Physics 101: Lecture 25
Ideal Gas Law and Kinetic Theory

Announcements

- Exam 3:

  Covers Lectures 17 - 23 (universal gravitation, fluid statics & dynamics, oscillations [mass at the end of springs and pendula], waves, interference and sound). **Please sign up for a slot if you haven't already done so**.

  Review session: Monday 6-7PM in Loomis 151.
  Please print and bring Exam 3 from Fall 2015 (we will discuss problems 1-21) Also bring problems 4 & 5 from Exam 3 Fall 2016.

- Final Exam:

  ➔ About 45 questions, evenly divided among all the topics covered in the course. Will include, proportionally, material after exam 3.

  ➔ You can sign up to take either exam in the gradebook. See section headed "Upcoming Paper Exam Information".

Molecular Picture of Gas

- Gas is made up of many individual molecules

- Number density is number of molecules/volume:
  - ➔$N/V = \rho/m$
  - ➔ρ is the mass density
  - ➔m is the mass for one molecule

    $1\ u = 1.66 \times 10^{-27}\ kg = 1/12$ of a mass of C^{12}

- Number of moles: $n = N / N_A$
  - ➔N_A = Avogadro's Number = $6.022 \times 10^{23}\ mole^{-1}$

- Mass of 1 mole of "stuff" in grams = molecular mass in u
  - ➔e.g., 1 mole of N_2 has mass of 2x14=28 grams

Number Density Clicker Q

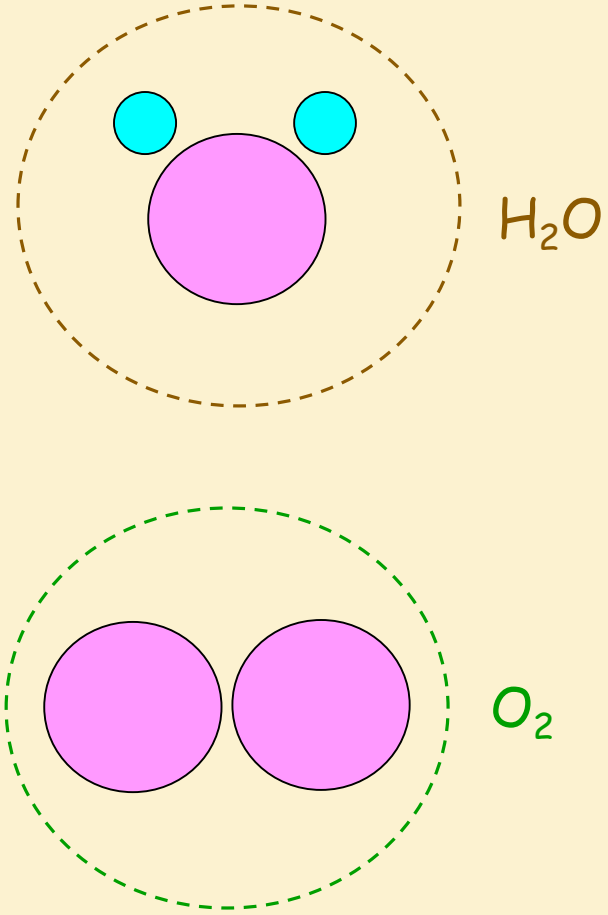
- Two identical gas cylinders are filled such that they have the same mass of gas (in the same volume). One cylinder is filled with Helium, the other with Oxygen. Which container has the larger number density (number of molecules per volume of the cylinder)?

  A) Helium B) Oxygen C) Same

Atomic Clicker Q I

Which contains the most molecules ?

