Chapter 3: figuring out full state of a substance given two pieces of info

3.1

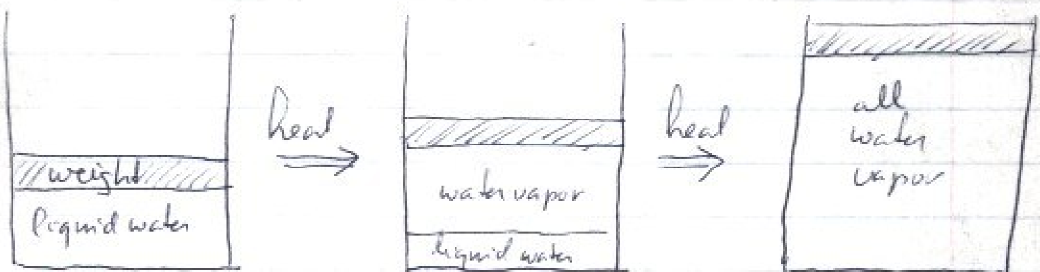
3.1 Definition of pure substances

"Homogeneous, invariable chemical composition".
Example: pure water (H_2O)
Air is not pure (it is O_2 and N_2) but we will pretend it is pure anyway. (If not cryogenic)

3.2 Phases and phase equilibria

To do thermo, you must figure out the right table, which requires figuring out the right phase.

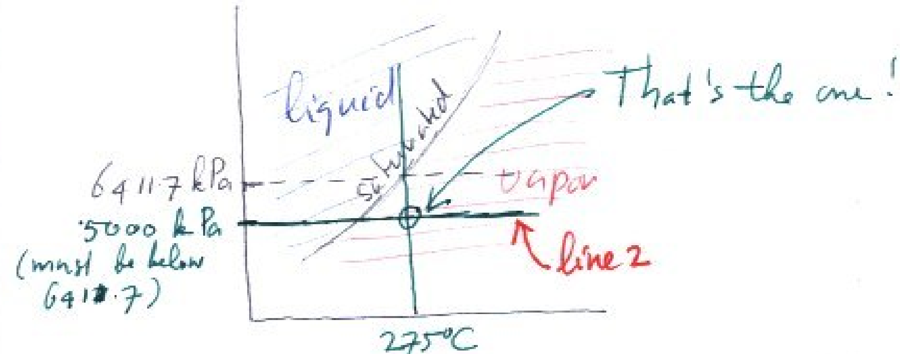
Example of phases for water



called compressed liquid or subcooled liquid	phase equilibrium: saturated water and saturated vapor	Superheated Vapor
Table B.1.4 A7 must be used if water	Table B.1.1 or A4 B.1.2 (equivalent) A5 must be used if water.	Table B.1.3 A6 must be used if water

General procedure to figure out a state, in outline

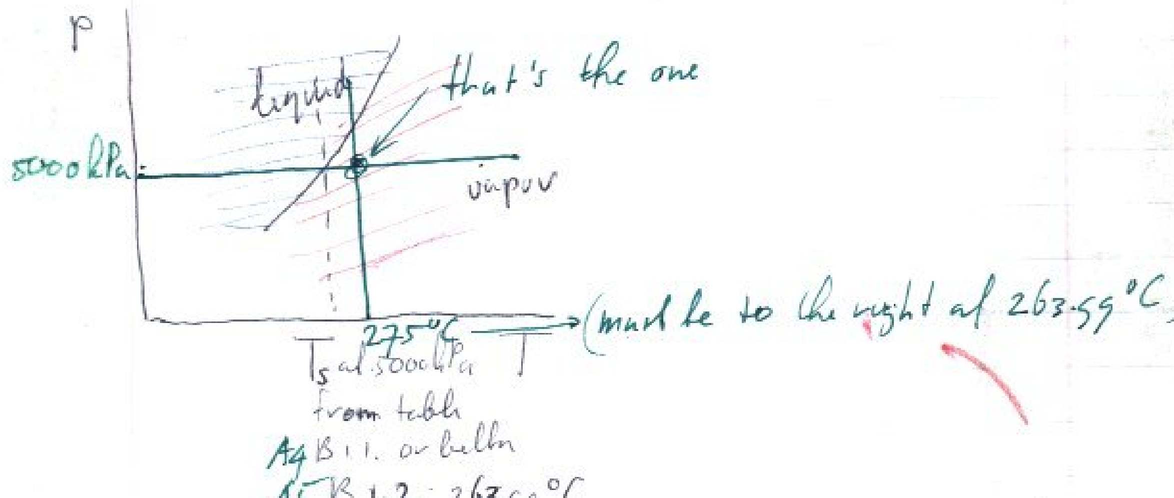
0) Draw diagram
1) Draw line ~~+~~ w/ drawn quantity in saturated tables find saturated version of other quantity.
2) Look in the tables
3) Draw line 2



