Physics 105 Class 18
THERMAL PHYSICS I

Temperature scales

Celsius (Centigrade)

Kelvin

Fahrenheit

What is temperature?

Zeroth Law of Thermodynamics: Two objects in thermal contact will come to thermal equilibrium (the same *temperature*)

Thermal expansion:

Lengths all change by the same *factor* (percentage) per degree.

$$\Delta L = \alpha L_o \Delta T$$

$$\Delta A = \gamma A_o \Delta T$$

$$\Delta V = \beta V_o \Delta T$$

$$\alpha_{steel} = (11 * 10^{-6} / {}^oC)$$

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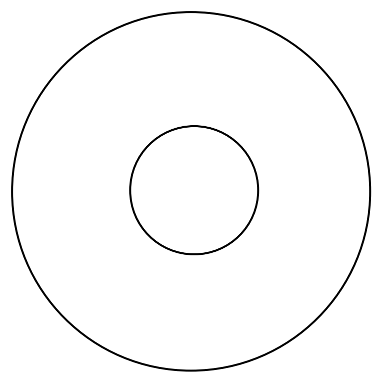
Why do most materials expand when heated?

Atomic "springs" (bonds) get weaker as amplitude of vibration increases.

P1. You heat a disc with a hole in it. Will the hole expand or shrink, or stay the same?

1. Expand
2. Shrink
3. Stay the same



Ideal gases:

1) Molecules collide like billiard balls
2) No attractive forces
3) Never condense into liquids or solids
4) Don't exist

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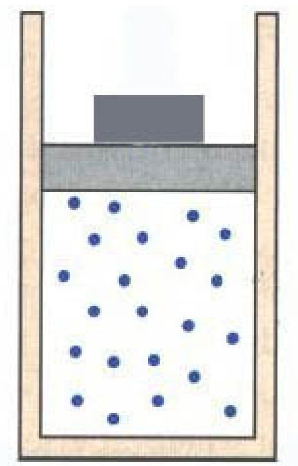
Most gases at room temp. and atmospheric pressure behave approximately as ideal gases.

Wish to explain behavior of huge numbers of particles in terms of simple variables: ____________

Experiments on ideal gases:

Hold T constant, increase P

Volume _________



Hold P constant, increase T:

Volume _________

Hold P,T constant, increase number of moles (n)

Volume _________

Combine the experimental results

$$\frac{PV}{nT} = \text{constant} = R$$

R = 8.31 J/mole°K

= 0.0831 liter-atm/mole°K

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Chemists measure quantity in **moles**:

1 mole = Avagadro's number (N_A)

n denotes # of moles

	molecular	**molar**
Relations:	N	$n=N/N_A$
masses:	m	M=

Ideal gas law:

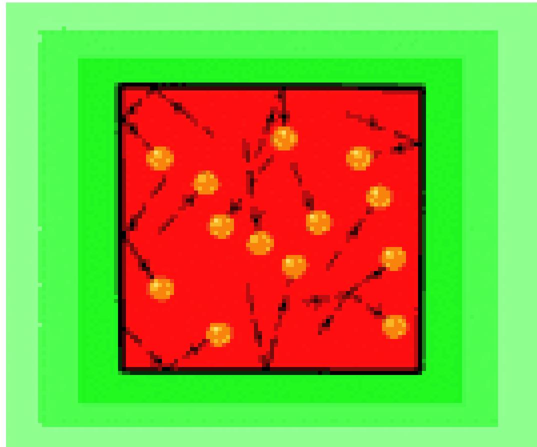
Remember, to use the ideal gas law, *T* must be in ______

Constants useful for gases:

1 atm = 1.01×10^5Pa = 14.7 lb/in^2

1 liter-atm=101 J

Volume of a mole of ideal gas at 1 atm, 0 C (standard temperature and pressure) 22.4 L/mol =0.0224 m^3/mol



Molecular view

Average kinetic energy

Average thermal velocity

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

Pressure and velocity:

Force per molecule per collision

F = ma = mΔv/Δt

Δv is proportional to v_{rms}

Δt is proportional to $\frac{1}{v_{rms}}$

Then $\mathbf{P_{total}}$ **is proportional to**

P2. You have a mixture of heavy and light molecules in an ideal gas.

The molecules that move the fastest are :

i. heavy
ii. light
iii. same

P3. If you have equal numbers of heavy and light molecules in the gas, the ones that exert the most pressure are: (see ideal gas law)

1) heavy
2) light
3) same

In an engine piston, with air at 1 atm, the volume is decreased from 200 cm^3 to 40 cm^3, while the temperature increases from 300 K to 800 K. Find the final pressure.

A half-liter spray can is "empty" (you can't get more out, but it contains air), at 20 C, room temperature. You throw it into the fire at 600 C.

P4. What quantities stay the same before and after if it doesn't burst?

P5. What are the initial absolute P and absolute T?

P6. Using the ideal gas law, what is the final P in the can (if it doesn't burst)?

If the spray can is not empty, but has 1 mole of water (18 g) in the can, what pressure does this water exert at 600 C when it is a gas (assuming the can doesn't break as the water turns into an ideal gas)?

P7. You have N molecules in your bike tire when the *gauge* pressure is 2 atm (30lb/in^2). How many total molecules would it take to get the *gauge* pressure in your tire to 4 atmospheres (assume volume doesn't change)? Answer as xN. Find the factor x.

P8. In your bike tire the *gauge* pressure is 4 atm(60 lb/in^2), at 20 ^{o}C. How hot (in ^{o}C) would you have to heat the tire, to get 8 atm gauge pressure, if N is fixed?

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Heat

Old view of heat (called "caloric")

Mechanical equivalent of heat

1 calorie = 4.186 J

Food calorie Cal, kcal

Raising your 500 kg car with the energy in a large cream-filled 500 Cal donut:

Compare to Empire State Building: 443 m.

Basal metabolic rate: about 1500 Cal/day.

Specific heat

How much does T rise when heat energy is added?

$$Q = mc\Delta T$$

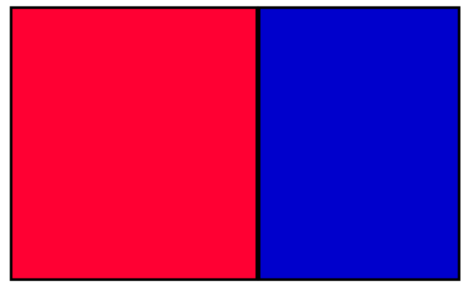
Typical specific heats	$\frac{J}{kg\ °C}$
Water	4186
Ice	2090
Steam	2010
Glass	840
Steel	500

P1. If you add 5 J to a mass of water, and 5 J to the same mass of steel, which one's temperature increases the most?

4. Water
5. Ice
6. Same

Calorimetry

Conservation of energy:



$Q_{\text{gained by cold objects}} = Q_{\text{lost by hot objects}}$

5 g of hot steel at 300 C is added to 100 g of water at 20 C. What is the final temperature?

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HOMEWORK HINTS: