ME321 10-02-2017

Independant and dependant properties:

- Two properties are independant if one can be varied without varying the other

  State postulate:
  The state of a simple compressible system is completely specified by two independant intensive properties.

- State: Conditions of a system characterized by the values of it's properties.

An equation of state relates a system of state properties.

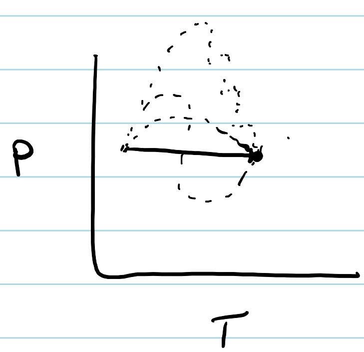
$$P = \rho R T$$

What is the state of the air in this room?

$$\boxed{\begin{array}{l} T = 20°C \\ P = 101\ kPa \end{array}} \xrightarrow{\text{Process}} \boxed{\begin{array}{l} T = 25°C \\ P = 101\ kPa \end{array}}$$

In this example the process may be heat addition.

The series of states through which a process passes is the <u>process path</u>

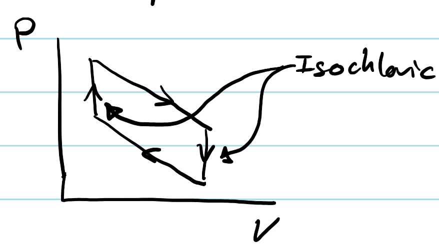


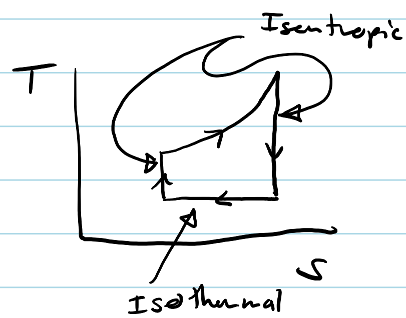
Types of processes.

iso → constant

isothermal	const. T
isobaric	const. P
isochlaric	const. V
isentropic	const. entropy
isenthalpic	cost. enthalpy

cycles - initial and final states are the same after some process.





Pure Substances

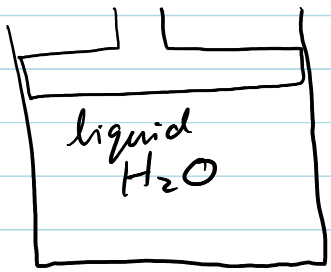
- A homogeneous substance with invariable chemical composition which may exist in multiple phases.

Phases of pure substances

Solid: close-packed molecules oscillating about a fixed position.
Liquid: not a fixed position
Gas: large separation

State 1:

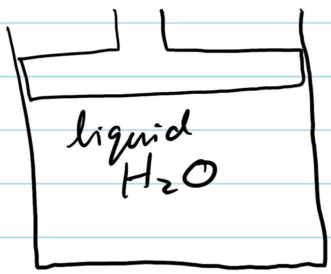
State 1



$P = 1\,atm$
$T = 20^\circ C$
$V = V_1$
} compressed liquid

Add Q until T reaches $100^\circ C$

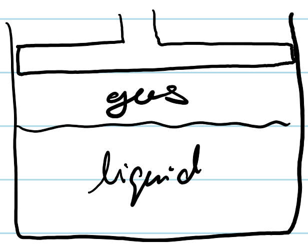
State 2



$P = 1\,atm$
$T = 100^\circ C$
$V_2 > V_1$
} saturated liquid "about to vaporize"

Add Q → phase change

State 3



$P = 1\,atm$
$T = 100^\circ C$
$V_3 > V_2$
} saturated liquid, saturated vapor

Temp const. for pressure P. → (T, P) const → ($T_{const.}$, $P_{const.}$)

