Physics 06-02 Ideal Gas Law and Kinetic Theory Name: ______________________

Ideal Gas Law

$$PV = NkT$$

P = absolute pressure (Pa), V = volume (m³), N = number of particles (unitless), k = Boltzmann's constant = $1.38 \times 10^{-23}\ J/K$, T = temperature (K)

- Large number of ________________ in a sample
- Convenient to have a ________________ for a large number of ________________

Mole (mol)

- Actually ________________
- Number of atoms of ________________ in ________________
- Number of atoms per mole = ________________

________________ number $N_A = 6.022 \times 10^{23}\ mol^{-1}$

Number of moles in a sample

$$n = \frac{N}{N_A}$$

n = number of moles, N = number of particles, $N_A = 6.022 \times 10^{23}\ mol^{-1}$

Number of moles can be found from mass

$$n = \frac{m}{molar\ mass}$$

n = number of moles, m = mass of sample (g), molar mass = same number as atomic mass from periodic table (g/mol)

Ideal Gas Law (moles)

$$PV = nRT$$

P = absolute pressure (Pa), V = volume (m³), n = number of moles (mol), R = universal gas constant (8.31 J/mol· K) = $N_A k$, T = temperature (K)

Kinetic Theory

T is average ________________ of molecules

$$PV = NkT = \frac{1}{3}Nm\overline{v}^2$$

$$\overline{KE} = \frac{1}{2}m\overline{v}^2 = \frac{3}{2}kT$$

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

v_{rms} = ave speed of one particle, k = 1.38×10^{-23} J/K, T = temperature (K), m = mass of one particle (kg)

Not all the ________________ go the same ________________

- Higher ________________, means higher ________________

An apartment has a living room whose dimensions are 2.5 m × 4.0 m × 5.0 m. Assume that the air in the room is composed of 79% nitrogen (N_2) and 21% (O_2). At a temperature of 22 °C and a pressure of 1.01×10^5 Pa, what is the mass of the air?

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Helium, a monatomic gas, fills a 0.010-m³ container. The pressure of the gas is 6.2×10^5 Pa. If there are 3 mol of gas, what is the temperature of the gas?

What is the v_{rms}?

Homework

1. Find out the human population of Earth. Is there a mole of people inhabiting Earth? If the average mass of a person is 60 kg, calculate the mass of a mole of people. How does the mass of a mole of people compare with the mass of Earth?
2. (a) Which, if either, contains a greater number of molecules, a mole of hydrogen (H_2) or a mole of oxygen (O_2)? (b) Which one has more mass? Give reasons for your answers.
3. A tightly sealed house has a large ceiling fan that blows air out of the house and into the attic. This fan is turned on, and the owners forget to open any windows or doors. What happens to the air pressure in the house after the fan has been on for a while, and does it become easier or harder for the fan to do its job? Explain.
4. Above the liquid in a can of hair spray is a gas at a relatively high pressure. The label on the can includes the warning "Do not store at high temperatures." Use the ideal gas law and explain why the warning is given.
5. The gauge pressure in your car tires is 2.50×10^5 N/m² at a temperature of 35.0°C when you drive it onto a ferry boat to Alaska. What is their gauge pressure later, when their temperature has dropped to −40.0°C? (OpenStax 13.22) **1.62 atm**
6. Large helium-filled balloons are used to lift scientific equipment to high altitudes. (a) What is the pressure inside such a balloon if it starts out at sea level with a temperature of 10.0°C and a pressure of 1 atm, and rises to an altitude where its volume is twenty times the original volume and its temperature is −50.0°C? (b) What is the gauge pressure? (Assume atmospheric pressure is constant.) (OpenStax 13.25) **0.0394 atm, −0.961 atm**
7. Calculate the number of moles in the 2.00-L volume of air in the lungs of the average person. Note that the air is at 37.0°C (body temperature). (OpenStax 13.28) $\mathbf{7.86 \times 10^{-2}}$ **mol**
8. An airplane passenger has 100 cm³ of air in his stomach just before the plane takes off from a sea-level airport. What volume will the air have at cruising altitude if cabin pressure drops to 7.50×10^4 N/m²? (OpenStax 13.29) **135 cm³**
9. An expensive vacuum system can achieve a pressure as low as 1.00×10^{-7} N/m² at 20°C . How many atoms are there in a cubic centimeter at this pressure and temperature? (OpenStax 13.31) $\mathbf{2.47 \times 10^{7}}$ **atoms**
10. (a) In the deep space between galaxies, the density of atoms is as low as 10^6 atoms/m³, and the temperature is a frigid 2.7 K. What is the pressure? (b) What volume (in m³) is occupied by 1 mol of gas? (c) If this volume is a cube, what is the length of its sides in kilometers? (OpenStax 13.38) $\mathbf{3.7 \times 10^{-17}}$ **Pa,** $\mathbf{6.0 \times 10^{17}}$ **m³, 840 km**
11. Some incandescent light bulbs are filled with argon gas. What is v_{rms} for argon atoms near the filament, assuming their temperature is 2500 K? (OpenStax 13.39) $\mathbf{1.25 \times 10^{3}}$ **m/s**
12. Average atomic and molecular speeds (v_{rms}) are large, even at low temperatures. What is v_{rms} for helium atoms at 5.00 K, just one degree above helium's liquefaction temperature? (OpenStax 13.40) **176 m/s**
13. (a) What is the average kinetic energy in joules of hydrogen atoms on the 5500°C surface of the Sun? (b) What is the average kinetic energy of helium atoms in a region of the solar corona where the temperature is 6.00×10^5 K ? (OpenStax 13.41) $\mathbf{1.20 \times 10^{-19}}$ **J,** $\mathbf{1.24 \times 10^{-17}} \boldsymbol{J}$
14. The escape velocity of any object from Earth is 11.2 km/s. (a) Express this speed in m/s and km/h. (b) At what temperature would oxygen molecules (molecular mass is equal to 32.0 g/mol) have an average velocity v_{rms} equal to Earth's escape velocity of 11.1 km/s? (OpenStax 13.42) **40320 km/h,** $\mathbf{1.58 \times 10^{5}}$ **K**
15. Much of the gas near the Sun is atomic hydrogen. Its temperature would have to be 1.5×10^7 K for the average velocity v_{rms} to equal the escape velocity from the Sun. What is that velocity? (OpenStax 13.47) $\mathbf{6.09 \times 10^{5}}$ **m/s**