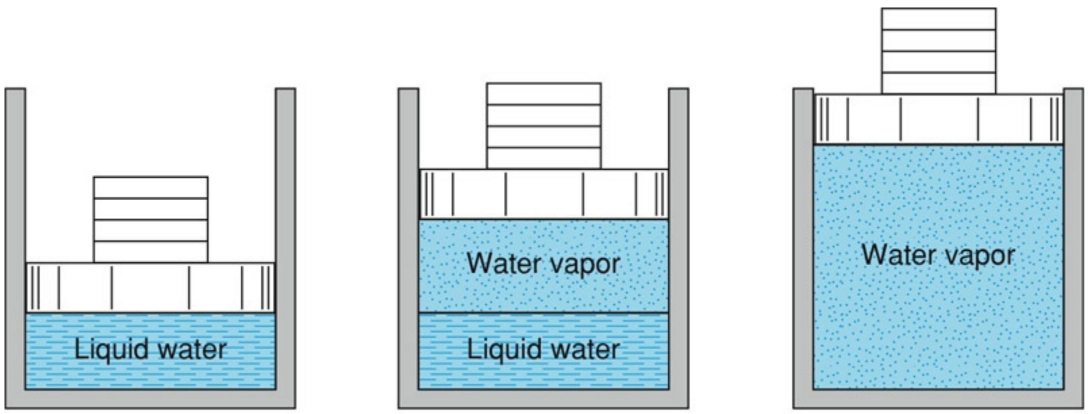
ENGR 3203
Properties of Pure Substances

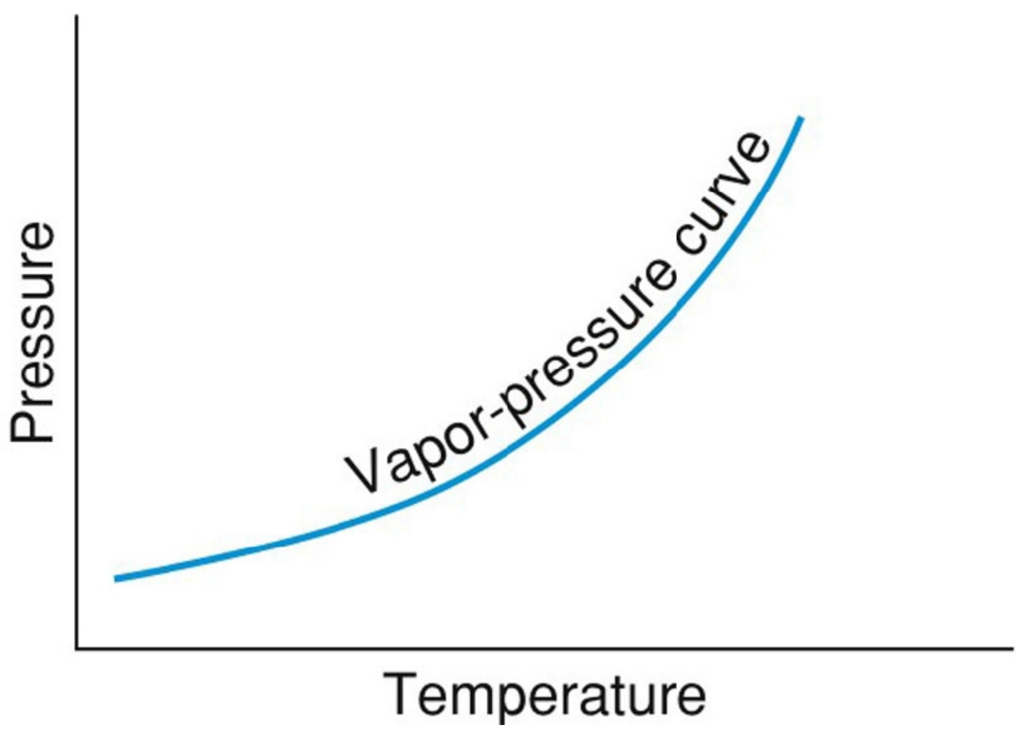
We will be dealing with pure substances? What are they?

