# Properties of Real Fluids

Last time we discussed balances of energy or the 1st Law of thermodynamics. We realized @ the end that if we calculated the change in internal energy, we still needed to know how to relate this to other properties of a fluid.

**Property**: Characteristics of a system that are determined without knowing the history of the system & can be measured @ an instant in time.

What are some of the properties of a substance?

$T, P, \rho, v, w, C_p, C_v, C_s, u, h, a, g, s \ldots \forall, m \ldots$

These properties can be divided into 2 parts:

**Extensive properties**: value of a property is equal to its sum over the entire system. mass, m. Volume, $\forall$, people, etc.

**Intensive properties**: a property that is not additive & is a measure of the energy state of the molecule, not the amount of molecules. Temperature, T, Pressure, P, Speed of sound, w. ~~Doesn't care about the total amount of molecules~~, 4.2 ME301 F2010

Are the properties of a ~~fluid~~ substance inter-related?

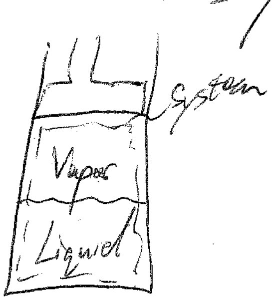
If I have a fluid in a container @ some T, P ⇒ $\rho$ if I heat it up, then cool it to the same T & P do I have the same density as before? ⇒ Yes!! $\rho$ is a property

- All fluids have a Surface of State: 3 dimensional surfaces that represents a fluid. Pg 125 6th edition
- A state of a system is simply a point on a surface of state.
- How many independent intensive properties do I need to define a state on that surface? → 2
- Where do we get values/numbers for the surface of state?

  Tables? Plots? Software? Simplifications?

  We will primarily use these 3 in class

- Tables: Back of your book/Properties supplemental
  - Which table do you use? ⇒ Depends on fluid & state
  - there are 3 different tables for water
    - Superheated vapor, - compressed liquid, - saturation/2-phase



⇒ If system is in equilibrium with 2 phases it is in a saturated state. T & P are not independent in 2-phase region, therefore we need another type of property.

Quality: relative amount of liquid & vapor in a system

$$\text{Quality} = x = \frac{\text{mass of vapor}}{\text{total mass}} = \frac{m_g}{m} \quad \text{or} \quad x = 1 - \frac{m_f}{m}$$

is $x = 1.0$ Saturated vapor

if $x = 0.0$, saturated liquid

- Sometimes it is easier to know the volumes of the individual phases than the masses.

German for liquid: fluids

German for vapor gas...

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

specific volume $\frac{m^3}{kg}$

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

$$\mathcal{V} = m_f v_f + m_g v_g \Rightarrow \frac{\mathcal{V}}{m} = \underbrace{\left(\frac{m_f}{m}\right)}_{(1-x)} v_f + \underbrace{\left(\frac{m_g}{m}\right)}_{x} v_g \quad \text{so}$$

$$\frac{\mathcal{V}}{m} = v = (1-x) v_f + (x) v_g \Rightarrow v = v_f + x(v_g - v_f) \quad \text{or} \quad x = \frac{(v - v_f)}{(v_g - v_f)}$$

So if we know T & x we can go to the tables $v_f + x(v_g - v_f) = \underline{v}$

If we have superheated vapor or compressed liquid, no quality to worry about. But what if T or P is in between rows?

Interpolate!!

