# Thermo Intro

## temperature

Fahrenheit

Celsius

Rankine

Kelvin

Room temp 20°C (~70°F)

↓

293K

$\Delta F = \frac{9}{5} \Delta C$

$T_F = \frac{9}{5} T_c + 32$

$T_K = T_c + 273.15$

Number, moles, molar mass, density

1 mole of things = $6.022 \cdot 10^{23}$ things

particle

atom

molecule

$N \rightarrow$ number of particles

$n \rightarrow$ number of moles

$C^{12}$ → 12 protons and neutrons
→ 6 protons

1 mole is a gram of protons and neutrons

**Ex.** mass of one proton?

mass of one proton × number of proton = mass of collection

$M$ → total mass of a collection

$m$ → mass of one particle

$$m \times N = M$$

$$m = \frac{M}{N} = \frac{1\,\text{gram}}{N_A}$$

$N_A$ → Avagadro's number $6.022 \cdot 10^{23}$

$$m = 1.7 \cdot 10^{-24} \text{ grams}$$

$$= 1.7 \cdot 10^{-27} \text{ kg}$$

What about $N_2$?

$$1 \text{ mole of } N_2 = 2 \cdot \left(14 \tfrac{g}{mol}\right) = 28\,g$$

Dry air?

78% $N_2$, 21% $O_2$, 1% Ar

$$0.78 \cdot (28\, g/mol) + 0.21 (32\, g/mol) + 0.01 (40\, g/mol) = 29\, g/mol$$

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Ideal Gas Law → an equation of state

→ state variables

- experimental law

number of particles

(microscopic) $\boxed{PV = N k_B T}$ → Boltzmann's constant

$$\boxed{k_B = 1.38 \cdot 10^{-23}\, J/K}$$

$P = \dfrac{F}{Area}$ $[Pa] = \left[\dfrac{N}{m^2}\right]$ $[m^3]$ → Temperature $[K]$

Alternative form $\rightarrow$ $PV = nRT$ (macroscopic)

$\hookrightarrow$ universal gas constant

$$N k_B = n \cdot R$$

$$N = n \cdot N_A \quad \leftarrow \text{definition of moles}$$

$$\cancel{n} \cdot N_A \cdot k_B = \cancel{n} \cdot R$$

$$N_A \cdot k_B = R = 6.022 \cdot \cancel{10^{23}} \frac{\text{part}}{\text{mol}} \, 1.38 \cdot \cancel{10^{-23}} \, J/K$$

$$R = 8.31 \, \frac{J}{K \cdot mol}$$

Volume of 1 mole of air at room temp and atmospheric pressure

$\hookrightarrow$ 293K or 300K

$\hookrightarrow$ 1 atm $= 1.013 \cdot 10^5$ Pa

$$V = \frac{nRT}{P} = \frac{1\,mol \cdot 8.31\,J/K\,mol \cdot 300K}{10^5\,Pa} = 0.024\,m^3$$

$$V_{cube} = s^3$$

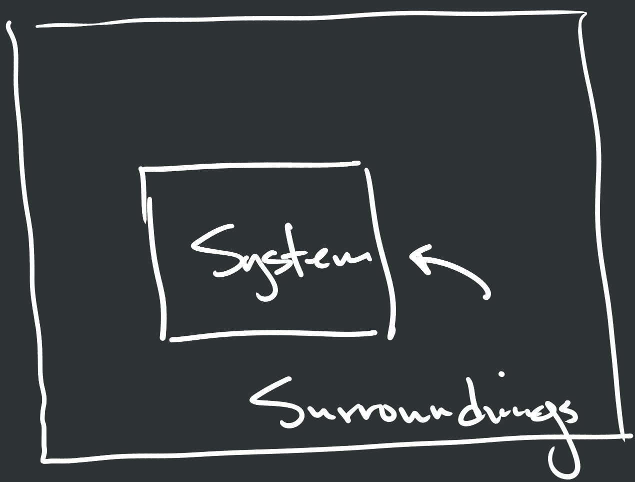
$$\sqrt[3]{0.024\ m^3} = s = 0.288\ m$$

$$\sim 30\ cm$$

Laws of Thermodynamics

0. Thermometers work
1. Conservation of Energy
2. Heat flows from high temp to low temp
   Entropy is maximized
   No perpetual motion machine
3. You can't reach absolute zero