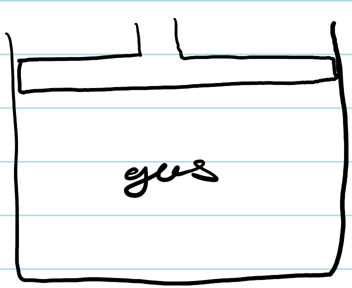
@ $T = 100^\circ C$ for a saturated mixture, you can find table A-4:

$$v_f = 0.001043\ m^3/kg \quad \text{(liquid)}$$
$$v_g = 1.6720\ m^3/kg$$

Note: $\rho = \frac{1}{v}$

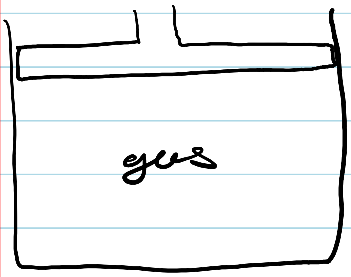
Add just enough Q until only vapor remains

State 4



$P = 1\,atm$
$T = 100^\circ C$
$V_4 > V_3$
} saturated vapor

State 5



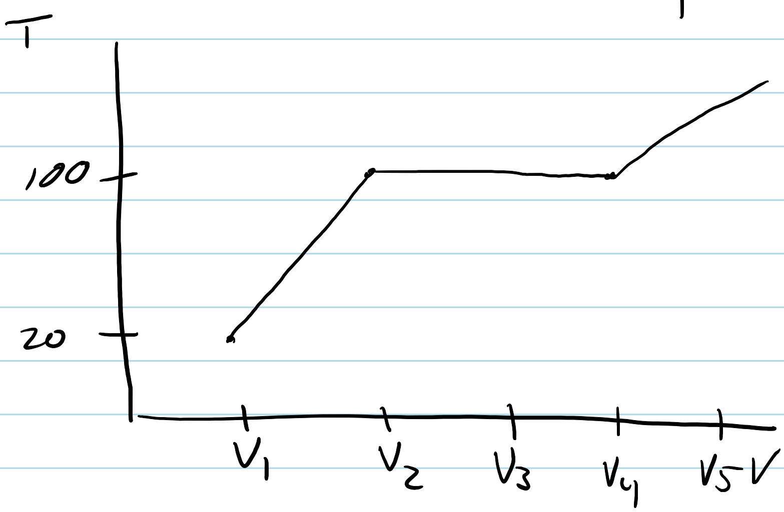
Add more Q

$Q \to T$

$P = 1\,atm$
$T > 100°C$
$V_5 > V_4$
— super-heated vapor

Phase A to Phase B

		finish	
start	Solid	liquid	vapor
solid		Latent heat of fusion	
liquid	Latent of fusion		Latent heat of vaporization
vapor		Latent of vaporization	