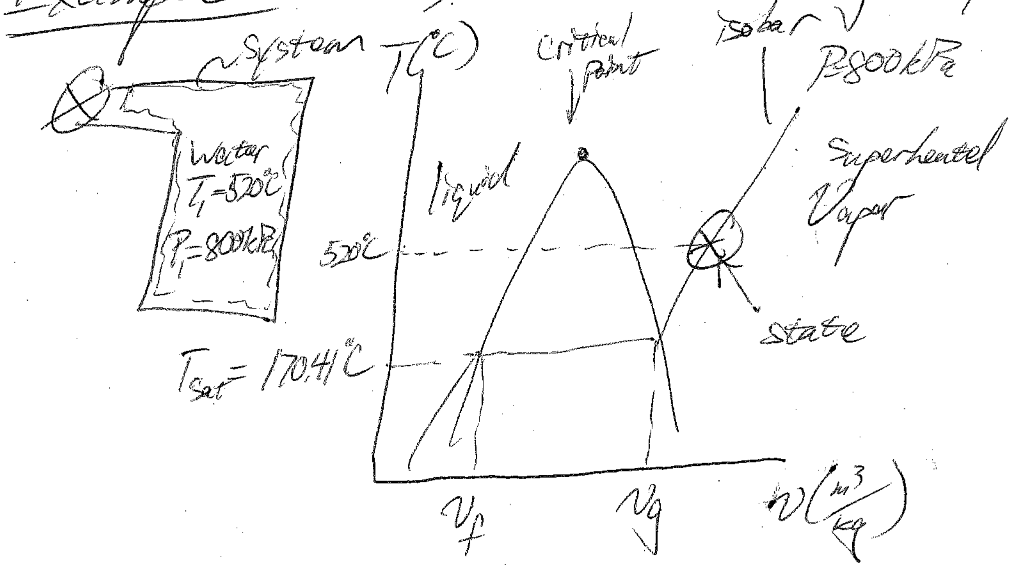
$$\frac{Y - Y_1}{Y_2 - Y_1} = \frac{\overset{Z}{\cancel{X}} - \overset{Z}{\cancel{X_1}}}{\underset{Z}{\cancel{X_2}} - \underset{Z}{\cancel{X_1}}} \Rightarrow \frac{v - v_1}{v_2 - v_1} = \frac{T - T_1}{T_2 - T_1}$$

Where 2 is for the row below, 1 is the row above, knowing T ⇒ v.

Example

4.4 F2010 ME301

**Example** a) Sketch a T-V diagram & locate the state



B) Determine the specific volume of the water $(m^3/kg)$ & the density.

- From superheated vapor tables. the entries closest to 800kPa, & T=520°C are

$v = P=800kPa,\ T=500°C,\ v_{low}=0.4433\ m^3/kg$

$v = P=800kPa,\ T=600°C,\ v_{high}=0.5018\ m^3/kg$

Interpolate!

$$\frac{v-0.4433}{0.5018-0.4433}=\frac{520-500}{600-500}\Rightarrow$$

$$\xRightarrow{\text{algebra}} v=\frac{520-500}{600-500}(0.5018-0.4433)+0.4433\Rightarrow \boxed{v_1=0.455\ m^3/kg}$$

$$\rho=\frac{1}{v}=\boxed{\rho=2.20\ kg/m^3}$$

Got to here

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C) If the mass of water in the container is m=7.2kg, what is the volume of the container $(m^3)$?

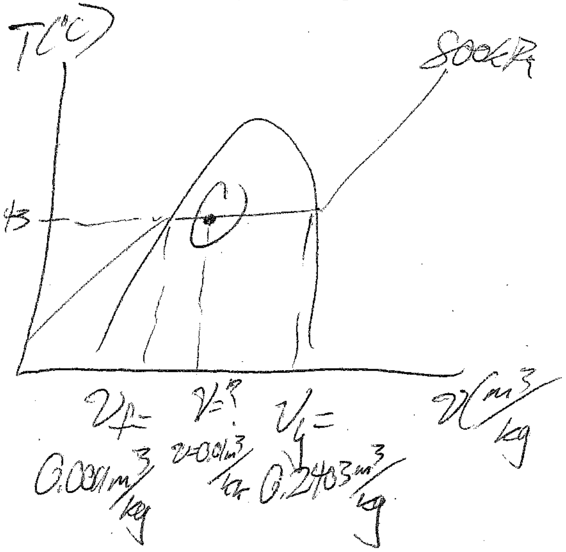
$$v=\frac{V}{m}\Rightarrow V=vm=7.2kg\,\bigg|\,\frac{0.455m^3}{kg}\Rightarrow \boxed{V=3.276m^3}$$

By just knowing the T, P & mass of the fluid, we determined the volume of the ~~fluid~~ container.

