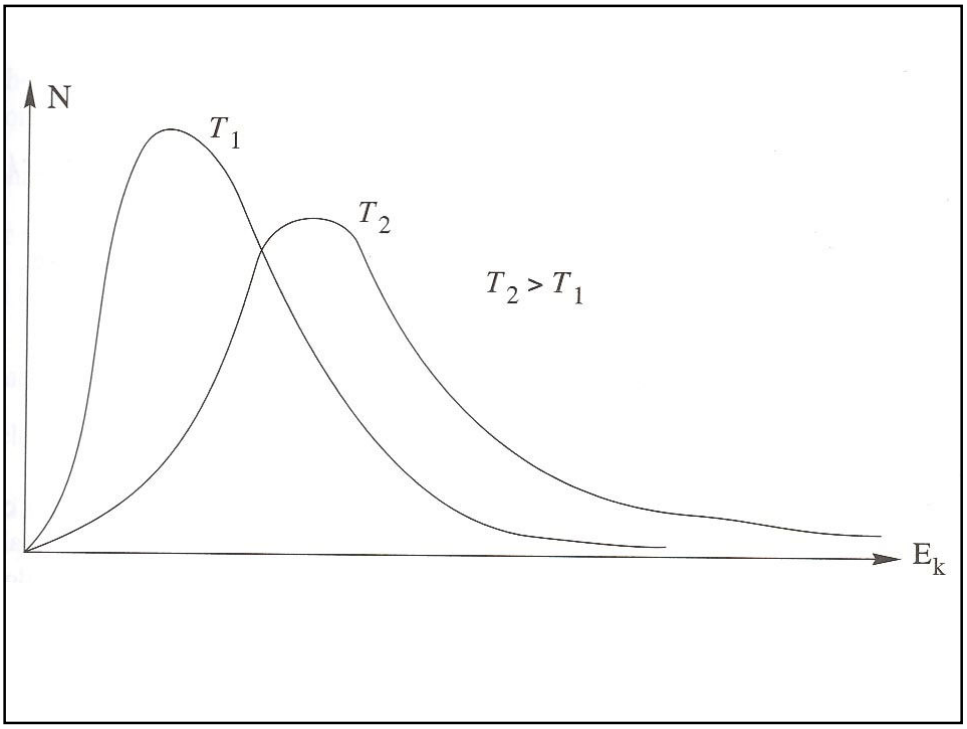
- Gases consist on small particles that are separated from one another by empty space
- The volume of the particles is small compared with the volume of the empty space
- Because gas particles are far apart, there are no significant attractive or repulsive forces among them

Particle Motion

- Gas particles are in constant, random motion
- Particles move in a straight line until they collide with other particles or with the walls of the container
- Collisions between gas particles are elastic (no kinetic energy is lost, only transferred from one particle to the other)

Particle Energy

- Two factors determine the kinetic energy of a particle: mass and velocity
- In a sample of a simple gas, all particles have the same mass, but not the same velocity (therefore, different kinetic energies)
- Temperature and kinetic energy are related
- Temperature is a measure of the average kinetic energy of the particles



Explaining the Behavior of Gases

- Low Density
  - Density is mass per volume
  - As the kinetic-molecular theory states, there is a great deal of space between gas particles
  - This means that there will be fewer gas molecules in a volume as compared to a solid

- Compression and Expansion
  - Since there is a lot of space between gas particles, it is easy to push the particles closer together (compression)
  - If the volume of the container is increased, the random motion of the molecules quickly fills all of the available space

- Diffusion
  - According to the kinetic-molecular theory, there are no significant forces of attraction between gas particles
  - Gas particles can easily flow past each other
  - Often the space into which a gas flows is already occupied by another gas
  - The random motion of the gas particles causes the gases to mix until they are evenly distributed
  - This is called diffusion

Explaining Liquids

- Density
  - Liquids are more dense than gases at the same temperature
  - But the particles in the liquid are more tightly held together by the intermolecular forces
  - Thus, more particles will be in the same volume (giving a larger density)

