

Lecture 1

Macroscopic object has # atoms of N_0 order

1L water, piece of chalk,
Atom $\sim N_0 = 6.02 \cdot 10^{23}$ in 1 g mol^{-1} of substance Avogadro's #
2g of H = $1 N_0$ H
16g of O
32g of O_2 } all = $1 N_0$

a mole of a substance has N_0 atoms

$$M \sim M_{\text{nucleus}} \quad M_2 = 2 \cdot (1.67 \cdot 10^{-24} \text{ g}) \Rightarrow \frac{2 \text{ g}}{2(1.67 \cdot 10^{-24} \text{ g})} \sim N_0$$

$\therefore \Psi_{\text{e}}$ would have 10^{24} coordinates

Temperature

$PV = \text{const}$ at constant T Boyle's law

Specific heat has temperature dependence $C_v = \frac{dE}{dT}$

What is the concept of temperature?

- 1) Defined by the means you measure it.
- 2) Concept of entropy
- 3) $PV = \text{constant} = \Theta$ perfect gas scale temperature
 $\Theta = f(P, V, \dots) \rightarrow$ equation of state = T absolute

In principle the equation of state can be derived from statistical mechanics. In equilibrium macroscopic properties like T, P are constant in time and uniform

Quasistatic Process

a system goes through a set of non-equilibrium states

Types of Quasistatic Processes

- ① Adiabatic $\Delta Q = 0$ no exchange of heat
- ② Isothermal $\Delta T = 0$

Laws of Thermodynamics

Statistical mechanics has much more predictive power
you get more out of 2nd law if you know statistical mechanics

First Law of Thermodynamics = Conservation of Energy

Stir water $W = \Delta E$ provided as ΔQ is low
internal energy of the system goes up
no heat exchange

H_2O molecular weight is 18
stir gives more velocity to the molecules

E_{internal} can be assigned to each equilibrium state
in CM system

Statement of the First Law

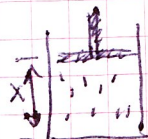
$$\Delta E = W + Q$$

$$dE = dQ + dW$$

ΔE depends only on the initial & final states
unique E for each state

W, Q are not functions of state
 d indicates that it is not a function of state

Pushing on a piston



$$dW = -F dx = -P A dx = -P dV \quad \text{for quasistatic infinitesimal process}$$

$$dW \geq -P dV \quad \text{not quasistatic, depends on friction or how fast you push down}$$

$$PV = RT = N_0 k T \quad \text{for one mole} \quad R = N_0 k = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$$

generally N molecules in gas $PV = NkT = \nu RT$
 ν number of moles of gas

$$k = R/N_0 = \frac{8.31 \text{ J K}^{-1}}{6.02 \cdot 10^{23}} \sim 1.38 \cdot 10^{-23} \text{ J K}^{-1}$$

Isothermal Process

$$\Delta W = \int dW = \int_{V_1}^{V_2} (-P dV) = -NkT \int_{V_1}^{V_2} \frac{dV}{V} = -NkT \ln(V_2/V_1)$$

example: compressing a gas

Heat Capacity

Specific Heat = H.C. per unit mass

H.C. is the amount of heat needed to change T by 1°

$$C_V = \left(\frac{\partial Q}{\partial T} \right)_V$$

$$C_P = \left(\frac{\partial Q}{\partial T} \right)_P$$

depends on the system

for a perfect gas $C_P - C_V = R$

For an adiabatic process of a perfect gas $PV^\gamma = \text{constant}$

$$\gamma = \frac{C_P}{C_V}$$

Do @ home Prove from C_V and C_P def & First Law \uparrow

$$C_P - C_V = \left(\frac{\partial Q}{\partial T} \right)_P - \left(\frac{\partial Q}{\partial T} \right)_V = \left(\frac{\partial \Delta E}{\partial T} \right)_P - \left(\frac{\partial W}{\partial T} \right)_P - \left(\frac{\partial \Delta E}{\partial T} \right)_V + \left(\frac{\partial W}{\partial T} \right)_V$$

$$= -\frac{\partial}{\partial T} \left(-NkT \ln \left(\frac{V_1}{V_2} \right) \right) + \frac{\partial}{\partial T} \left(-NkT \ln \left(\frac{P_1}{P_2} \right) \right) = Nk \ln \frac{V_1}{V_2} - Nk \ln \frac{P_1}{P_2}$$

$$C_P - C_V = R \ln \left(\frac{V_1 P_1}{V_2 P_2} \right) \rightarrow \ln \left(\frac{V_1 P_1}{V_2 P_2} \right)^{\frac{1}{C_P - C_V}}$$