D) What if I just knew that $P=800kPa$, $\mathcal{V}=3.276m^3$ but $m=327.6kg$

Can I locate this state on an EOS or T-v diagram?

$\mathcal{V}$ & $m$ are both extensive $\overset{\text{mass dependent}}{\text{properties}}$ & don't help us directly define the state! but $v=\frac{\mathcal{V}}{m}=\frac{3.276m^3}{327.6\,kg} \Rightarrow v=0.01\,m^3/kg$



E) What is the mass of the liquid & vapor in the container?

$$x=\frac{(v-v_f)}{(v_g-v_f)} \Rightarrow \frac{(0.01-0.0011)}{(0.2403-0.0011)} \Rightarrow \boxed{x=0.0372}$$

$$x=1-\frac{m_f}{m} \text{ so } m_f=(1-x)m \Rightarrow (1-0.038)327.6kg \Rightarrow \boxed{m_f=315.2kg \text{ liquid}}$$

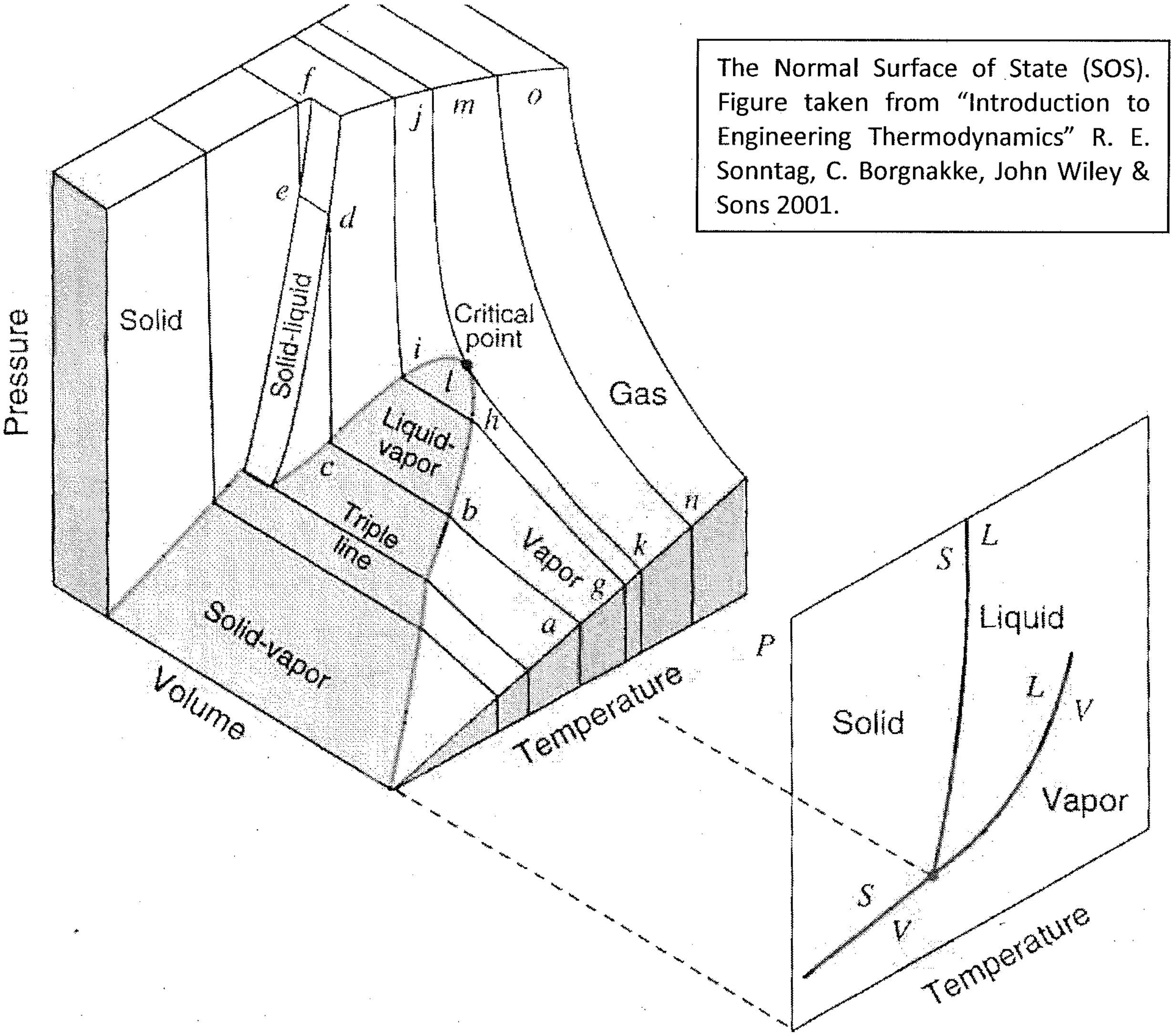
$$m_g=m-m_f \Rightarrow \boxed{m_g=12.4kg}$$

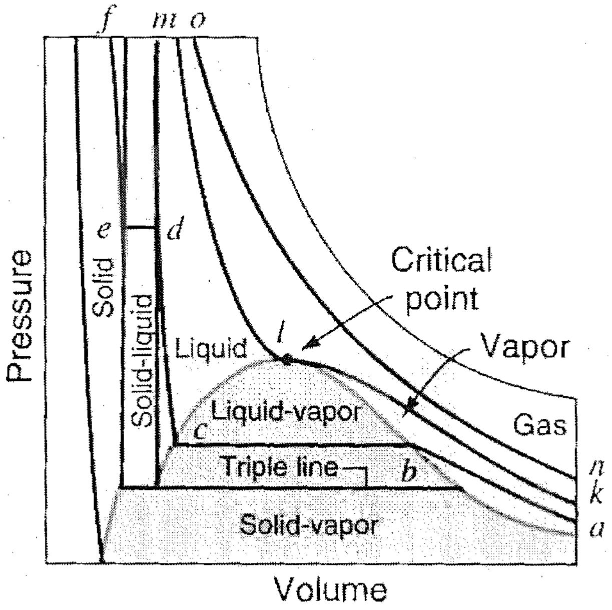
## Now do it in ees

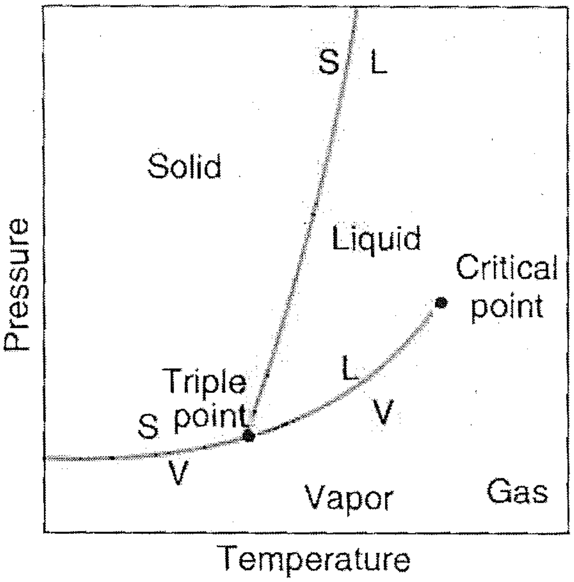
For a real fluid in ees, we can look up properties very easily

v = volume('fluid', T=T, P=P)