- Compression
  - Because the particles are held closer together, there is less empty space
  - We can push the particles a little closer together but it takes a tremendous amount of pressure

- Fluidity
  - The ability to flow
  - Both gases and liquids are fluids
  - A liquid can diffuse through another liquid, but because of the intermolecular forces between the particles, it is slow

- Viscosity
  - The measure of the resistance of a liquid to flow
  - The particles in a liquid are close enough for attractive forces to slow their movement as they flow past one another
  - Viscosity is determined by the type of intermolecular forces, the shape of the particles, and the temperature
    - The stronger the attractive forces, the higher the viscosity
    - Higher temperature, means more kinetic energy, meaning the particles have more motion, resulting in lower viscosity

Solids

- According to the kinetic-molecular theory, a mole of solid particles have the same kinetic energy as a mole of liquid particles at the same temperature
- That means that the particles must be in constant motion
- So why does a solid have a definite shape and a liquid doesn't?

- Density
  - The particles are more closely packed than in a liquid (more particles in the same volume)
  - Therefore, a solid is more dense

Structure of Solids

- Crystalline
  - Ionic
  - Covalent network
  - Molecular
  - Metallic
- Amorphous

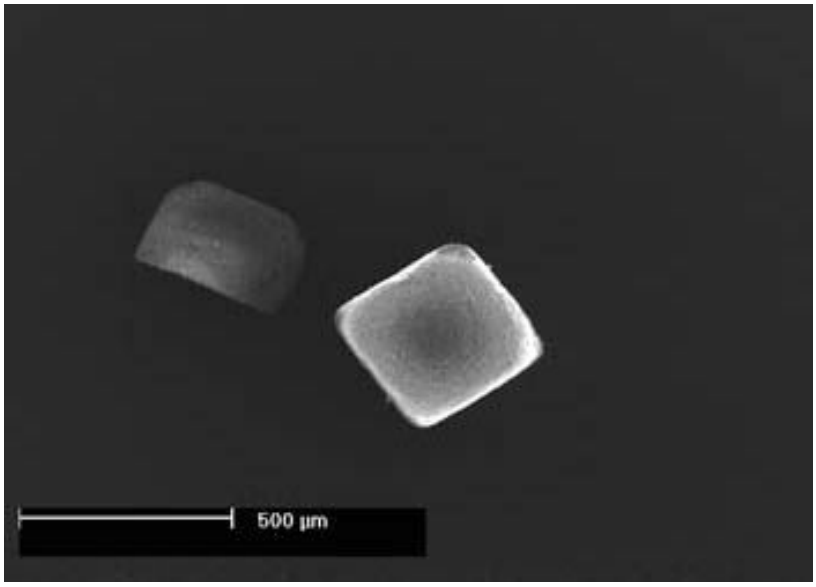
Crystalline Solids

- The particles are held together in a predictable way
- The atoms, ions or molecules are arranged in an orderly, geometric, three-dimensional structure
- The individual pieces are called crystals

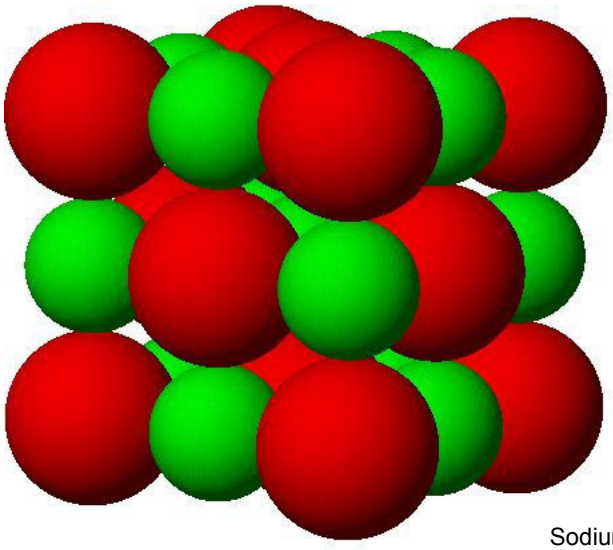
Ionic

- Each ion is surrounded by ions of opposite charge
- The type of ions and the ratio of ions determines the structure of the lattice and the shape of the crystal
- Hard
- High melting point
- Poor conductivity

