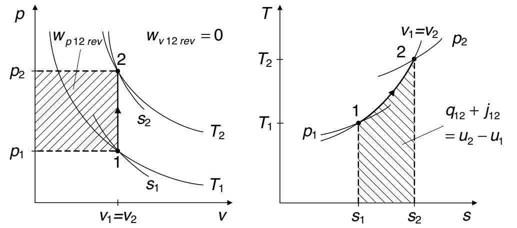
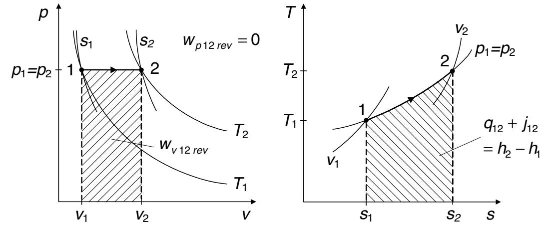
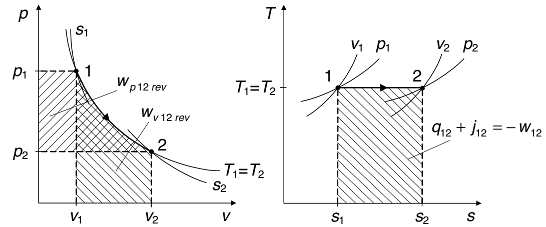
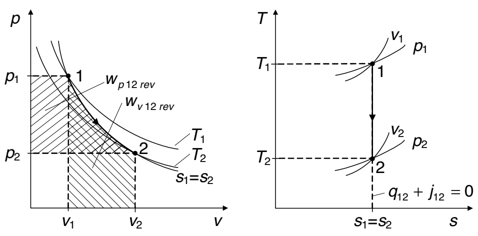
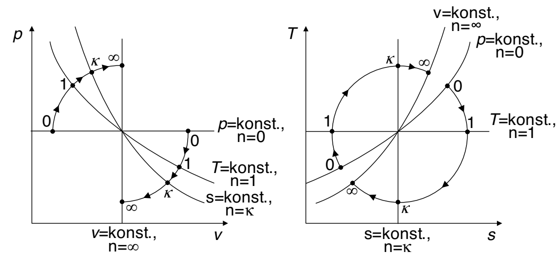
Special state changes with perfect gases (without consideration of kinetic and potential energies)

Ideal gas	**$v =$ constant: Isochoric state change**	**$p =$ constant: Isobaric state change**	**$T =$ constant: Isothermal state change**
Therm. state equation $pV = n\,R\,T$ $R = 8.314\,\mathrm{J/mol\,K}$ $pV = m\,R_i\,T$ $R_i = \frac{R}{M_i}$ $p\,v = R_i\,T, \quad \rho = \frac{p}{R_i\,T}$ $R_i = c_p - c_v, \quad \kappa = \frac{c_p}{c_v}$ $c_v = \frac{R_i}{\kappa - 1}, \quad c_p = \frac{\kappa\,R_i}{\kappa - 1}$	 $v =$ const.: $\frac{p_1}{T_1} = \frac{p_2}{T_2} = \frac{p}{T} =$ const. $w_{v\,12\,rev} = 0 \quad (\mathrm{d}v = 0)$ $w_{p\,12\,rev} = v\,(p_2 - p_1) = \frac{p_2 - p_1}{\rho}$	 $p =$ const.: $\frac{v_1}{T_1} = \frac{v_2}{T_2} = \frac{v}{T} =$ const. $w_{v\,12\,rev} = -p\,(v_2 - v_1) = -R_i\,(T_2 - T_1)$ $w_{p\,12\,rev} = 0 \quad (\mathrm{d}p = 0)$	 $T =$ const.: $p_1\,v_1 = p_2\,v_2 = p\,v =$ const. $w_{v\,12\,rev} = -p_1\,v_1\,\ln\frac{v_2}{v_1} = \underbrace{p_1\,v_1\,\ln\frac{p_2}{p_1}}_{[J]} = \underbrace{R_i\,T\,\ln\frac{p_2}{p_1}}_{[J/kg]}$ $w_{p\,12\,rev} = w_{v\,12\,rev}$
1st LT closed system $q_{12} + w_{12} = u_2 - u_1$ Rev. volume change work: $w_{v\,12\,rev} = -\int_1^2 p\,\mathrm{d}v$ $w_{v\,12} = w_{v\,12\,rev} + j_{12}$ Overall work: $w_{12} = w_{v\,12} + w_{W\,12} + w_{el\,12}$	$q_{12} + w_{12} = u_2 - u_1$ Rev. SC: $w_{12} = w_{v\,12\,rev} = 0 \quad (\mathrm{d}v = 0)$ $q_{12\,rev} = u_2 - u_1 = c_v\,(T_2 - T_1)$	$q_{12} + w_{12} = u_2 - u_1$ Rev. SC: $w_{12} = w_{v\,12\,rev} = -p\,(v_2 - v_1)$ $q_{12\,rev} = u_2 - u_1 + p\,(v_2 - v_1) = h_2 - h_1$ $q_{12\,rev} = c_p\,(T_2 - T_1)$	$q_{12} + w_{12} = u_2 - u_1 = c_v\,(T_2 - T_1) = 0$ $q_{12} = -w_{12}$ Rev. SC: $q_{12\,rev} = -w_{v\,12\,rev}$ $q_{12\,rev} = p_1\,v_1\,\ln\frac{v_2}{v_1} = -p_1\,v_1\,\ln\frac{p_2}{p_1} = -R_i\,T\,\ln\frac{p_2}{p_1}$