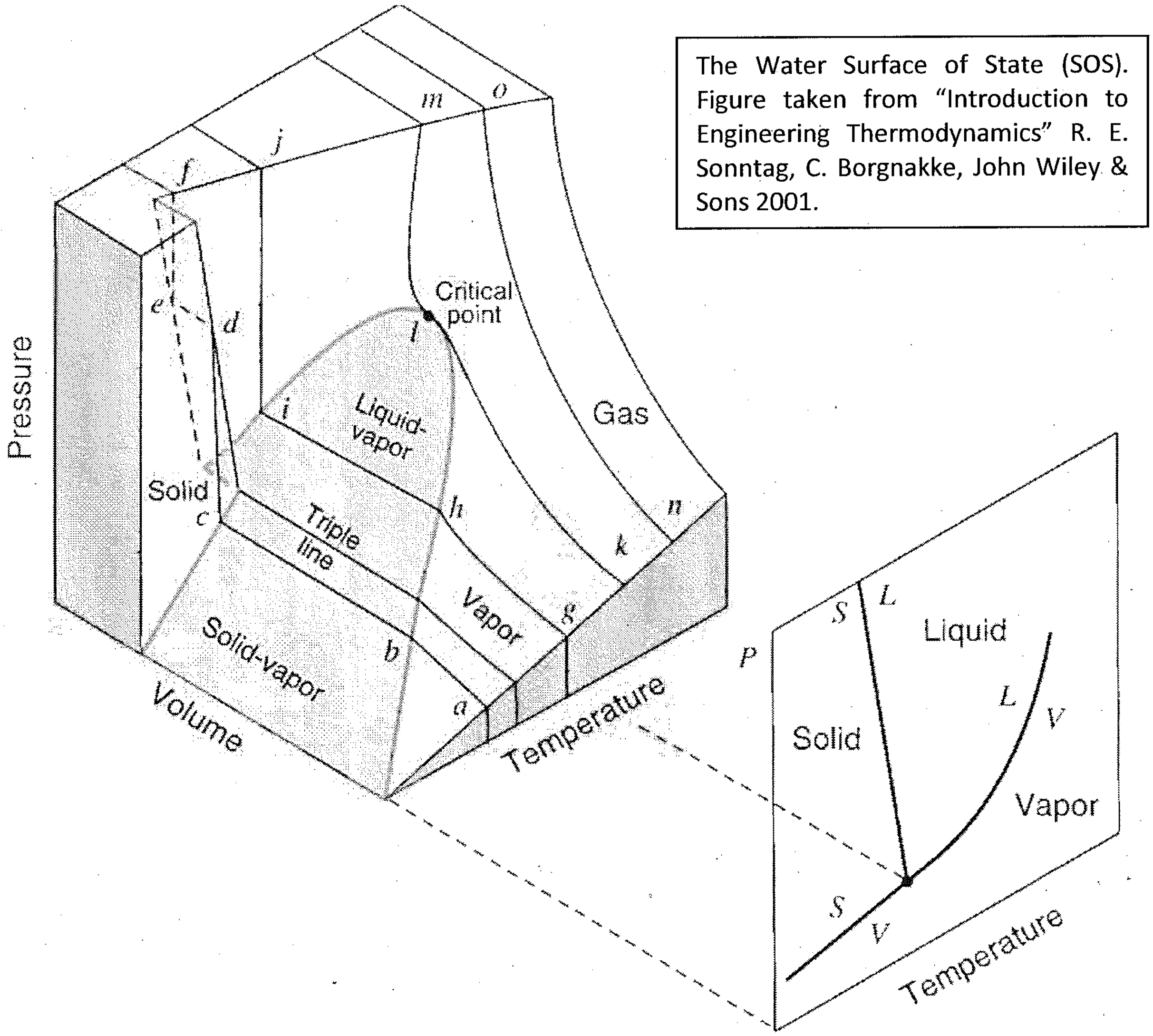
The Normal Surface of State (SOS). Figure taken from "Introduction to Engineering Thermodynamics" R. E. Sonntag, C. Borgnakke, John Wiley & Sons 2001.

