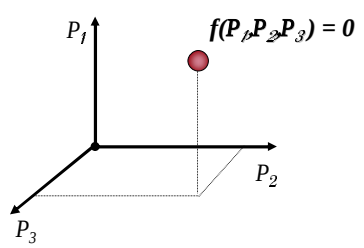
EVALUATING THERMODYNAMIC PROPERTIES

The P-V-T Surface for Water

The state principle...

Description of thermodynamic state



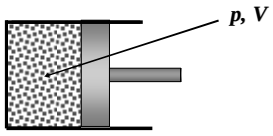
Experimental basis for the description of the thermodynamic state

One independent property ***for each way that the energy of the system can be varied independently.***

Experimental basis

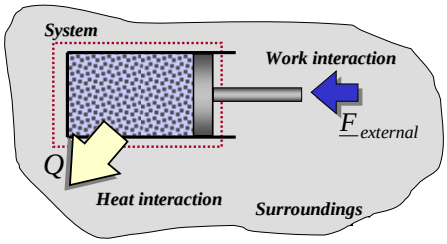
The number of independent properties that uniquely describes the state of the system is the number of relevant work interactions plus one.

Simple, compressible systems



In simple chemical systems, there is only one way to alter E, or U, by work via a quasistatic process.

Simple chemical systems



Interactions = 2
Properties Needed = 3

Simple compressible systems

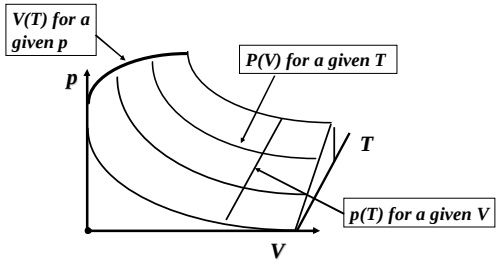
$$f(p,V,T) = 0$$

$$p = p(V,T)$$

$$V = V(p,T)$$

p-V-T surfaces…

P-v-T Surfaces

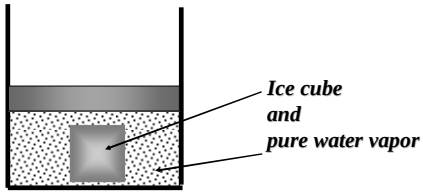


State equations

$f(p,v,T) = 0$	$f(U,V,T) = 0$
$p(v,T) = p$	$U = U(V,T)$
$v(p,T) = v$	$V = V(U, T)$
$T(p,v) = T$	$T = T(U,V)$

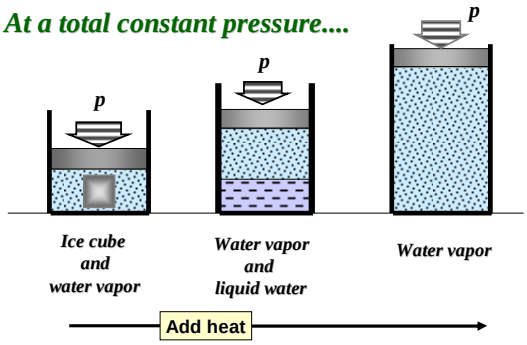
The p-V-T surface for water…

The P-v-T surface for water



Solid-vapor equilibrium.

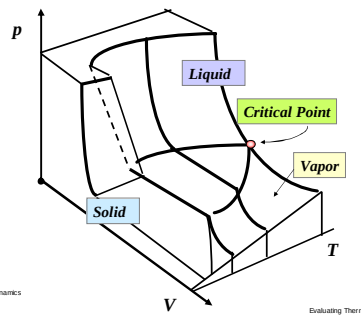
At a total constant pressure....