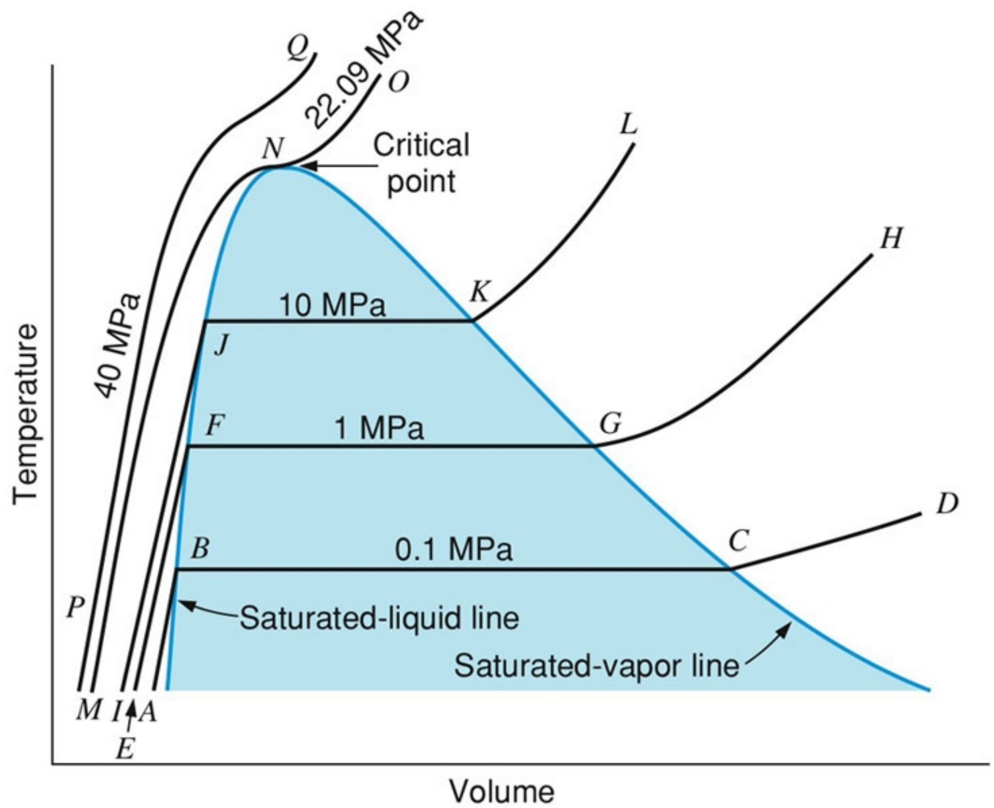
What is a simple compressible substance (SCS)?

Phase change of a pure substance.



(a) (b) (c)



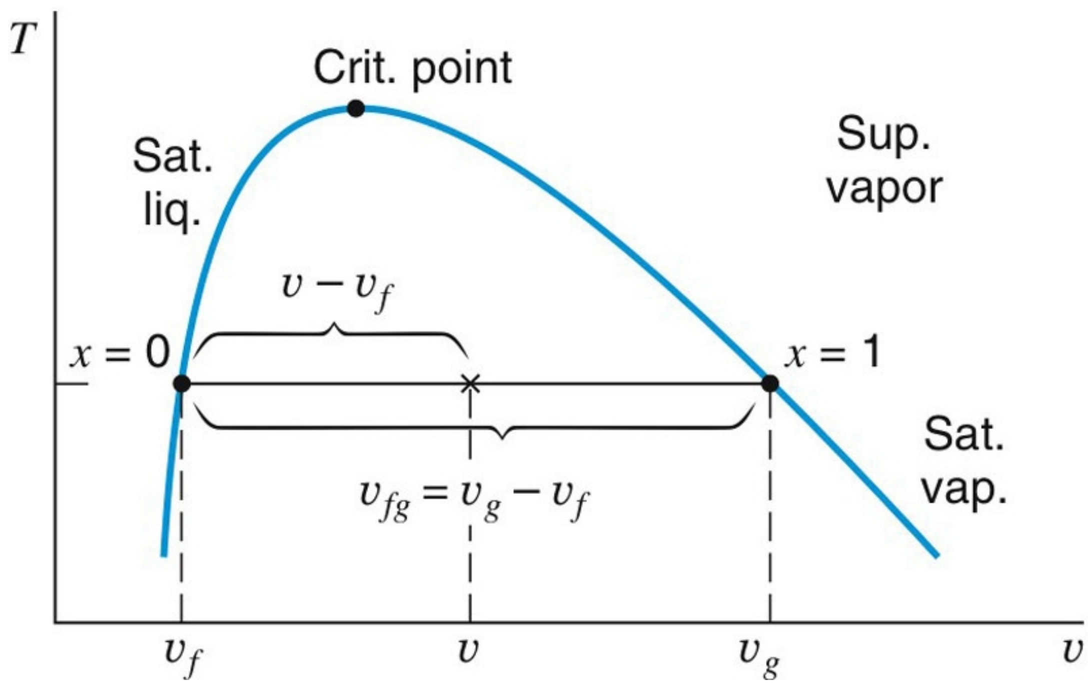


compressed liquid (cl)
saturated liquid (sat. liq.l --- *subscript f*)
saturated mixture (sat. mix.)
saturated vapor (sat. vap. --- *subscript g*)
superheated vapor (sh)
saturated solid (sat. sol. --- *subscript i*)

Some applications above critical point. These substances are just called *fluids*. Some basic critical point data is on p. ___ in Table _____ in the book.

Quality (x) $x = \frac{m_{vapor}}{m_{total}}$ $x_{sat. Liq.}$ = ________, $x_{sat. Vap.}$ = ________

Properties for cl, sat. liq., sat. vap., sh, sat. sol., are tabulated in the appendices, but you need to also find properties of sat. mixtures as well.

