Reese Ch. 14, part A (pp. 639-649)

- · Kinetic Theory of Gases
- The Ideal Gas Approximation
- Interpretation of Gas Pressure
- The Meaning of the Absolute Temperature
- Internal Energy and Specific Heats

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Assumptions of Classical Kinetic Theory of an Ideal Gas: 1-2-3

- 1. The number of molecules N in the gas is very large.
- The volume V of the gas is much larger than the total volume occupied by the particles themselves: V>>NV_{molec}.
- 3. The molecules obey Newton's laws.

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Assumptions of Classical Kinetic Theory of an Ideal Gas: 4-5-6

- 4. A molecule is equally likely to be moving in any direction.
- 5. The molecules interact with each other and with the walls of the container only via elastic collisions.
- 6. The gas is in thermal equilibrium with its surroundings.

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Assumptions of Classical Kinetic Theory of an Ideal Gas: 7

7. The molecules of the gas are identical and indistinguishable.

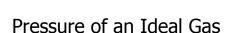
NOTE:

This last assumption means that the initial treatment is applicable only to an isotopically pure gas of a single element or compound. However, the treatment is easily modified to describe mixtures.

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- By carefully considering the elastic collisions of individual molecules with an area A of the container wall, we find that the time-averaged rate of momentum transfer is directed along the outward normal: $\vec{F} = \hat{n} \left(\frac{N\mu}{v^2} \right) / v^2 \right) A$
- Therefore the pressure (outward normal force per unit area) is given by:

$$P = \left(\frac{N\mu}{3V}\right) \left\langle v^2 \right\rangle = \left(\frac{2N}{3V}\right) \left[\frac{1}{2}\mu \left\langle v^2 \right\rangle\right]$$

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Meaning of the Absolute Temperature

• Kinetic theory gives:

$$PV = \frac{2N}{3} \left(\frac{1}{2} \mu \langle v^2 \rangle \right)$$

• The ideal gas law is:

$$PV = NkT$$

• This implies that:

$$\frac{1}{2}\mu\langle v^2\rangle = \frac{3}{2}kT$$

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Molecular speeds

• The root-mean-square (rms) speed is easily found:

$$v_{rms} \equiv \sqrt{\left\langle v^2 \right\rangle} = \sqrt{\frac{3kT}{\mu}} = \sqrt{\frac{3RT}{M}}$$

The average speed is less than the rms speed. Using the Maxwellian distribution:

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 $\langle v \rangle = \sqrt{\frac{8kT}{\pi\mu}} \approx 0.92 v_{rms}$

and the most probable speed is:

$$v_{mp} = \sqrt{\frac{2kT}{\mu}} \approx 0.82 v_{rms}$$

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Ideal Gas Mixtures

- The preceding implies that two different pure gases at the same temperature have the same average translational kinetic energy per molecule. We expect (and experiments confirm) in a gas mixture at a certain temperature T, the average molecular translational kinetic energies are equal.
- Furthermore, the pressure exerted by an ideal gas mixture is just the sum of the pressures that each gas by itself would exert.

$$P = \sum_{i} P_{i} = \sum_{i} \frac{N_{i}kT}{V} = \frac{\left(\sum_{i} N_{i}\right)kT}{V}$$

This is called the law of partial pressures.

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Internal Energy and Specific Heat of a Monatomic Ideal Gas

• The <u>internal energy</u> of a monatomic ideal gas is just the sum total of the translational kinetic energies of the N molecules:

 $U = N\left(\frac{3}{2}kT\right) = \frac{3}{2}NkT$

 If a gas is heated at constant volume, it does zero work, so C_v, the molar specific heat at constant volume of a monatomic ideal gas, is:

 $c_V = \frac{3}{2} N_A k = \frac{3}{2} R$

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Heating an Ideal Gas at Constant Pressure

- If an ideal gas is heated at constant pressure, it expands and does work. This means that the amount of heat transfer needed to produce a given temperature rise is greater for isobaric heating than for isochoric heating: $\boxed{c_P = c_V + R}$
- The above equation holds for any gas (monatomic or not) whose internal energy only depends on its temperature.

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Specific Heats for Diatomic and Polyatomic Gases

- The molar specific heat at constant volume for a diatomic or polyatomic gas is greater than 3R/2.
- This indicates that when such a gas is heated, energy is being transferred not only into translational kinetic energy of the molecules, but also into forms of energy internal to the molecules.

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