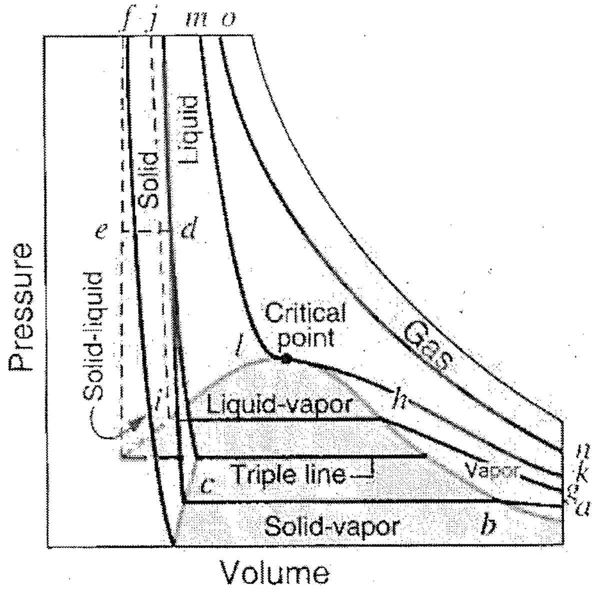


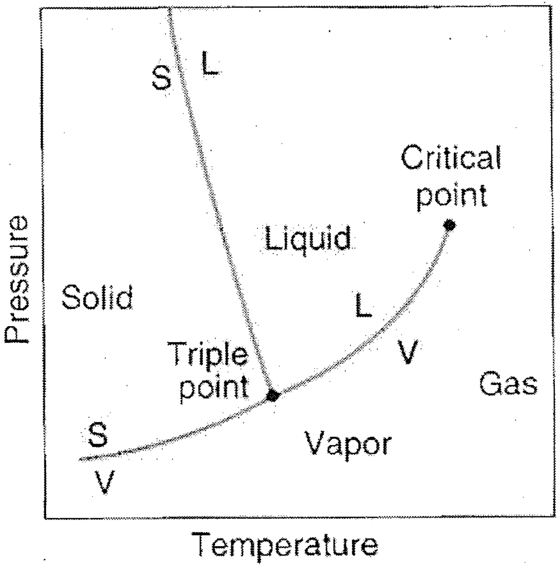


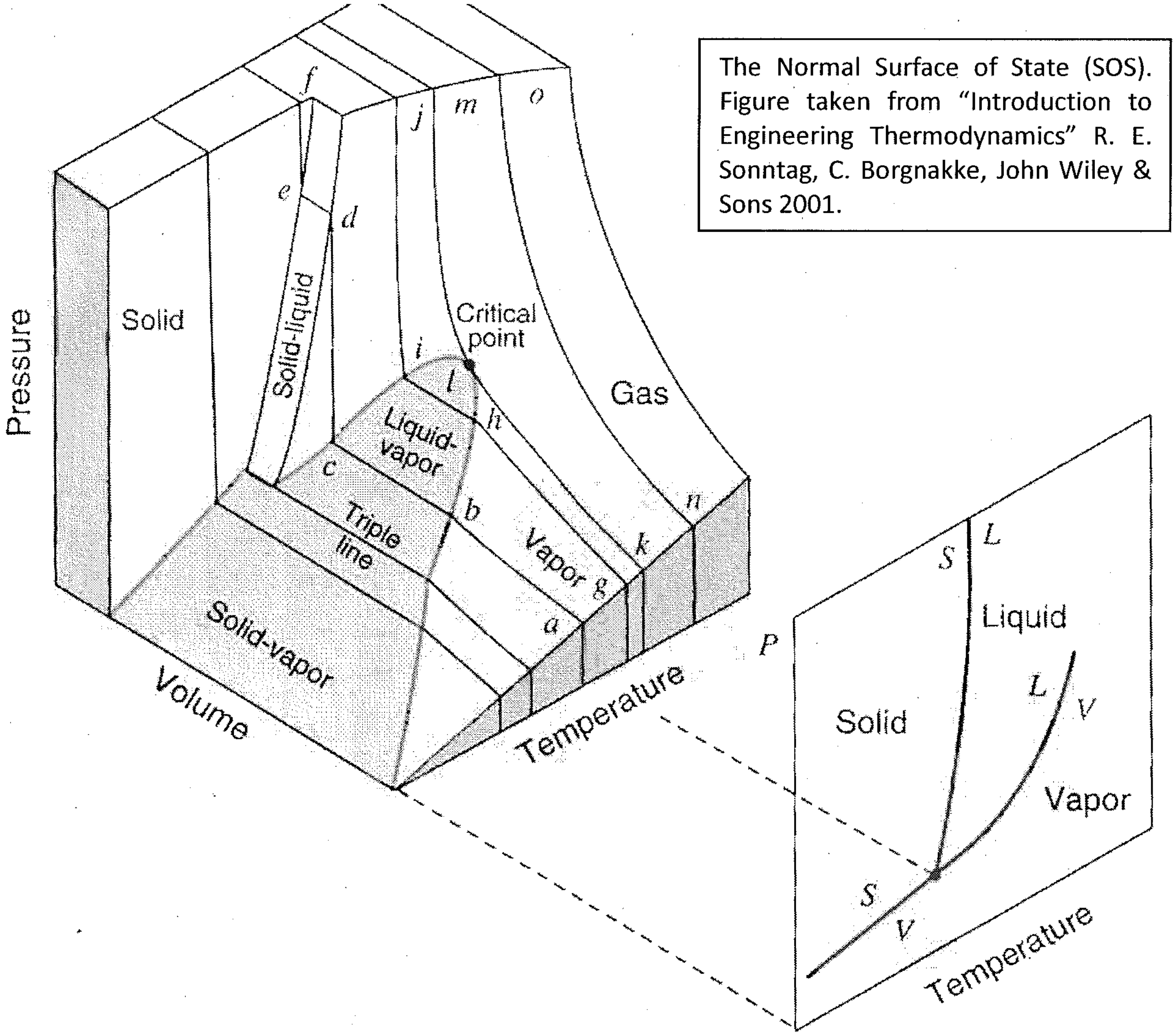


The Water Surface of State (SOS). Figure taken from "Introduction to Engineering Thermodynamics" R. E. Sonntag, C. Borgnakke, John Wiley & Sons 2001.









