Thermal Power Plants

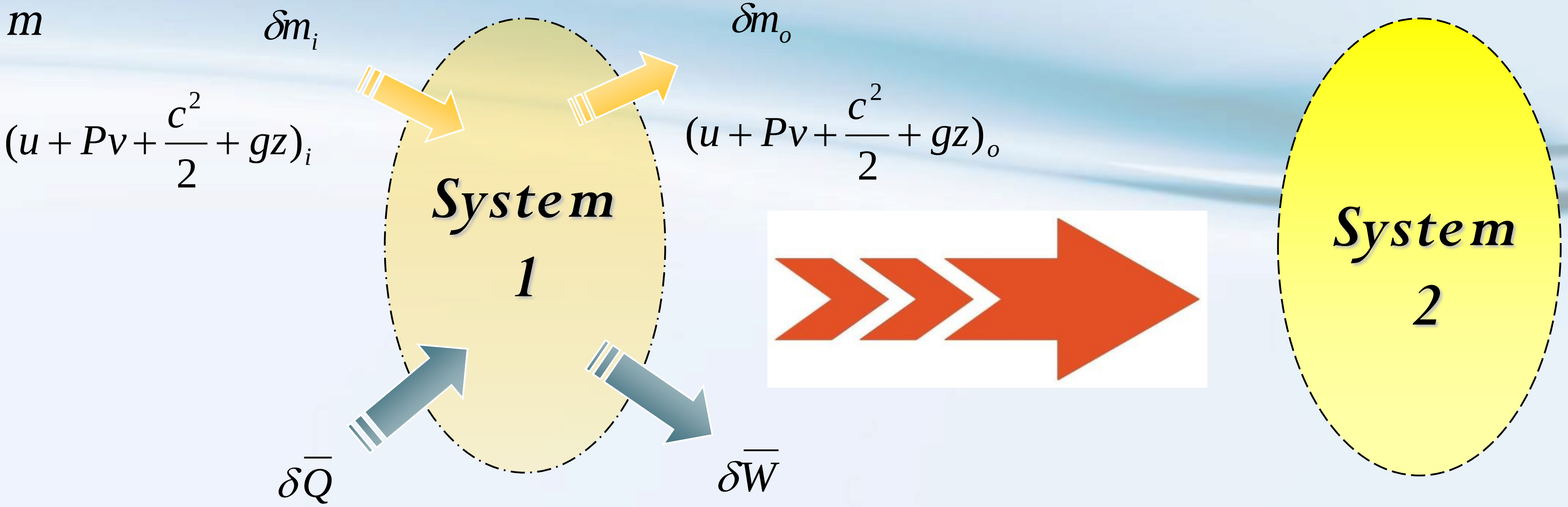
Section-1

-Fundamentals of thermodynamics principles:

1. First law of thermodynamics:

Energy can neither be created nor destroyed; it can only be transformed from one form to another

$$Inlet\ Energy\ -\ Outlet\ Energy\ =Final\ energy\ of\ system\ -\ Initial\ energy\ of\ system$$



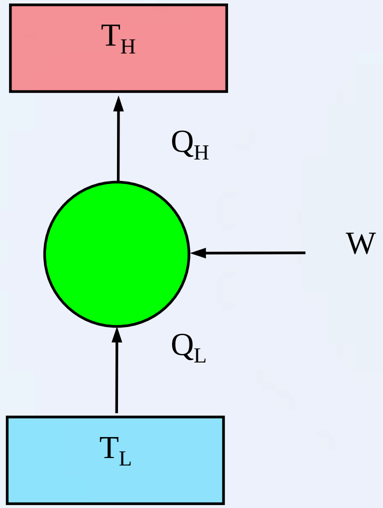
When system at rest: $Q_{12} - W_{12} = u_2 - u_1 \quad J/kg$

2. Second law of thermodynamics:

"It is impossible to convert heat completely to work; a part of it must be rejected to a heat sink at a lower temperature"

- For reversible heat engine: $\frac{Q_H}{Q_L} = \frac{T_H}{T_L}$

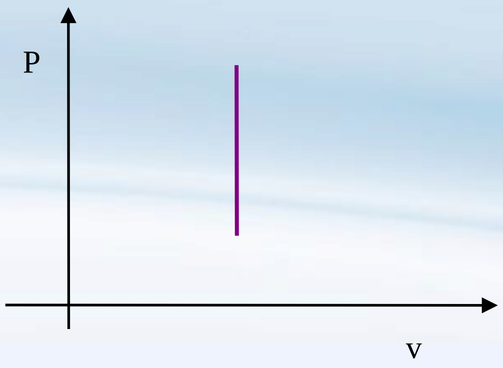
- For actual heat engine:

