P2211K

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Chapter 16: Ideal Gases, etc.

- Atoms, Moles, mass, and Avogadro's number (16.2)
  - A "mole" describes a specific number of atoms or molecules—Avogadro's number (6.02×10^{23}), to be specific.
  - Atomic number (***Z***) is the number of protons in the nucleus, which determines the atom's chemical properties.

TABLE 16.1 Densities of materials

Substance	ρ (kg/m^3)
Air at STP*	1.3
Ethyl alcohol	790
Water (solid)	920
Water (liquid)	1000
Aluminum	2700
Copper	8920
Gold	19,300
Iron	7870
Lead	11,300
Mercury	13,600
Silicon	2330

*$T = 0°C$, $p = 1$ atm

  - Atomic mass (***A in amu***) is approximately the number of protons + neutrons in the nucleus. Some atoms have nuclei with different numbers of neutrons, and thus different atomic masses. These are isotopes and they occur in natural abundances different for each element.
  - An atom's atomic mass (***in amu***) specifically is the ratio of its mass to that of the isotope carbon-12 (^{12}C).
  - A mole of atoms (or molecules) has a total mass equal to the atomic (or molecular) mass in grams—the gram atomic (or molecular) mass. For example, the atomic mass of hydrogen (from the periodic chart in the book, Appendix B) is $m_H = 1.0$, and that for oxygen is $m_O = 16.0$, so the molecular mass for water (H_2O) is $m_{water} = 2m_H + m_O = 18.0$. At the atomic / molecular level the units are *amu*, but one mole of water has mass 18.0 grams.

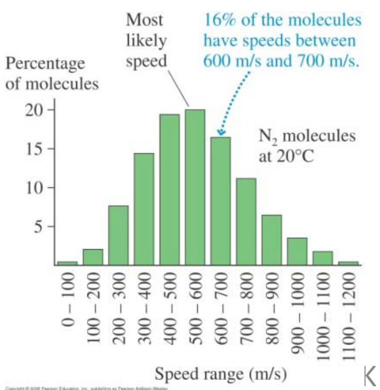
Question: How many moles are in a 5.00 cm x 5.00 cm x 5.00 cm cube of copper?

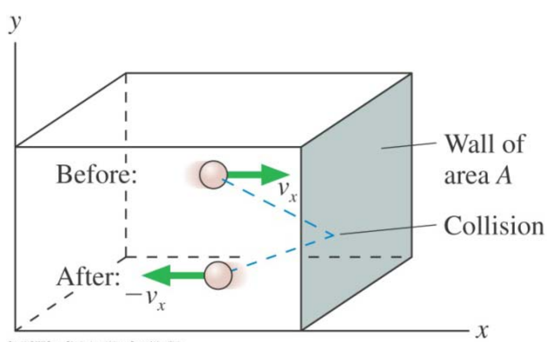
$V = 125\ cm^3 = 125 \times 10^{-6}\ m^3$; $M = (8.92 \times 10^3\ kg / m^3)*(125 \times 10^{-6}\ m^3) = 1.115\ kg$

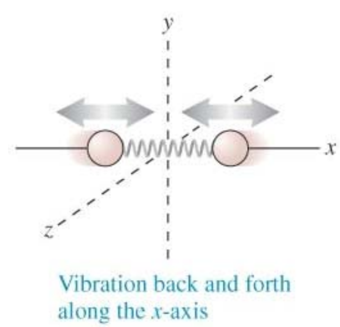
1.115 kg = 1115 g; gmw of Cu = 63.5 amu; 1115 / 63.5 = 17.6 mol

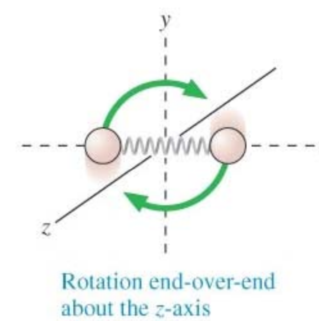
Chapter 16: Ideal Gases, etc., cont.

- Temperature (16.3)
  - Temperature basically is an "indicator" rather than a physical quantity. However it is represented with a variety of scales, the most common of which are the Fahrenheit (F), the Celsius (C),and the Kelvin (K) scales.
  - The F & C scales are based on two observable properties of water—its boiling and freezing points. For F, freezing is assigned the value 32 with boiling at 212 (a difference of 180 units); for C, freezing is 0 and boiling is 100 (a difference of 100 units). Thus, °C = (°F – 32)*5/9, and °F = 32 + (9/5) °C
  - The Kelvin scale is the extrapolation of Celsius to the temperature at which the pressure goes to 0 in a constant-volume gas thermometer (-273° C). This value is assigned 0 K so that freezing is 273 K. K = °C + 273
- Ideal gases & the ideal gas law (16.5)
  - In an ideal gas, the atoms (or molecules) are widely separated and interact only by perfectly elastic collisions. In addition, they interact with the walls of their container only by perfectly elastic collisions.
  - From this perspective, the pressure on the walls of the container is the result of the average number of collisions / time, and the atoms' (or molecules') average kinetic energy is the direct effect of temperature {See sections 18.1 & 18.2 for a discussion of the kinetic basis for temperature, heat energy, and pressure.}









Chapter 16: Ideal Gases, etc., cont.

- Ideal gases & the ideal gas law, cont. (16.5)
  - The ideal gas law: ***PV = nRT***, where P is the pressure on the container, V is its volume, T is the gas's temperature, n is the number of moles in the gas, and R = 8.31 J/mol/K is the "gas constant."
  - From the gas law, we can see that PV/T = nR and is constant for a specific amount of an ideal gas, a result leading to the relation $P_1V_1/T_1 = P_2V_2/T_2$. Thus, the well-known ideal gas relations follow: $P_1V_1 = P_2V_2$ when T is constant; $P_1/T_1 = P_2/T_2$ when V is constant; and $V_1/T_1 = V_2/T_2$ when P is constant.

Problem 16-26: A 30 cm diameter vertical cylinder is sealed at the top by a frictionless 25 kg piston. The piston is h_1 = 90 cm above the bottom when the gas temperature is 310° C. The air above the piston is at 1.00 atm pressure. (1 atm = 101.3 kPa = 101.3×10^3 N/m²)

a. What is the gas pressure inside the cylinder?

$P = 1\text{ atm} + mg / A = [101.3\times10^3 + 25*9.8 / \pi / (0.15)^2]\text{N/m}^2 = (101.3 + 3.466)\times10^3\text{ N/m}^2$

P = 104.8 kPa

b. What will the pressure be if the temperature is lowered to 20 °C?

Pressure doesn't change because it's controlled by the external P and the weight of the piston.

c. What will the height of the piston be if the temperature is lowered to 20 °C?

$V = (A)\text{x(height)} = \pi\ (0.15)^2\ (0.9)\text{ m}^3 = 0.0636\text{ m}^3 = 6.36\times10^{-2}\text{ m}^3$; $V_2 / T_2 = V_1 / T_1$

$V_2 = V_1\ (T_2 / T_1) = (293 / 583)\ 6.36\times10^{-2}\text{ m}^3 = 3.20\times10^{-2}\text{ m}^3$

$h_2 = V_2 / A = 45.2$ cm

- Processes: constant volume, constant pressure, and constant Temperature (16.6)
- Vocabulary (p. 500)