- NaCl



- NaCl



Sodium – green

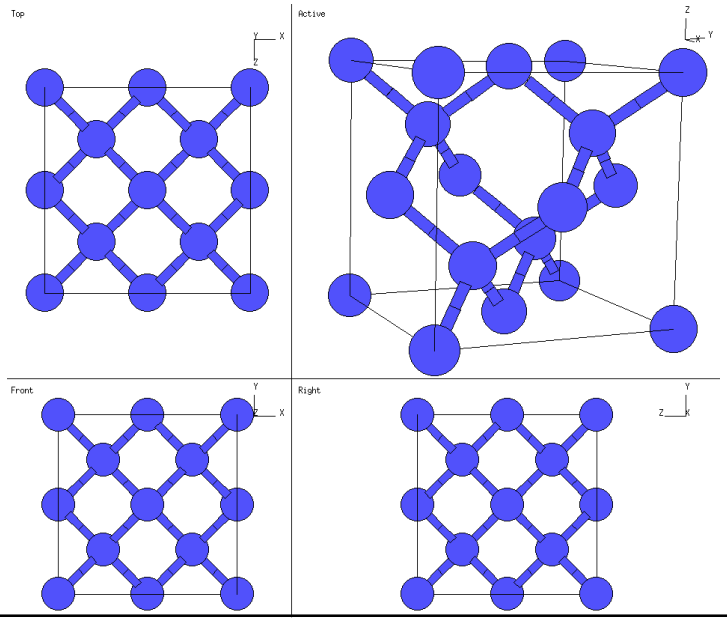
Chlorine – red

Covalent Network

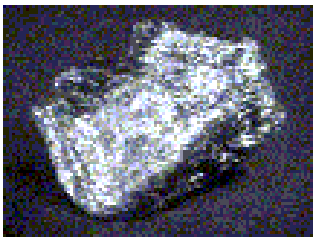
- Atoms held together by covalent bonds
- Very hard
- Very high melting points
- Often poor conductivity