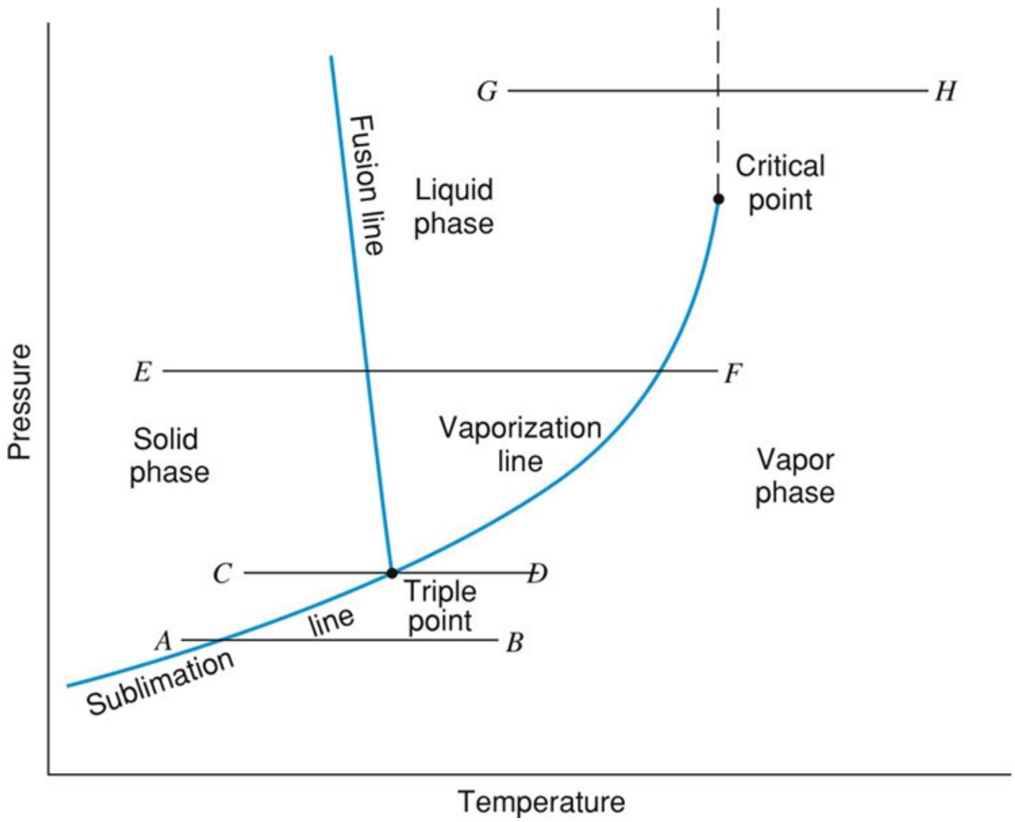


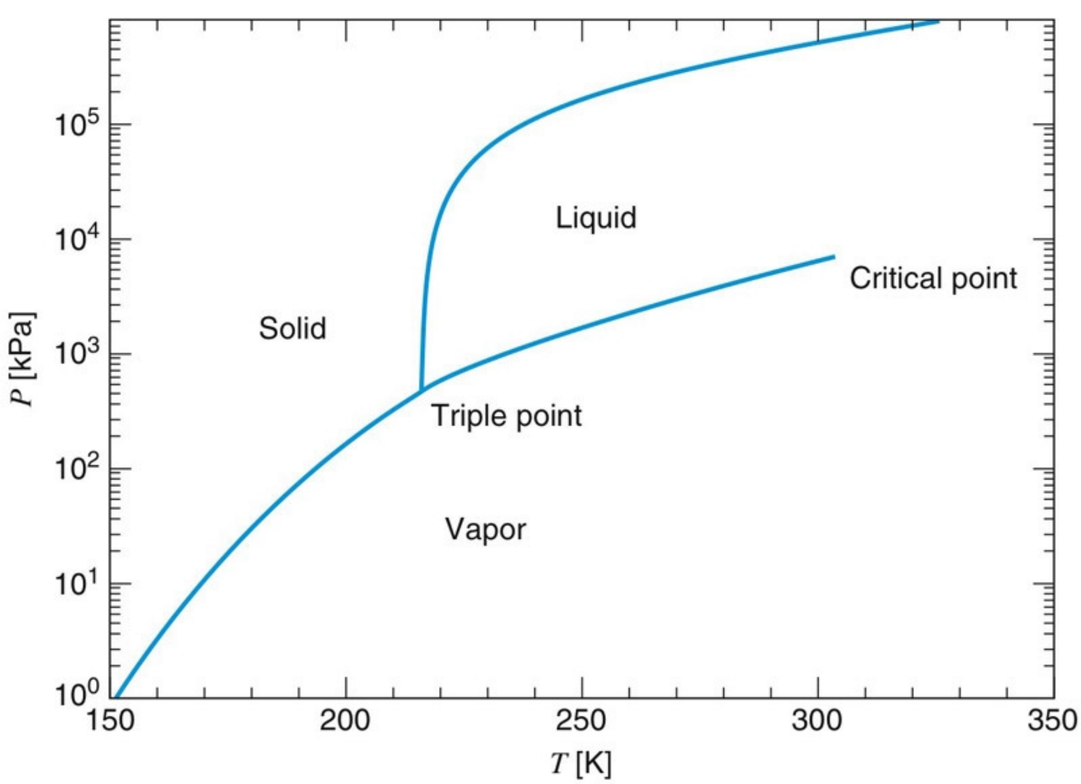
Start with $\not{V} = \not{V}_{liq} + \not{V}_{vap}$

