Modern
Day 16

Outline

Spent 1 hr on these: 1. Peer review of longer reports; 2. Reorganizing data for linear fits

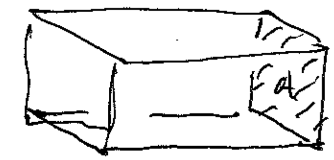
0. Lab Announcements
I. Last time
II. Temperature continued
III. Ideal Gas Law

• Temperature

- heating causes expansion "thermal expansion"
- temperature is a measure of average (random) kinetic energy
- Absolute Zero: $-273^\circ C$: all molecular motion ceases (classically)

$\#\,^\circ K = \#\,^\circ C + 273$

I. • Kinetic Theory



Collisions with walls cause the pressure, we found

$$PV = \frac{1}{3} N m \langle v^2 \rangle$$

and

$$PV = \frac{2}{3} N \langle E \rangle$$

II (4) Boltzmann's constant

Boltzmann turned the observation that temp = ⟨kinetic energy⟩ into an equation:

$$\boxed{\langle E \rangle = \tfrac{3}{2} k T}$$

$\langle E \rangle$ = ave. kinetic energy molecules
k: Boltzmann's constant, 1.38×10^{-23} J/K
T: (Kelvin) Temperature

III Ideal Gas Law

(1) Combine $\langle E \rangle = \frac{3}{2} kT$ with kinetic theory:

$$PV = \frac{2}{3} N \langle E \rangle \text{ and we get}$$

$$\boxed{PV = NkT}$$

(2) "Standard" # of molecules: Avogadro's #:

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

$$\boxed{1 \text{ mole} = N_A \text{ molecules}}$$

Let n = # of moles: $N = n N_A$

Then,

$$PV = n(N_A k)T$$

and let

$$N_A k = 6.02 \times 10^{23} (1.38 \times 10^{-23})$$

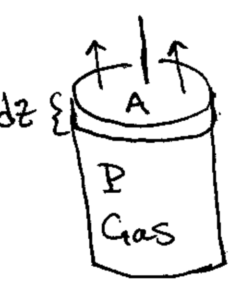
$$= 8.31 \, J/K$$

$$\equiv R \text{ (ideal gas constant)}$$

So also,

$$\boxed{PV = nRT}$$

IV How much work is done (on the outside) by expanding gas?



$$dW = F dz = P \underbrace{A dz}_{dV} = P dV$$

$$\Rightarrow \boxed{dW = P dV}$$

or

$$W = \int P \, dV$$

Ex. 1: Expansion at constant pressure

$$W = P \int dV = P(V_f - V_i)$$

Ex. 2: Ideal gas expanding at constant temperature

Can use $PV = nRT \Rightarrow P = \frac{nRT}{V}$

so,

$$W = \int P dV = nRT \int \frac{1}{V} dV$$

$$= nRT \left[\ln(V_f) - \ln(V_i) \right]$$

$$= nRT \ln(V_f / V_i).$$