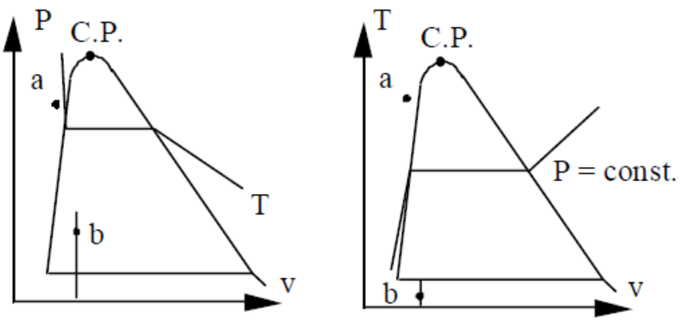
Chapter 03 Solved Problems

Problem 3.23

a) H_2O T = 260°C P = 5 MPa Table B.1.1 **or** B.1.2
B.1.1 For given T: Psat = 4.689 MPa
P > Psat => **compressed liquid**
B.1.2 For given P: Tsat = 264°C
T < Tsat => **compressed liquid**

b) H_2O T = −2°C P = 100 kPa Table B.1.1 T < Ttriple point
Table B.1.5 at −2°C: Psat = 0.518 kPa
since P > Psat => **compressed solid**



Problem 3.24

a) Water 100°C, 500 kPa
From Table B.1.1 Psat(100°C) = 101.3 kPa
500 kPa > Psat then it is compressed liquid
OR from Table B.1.2 Tsat(500 kPa) = 152°C
100°C < Tsat then it is subcooled liquid = compressed liquid

b) Ammonia (NH_3) -10°C, 150 kPa
Table B.2.1: P < Psat(-10 °C) = 291 kPa Superheated vapor

c) R-410a 0°C, 350 kPa
Table B.4.1: P < Psat(0 °C) = 799 kPa Superheated vapor.

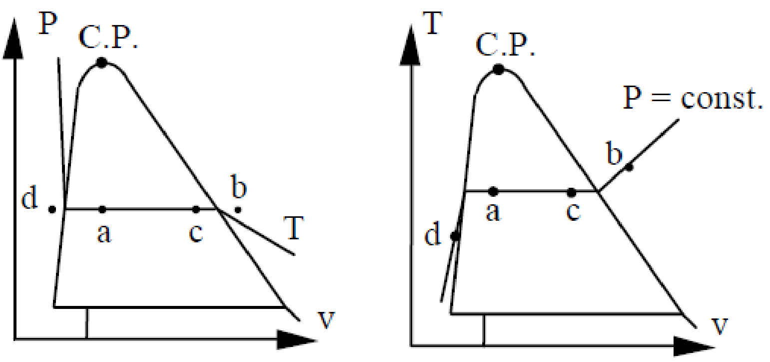
Problem 3.25

a) P = 10 MPa, v = 0.003 m^3/kg
B.1.2 at 10 MPa
v_f = 0.001452; v_g = 0.01803 m^3/kg,
=> $v_f < v < v_g$ => so mixture of liquid and vapor.

b) 1 MPa, 190°C : Only one of the two look-ups is needed
 P < Psat = 1254.4 kPa so it is superheated vapor
 T > Tsat = 179.91°C so it is superheated vapor

c) 200°C, 0.1 m^3/kg: B.1.1
 v_f = 0.001156 m^3/kg; v_g = 0.12736 m^3/kg,
 => $v_f < v < v_g$ => so mixture of liquid and vapor.

d) 10 kPa, 10°C : Only one of the two look-ups is needed
 B.1.1: P > Pg = 1.2276 kPa so compressed liquid
 B.1.2: T < Tsat = 45.8°C so compressed liquid