1st LT open system $q_{12} + w_{t\,12} = h_2 - h_1$ Rev. pressure change work: $w_{p\,12\,rev} = \int_1^2 v\,\mathrm{d}p$ Technical work: $w_{t\,12} = \int_1^2 v\,\mathrm{d}p + j_{12}$	$q_{12} + w_{t\,12} = h_2 - h_1$ Rev. SC: $w_{t\,12} = w_{p\,12\,rev} = v\,(p_2 - p_1)$ $q_{12\,rev} = h_2 - h_1 - v\,(p_2 - p_1) = u_2 - u_1$ $q_{12\,rev} = c_v\,(T_2 - T_1)$	$q_{12} + w_{t\,12} = h_2 - h_1$ Rev. SC: $w_{t\,12} = w_{p\,12\,rev} = 0 \quad (\mathrm{d}p = 0)$ $q_{12\,rev} = h_2 - h_1 = c_p\,(T_2 - T_1)$	$q_{12} + w_{t\,12} = h_2 - h_1 = c_p\,(T_2 - T_1) = 0$ $q_{12} = -w_{t\,12}$ Rev. SC: $q_{12\,rev} = -w_{p\,12\,rev}$ $q_{12\,rev} = p_1\,v_1\,\ln\frac{v_2}{v_1} = -p_1\,v_1\,\ln\frac{p_2}{p_1} = -R_i\,T\,\ln\frac{p_2}{p_1}$
2nd LT / entropy $\mathrm{d}s = \frac{\mathrm{d}q + \mathrm{d}j}{T}$ $\mathrm{d}s = \frac{\mathrm{d}u + p\,\mathrm{d}v}{T} = \frac{\mathrm{d}h - v\,\mathrm{d}p}{T}$	$\mathrm{d}s = \frac{\mathrm{d}u}{T} = \frac{c_v\,\mathrm{d}T}{T} \Rightarrow s_2 - s_1 = c_v\,\ln\frac{T_2}{T_1}$	$\mathrm{d}s = \frac{\mathrm{d}h}{T} = \frac{c_p\,\mathrm{d}T}{T} \Rightarrow s_2 - s_1 = c_p\,\ln\frac{T_2}{T_1}$	$\mathrm{d}s = \frac{p\,\mathrm{d}v}{T} = \frac{R_i\,\mathrm{d}v}{v} \Rightarrow s_2 - s_1 = R_i\,\ln\frac{v_2}{v_1}$ $\mathrm{d}s = -\frac{v\,\mathrm{d}p}{T} = -\frac{R_i\,\mathrm{d}p}{p} \Rightarrow s_2 - s_1 = -R_i\,\ln\frac{p_2}{p_1}$

Ideal gas	$s=$ constant: Isentropic state change	$n=$ constant: Polytropic state change
Therm. state change $pV = n\,R\,T$ $R = 8.314\,\mathrm{J/mol\,K}$ $pV = m\,R_i\,T$ $R_i = \dfrac{R}{M_i}$ $p\,v = R_i\,T, \quad \rho = \dfrac{p}{R_i\,T}$ $R_i = c_p - c_v, \quad \kappa = \dfrac{c_p}{c_v}$ $c_v = \dfrac{R_i}{\kappa - 1}, \quad c_p = \dfrac{\kappa\,R_i}{\kappa - 1}$	 $s=\text{const}: \quad p_1\,v_1^\kappa = p_2\,v_2^\kappa = \text{const.