The given state is in the red region, so it is superheated vapor.

(To get more data on the state, use table B.1.3: v =
A6

Note: Could have drawn pressure first

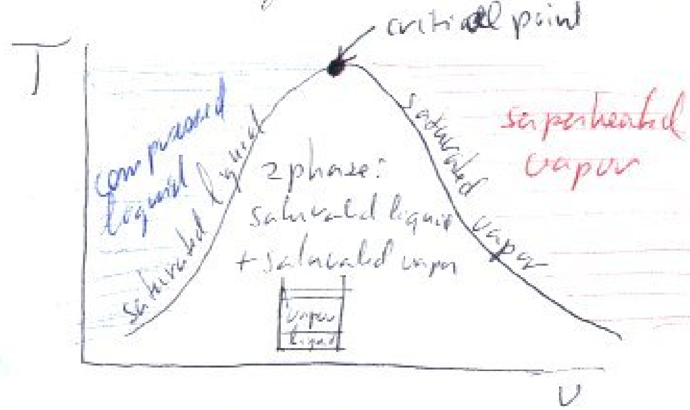


1) Line 1
2) Find drawn quantity in saturated tables
read off saturated value of second quantity
3) Line 2

3.31 a) Given: H_2O @ 275 °C and 5 MPa
3.18 a Asked: What is the phase?

Answer using Tv diagram

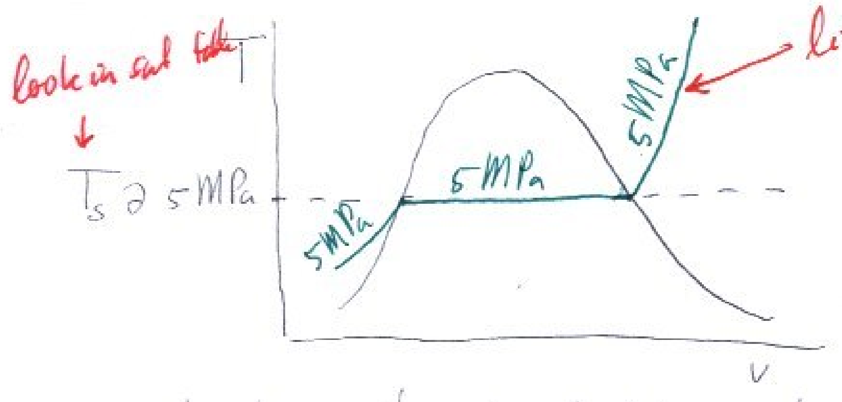
Sketch Tv diagram. Must remember how it looks: bell shape



Draw 5 MPa isobar: must remember:

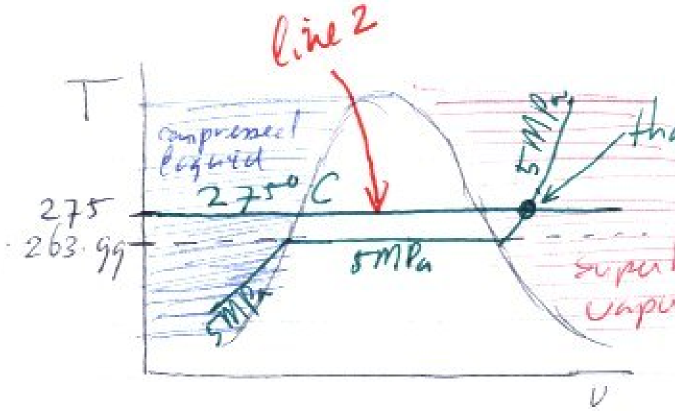
isobars go up in Tv
(except in 2 phase part)

use red for isotherms, not green



Look up the saturated temperature at 5 MPa
(See a pattern here?)