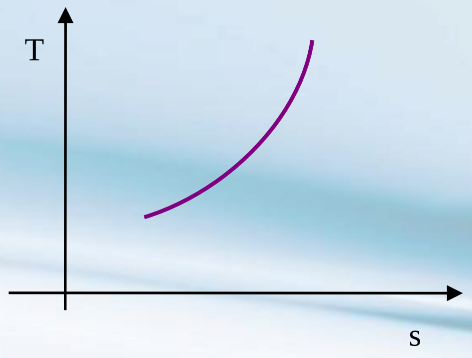


$$\eta = \frac{W}{Q_H}$$

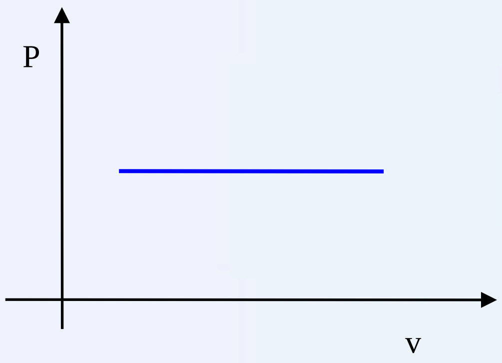
2. Thermodynamic processes:

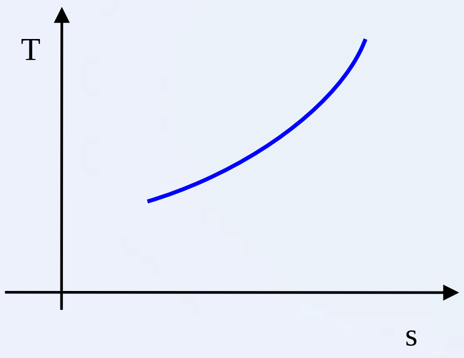
A-Constant volume process (isochoric or isometric)





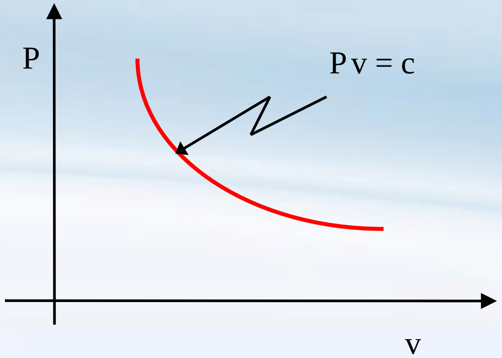
B-Constant pressure process (isobaric)

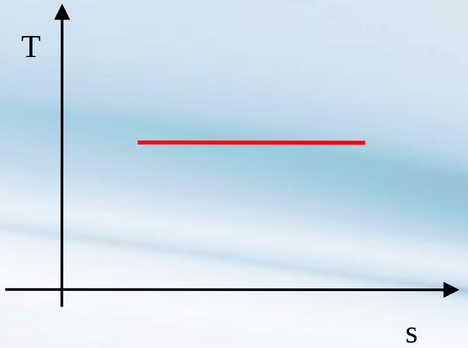




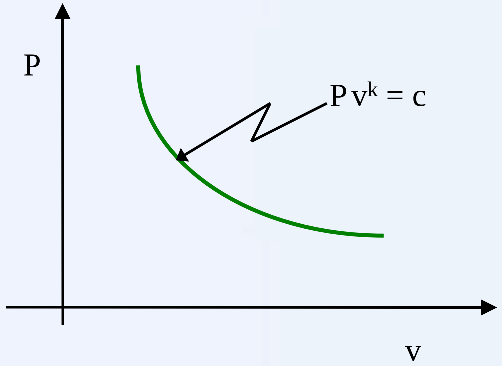
2. Thermodynamic processes:

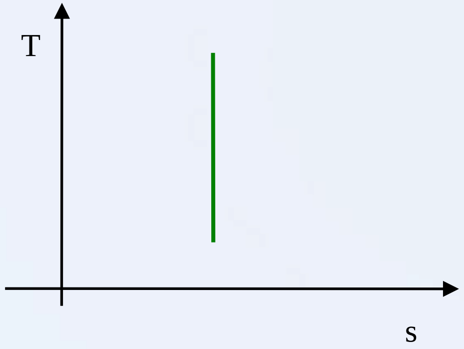
C-Constant temperature process (isothermal)