# $1^{st}$ Law → Conservation of Energy




Energy of a system can change

**Work** + **Heat**

Work ↳ Force applied over distance

Heat ↳ spontaneous flow of energy due to a difference in temperature

$$dU = Q + W$$

→ $$dU = đQ + đW$$

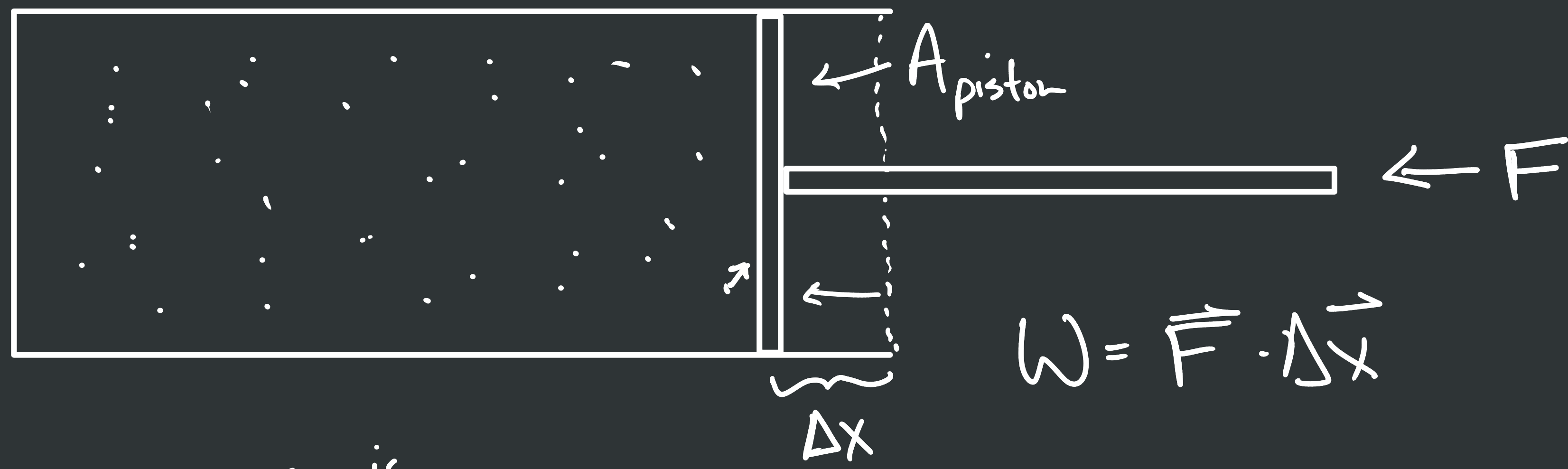
↑ inexact differential

$$\cancel{dQ = Q(x+dx) - Q(x)}$$

$$dU = \delta Q + \delta W$$

↳ internal energy of the system, heat is added or work is done to the system they are positive

# Compression Work (or Expansion)




$$W = \vec{F} \cdot \vec{\Delta x}$$

$$P_{gas} = \frac{F_{gas}}{A_{piston}}$$

assuming pressure is uniform throughout the chamber

↳ compression (expansion) must happen *quasistatically*

$$W = P_{gas} \cdot \underbrace{A_{piston} \cdot \Delta x}_{\Delta V}$$

$$\downarrow$$

$$W = -P\Delta V$$

$\Delta V$ is (-) in compression but energy is increasing

$$dU = đQ + đW \qquad đW = -P\,dV \qquad W = \int -P\,dV$$