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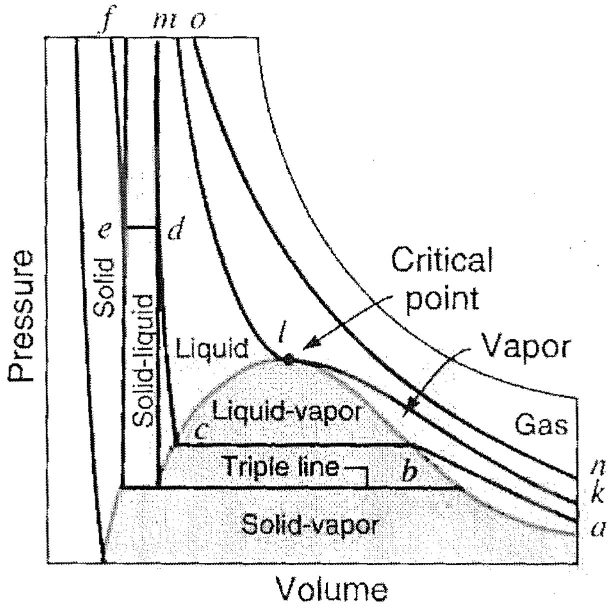

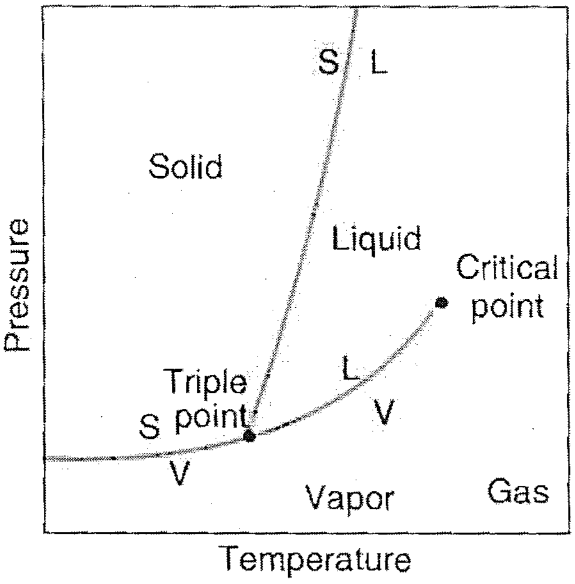

The Water Surface of State (SOS). Figure taken from “Introduction to Engineering Thermodynamics” R. E. Sonntag, C. Borgnakke, John Wiley & Sons 2001.