5 - Summary

1 - Temperature and Heat

Kelvin-Celsius Conversion:

$$T_K = T_C + 273.15$$

Linear and Volume Expansion:

$$\Delta L = \alpha L_o \Delta T \quad \text{and} \quad \Delta V = \beta V_o \Delta T \qquad \text{(where } 3\alpha = \beta\text{)}$$

Tensile Strength-Expansion Relation

$$\frac{F}{A} = -Y\alpha\Delta T$$

Specific Heat

$$Q = mc\Delta T \quad \text{and} \quad Q = nC\Delta T \qquad (C \text{ is molar specific heat})$$

2- Thermal Properties of Matter

Ideal gas law:

$$pV = nRT = NkT$$

(where the latter is expressed on a per-molecule basis)

Average translational kinetic energy of n moles of ideal gas:

$$K_{\text{tr}} = \frac{3}{2}nRT$$

Average translational kinetic energy of a gas molecule:

$$\frac{1}{2}m(v^2)_{\text{av}} = \frac{3}{2}kT$$

(note that m refers to the mass of a single molecule)

Root mean-square speed of a gas molecule:

$$\begin{aligned} v_{\text{rms}} &= \sqrt{(v^2)_{\text{av}}} \\ &= \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}} \end{aligned}$$

Molar specific heat (constant volume):

$$C_v = \frac{3}{2}R = 12.47\,\mathrm{J/mol\,K} \qquad \text{(ideal gas of point particles)}$$
$$C_v = \frac{5}{2}R = 20.79\,\mathrm{J/mol\,K} \quad \text{(diatomic gas, including rotation)}$$
$$C_V = 3R = 24.9\mathrm{J/mol\,K} \qquad \text{(Rule of Dulong and Petit)}$$

3 - 1st Law of Thermodynamics

1st Law of Thermodynamics (Internal Energy U):

$$\Delta U = Q - W$$

Work done (pV graph)

$$W = \int_{V_1}^{V_2} p\,dV \qquad \text{(or area under the pV curve)}$$

(Note: Internal Energy U is independent of path taken)

Adiabatic Process:

No heat transfer into or out of a system (such that Q = 0).

$$U_2 - U_1 = \Delta U = -W$$

Isochoric Process:

Constant volume process.
When the volume of a system is constant, it does no work on its surroundings (W = 0)

$$U_2 - U_1 = \Delta U = Q$$

Isobaric Process:

Constant pressure process.
In this case, ΔU, Q, and W are not zero, but W would then be straightforward:

$$W = p(V_2 - V_1)$$

Isothermal Process:

Constant temperature process.
For a process to be isothermal, heat flow into or out of a system must occur slowly enough that thermal equilibrium is maintained.

Heat Capacities

Heat capacities can be measured for constant volume or constant pressure (C_v vs C_p).

Constant Volume and Pressure Relation

$$C_p = C_v + R$$

Ratio of Heat Capacities

$$\gamma = \frac{C_p}{C_v}$$

Work done by an ideal gas, adiabatic:

$$W = nC_v(T_1 - T_2) = \frac{C_v}{R}(p_1V_1 - p_2V_2) = \frac{1}{\gamma - 1}(p_1V_1 - p_2V_2)$$

4 - 2nd Law of Thermodynamics

The state of entropy of the entire universe will always increase over time.

Reservoirs:

$$W = Q = Q_h + Q_c = |Q_h| - |Q_c|$$

Thermal Efficiency:

$$e = 1 + \frac{Q_c}{Q_h} = 1 - \left|\frac{Q_c}{Q_h}\right|$$

Refrigerators:

$$|Q_h| = Q_c + |W|$$

Clausius Statement:

"Heat never flows spontaneously from lower temperature to higher temperature without work."

Carnot Engine:

Heat transfer in a Carnot Engine:

$$\frac{Q_c}{Q_h} = -\frac{T_c}{T_h} \text{ or } \frac{|Q_c|}{|Q_h|} = \frac{T_c}{T_h}$$

Efficiency:

$$e_{\text{carnot}} = 1 - \frac{T_c}{T_h} = \frac{T_h - T_c}{T_h}$$