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

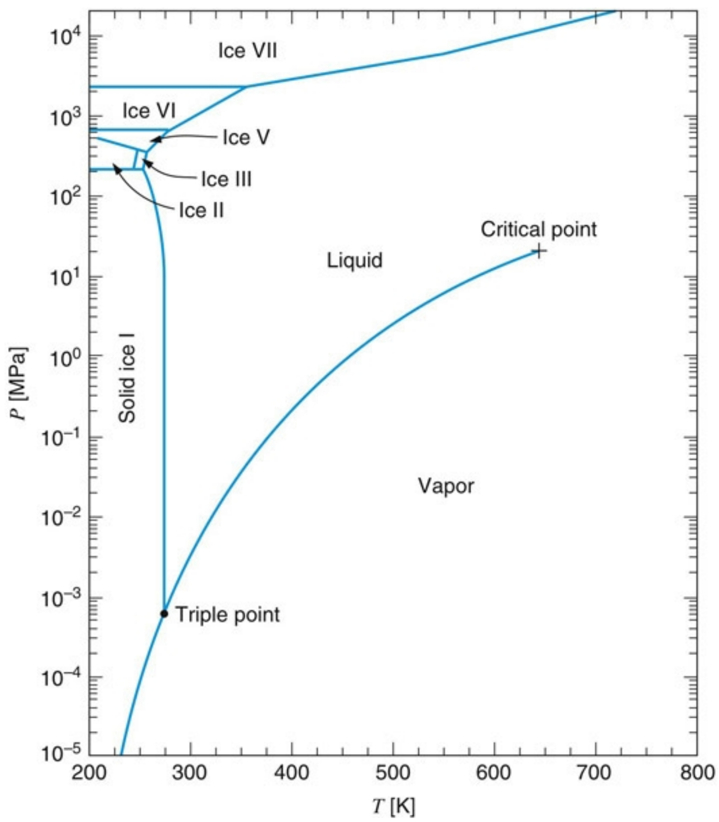
All SCS's can exist in all three phases at once... the ***triple point.*** Some triple point data is on p. ______ in Table ______ in your book.

Note water and other water solutions are unusual they expand on freezing.





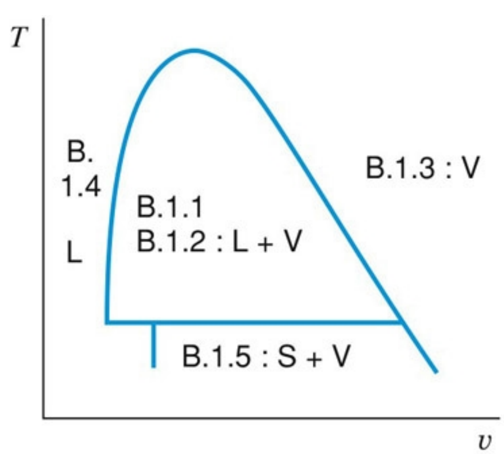
Thermodynamic Surfaces



See http://evan.lemley.org/courses/engr3203_spring_2010/engr3203.php for links to some ice researchers.

Tables of Data in the appendices

Need two independent properties to fix the thermodynamic state. Then can use tables --



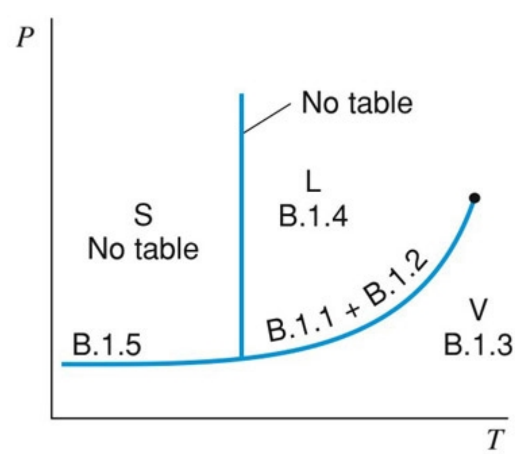


Table B.1.1 are steam tables (Keenan, Keyes, and Moore)

Example

State a: T = 120 ˚C and p = 500 kPa

For 120 ˚C what is p_{sat}? _______________ kPa

$\underline{p_{sat} <}$ or $\underline{p_{sat} > p}$?

------- what is the phase? _________________

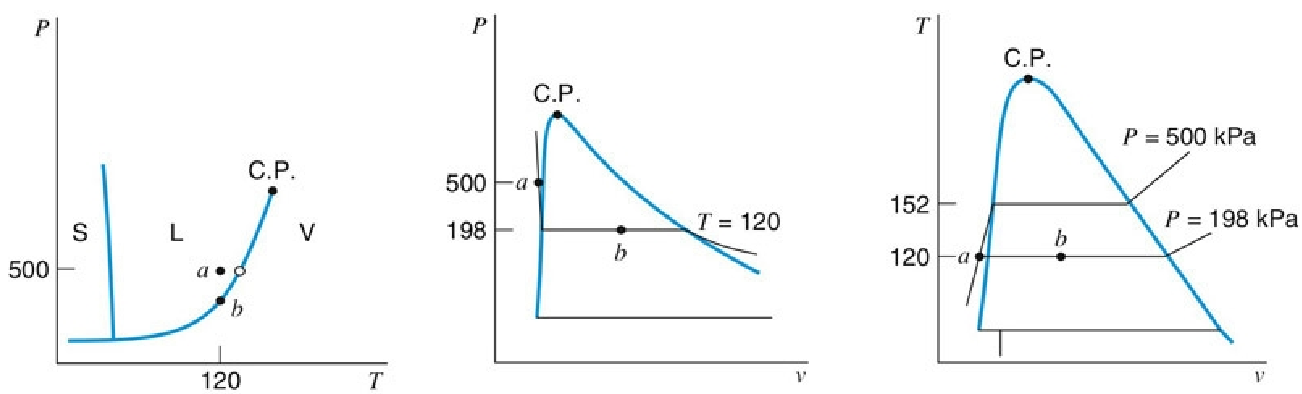
State b: T = 120 ˚C and v= 0.5 m^3/kg

For 120 ˚C what is v_f _______________ m^3/kg

For 120 ˚C what is v_g _______________ m^3/kg

$\underline{v \text{ is} < v_f}$ or $\underline{> v_g}$ or $\underline{> v_f \text{ and} < v_g}$