Problem 3.33

P [kPa]	T [°C]	v [m³/kg]	x
a) 500	20	**0.001002**	**Undefined**
b) 500	**151.86**	0.20	**0.532**
c) 1400	200	**0.14302**	**Undefined**
d) **8581**	300	**0.01762**	0.8

a) Table B.1.1 P > Psat so it is compressed liquid => Table B.1.4

b) Table B.1.2 vf < v < vg so two phase L + V
 $x = (v - v_f)/v_{fg}$ = (0.2 – 0.001093) / 0.3738 = 0.532
 T = Tsat = 151.86°C

c) Only one of the two look-up is needed
 Table B.1.1 200°C P < Psat = => superheated vapor
 Table B.1.2 1400 kPa T > Tsat = 195°C
 Table B.1.3 sub-table for 1400 kPa gives the state properties

d) Table B.1.1 since quality is given it is two-phase
 $v = v_f + x \times v_{fg}$ = 0.001404 + 0.8 × 0.02027 = 0.01762 m^3/kg

Problem 3.35

a) −15°C, 500 kPa
 Table B.4.1: P > Psat = 480.4 kPa, so compressed liquid.
 $v \approx v_f$ = 0.000815 m^3/kg

b) 20°C, 1000 kPa
Table B.4.1: P < Psat = 1444 kPa, so superheated vapor

Table B.4.2: $v = 0.02838\ m^3/kg$

c) 20°C, quality 25%
Table B.4.1: $v_f = 0.000815\ m^3/kg$, $v_{fg} = 0.01666\ m^3/kg$ so
$v = v_f + x\ v_{fg} = 0.000815 + 0.25 \times 0.01666 = 0.00498\ m^3/kg$

Problem 3.40

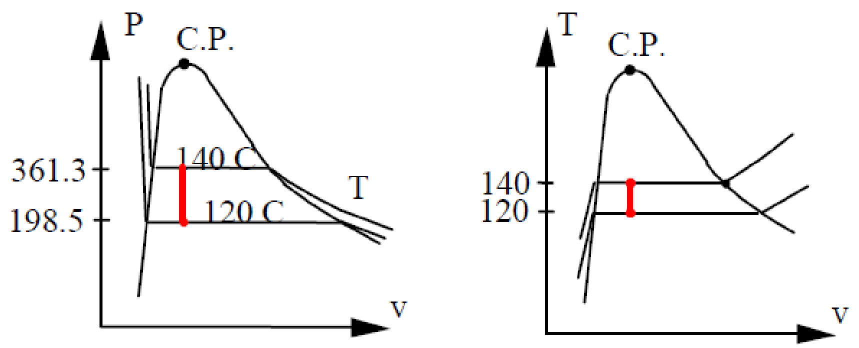
You want a pot of water to boil at 105°C. How heavy a lid should you put on the 15 cm diameter pot when P_{atm} = 101 kPa?
Table B.1.1 at 105°C : Psat = 120.8 kPa

$A = \frac{\pi D^2}{4} = 0.01767\ m^2$

Fnet = (Psat –Patm) A = (120.8 - 101) kPa × 0.01767 m^2= 0.3498 kN = 350 N
Fnet = m_{LID} g
m_{LID} = Fnet/g = 350/9.807 = 35.7 kg

Problem 3.41

State 1 from Table B.1.1 at 120°C
$v = v_f + x\ v_{fg} = 0.001060 + 0.25 \times 0.8908 = 0.22376\ m^3/kg$
State 2 has same v at 140°C also from Table B.1.1
$x = (v - v_f)/v_{fg} = (0.22376 - 0.00108)/0.50777 = 0.4385$
P = Psat = 361.3 kPa

