

## Entropy change for liquids and solids

\* typically liquids (and some) solids are incompressible

Specific volumes are almost always constant for a given temperature change

$$dv = v_2(T_2) - v_1(T_1) \approx 0$$

$$\Rightarrow \Delta S = \int_1^2 \frac{du}{T} + \int_1^2 \frac{P dv}{T} \approx \int_1^2 \frac{C_v dT}{T} \approx \int_1^2 \frac{C_p dT}{T} \quad \boxed{C_v \approx C_p \text{ for Solids + liquids}}$$

$$\Rightarrow \Delta S = \int_1^2 \frac{C_r dT}{T} \approx C_r^{\text{avg}} \ln(T_2/T_1)$$

Isentropic process on an incompressible substance

$$\Delta Q = 0$$

$$(\Delta S = 0) + (\Delta v = 0)$$

$$\Delta S = C_r^{\text{avg}} \ln(T_2/T_1) = 0 \Rightarrow \ln(T_2/T_1) = 0 \Rightarrow T_2 = T_1$$

Isentropic

$$\Delta S = 0$$

Isentropic & Incompressible

## Entropy change for an ideal gas

$$Pv = R_{\text{gas}} T \quad (PV = n R_{\text{gas}} T)$$

Tds 1

$$ds = \frac{du}{T} + \frac{P dv}{T}$$

$$ds = \frac{C_v dT}{T} + \frac{R_{\text{gas}} dv}{v T}$$

$$\Delta S = S_2 - S_1 = \int_1^2 \frac{C_r dT}{T} + R_{\text{gas}} \int_1^2 \frac{dv}{v}$$

$$\Delta S \approx C_r^{\text{avg}} \ln(T_2/T_1) + R_{\text{gas}} \ln(v_2/v_1)$$

Tds 2

$$ds = \frac{dh}{T} - \frac{v dP}{T}$$

$$ds = \frac{C_p dT}{T} - \frac{R_{\text{gas}} dP}{P T}$$

$$S_2 - S_1 = \int_1^2 \frac{C_p dT}{T} - R_{\text{gas}} \int_1^2 \frac{dP}{P}$$

$$\Delta S \approx C_p^{\text{avg}} \ln(T_2/T_1) - R_{\text{gas}} \ln(P_2/P_1)$$

average specific heat analysis

Exact analysis  $\rightarrow$  (variable specific heats)