} \quad \Rightarrow \quad \dfrac{T_2}{T_1} = \left(\dfrac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} = \left(\dfrac{v_1}{v_2}\right)^{\kappa-1}$ $w_{v\,12\,rev} = \dfrac{p_1\,v_1}{\kappa-1}\left[\left(\dfrac{v_1}{v_2}\right)^{\kappa-1} - 1\right] = \text{etc. (replace)}$ $w_{p\,12\,rev} = \kappa\,w_{v\,12\,rev} = \kappa\,\dfrac{p_1\,v_1}{\kappa-1}\left[\left(\dfrac{v_1}{v_2}\right)^{\kappa-1} - 1\right] = \text{etc. (replace)}$	 Polytrope: $pv^n =$ konst. Isobare: n=0, $pv^0 =$ konst. Isotherme: n=1, $pv =$ konst. Isentrope: n=κ, $pv^\kappa =$ konst. Isochore: n=∞, $pv^\infty =$ konst. $n = \dfrac{\ln\frac{p_2}{p_1}}{\ln\frac{v_1}{v_2}} = \dfrac{\ln\frac{p_2}{p_1}}{\ln\frac{p_2}{p_1} - \ln\frac{T_2}{T_1}}$ $n=\text{const}: \quad p_1\,v_1^n = p_2\,v_2^n = \text{const.} \quad \Rightarrow \quad \dfrac{T_2}{T_1} = \left(\dfrac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \left(\dfrac{v_1}{v_2}\right)^{n-1}$ $w_{v\,12} = \dfrac{p_1\,v_1}{n-1}\left[\left(\dfrac{v_1}{v_2}\right)^{n-1} - 1\right] = \text{etc. (replace, } n \neq 1)$ $w_{p\,12} = n\,w_{v\,12} = n\,\dfrac{p_1\,v_1}{n-1}\left[\left(\dfrac{v_1}{v_2}\right)^{n-1} - 1\right] = \text{etc. (replace, } n \neq 1)$
1st LT closed system $q_{12} + w_{12} = u_2 - u_1$ Rev. volume change work: $w_{v\,12\,rev} = -\displaystyle\int_1^2 p\,\mathrm{d}v$ $w_{v\,12} = w_{v\,12\,rev} + j_{12}$ Overall work: $w_{12} = w_{v\,12} + w_{W\,12} + w_{el\,12}$	$q_{12} + w_{12} = u_2 - u_1$ Isentropic means adiabatic ($q_{12} = 0$) and reversible ($j_{12} = 0$): $w_{12} = w_{v12\,rev} = u_2 - u_1 = c_v\,(T_2 - T_1)$ $w_{v12\,rev} = \dfrac{p_1\,v_1}{\kappa-1}\left[\left(\dfrac{v_1}{v_2}\right)^{\kappa-1} - 1\right] = \dfrac{R_i\,T_1}{\kappa-1}\left[\left(\dfrac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} - 1\right] = \text{etc.}$	$q_{12} + w_{12} = u_2 - u_1 = c_v\,(T_2 - T_1)$ $w_{12} = w_{v\,12} = \dfrac{R_i}{n-1}\,(T_2 - T_1) = c_v\,\dfrac{\kappa-1}{n-1}\,(T_2 - T_1) =$ $= \dfrac{p_1\,v_1}{n-1}\left[\left(\dfrac{v_1}{v_2}\right)^{n-1} - 1\right] = \text{etc.