0. Physical constants

$k = 1.381 \times 10^{-23} J/K = 8.617 \times 10^{-5} eV/K$, $N_A = 6.022 \times 10^{23}$, $R = 8.315 J/mol \cdot K$, $h = 6.626 \times 10^{-34} J \cdot s = 4.136 \times 10^{-15} eV \cdot S$

1. Energy in Thermal Physics

1.1. **Thermal equilibrium.** *Temperature* is a measure of the tendency of an object to spontaneously give up energy to its surroundings. When two objects are in thermal contact, the one that tends to spontaneously *lose* energy is at the *higher* energy. Room temperature $300K$

1.2. **The ideal gas.** $PV = nRT = Nk_BT$. n is no of moles, $N = nN_A$ is number of molecules. $k_B = R/N_A$. Latter equation is valid when avg. space b/w molecules is larger than size of molecules. $\bar{E}_{K,trans} = \frac{3}{2}kT$.

1.3. **Equipartition of energy.** Theorem: at temperature T, the average energy of any quadratic degree of freedom is $\frac{1}{2}kT$. $U_{thermal} = Nf\frac{1}{2}kT$. Monoatomic gas: $f = 3$. Diatomic gas: $f = 5, 6$ (3 trans., 2-3, rot.) or $f = 8$ (3 trans., 3 rot., 2 vibr. K, P). Solid: $f = 6$ (6 vibr. 3K, 3P). Some vibrational energies may be "frozen out" at room temperature.

1.4. **Heat and work.** First law of thermodynamics $\Delta U = Q + W$. The change in energy is equal to the heat added and the work done. Heat transfer happens by *conduction*, *convection* and *radiation*.

1.5. **Compression work.** Consider a piston. The force is $F = PA$. Assumes that the pressure is uniform. Compression must be slow enough so the gas has time to continually equilibrate to the changing conditions $\rightarrow$ *quasistatic*. A compressed gas, i.e. negative ΔV gives $W = F\Delta x = PA\Delta x = -P\Delta V$.

1.5.1. *Compression of ideal gas.* Two idealised ways: *Isothermal* compression is so slow that the temperature of the gas does not rise (quasistatic). *Adiabatic* compression is so fast that no heat escapes during the compression. $VT^{f/2} =$ constant, $V^\gamma P =$ constant. $\gamma = \frac{f+2}{f}$ is the adiabatic exponent.

1.6. **Heat capacities.** Amount of heat needed to raise an object's temperature, per degree temperature increase: $C = \frac{Q}{\Delta T} = \frac{\Delta U - W}{\Delta T}$. $W = 0$ and $V =$ constant is called heat capacity heat capacity at *constant volume*, else there would be compression work, $-P\Delta V$. $C_V = \left(\frac{\partial U}{\partial T}\right)_V$. If an object expand when heated and do work on surroundings, there is negative W. At constant P, Q i unambiguous $\rightarrow$ heat capacity at *constant pressure*: $C_P = \left(\frac{\Delta U - (-P\Delta V)}{\Delta T}\right)_P = \left(\frac{\partial U}{\partial T}\right)_P + P\frac{\partial V}{\partial T}_P$.

Latent heat. During a face transformation $C = \frac{Q}{\Delta T} = \frac{Q}{0} = \infty$. While $L = \frac{Q}{m}$ is the heat required to accomplish the transformation, the *latent heat*.