

Useful Relations from Thermodynamics

- Equations that are always true regardless of process

$$\begin{aligned}
 Q &= \Delta U + W & ; & & PV &= nRT = Nk_bT \\
 \Delta U &= nC_v\Delta T & ; & & W &= \int PdV \\
 C_p &= \frac{d+2}{2}R & ; & & C_v &= \frac{d}{2}R \\
 C_p &= C_v + R & ; & & \gamma &= \frac{C_p}{C_v} = \frac{d+2}{d} \\
 dS &= \frac{dQ}{T} & ; & & \Delta S &= \int \frac{dQ}{T} \\
 \Delta S &= nC_v \ln(T_f/T_i) + nR \ln(V_f/V_i)
 \end{aligned}$$

- Equations that are true only for adiabatic processes.

$$\begin{aligned}
 PV^\gamma &= \text{constant} & ; & & TV^{\gamma-1} &= \text{constant} \\
 Q &= 0 & ; & & \Delta S &= 0 & ; & & \Delta U &= -W
 \end{aligned}$$

- Equations that are only true for isobaric processes.

$$\begin{aligned}
 W &= P(V_f - V_i) = nR(T_f - T_i) \\
 Q &= nC_p\Delta T & ; & & \Delta S &= nC_p \ln(T_f/T_i) = nC_p \ln(V_f/V_i)
 \end{aligned}$$

- Equations that are only true for isothermal processes.

$$\begin{aligned}
 \Delta U &= 0 & ; & & Q &= W & ; & & W &= nRT \ln(V_f/V_i) \\
 \Delta S &= nR \ln(V_f/V_i)
 \end{aligned}$$

- Equations that are only true for constant volume processes.

$$W = 0 & ; & Q = \Delta U & ; & \Delta S = nC_v \ln(T_f/T_i)$$

- Equations relating to heat engines

$$\begin{aligned}
 e &= \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H} & ; & & W &= Q_H - Q_C \\
 e_c &= 1 - \frac{T_C}{T_H}
 \end{aligned}$$