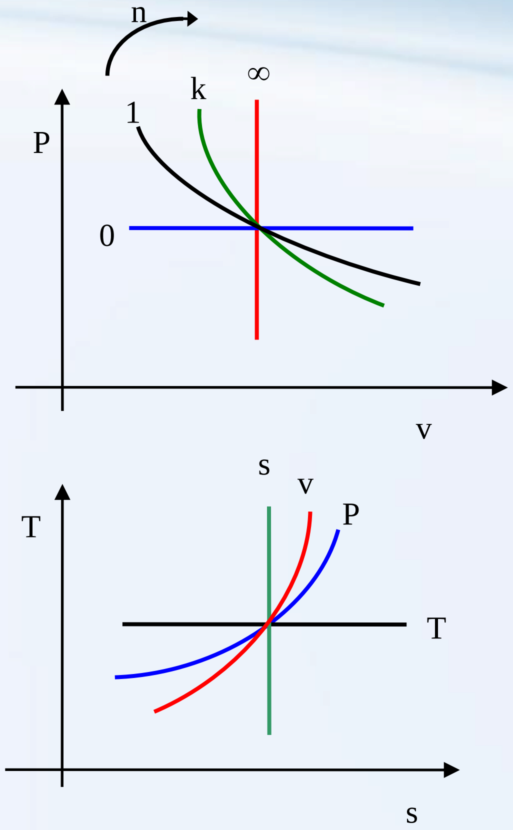
D-Constant entropy process (isentropic)

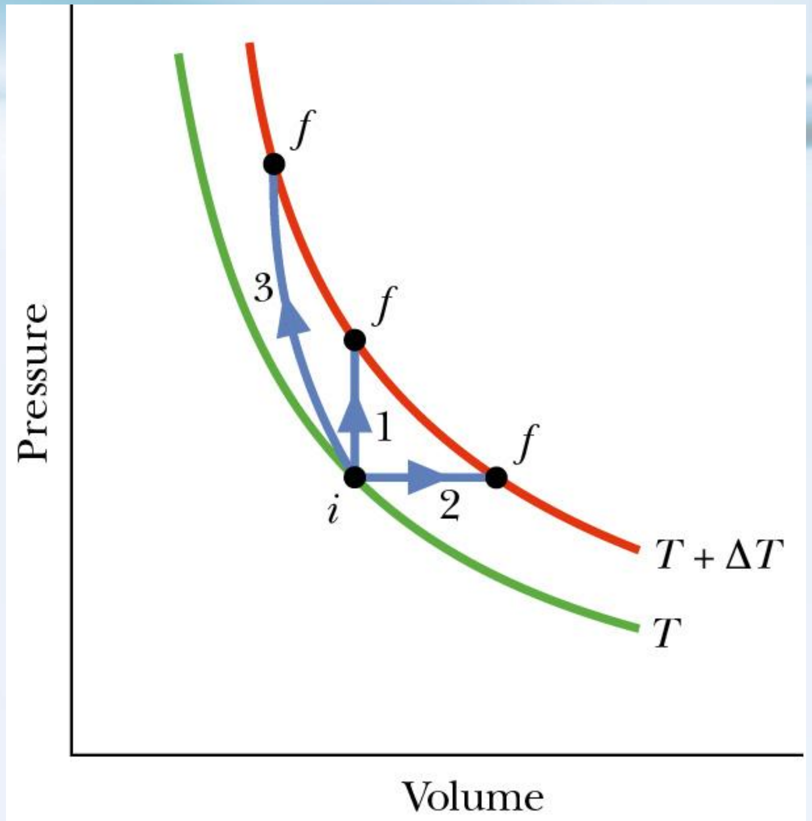




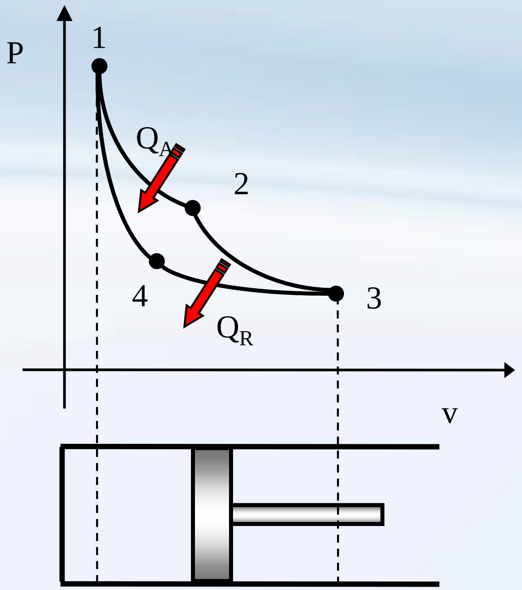
2. Thermodynamic processes:

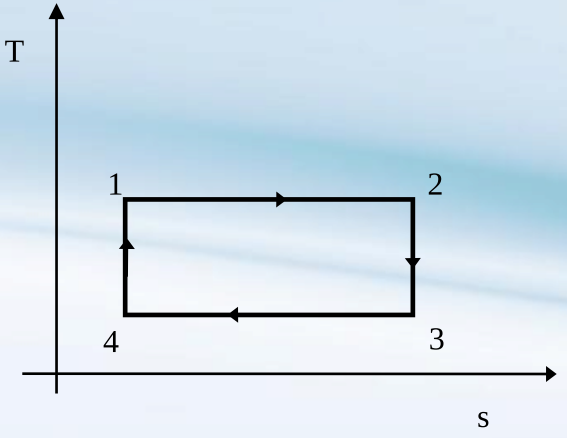
- for n ≠ 1 ➡ $W = \dfrac{P_1 v_1 - P_2 v_2}{n-1} \quad J/kg$
- for n = 1 ➡ $W = Pv \ln \dfrac{v_2}{v_1} \quad J/kg$





- In a ***Carnot cycle*** the working substance is subjected to a cyclic operation consisting of two isothermal and two isentropic (adiabatic + reversible) processes.



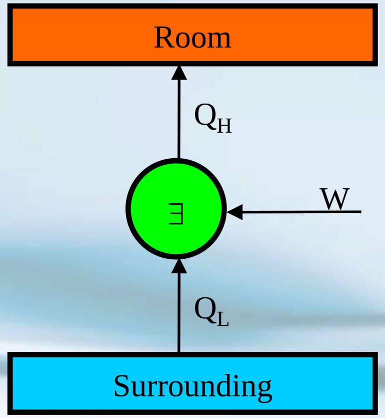


- *1-2 isothermal expansion [**heat addition**]*
- *2-3 isentropic expansion*
- *3-4 isothermal compression [**heat rejection**]*
- *4-1 isentropic compression*