A5 Table B.1.2. $T_s = 263.99$. Mark and then draw the 275 °C isotherm:

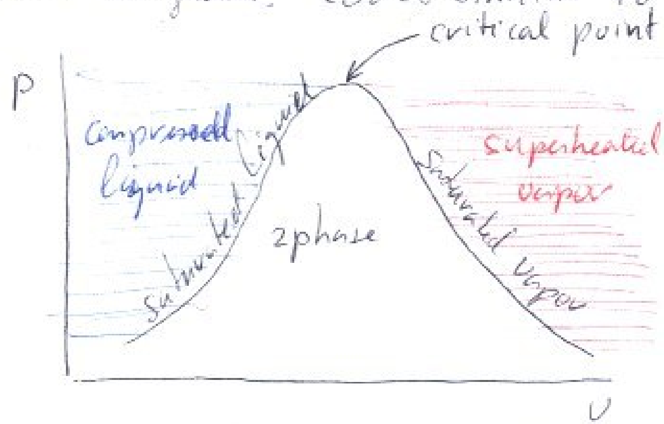


We followed the "broken line first" method:
we draw the broken 5MPa isobar first

3.31a
3.18a

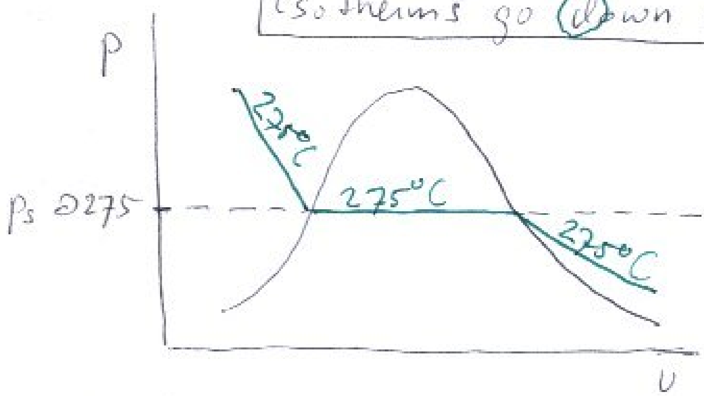
Answer using pv diagram:

Sketch diagram. Looks similar to Tv

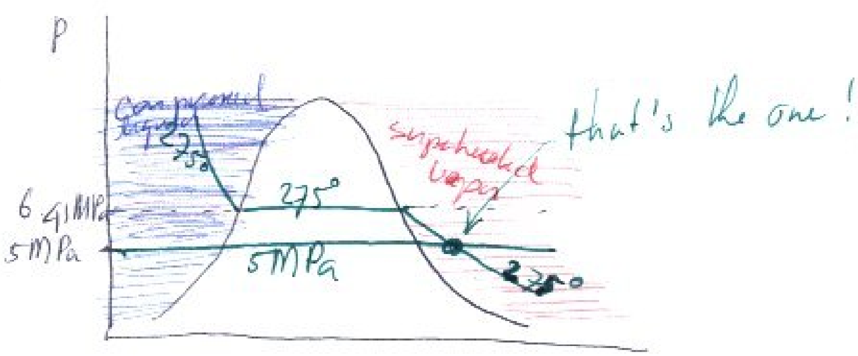


Broken line first: draw the broken 275°C isotherm first

isotherms go down in pv

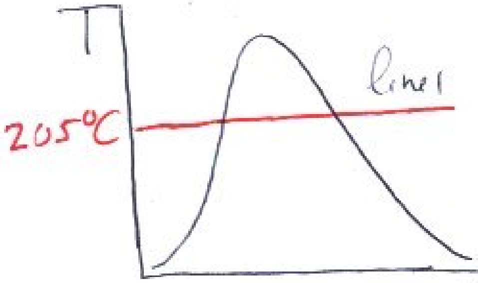


Look up p_s @ 275°C in table B.1.1: p_s = 6411.7 kPa = 6.41 MPa. Mark in graph and then draw the 5 MPa isobar