------- what is the phase? _________________



Example

Saturated Water: m_{liquid} = 0.4 kg & m_{vapor} = 0.6 kg & T = 160 °C

What is p_{sat}? ________________ kPa

What is x? ________________

What is v? ________________ m^3/kg

Example

Saturated Water @ p = 917 kPa

What is T_{sat}? ________________ °C

What is v? ________________ m^3/kg (see http://evan.lemley.org/courses/engr3203_spring_2010/linear_interpolation.pdf)

Example

Nitrogen: T = -53.2 °C & p = 600 kPa

What is v? ____________

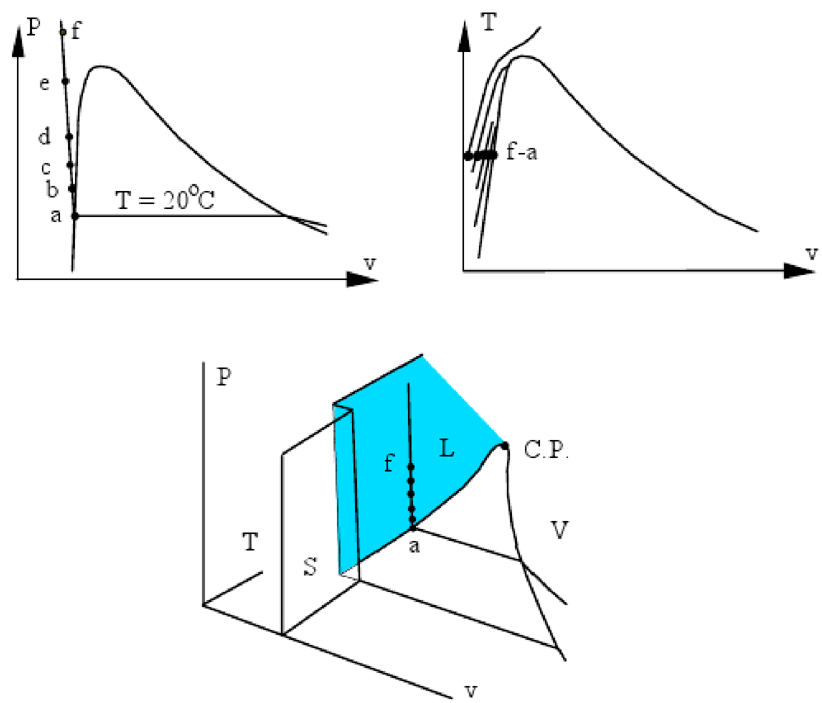
What table did I look in to figure this out? __________

Nitrogen: T = 100 K & v = 0.008 m^3/kg

What is x? ____________

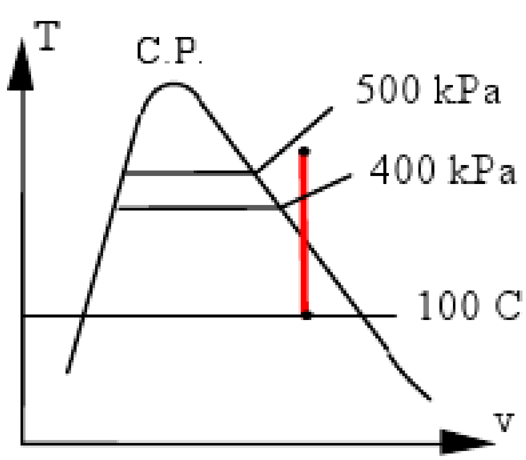
Example

Refer to Fig. 3.18. How much is the change in liquid specific volume for water at 20˚C as you move up from state i towards state j reaching 15,000 kPa?



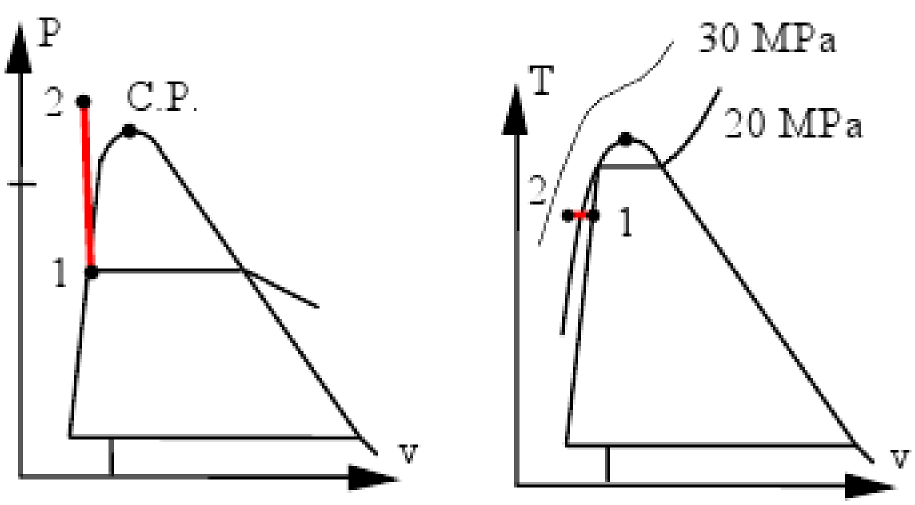
Example

A sealed rigid vessel has volume of 1 m^3 and contains 2 kg of water at 100°C. The vessel is now heated. If a safety pressure valve is installed, at what pressure should the valve be set to have a maximum temperature of 200°C?