Coefficient of Performance

- ***For heat pump :***

$$COP_p = \beta_p = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_L}$$

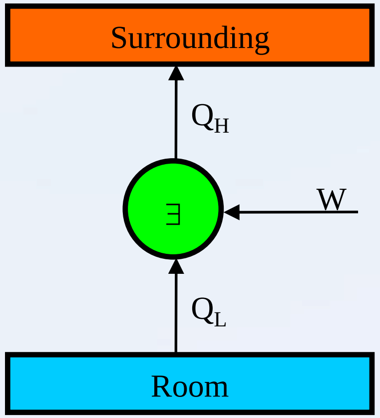


- ☐ ***for reversed Carnot heat pump :***

$$COP_{p_C} = \beta_{p_C} = \frac{T_H}{T_H - T_L}$$

- ***For refrigerator :***

$$COP_R = \beta_R = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L}$$



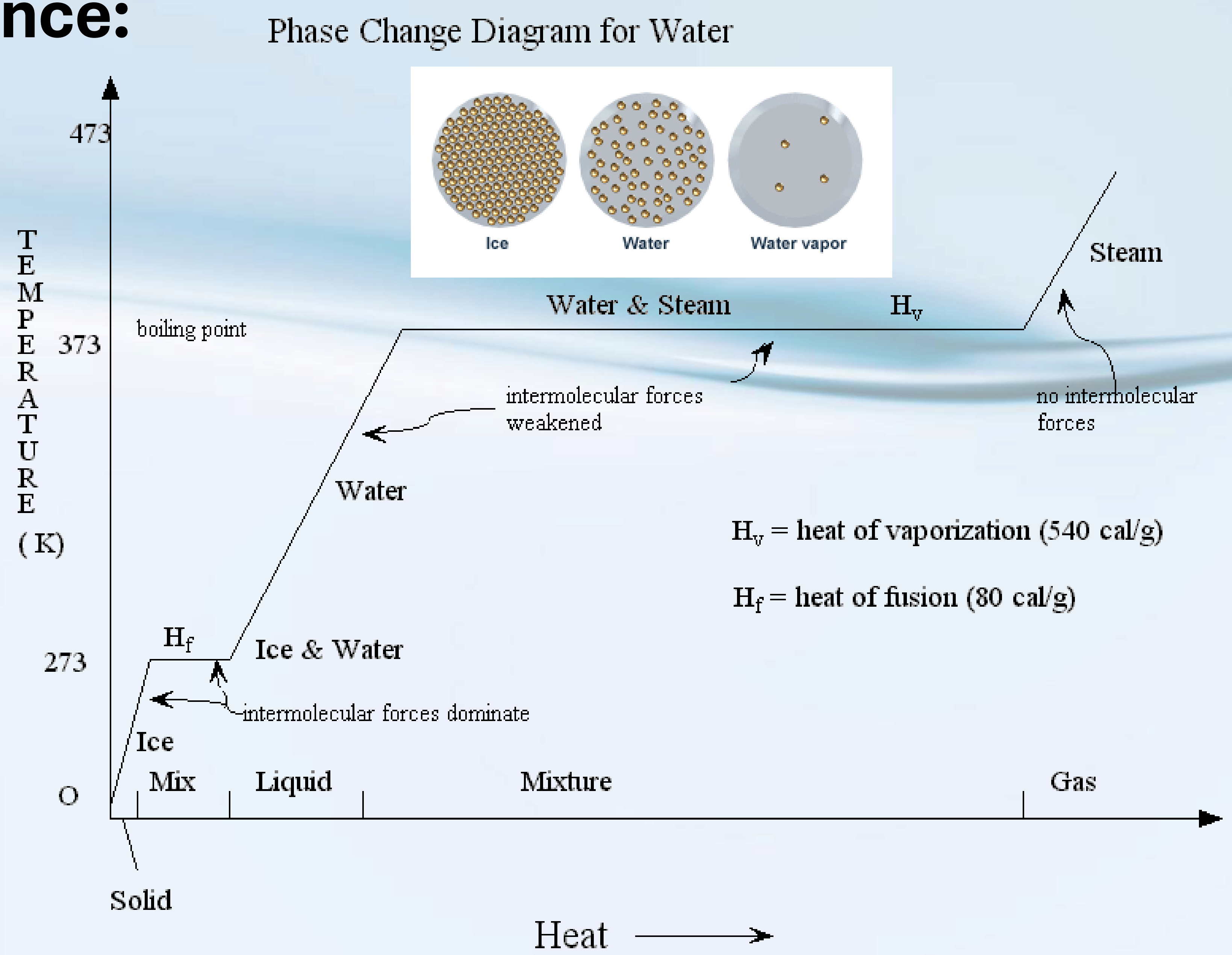
- ☐ ***for reversed Carnot refrigerator :***

