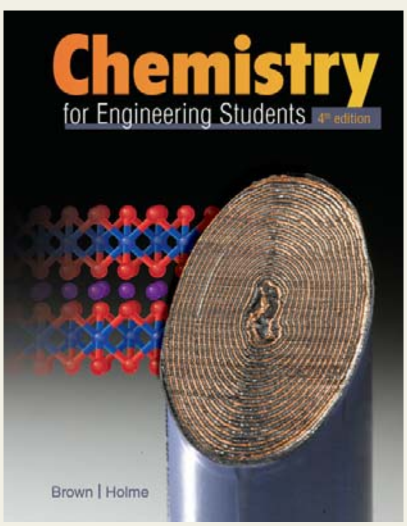
Homework Assignments:

- Quiz 2 (Covers the Chapters 3 and 4) is posted in canvas and due Monday 11:59 pm
- Chapter 4 HW due September 26, 11:55 pm
- Exam 1 will be on September 26 (Wednesday) during normal class time, 50 minutes (20 - 25 MCQs), covers chapters 1, 2, 3, and 4
  - ✓ Please bring a scantron sheet, pencil, scientific calculator and student ID



Chapter 5

Gases

Edited by Dr. Katugampola

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Natural Gas

- Natural gas is a mixture of chemical compounds
- Methane is the main component of natural gas
- Other gases are always present in natural gas

Gas	Formula	Percentage Range
Methane	CH_4	70–90%
Ethane, propane, butane	C_2H_6, C_3H_8, C_4H_{10}	0–20%
Carbon dioxide	CO_2	0–8%
Hydrogen sulfide	H_2S	0–5%
Nitrogen	N_2	0–5%
Oxygen	O_2	0–0.2%
Noble gases	He, Ne, Ar, Xe	Trace

Properties of Gases

- Expand to fill the volume of any container
- Have much lower densities than solids or liquids
- Have highly variable densities, depending on conditions
- Mix with one another thoroughly
- Change volume dramatically with changing temperature

Ideal gas law

- The ideal gas law is the quantitative relationship between pressure or P, volume or V, number of moles of gas present or n, and the absolute temperature or T
- R is the universal gas constant
  - $R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$; used in most gas equations
  - $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$; used in equations involving energy

$$PV = nRT$$

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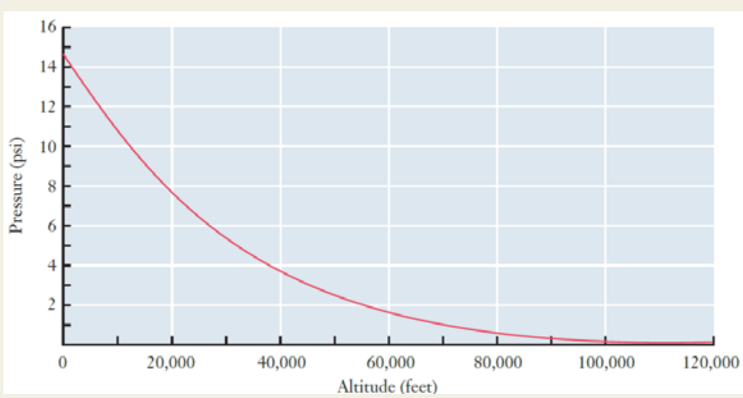
Pressure

- Pressure is force per unit area $P = \frac{F}{A}$
- As altitude increases, atmospheric pressure decreases



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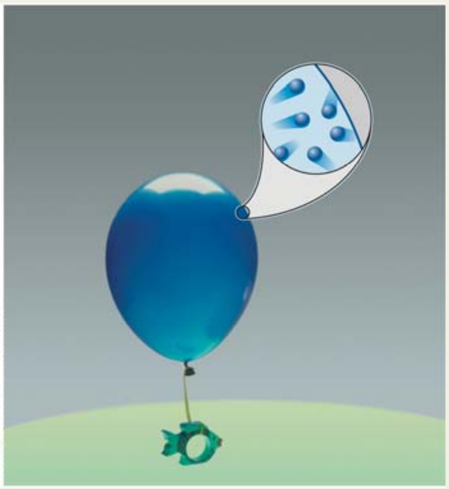
Pressure (continued)



- Pressure results from molecular collisions between gas molecules and container walls
  - Each collision exert a small amount of force
  - Summation of the forces of all molecular collisions produces the macroscopic amount of pressure

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How do gases exert pressure?

