PHYS 213

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Contents

Chapter 1

Intro to Thermal Physics

conservation of energy??????????????

$$W = \int \vec{F}\,dx$$

sfhfjdvsddjvjsh
pressure is forc iver an area

$$dU = dQ - pdV$$

1.0.1 Heat Transfer

$$\Delta U_{hot} < 0 \qquad \Delta U_{cold} > 0$$

1.1 Some basic ass AP chem specific heat

1.2 Entropy

Based on the amount of possible ways a thing can be arranged (permutations)

When rolling 2 dice, the sum of 7 has the highest entropy

1.2.1 Process

- compute S as a function of macrostate variables

- Write down what can change and what cannot

- Maximize S with respect to the variables that can change

1.2.2 Equilibrium Positiion of a particle

$$S = Nk \ln V + f(U, N)$$

$$\frac{dS}{dV_1} = 0 = \frac{dS_1}{dV_1} + \frac{dS_2}{dV_2}\frac{dV_2}{dV_1}$$

1.2.3 Equations/Relationships

$$\frac{1}{T} = (\frac{dS}{dU})_{V,N}$$

$$C_V = (\frac{dQ}{dT})_{V,N}$$

$$\Delta S = \int_{T_i}^{T_f} \frac{C_V(T)}{T} dT$$

important

$$\Delta U = \int_{T_i}^{T_f} C_V(T) dT$$

$$dS = \frac{dU}{T} + \frac{P}{T} dV = \frac{dQ}{T}$$

1.3 Ideal Gas Law

$$pV = NkT \rightarrow pV = N\frac{m(|v|^2)}{3}$$

1.4 Quasistatic Processes

- isothermal = constant temp

- isochoric = constant volume

- isobaric = constant pressure

- adiabatic = $\Delta S = 0$

Isothermal processes are reversable
Isobaric processes are not

1.4.1 PV Diagrams

pressure on y-axis, volume on x-axis

$$W_{on} = -\int p(V)\, dV$$

1.5 Heat Engines

heat gas to push piston, do work to put piston back.

$$dS = \frac{dQ}{T} \rightarrow \Delta S = -\frac{Q_h}{T}$$

1.5.1 Efficiency

$$\epsilon = \frac{W_{by2} + W_{by4}}{Q_h}$$

$$\frac{Q_H}{Q_C} \leq \frac{T_H}{T_C}$$

$$\epsilon = \frac{W_{by}}{Q_H} = \frac{Q_H - Q_C}{Q_H} \rightarrow$$

$$\epsilon = \frac{W_{by}}{Q_H} \leq 1 - \frac{Q_C}{Q_H}$$

1.5.2 Heat Pumps/Refrigerators

COP is coefficient of performance Heat pump

$$COP = \frac{Q_H}{W_{ON}} \leq \frac{1}{1 - \frac{T_C}{T_H}}$$

Refrigerator

$$COP = \frac{Q_C}{W_{ON}} \leq \frac{1}{\frac{T_H}{T_C} - 1}$$

1.6 Gibbs Free Energy

Easier formula to figure out whether something is reversible

$$G = U - TS + pV$$

$$G = \frac{dU}{dX} + p\frac{dV}{dX} - T\frac{dS}{dX}$$

1.6.1 Chemical Potential

$$\mu_A = \frac{dG_A}{dN_A}$$

$$G = \mu N$$

Minimize Free Energy

$$\frac{d(G_A + G_B)}{dN_A} = 0 \qquad N_A + N_B = N_{tot}$$

1.7   Something with Processes

$$dS = \frac{1}{T}dU + \frac{p}{T}dV - \frac{\mu}{T}dN$$
$$G = U + pV - TS$$
$$dU = TdS - pdV + \mu dN$$
$$dG = Vdp + \mu dN - SdT$$
$$d\mu_x = \frac{V_x}{N_x}dp - \frac{S_x}{N_x}dT$$
$$\frac{V_x}{N_x} = \text{ density} \qquad \frac{S_x}{N_x} = \text{ entropy per particle}$$

The reasoon that materials change in the order of solid-liquid-gas is because the density increases with each of those which increases chemical potential

1.8   Ideal Solutions

$$\frac{N_{sugar}}{N_{water}} \propto e^{\frac{\Delta}{kT}}$$

It costs energy to dissolve particles in a solution
its all microstates

$$\Omega(N) = \frac{N_{water}}{N}$$

so if you add salt (not water molecule)

$$\Delta S(N+1) - \Delta S(N) = k \ln\left(\frac{N_{h2O}}{N}\right)$$

Assume solid molecule don't interact. Assume constant energy cost per salt added no matter the number of salt

$$G(N+1) - G(N) = \Delta_{sol} - Tk \ln\left(\frac{N_{H2O}}{N}\right) = 0$$

$$\Delta_{sol} = Tk \ln\left(\frac{N_{H2O}}{N}\right) \rightarrow \frac{\Delta_{sol}}{kT} = \ln\left(\frac{N_{H2O}}{N}\right) \rightarrow e^{\frac{\Delta_{sol}}{kT}} = \frac{N_{H2O}}{N} \rightarrow$$

$$\frac{N}{N_{H2O}} = e^{\frac{\Delta_{sol}}{kT}}$$

doesnt actually work, but is proportional to

$$\frac{N}{N_{H2O}} = n_s e^{\frac{\Delta_{sol}}{kT}}$$

You have you figure out n_S yourself

1.8.1 Goofy Silly Graph

slope of graph is proportional to $-\Delta sol$

1.8.2 Effects on Phase Diagrams

lowers freezing point, increases boiling point.
    Basically just makes everything want to be a liquid

1.9 Boltzmann Factors

microstate probability is dependent on temperature

$$P(e) \approx e^{\frac{-E}{kT}}$$

equilibrium means minimized Gibbs free energy

$$E = \frac{1}{2}mv^2 + mgy$$

$$P(h) = \frac{e^{\frac{-E}{kT}}}{Z}$$

$$P(h_1)/P(h_2) = e^{mg(h_1-h_2)}kT$$

assume temperature does not change with height

1.9.1 Centrifuge

its literally the same as gravity, just sideways

1.9.2 More Boltzmann Factor Stuff

$$f_i = e^{\frac{-E_i}{kT}}$$

1.9.3 Quantum Mechanics

$$P(i) = \frac{e^{\frac{-E_i}{kT}}}{\sum e^{\frac{-E_i}{kT}}}$$

increase heat to make all possible microstates equal
max entropy is $k \ln 2$

1.10   Semiconductors

Remember Band Gaps from 214

    That except semiconductors have a valence band that doesnt conduct electricity at all and a higher energy conduction band, so if you add energy and get electrons in the conduction band, then it conducts

$$\rho = \frac{N_{conduction}}{N_{atoms}} = e^{\frac{-\Delta}{2kt}}$$

insulator $=$ large Δ

1.10.1   Neutrality

$$N_e = N_C$$
$$n_e = \frac{1}{Z}\exp\left(\frac{-\Delta}{2kt}\right)$$

Chapter 2

Final Study

2.0.1 Changing Boiling Point

$$d\mu_{liquid} = d\mu_{gas}$$
$$V_l dp - S_l dT = V_g dp - S_g dT$$
$$(V - V)dp = S - S dT$$

2.1 All Sortsa Boltzmann Factors

$$\text{resistivity } = e^{-\Delta/2kT}/Z$$
$$p = e^{-E/kT}/Z$$
$$p = e^{-mgh/kT}/Z$$