} \quad (n \neq 1)$ Rev. SC: $w_{12} = w_{v12\,rev}$ $q_{12\,rev} = c_v\,\dfrac{n-\kappa}{n-1}\,(T_2 - T_1) = \dfrac{n-\kappa}{\kappa-1}\,\dfrac{p_1\,v_1}{n-1}\left[\left(\dfrac{v_1}{v_2}\right)^{n-1} - 1\right] = \text{etc.} \quad (n \neq 1)$
1st LT open system $q_{12} + w_{t\,12} = h_2 - h_1$ Rev. pressure change work: $w_{p\,12\,rev} = \displaystyle\int_1^2 v\,\mathrm{d}p$ Technical work: $w_{t\,12} = \displaystyle\int_1^2 v\,\mathrm{d}p + j_{12}$	$q_{12} + w_{t\,12} = h_2 - h_1$ Isentropic means adiabatic ($q_{12} = 0$) and reversible ($j_{12} = 0$): $w_{t\,12} = w_{p\,12\,rev} = \kappa\,w_{v\,12\,rev} = h_2 - h_1 = c_p\,(T_2 - T_1)$ $w_{p\,12\,rev} = \kappa\,\dfrac{p_1\,v_1}{\kappa-1}\left[\left(\dfrac{v_1}{v_2}\right)^{\kappa-1} - 1\right] = \kappa\,\dfrac{R_i\,T_1}{\kappa-1}\left[\left(\dfrac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} - 1\right] = \text{etc.}$	$q_{12} + w_{t\,12} = h_2 - h_1 = c_p\,(T_2 - T_1)$ $w_{t\,12} = w_{p\,12} = n\,w_{v\,12} = n\,\dfrac{p_1\,v_1}{n-1}\left[\left(\dfrac{v_1}{v_2}\right)^{n-1} - 1\right] = \text{etc.} \quad (n \neq 1)$ Rev. SC: $w_{p\,12\,rev} = n\,w_{v\,12\,rev} = \dfrac{n\,R_i}{n-1}\,(T_2 - T_1) = \text{etc.}$ $q_{12\,rev} = c_v\,\dfrac{n-\kappa}{n-1}\,(T_2 - T_1) = \dfrac{n-\kappa}{\kappa-1}\,\dfrac{p_1\,v_1}{n-1}\left[\left(\dfrac{v_1}{v_2}\right)^{n-1} - 1\right] = \text{etc.} \quad (n \neq 1)$
2nd LT / entropy $\mathrm{d}s = \dfrac{\mathrm{d}q + \mathrm{d}j}{T}$ $\mathrm{d}s = \dfrac{\mathrm{d}u + p\,\mathrm{d}v}{T} = \dfrac{\mathrm{d}h - v\,\mathrm{d}p}{T}$	$\mathrm{d}s = \dfrac{\mathrm{d}q + \mathrm{d}j}{T} = 0 \Rightarrow s_2 - s_1 = 0$	$s_2 - s_1 = c_v\,\dfrac{n-\kappa}{n-1}\,\ln\dfrac{T_2}{T_1} \quad (\text{for } n \neq 1)$ $s_2 - s_1 = c_v\,\ln\dfrac{T_2}{T_1} + R_i\,\ln\dfrac{v_2}{v_1} = c_p\,\ln\dfrac{T_2}{T_1} - R_i\,\ln\dfrac{p_2}{p_1}$