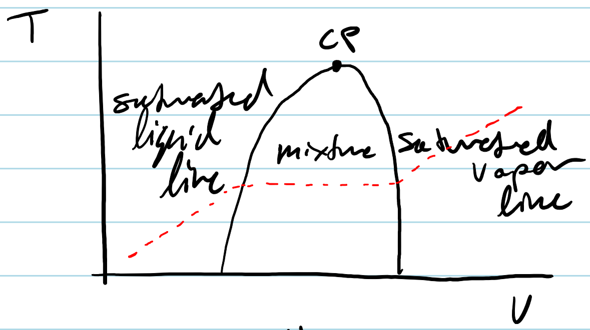


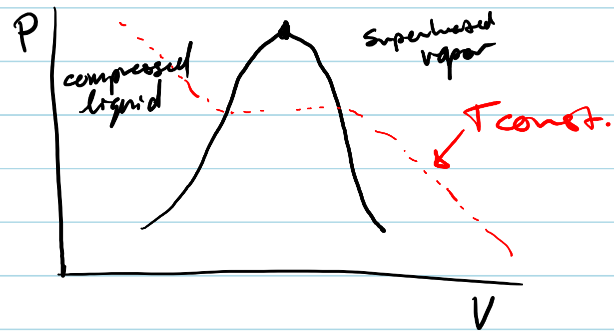
@ 1atm

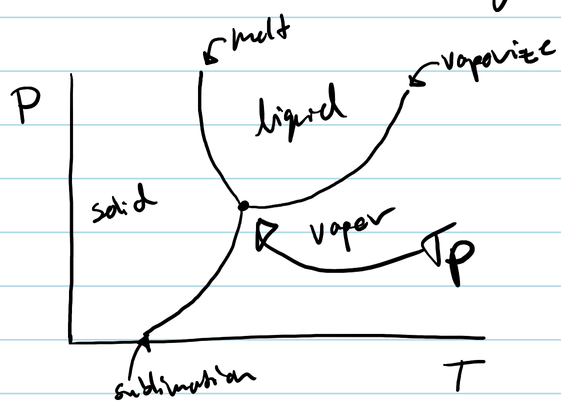
Critical Point – the point under sufficient pressure at which the energy associated with a phase change approaches zero. This pressure is called $P_{critical}$

The dome defined by the end points of the saturated mix lines is called the saturation dome.

For water, the critical point is defined by
$P_{cr} = 22.06\,MPa$, $T_{cr} = 373.95\,°C$, and
$V_{cr} = 0.003106\ m^3/kg$







A plot of P vs. T for a pure substance is known as a phase diagram.

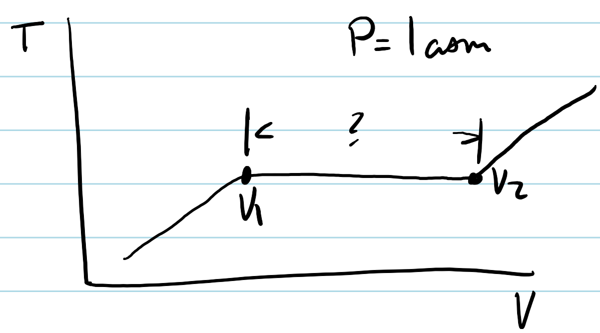
← A substance that expands on freezing.

<u>Opposites</u>

sublimation → reverse sublimation

melting → freezing

vaporization → condensation



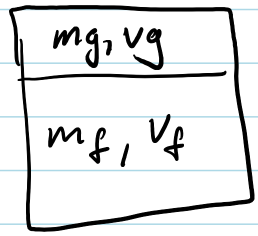
We can find out how much of each phase we have by interpolating volume!

$$\text{Quality } x = \frac{\text{mass saturated vapor}}{\text{total mass}} = \frac{m_g}{m_g + m_f}$$

saturated liquid → $0 \leq x \leq 1$ ← saturated vapor

Consider the saturated mixture.

$$\mathcal{V} = \mathcal{V}_f + \mathcal{V}_g$$



$$m = m_f + m_g$$

$$\mathcal{V}_f = m_f v_f \qquad \mathcal{V}_g = m_g \mathcal{V}_g$$

$$m v = m_f v_f + m_g v_g$$

$$\mathcal{V} = \frac{m_f v_f + m_g v_g}{m}$$

$$\mathcal{V} = \frac{m_f}{m} v_f + \frac{m_g}{m} v_g$$

$$x = \frac{m_g}{m_f + m_g} = \frac{m_g}{m}$$

$$\frac{m_f}{m} = \frac{(m_g + m_f) - m_g}{m} = 1 - x$$

$$v = (1-x)\, v_f + x\, v_g$$

It follows that if we have a saturated mixture with quality x: The properties of the mixture are given by:

$$\text{prop mix} = (1-x)\begin{pmatrix}\text{prop sat}\\ \text{liquid}\end{pmatrix} + (x)\begin{pmatrix}\text{prop sat}\\ \text{vapor}\end{pmatrix}$$