

Always True For Any Closed System:

- $\Delta U = Q - W$ where Q is heat into the system, W work done by the system. (Often useful to write as $Q = \Delta U + W$.)
- For quasi-static (i.e. near-equilibrium) processes, $W = \int p dV =$ area under curve on $p - V$ diagram (careful of sign!)
- At constant volume, $Q = mc_V\Delta T = nC_V\Delta T$.
- At constant pressure, $Q = mc_P\Delta T = nC_P\Delta T$.
- U is a state variable (and thus depends only on T, p, V, n .)
- For any cycle, T, p, V, n come back to themselves; therefore $\Delta U = 0$ and $Q = W$ for any complete cycle.

Ideal Gas Thermodynamics (Formulas for *ideal gas only*, except where marked “always true”)

* $pV = nRT$

* $C_V = \frac{\delta}{2}R$, $C_P = \frac{\delta+2}{2}R = C_V + R$, $\gamma = C_P/C_V = \frac{\delta+2}{\delta}$; $\delta \geq 3$, so $\frac{5}{3} \leq \gamma \leq 2$.

* $U = nC_V T = \frac{\delta}{2}nRT = \frac{\delta}{2}pV$

Free Expansion: $Q = 0$, $W = 0$ so $\Delta U = 0$ (always true in free expansion) so $\Delta T = 0 \Rightarrow pV = \text{constant}$.

Isobaric process: $p = \text{constant}$ so $W = p\Delta V$ (always true for isobaric) and $V/T = \text{constant}$. Compute to find $\Delta U = nC_V\Delta T$, $Q = \Delta U + W$.

Isovolumetric process: $V = \text{constant}$ so $W = 0$ and $Q = \Delta U$ (always true for isovolumetric.) $p/T = \text{constant}$, use to find $Q = \Delta U = nC_V\Delta T$.

Isothermal process: $T = \text{constant}$, so $pV = \text{constant}$ and $\Delta U = 0$ (ideal gas only!) and $Q = W$. Use $p = \text{constant}/V$ to show $W = \int p dV = nRT \ln(V_2/V_1)$.

Adiabatic process: $Q = 0$ so $\Delta U = -W$ (always true for adiabatic). p, V, T all change. We saw $pV^\gamma = \text{constant}$; since $pV/T = \text{constant}$ for ideal gas, this implies $TV^{\gamma-1} = \text{constant}$ and $p^{1-\gamma}T^\gamma = \text{constant}$.