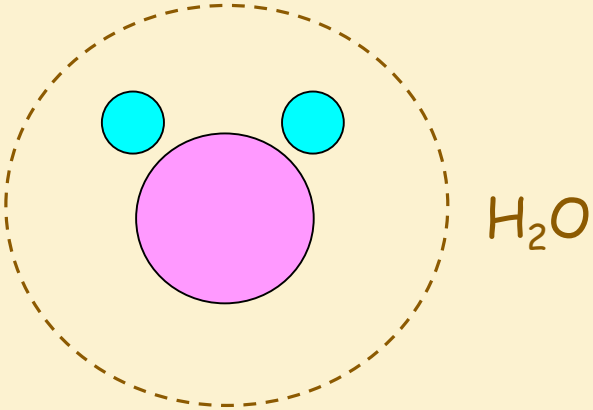
1. A mole of water (H_2O)
2. A mole of oxygen gas (O_2)
3. Same

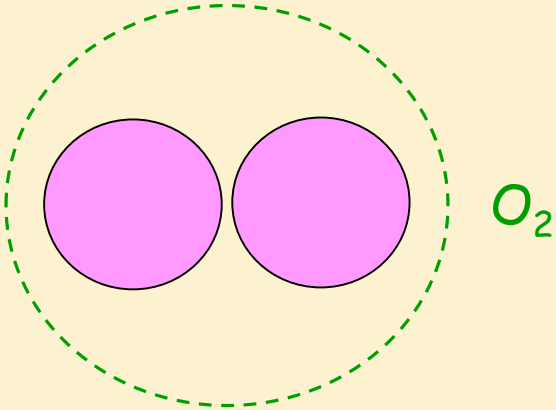


Atomic Clicker Q II

Which contains the most atoms ?

1. A mole of water (H_2O)
2. A mole of oxygen gas (O_2)
3. Same

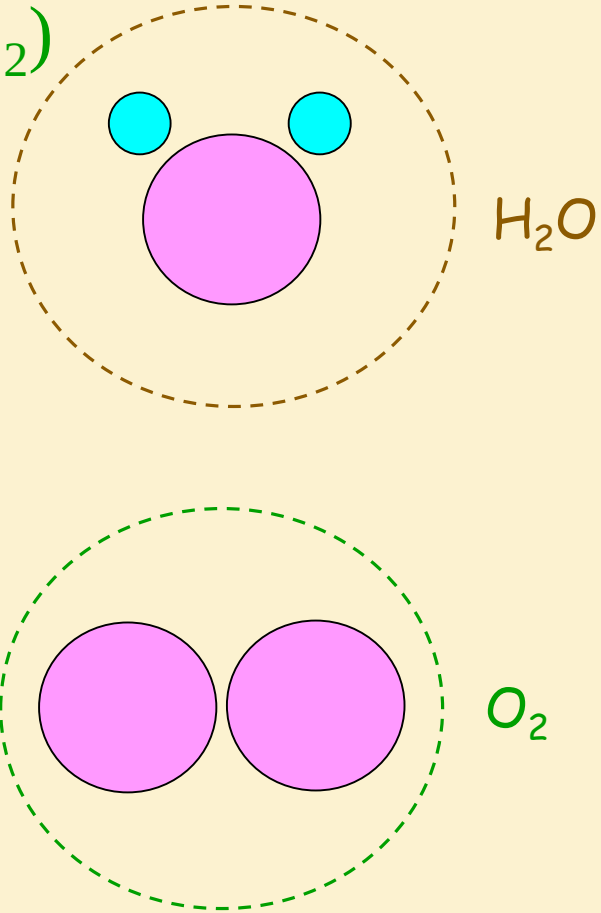




Atomic Clicker Q III

Which weighs the most ?

1. A mole of water (H_2O)
2. A mole of oxygen gas (O_2)
3. Same



The Ideal Gas Law

- $P\,V = N\,k_B\,T$ or $P = (N/V)\,k_B\,T$
  - ➔ P = pressure in N/m^2 (or Pascals)
  - ➔ V = volume in m^3
  - ➔ N = number of molecules
  - ➔ T = absolute temperature in K
  - ➔ k_B = Boltzmann's constant = 1.38×10^{-23} J/K
  - ➔ Note: P V has units of N-m or J (energy!)
- $P\,V = n\,R\,T$ (get this by multiplying top eqn by N_A/N_A)
  - ➔ n = number of moles
  - ➔ R = ideal gas constant = $N_A k_B$ = 8.31 J/mol/K

Checkpoint 2

Two monatomic gases, helium and neon, are mixed and in thermal equilibrium at temperature T. Therefore,

A) The helium atoms have the same average translational kinetic energy as the neon atoms.

