

Today

- I. Days that we'll be taking a break: no class Wed Nov 25th, or Fri Nov 27th.
- II. Upcoming exam, a week from this Friday, Nov 6th.
- III. Last Time
- IV. Internal Energy
- V. Heat

I. Yanpei Deng this week due to exam (will help in the lab. She's available M from 7-8pm in Brody lab).

This week: Antu Antu will be providing homework support. Hours are: Tu 8-9pm, Th 8-9pm.

III. Work done by a gas, in particular work done in “quasistatic process,

$$W = - \int_{V_i}^{V_f} P dV.$$

We conventionally decided to focus on the work done *on* the system. In particular, we took work done on the system to be positive.

Ideal gas law: $PV = NkT = nRT$,

Here N is the number of molecules in the gas, n is the number of moles of gas, and k is Boltzmann’s const, and R is the ideal gas constant. A mole is Avagadro’s number of particles

$$N_A = 6.02 \times 10^{23}.$$

This used Boltzmann’s equation: $\overline{K.E.} = \frac{3}{2}kT$

IV. Internal Energy

Translation energy: $\overline{K.E.} = \frac{3}{2}kT$. We can translate in three different dimensions, this actually explains the presence of the 3 in Boltzmann's equation. But, kinetic energy is not the only kind a molecule can have.

Internal Energy: Total thermal energy of all the molecules in sample (all forms—not just translation K.E., e.g. rotational, potential energy, vibrational, ...)

Equipartition Principle: Each “degree of freedom” (form of energy) gets, on average, the *same* thermal energy, in equilibrium at temperature T . Counting the number of degrees of freedom is a slippery task (in part because the number of degrees of freedom can depend on the current T).

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Trans. K.E.: 3 degrees of freedom (x,y,z).

Rotation E.: for diatomic, 2 degrees (rotation around the molecular axis doesn't count)

for a polyatomic molecule: 3 degrees of freedom (rotation about x,y, or z)

vibrational: diatomic has 2 degrees of freedom

The total number of degrees of freedom per molecule we will call f . E.g. a diatomic molecule with 3D trans., rotations, and vibrations has $f = 7$.

IV. Equipartition Principle: At temperature T , each degree of freedom for each molecule gets, on average,

$$\frac{1}{2}kT \text{ of energy}$$

Adding up all of this energy gives the total internal energy of the system:

$$U = Nf \frac{1}{2}kT.$$

Note: internal energy is a function of T (and amount of stuff, N)

One final form

$$U = \frac{1}{2}fnRT.$$

V. Heat: energy transferred from a hot object to a cold object by virtue of a difference in temperature.

N.B.: Heat is energy in transit.

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Conservation of energy can now be stated as the 1st law of Thermodynamics:

$$\Delta U = Q + W.$$

Hal's Office Hours Reminder:

Tu 2-3pm (Rose 108/110), W 5-6pm (Brody Labs), Th 5-6:30pm (Rose 108/110)