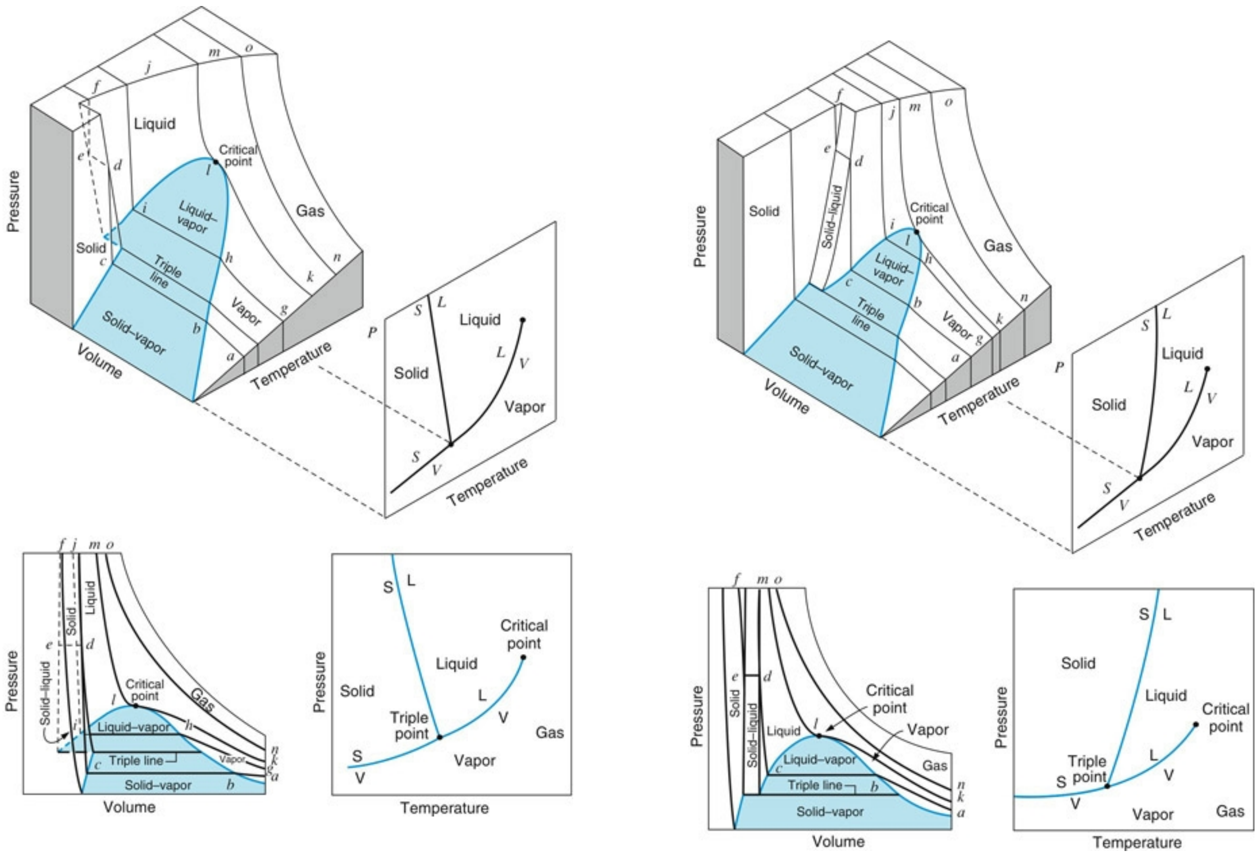


Example

Saturated liquid water at 60°C is put under pressure to decrease the volume by 1% keeping the temperature constant. To what pressure should it be compressed?



Thermodynamic Surfaces



Ideal Gas Law

In gases that are low enough density the molecules rarely interact and a basic *equation of state* can be used to describe their properties. The Ideal Gas Law is

$p\bar{V} = n\bar{R}T$ where

p	=	pressure [kPa]
$\bar{V}$	=	volume [m^3]
n	=	number of moles [kgmol]
$\bar{R}$	=	universal gas constant = 8.3145 [kN-m/kgmol/K]
T	=	temperature [K]

We usually use a different form of the gas law ---

$pv = RT$

v = specific volume [m^3/kg]

R = $\bar{R}/M$ where M [kg/kgmol] is molecular mass [kJ/kg/K]

Can also write gas law as

$$p\bar{v} = \bar{R}T$$
$$p V\!\!\!/ = mRT$$

Example

A pneumatic cylinder (a piston cylinder with air) must close a door with a force of 500 N. The cylinder cross-sectional area is 5 cm^2 and its volume is 50 cm^3. What is the air pressure and its mass?

