Thermo Physics Review

Arden Rasmussen

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Contents

1 3D-Ideal Gas Law

$$P\cancel{V} = NkT \tag{1}$$
$$Nk = nR \tag{2}$$

1.1 Equipartition Theorem

Only true if f is quadratic. E.g. If kinetic energy and potential energy are given by quadratic functions

$$y = nf\frac{1}{2}kT \tag{3}$$
$$f = 3 \quad \text{Monatomic} \tag{4}$$
$$f = 5 \quad \text{Diatomic} \tag{5}$$

2 1-st Law

$$U = Q + W \tag{6}$$

Values are $(+)$ if work or heat is added or done *on* the system. Values are $(-)$ if work or heat is removed from or done *by* the system.

$$dW = -Pd\cancel{V} \tag{7}$$
$$W = -\int_{\cancel{V}_i}^{\cancel{V}_f} Pd\cancel{V} \tag{8}$$

2.1 Cycles

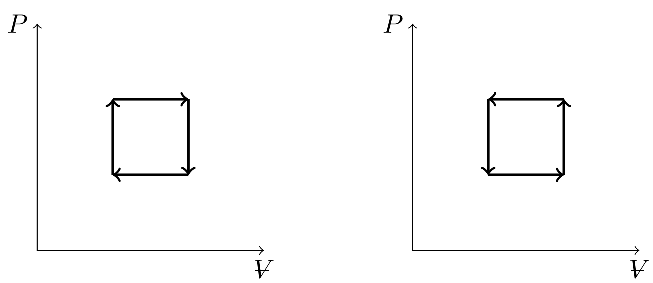

Figure 1: Left is Heat engine cycle. Right is Refrigerator cycle.

Efficiency is given by benefit divided by cost. Maximum efficiency is only found in the Caront Cycle.

$$Eff_{max} = 1 - \frac{T_C}{T_H} \tag{9}$$

3 Gas Expansion

Isothermal Temperature is constant $T = \text{const.}$

Abiabatic No heat is transferred $Q = 0$, $P\cancel{V}^{\frac{2+f}{f}} = \text{const}$, $\Delta S = 0$.

$$C_{\cancel{V}} = \frac{\partial U}{\partial T} \quad C_P = \frac{\partial U}{\partial T} + P\left(\frac{\partial \cancel{V}}{\partial T}\right)_P \tag{10}$$

$$C_{\cancel{V}} = \frac{1}{2} f N K \quad C_P = Nk\left(\frac{f+2}{2}\right) \quad \text{Only for ideal gasses} \tag{11}$$

4 Multiplicity

Einstien Solid

$$\Omega = \frac{(N+q-1)!}{q!\,(N-1)!} \approx \left(\frac{eq}{N}\right)^N$$

Two Level System

$$\Omega = \frac{N!}{N_\uparrow! N_\downarrow!} = \frac{N!}{N_\uparrow!\,(N-N_\uparrow)!}$$

Ideal Gas

$$\Omega = \frac{\cancel{V}^N}{N! h^{3N}} \left[\frac{2\pi^{\frac{3N}{2}}}{\left(\frac{3N}{2}-1\right)!} \cdot (2mU)^{\frac{3N-1}{2}}\right]$$

5 Entropy and Heat

Heat Capacities

$$C_V \equiv \left(\frac{\partial U}{\partial T}\right)_{N,V} \tag{12}$$

$$\tag{13}$$

For an Einstein solid with $q \gg N$

$$C_V = \frac{\partial}{\partial T}(NkT) = Nk \tag{14}$$

For a monatomic ideal gas

$$C_V = \frac{\partial}{\partial T}\left(\frac{3}{2}NkT\right) = \frac{3}{2}Nk \tag{15}$$

Measuring Entropies

$$dS = \frac{dU}{T} = \frac{Q}{T} \tag{16}$$

$$dS = \frac{C_V dT}{T} \tag{17}$$

$$\Delta S = S_f - S_i = \int_{T_i}^{T_f} \frac{C_V}{T} dT \tag{18}$$

$$C_V \to 0 \quad \text{as} \quad T \to 0 \tag{19}$$

6 Thermo-Dynamic Potentials

$$S = S(N, \not{V}, U) \tag{20}$$

$$dS = \frac{\partial S}{\partial N} dN + \frac{\partial S}{\partial \not{V}} d\not{V} + \frac{\partial S}{\partial U} dU \tag{21}$$

$$= -\frac{\mu}{T} dN + \frac{P}{T} d\not{V} + \frac{1}{T} dU \tag{22}$$

$$dU = TdS + \mu dN \tag{23}$$

$$\frac{\partial U}{\partial S} = T \quad \frac{\partial U}{\partial N} = \mu \quad \frac{\partial U}{\partial \not{V}} = -P \tag{24}$$

Enthalpy $H \equiv U + P\not{V} \quad T = 0$

Helmholts Free Energy $F \equiv U - TS \quad P = 0$

Gibbs Gree Energy $G \equiv U - TS + P\not{V}$

7 Boltzmann Statistics

7.1 Partition Function

$$\boxed{Z \equiv \sum_s e^{-\frac{E(s)}{kT}}} \tag{25}$$

Where s are the possible states of a single particle. Z cannot be measured but it contains all the information relevant to a system.

7.2 Boltzmann Distribution

$$\boxed{P(s) = \frac{e^{-\frac{E(s)}{kT}}}{Z}} \tag{26}$$

This gives the probability of a particle being in any given state s. Using this and the partition function, anything about a system can be derived.