- Diamond

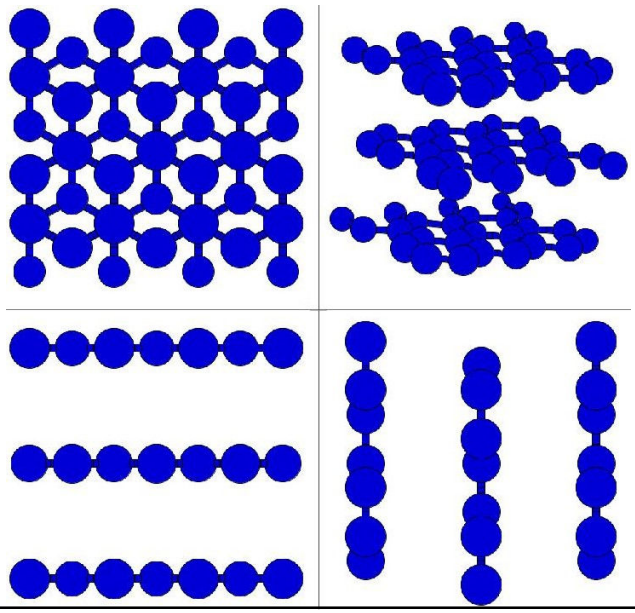
- Diamond



- Graphite



- Graphite

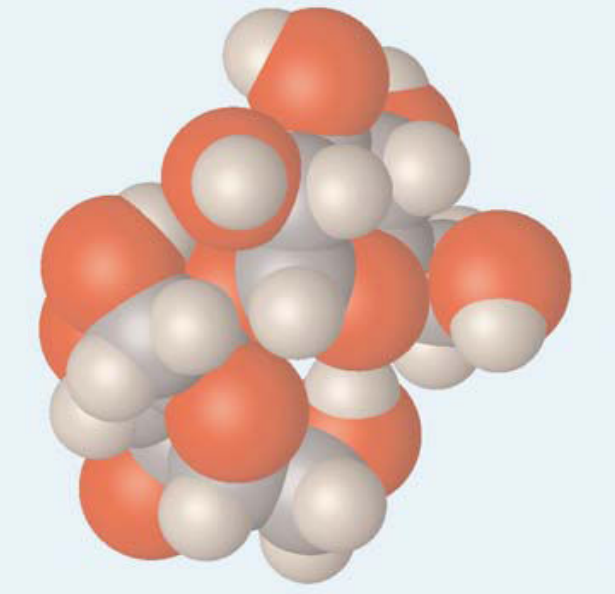


Molecular

- Molecules are held together by various forces or hydrogen bonds
- Most molecular substances are not solids at room temperature
- Molecular compounds like sugar are solids at room temperature because of their large molar masses
- Fairly soft
- Low to moderately high melting points
- Poor conductivity

- Sugar

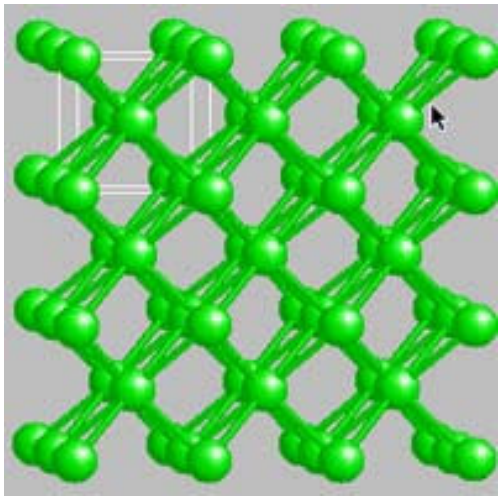
- Sugar



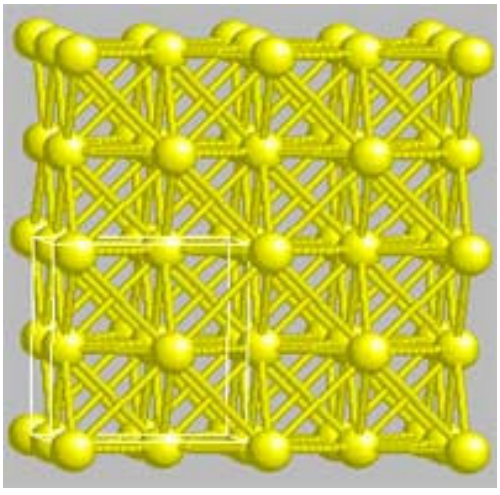
Metallic

- Atoms surrounded by mobile valence electrons
- The strength of the bonds between cations and electrons varies among metals and accounts for their wide range of physical properties
- Soft to hard
- Low to very high melting points
- Malleable and ductile
- Excellent conductivity

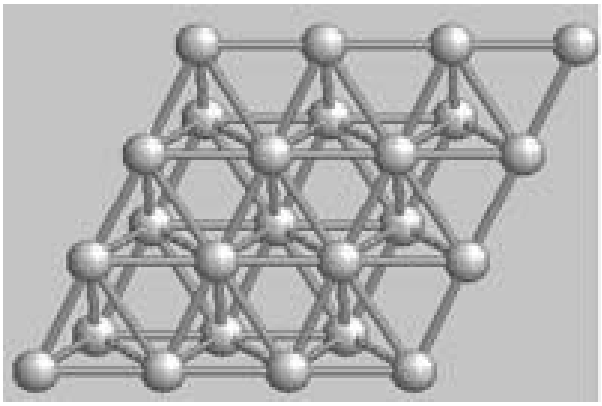
- Iron



- Gold



- Zinc



Amorphous Solids

- The particles are not arranged in a regular repeating pattern
- An amorphous solid often occurs when a molten material cools too quickly to allow enough time for crystals to form
- Examples
  - Glass, rubber, many plastics

- Glass (SiO_2)