Example

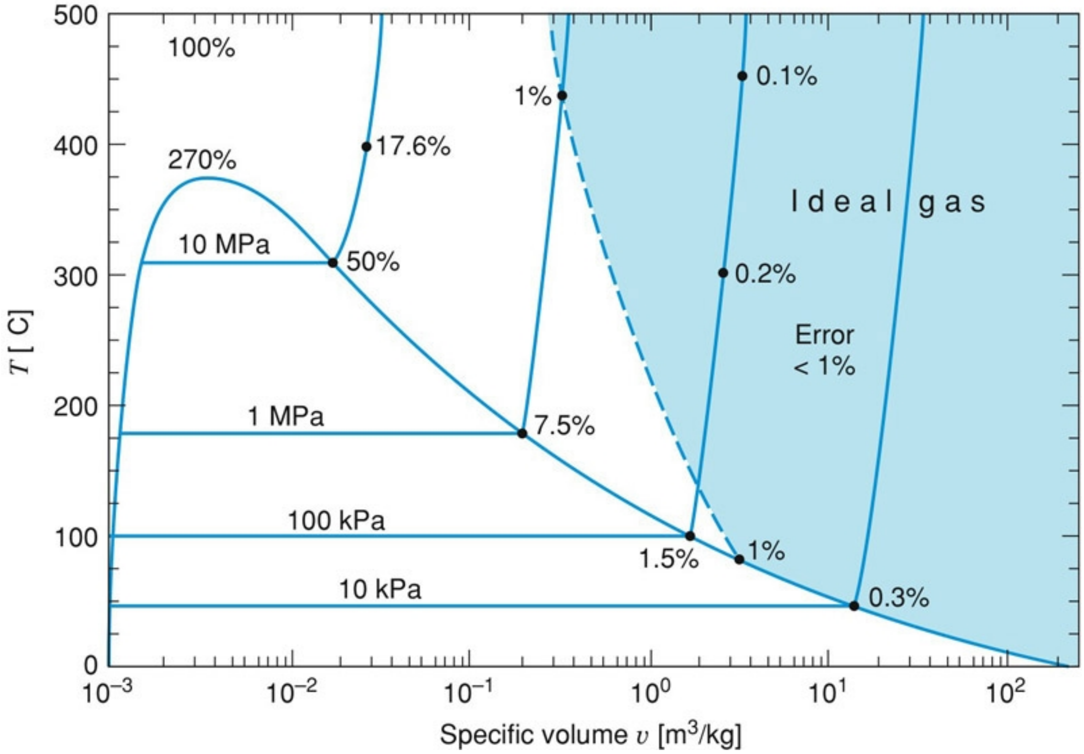
Air in an internal combustion engine has 227˚C, 1000 kPa with a volume of 0.1 m^3. Now combustion heats it to 1500 K in a constant volume process. What is the mass of air and how high does the pressure become?

Example

Helium in a steel tank is at 36 psia, 540 R with a volume of 4 ft^3. It is used to fill a balloon. When the pressure drops to 20 psia, the flow of helium stops by itself. If all the helium still is at 540 R, how big a balloon is produced?

Example

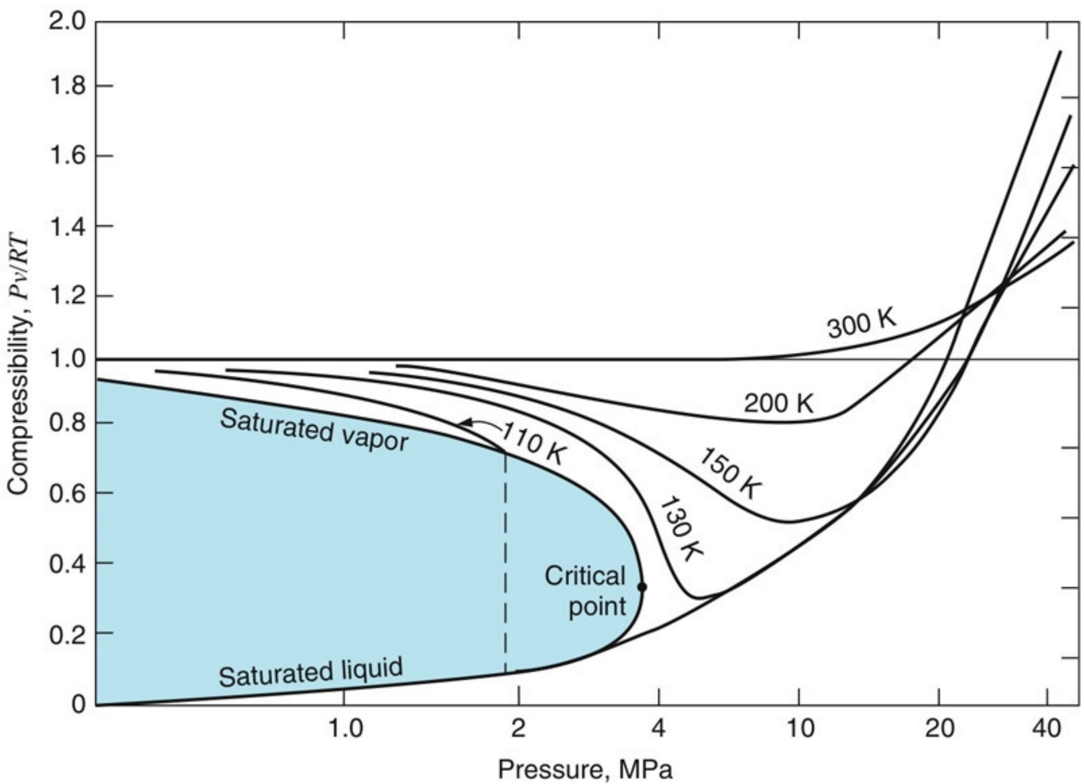
A cylindrical gas tank 3 ft long, inside diameter of 8 in., is evacuated and then filled with carbon dioxide gas at 77 F. To what pressure should it be charged if there should be 2.6 lbm of carbon dioxide?