B) Each atom has a different average translational kinetic energy.

C) There is a difference of 3/2 kT in the average translational kinetic energy between helium atoms and neon atoms.

Ideal Gas Law Clicker I

PV = nRT

You inflate the tires of your car so the pressure is 30 psi, when the air inside the tires is at 20 degrees C. After driving on the highway for a while, the air inside the tires heats up to 38 C. Which number is closest to the new air pressure?

DEMO: Air-molecules

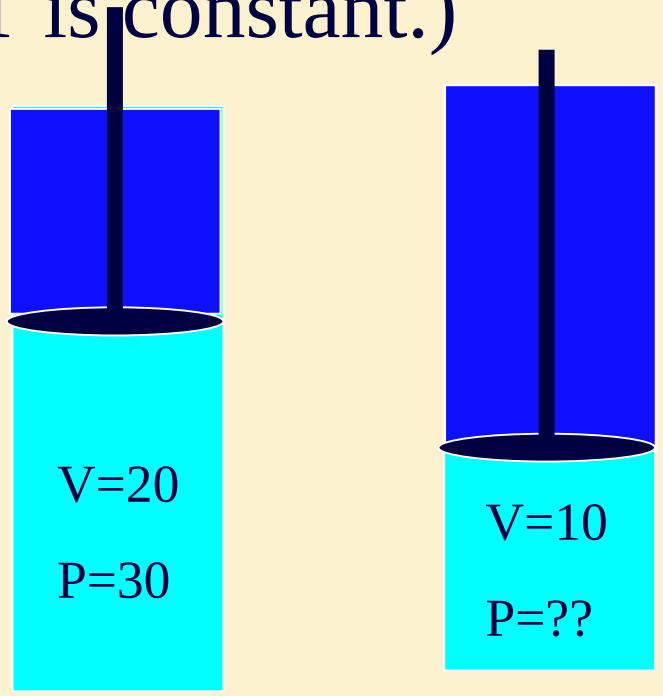
1) 16 psi 2) 32 psi 3) 57 psi

Ideal Gas Law: Clicker II
pV = nRT

- A piston has volume 20 ml, and pressure of 30 psi. If the volume is decreased to 10 ml, what is the new pressure? (Assume T is constant.)

1) 60 2) 30 3) 15

DEMO: Boyle's Law



Balloon Clicker 1

- What happens to the pressure of the air inside a hot-air balloon when the air is heated? (Assume V is constant)

1) Increases 2) Same 3) Decreases

Balloon Clicker 2

- What happens to the buoyant force on the balloon when the air is heated? (Assume V remains constant)

1) Increases 2) Same 3) Decreases

Balloon Clicker 3

- What happens to the number of air molecules inside the balloon when the air is heated? (Assume V remains constant)

1) Increases 2) Same 3) Decreases

DEMO

Ideal Gas Law: Demos
pV = nRT

- When T is constant, PV is constant (Boyle's Law)
  - ➔Boyle's law demo (Done earlier)

- When P is constant, V is proportional to T
  - ➔Helium and oxygen in LN_2 (Balloon in LN_2)

- When V is constant, P is proportional to T
  - ➔Explosion! (Cannon DEMO)

Summary

- Gas is made up of molecules
- Ideal Gas Law $PV = n R T$
  - ➔ P = pressure in N/m^2 (or Pascals)
  - ➔ V = volume in m^3
  - ➔ n = # moles
  - ➔ R = 8.31 J/ (K mole)
  - ➔ T = Temperature (K)