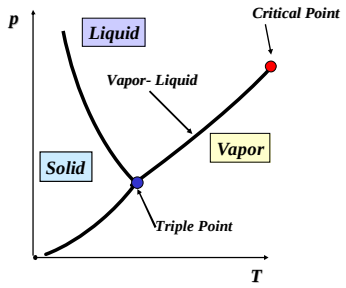
The p-V-T surface for water

- **Solid in equilibrium with vapor (0 ^{o}C)**
- **Solid in equilibrium with vapor and liquid (0 ^{o}C)**
- **Liquid and vapor in equilibrium (0 < T < 100 ^{o}C)**
- **Saturated Vapor (T = 100 ^{o}C)**
- **Superheated Vapor (T > 100 ^{o}C)**

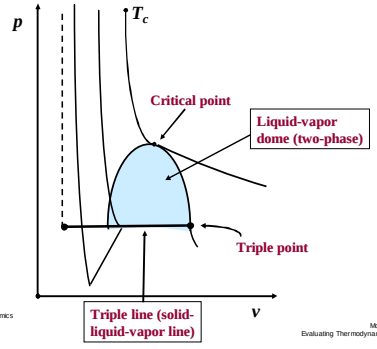
The P-v-T surface for water



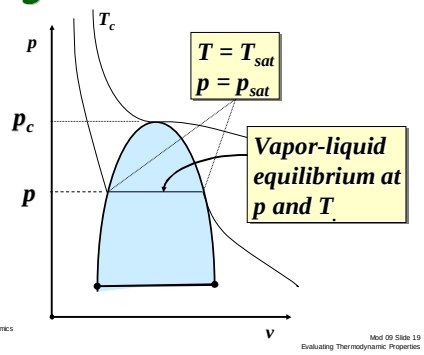
The p-T plane for water



P-v diagram for water

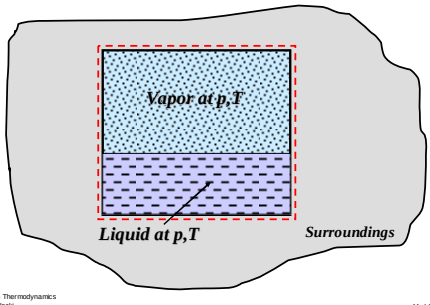


P-v diagram for water



Quality...

Liquid-vapor equilibrium



Quality defined

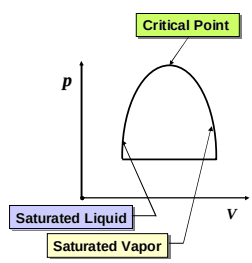
$$x = \frac{m_{vapor}}{m_{liquid} + m_{vapor}}$$

The two-phase region for water

$$V = V_l + V_g$$

$$v = v_l + v_g$$

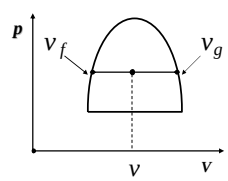
$$v_{fg} = v_g - v_l$$



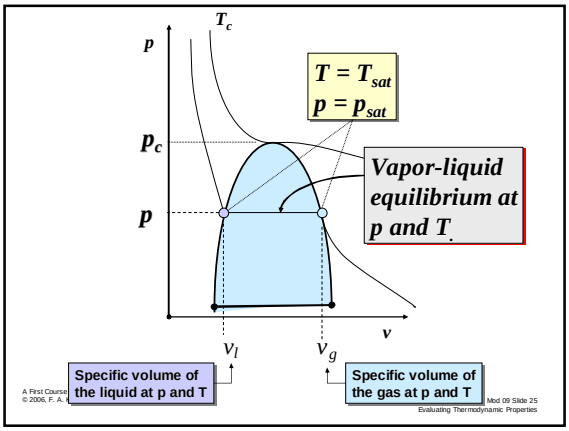
Relations in the two-phase region (vapor-liquid equilibrium)

$$v = v_l + v_g$$

$$v_f < v < v_g$$



Quality, x, allows location of states inside the vapor-liquid region.



Quality

$$x = \frac{m_{vapor}}{m_{liquid} + m_{vapor}}$$

$$v_{fg} = v_g - v_f$$

$$v = v_f + x v_{fg}$$

$$v = x v_g + (1 - x) v_{fg}$$

Internal energy in the vapor-liquid region

$$u_{fg} = u_g - u_f$$

$$u = u_f + x u_{fg}$$

$$u = x u_g + (1 - x) u_{fg}$$

Key concepts and terms

Critical point

P - v - T surface

Quality

Saturation pressure

Saturation temperature

State equation

State surface

The State Principle

Triple point