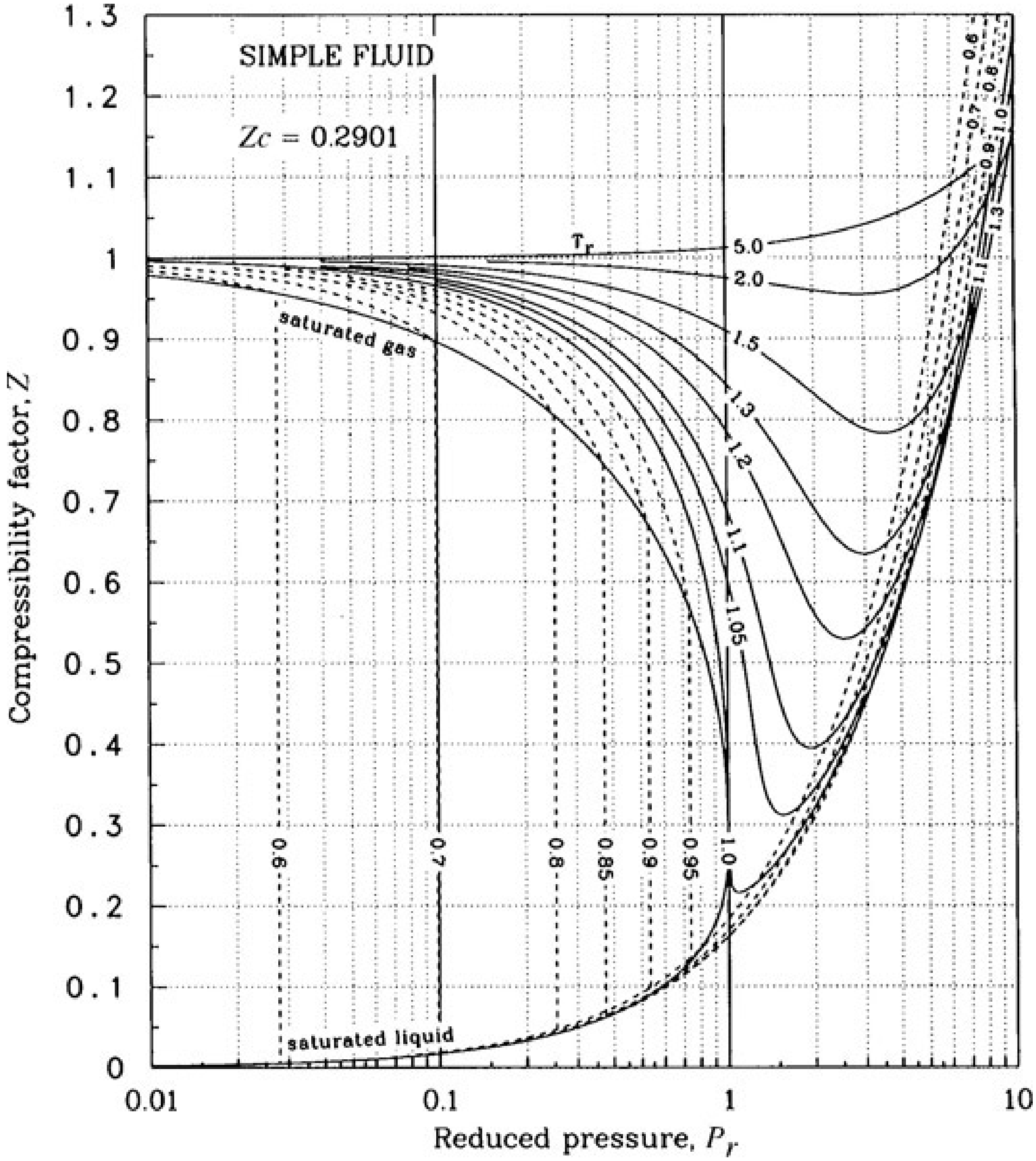


Compressibility (Z)

P v = Z RT

If Z is close to 1 can treat gas as ideal. Can use chart





To use the generalized compressibility chart:

1. Need to calculate reduced pressure (p_r) and reduced temperature (T_r)

$$p_r = \frac{p}{p_{critical}} \qquad T_r = \frac{T}{T_{critical}}$$ <u>*use absolute units for these*</u>

2. horizontal axis is logarithmic – (not linear)

How close to ideal gas behavior (find Z) is ammonia at saturated vapor, 100 kPa? How about saturated vapor at 2000 kPa?

Find the compressibility for carbon dioxide at 60oC and 10 MPa using Fig. D.1

A substance is at 70 F, 300 lbf/in.2 in a 10 ft3 tank. Estimate the mass from the compressibility chart if the substance is a) air, b) butane or c) propane.