$$COP_{R_C} = \beta_{R_C} = \frac{T_L}{T_H - T_L}$$

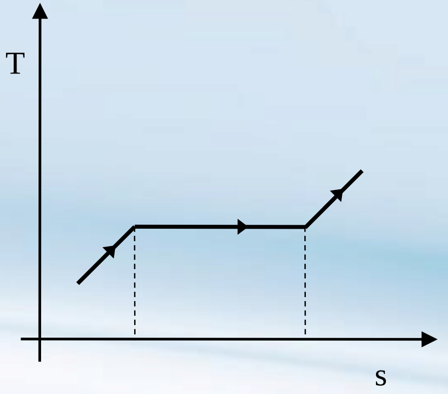
Ideal Gas Formulas

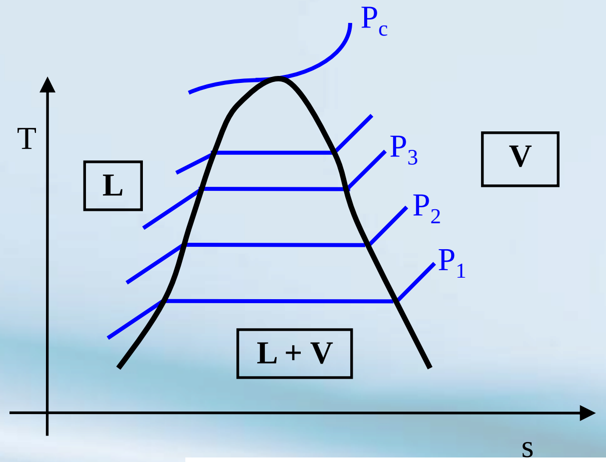
Process	Constant Volume	Constant Pressure	Isothermal	Isentropic	Polytropic
n	∞	0	1	k	$0 \le n \le$
P,v,T relations	$\frac{P_2}{P_1}=\frac{T_2}{T_1}$	$\frac{v_2}{v_1}=\frac{T_2}{T_1}$	$P_1v_1=P_2v_2$	$\frac{P_2}{P_1}=\left(\frac{v_1}{v_2}\right)^k=\left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}}$	$\frac{P_2}{P_1}=\left(\frac{v_1}{v_2}\right)^n=\left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}$
$\int Pdv$	0	$P(v_2-v_1)$	$Pv\ln\frac{v_2}{v_1}$	$\frac{P_1v_1-P_2v_2}{k-1}$	$\frac{P_1v_1-P_2v_2}{n-1}$
$-\int vdP$	$v(P_1-P_2)$	0	$Pv\ln\frac{P_1}{P_2}$	$\frac{k(P_1v_1-P_2v_2)}{k-1}$	$\frac{n(P_1v_1-P_2v_2)}{n-1}$
u_2-u_1	$c_v(T_2-T_1)$	$c_v(T_2-T_1)$	0	$c_v(T_2-T_1)$	$c_v(T_2-T_1)$
h_2-h_1	$c_P(T_2-T_1)$	$c_P(T_2-T_1)$	0	$c_P(T_2-T_1)$	$c_P(T_2-T_1)$
Q	$c_v(T_2-T_1)$	$c_P(T_2-T_1)$	$Pv\ln\frac{v_2}{v_1}$	0	$c_n(T_2-T_1)$
Specific Heat	c_v	c_P	∞	0	$c_n=\frac{c_v(k-n)}{1-n}$
s_2-s_1	$c_v\ln\frac{T_2}{T_1}$	$c_P\ln\frac{T_2}{T_1}$	$R\ln\frac{v_2}{v_1}$	0	$c_n\ln\frac{T_2}{T_1}$

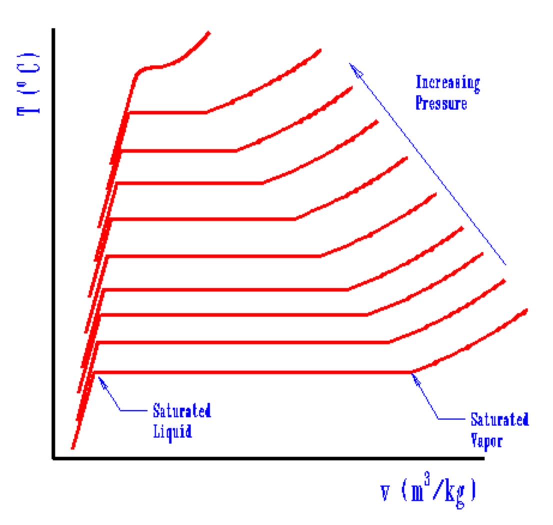
Pure substance:

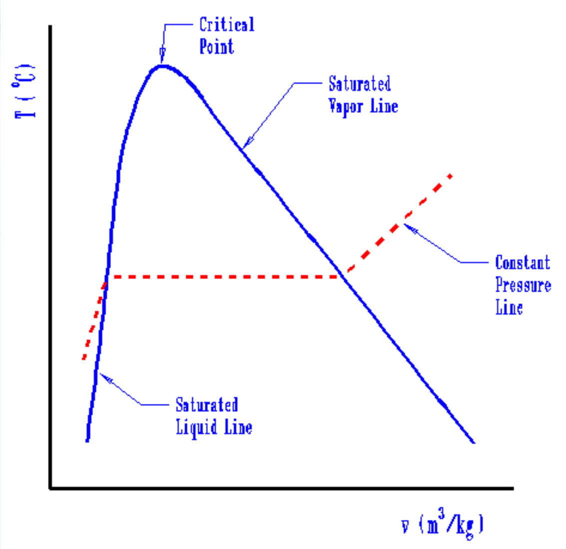


Saturation lines:









There are two saturation lines; saturated liquid line (SLL) and saturated vapor line (SVL). Between these saturation lines there is a mixture of liquid and vapor. In the mixed-phase regions, temperature and pressure cannot be specified independently.

Tripple point:

- The phase diagram is P-T diagram. It consists of three saturation lines; solid-liquid line, liquid-gas line and solid-gas line.