Made-up example

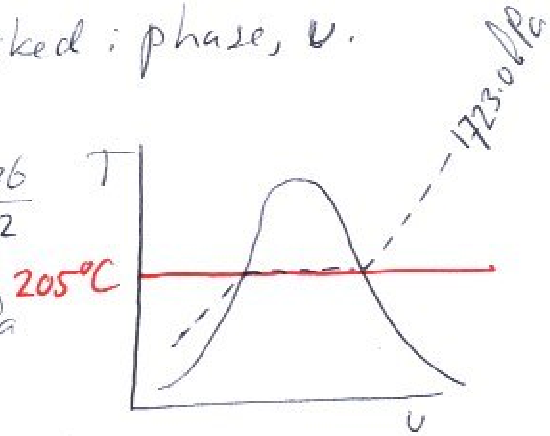
Water, 205 °C, P = 5000 kPa. Asked: phase, v.

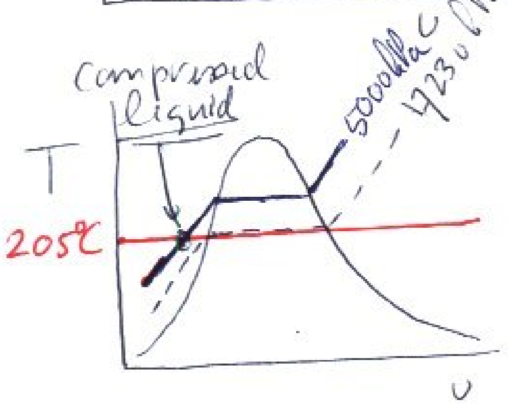


Saturated Table B.1.1, p $\frac{676}{512}$

at 205 °C:

$P_s = 1723.0$ kPa





It's compressed liquid, so look in table B.1.4, page $\frac{688}{524}$ to find v.

Temp °C	v m³/kg	
	500 kPa	2000 kPa
	5000 kPa	10000 kPa
200	0.001153	
220	0.001187	

Problem: 205 °C is not in the table. (If it was 200°, v would be 0.001153 m³/kg)

(Must use linear interpolation)

Procedure

Given value that is <u>not</u> in the table : $g = 205°C$

Values that <u>are</u> in the table : $g_1 = 200°C$ $\quad g_2 = 220°C$

Surrounding

Corresponding values of the desired quantity $v = d$ $\quad d_1 = 0.001153 \frac{m^3}{kg}$ $\quad d_2 = 0.001187 \frac{m^3}{kg}$

Magical formula

$$d = d_1 + \frac{g - g_1}{g_2 - g_1}(d_2 - d_1)$$

Put in the numbers :

$$v = 0.001153 \frac{m^3}{kg} + \frac{205 - 200}{220 - 200} \frac{°C}{°C} (0.001187 - 0.001153) \frac{m^3}{kg}$$

$$= \underline{0.0011615 \ m^3/kg}$$

What if you do not have a table for the compressed liquid? Only water has one in the book

~~For~~ Compressed liquids, can be approximated by saturated liquids at the right temperature (and wrong pressure)

~~Ex~~ To check it, look in table B.1.1 at 205°C (and the wrong pressure 1723 kPa ≠ 5000 kPa):

$v_{c.L.} \approx v_{f,sat} = 0.001164 \frac{m^3}{kg}$: only a few promile different from the correct value $0.0011615 \frac{m^3}{kg}$

11/15/ ~~up~~ end