

Thermal Physics

Topic Outline should have been printed off by today
 WebAssign: Temperature scales—due Thursday Morning before school

Warm-up #1:

- Describe the picture to the right. What is it? What is it measuring? How is it measuring it?



Warm-up #2:

- Silently and individually describe what you observe happening during the demonstration
- Of the two plates, which would you expect to feel the coldest? Explain your reasoning.

Temperature...what IS it?

- Scalar Quantity
- Gives an indication of the “hotness” or “coldness” of an object
- Measured with a Thermometer
- (the temperature of the thermometer is equal to the temperature of the object being measured when the two are in **thermal equilibrium**)
- So...how do thermometers work?

Thermometric Properties of Matter

- Those physical properties of matter that change dependent on the temperature of the matter
- Thermometers are designed by using one of the following:
 - Thermal Expansion of Liquids (i.e. in capillary tube)
 - Electrical Resistance of a conducting wire
 - Pressure of a gas contained in a fixed volume
 - Linear expansion of solids (i.e. Bi-metallic Strip)
 - Color of a solid heated to high temperatures

How could you make a thermometer?

- Calibration of a scale:
 - Determine the position (condition) of the thermometric property at two known, fixed points
 - Common fixed points:
 - Freezing point of distilled water at standard air pressure
 - Boiling point of distilled water at standard air pressure
 - Values assigned to fixed points, space between divided into an evenly spaced scale.

Temperature Scales

- Fahrenheit (developed in 1724)
 - American meteorological temperature scale
- Celsius (developed in 1742)
 - Most common scale used for scientific measurements
- Kelvin (developed in 1848)
 - Fundamental unit of temperature
 - Used for all temperature-related calculations
 - 1 Kelvin degree (K°) is exactly the same size as 1 degree Celsius (°C)

$$T_F = \frac{9}{5}T_C + 32$$

$$T_K = T_C + 273.15$$

Comparisons of temperature scales:

- Dry ice: -79 °C (194 K)
- Liquid Nitrogen: -200 °C (73 K)
- Surface temperature of the sun: ~6000 K
- Empty space: 2.7 K
- Bose-Einstein Condensate ≈10⁻⁹ K

Kelvin Temperature Scale Calibration:

- Absolute Zero:
 - Molecular motion becomes a minimum
 - (Theoretically, there is no motion at all—since it's never been reached, there's no proof to that)
 - Lower fixed point on Kelvin scale = 0 K

Triple point (of water)

- Upper fixed point of Kelvin Scale
- Temp. at which saturated water vapor, pure liquid water and melting ice are in equilibrium.
- 273.16 K

Temperature: the average kinetic energy per molecule
 →for gases: $E_k = (3/2) k \cdot T$

- k = boltzmann constant = $1.38 \times 10^{-23} \text{ J} \cdot \text{K}^{-1}$

Distributions of kinetic energies:

Internal Energy: the sum total of the potential energy and the kinetic energy of the particles in the system

- Potential Energy:
 - Bond energy:** the energy stored in chemical bonds
 - Intermolecular forces of attraction between particles
- Kinetic Energy:
 - Comes from translational, rotational, and vibrational motion
 - Translational:** Energy resulting from moving in a straight line
 - Rotational:** Energy resulting from spinning about an axis
 - Vibrational:** Energy resulting from the back-and-forth motion of an object (molecule, atom...) centered at one fixed position

Solids: Mainly vibrational energy

Liquids: Mainly vibrational energy, some rotational energy; a little translational energy

Gases: Mainly translational and rotational energy

Thermal Energy Transfer

- **Conduction:** the process by which a temperature difference causes the transfer of thermal energy from the hotter region to the colder region.
 - Occurs as kinetic energy is transferred through particle collisions
 - Occurs in solids, liquids and gases
 - Gases: slow transfer of energy
 - Liquids: slow transfer of energy
 - Solids: metal → typically good conductors
non-metal → typically good insulators
 - There is **no net movement** of the particles

• Convection:

- The process in which a temperature difference causes the **mass movement of fluid particles** from areas of high thermal energy to areas of low thermal energy
 - Does **not** occur in solids
 - Occurs because of the density differences between the hotter molecules (more energy, farther apart, lower density) and the colder molecules (less energy, closer together, higher density) in a fluid
 - Convection currents: associated with...
 - Weather patterns (El Nino) and ocean currents
 - Electrical power production (NELHA in Hawaii)
 - Boiling water
 - Heating a home (forced air heaters...)
 - Etc.

• Radiation:

- Energy produced by a source because of its temperature that travels as electromagnetic waves.
 - Does not require the presence of matter
 - Thermal radiation from the Sun is the primary source of thermal energy for Earth
 - Much is reflected back to space, some is absorbed/transmitted to heat our atmosphere
 - Primarily InfraRed radiation, temps <1000 °C
 - Best absorbers and radiators of energy = dull, black
 - Worst = transparent or shiny objects
 - Examples:
 - Light bulb, electric heater, ...

Heat vs. Temperature...

• Warm-up Question:

What is the difference between heat and temperature and internal energy?

- **Heat** is a form of energy that is transferred from one body into another as a result of a difference in temperature
- (absolute) **Temperature** is a measure of the average kinetic energy of the molecules of a substance
- **Internal Energy** is the total kinetic energy plus any potential energy associated with forces and bonds between molecules in a substance

Kinetic Theory of Matter

- All matter is composed of extremely small particles
- All particles are in constant motion
- If particles collide with neighboring particles, they conserve their kinetic energy
- A mutual attractive force exists between the particles

Kinetic Theory of Matter

- **Brownian Motion** — the evidence of constant motion of particles
- Macroscopic characteristics of solids, liquids, and gases:

Characteristic	Solid	Liquid	Gas
Shape	Definite	Variable	Variable
Volume	Definite	Definite	Variable
Compressibility	Almost Incompressible	Very slightly compressible	Highly Compressible
Diffusion	Small	Slow	Fast
Comparative Densities	High	High	Low



Moles and Molar Mass

- A fundamental unit to measure the quantity of particles in a substance
- 1 mole of any substance has the same number of particles as the number of atoms in exactly 12 g of Carbon-12 (Avogadro's constant)

$$N_A = 6.02 \times 10^{23} \text{ molecules} \cdot \text{mol}^{-1}$$

Moles and Molar Mass

- **Molar mass:** the mass (g) of one mole of a substance.
 - On the periodic table: the mass given for each element is the average molar mass—round to the nearest whole number.
- Determining molar mass of a molecule:
 - Determine the molar mass of each element, and multiply by the subscript (if there is one)
 - Add together the molar mass for each element in the compound to obtain a molecular molar mass

- Determine the molecular molar mass of:
 -
 -

- How many molecules are there in 0.275 kg of
 -
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Kinetic Model of an Ideal Gas:

- This model extends the assumptions of the Kinetic Theory of Matter in order to relate the macroscopic behavior of an ideal gas to the microscopic behavior of its molecules.
 1. Gases consist of tiny particles called atoms (for Noble Gases) or molecules
 2. The total number of molecules in any sample of a gas is extremely large*
 3. The molecules are in constant random motion

*see slide about Avogadro's number

Kinetic Model of an Ideal Gas:

4. The range of the intermolecular forces is small compared to the average separation of the molecules
5. The size of the particles is relatively small compared with the distance between them
6. Collisions of short duration occur between molecules and the walls of the container and the collisions are perfectly elastic
7. No forces act between particles except when they collide, and hence particles move in straight lines
8. Between collisions the molecules will obey Newton's Laws of Motion