- The mass of the molecules exerts gravity
- The molecules repel other objects
- The molecules react with other objects
- The molecules collide with each other and container wall

Answer: The molecules collide with each other and container wall

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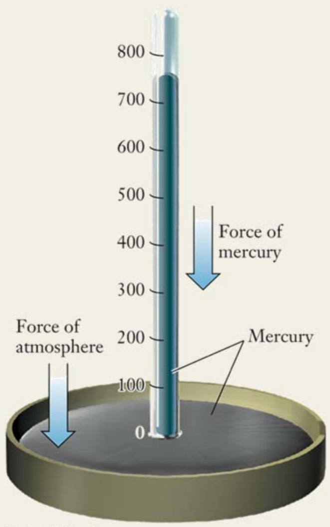
Measuring Pressure



- A barometer is used to measure atmospheric pressure
  - Height of the mercury column is proportional to the applied pressure
- Units of pressure
  - 1 torr = 1 mm Hg
  - 1 atm = 760 torr (exactly)
  - 1 atm = 101,325 Pa (exactly)
  - 760 torr = 101,325 Pa (exactly)

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Which is the highest pressure?

1) 2.31 atm
2) 1540 torr
3) 1.45 × 10^5 Pa

1 torr = 1 mm Hg
1 atm = 760 torr (exactly)
1 atm = 101,325 Pa (exactly)
760 torr = 101,325 Pa (exactly)

Answer: 2.31 atm

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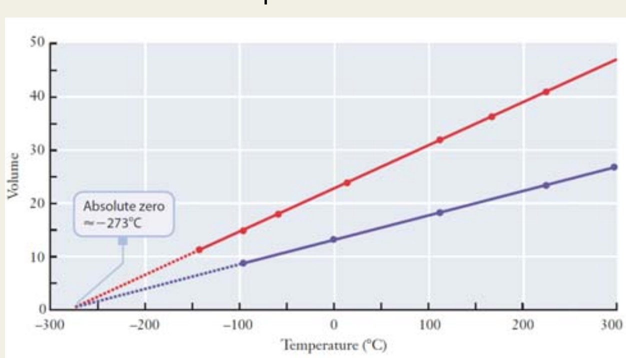
History and Application of the Gas Law

- Gases change significantly when the conditions are altered
- Three gas laws
  - Charles's law: Relationship between T and V
  - Boyle's law: Relationship between P and V
  - Avogadro's law: Relationship between n and V
- These three gas laws incorporated into the ideal gas law

Charles's Law

- Jacques Charles studied the relationship between volume and temperature
  - Plots of V versus T for different gas samples converged to the same temperature at zero volume
    - Basis of the Kelvin temperature scale



Charles's Law

- For fixed/constant pressure and fixed number of moles of gas, the volume and the absolute temperature of a gas are directly proportional

P, n $$V \propto T$$

- All of the fixed terms can be factored out of the ideal gas law as a new constant that can be used to relate two sets of conditions

$$\frac{V_1}{T_1} = \frac{nR}{P} = \text{constant} = \frac{V_2}{T_2}$$

Here the subscripts "1" and "2" indicate the conditions before and after the change takes place.

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Boyle's Law

- The number of moles and temperature remains constant. So, pressure and volume are inversely proportional

n, T $$V \propto \frac{1}{P}$$

- All of the fixed terms can be factored out as a new constant that can be used to relate two sets of conditions

$$P_1V_1 = nRT = \text{constant} = P_2V_2$$

  - R is a universal constant

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Avogadro's Law

- For fixed pressure and temperature, the volume and moles of a gas are directly proportional

P, T $\quad V \propto n$

$$\frac{V_1}{n_1} = \frac{RT}{P} = \text{constant} = \frac{V_2}{n_2}$$

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Example Problem

1) A common laboratory cylinder of methane has a volume of 49.0 L and is filled to a pressure of 154 atm. Suppose that all of the CH_4 from this cylinder is released and expands until its pressure falls to 1.00 atm. What volume would the CH_4 occupy?

In this case, n and T are constant, and R is always constant. So,

$$PV = nRT = \text{constant}$$

Therefore, $P_1V_1 = P_2V_2$

Solving this for the final volume (V_2) gives

$$V_2 = \frac{P_1V_1}{P_2}$$

We know all three terms on the right: $P_1 = 154$ atm, $V_1 = 49.0$ L, and $P_2 = 1.00$ atm. Insert those above and solve:

$$V_2 = \frac{(154\ \text{atm})\,(49.0\ \text{L})}{(1.00\ \text{atm})} = 7550\ \text{L}$$

Example Problem

2) A balloon is filled with helium and its volume is 2.2 L at 298 K. The balloon is then dunked into a thermos bottle containing liquid nitrogen.
   - When the helium in the balloon has cooled to the temperature of the liquid nitrogen (77 K), what will the volume of the balloon be?

As in the discussion above, we have

$$\frac{V}{T} = \frac{nR}{P} = \text{constant}$$

So

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Solve this for the final volume (V_2):

$$V_2 = \frac{V_1 T_2}{T_1}$$

Because the three terms on the right are known, we can just insert values and solve:

$$V_2 = \frac{(2.2\ \text{L})\,(77\ \text{K})}{(298\ \text{K})} = 0.57\ \text{L}$$