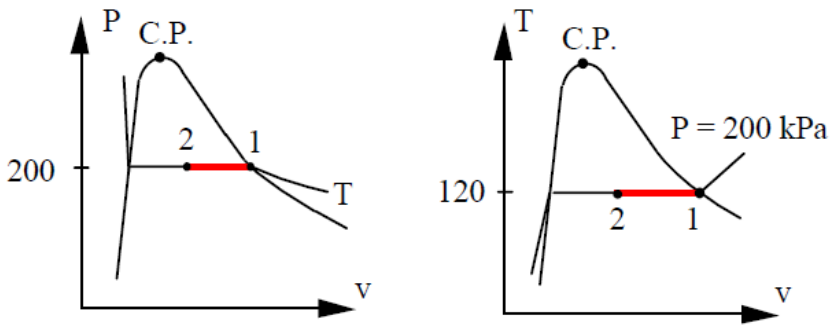


Problem 3.43

Saturated water vapor at 200 kPa is in a constant pressure piston cylinder. At this state the piston is 0.1 m from the cylinder bottom.

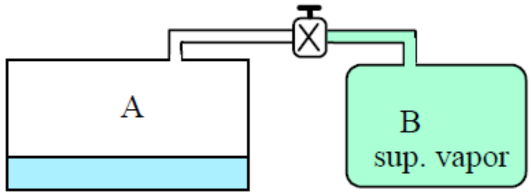
State 1: B 1.2 $v_1 = v_g$ (200 kPa) = 0.8857 m^3/kg, T_1 = 120.2°C
Process: P = constant = 200 kPa
State 2: P, $v_2 = v_1/2 = 0.44285\ m^3/kg$
Table B.1.2 $v_2 < v_g$ so two phase T_2 = Tsat = 120.2°C
Height is proportional to volume

$h_2 = h_1 \times v_2/v_1 = 0.1 \times 0.5 = 0.05m$



Problem 3.50

Control volume: both tanks. Constant total volume and mass process.



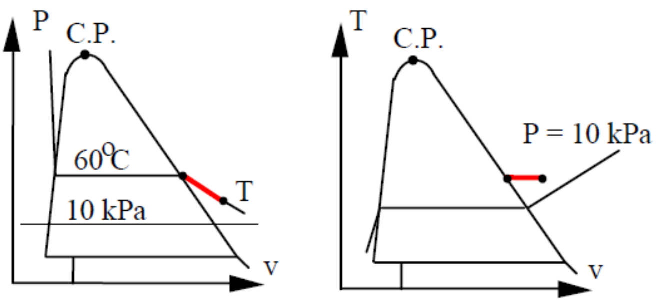
State A1: (P, v) $m_A = V_A/v_A = 1/0.5 = 2$ kg

State B1: (P, T) Table B.1.3 $v_B = 0.6173$ m^3/kg
$\Rightarrow V_B = m_B v_B = 3.5 \times 0.6173 = 2.1606$ m^3

Final state: $m_{tot} = m_A + m_B = 5.5$ kg
$V_{tot} = V_A + V_B = 3.1606$ m^3
$v_2 = V_{tot}/m_{tot} = 0.5746$ m^3/kg

Problem 3.53

Initial state: v = 7.6707 m^3/kg from table B.1.1
Final state: $v = 1.10 \times v_g = 1.1 \times 7.6707 = 8.4378$ m^3/kg
Interpolate at 60°C between saturated (P = 19.94 kPa) and superheated vapor P = 10 kPa in Tables B.1.1 and B.1.3
$P \cong 19.941 + (10 - 19.941) \text{ x } (8.4378 - 7.67071)/(5.3345 - 7.6707) = 18.9$ kPa



Problem 3.70

The mass comes from knowledge of state 1 and ideal gas law
$m = P_1V_1 / RT_1 = 1000$ kPa × 0.1 m^3/(0.287 kJ/kgK × (227 + 273) K)= 0.697 kg

The final pressure is found from the ideal gas law written for state 1 and state 2 and then eliminate the mass, gas constant and volume ($V_2 = V_1$) between the equations
$P_1 V_1 = m RT_1$ and $P_2 V_2 = m RT_2$
$P_2 = P_1 \times T_2/T1 = 1000 \times 1500500 =$ **3000 kPa**

Problem 3.72

m = PV/RT = 600 × 1/(0.2968 × 400) = 5.054 kg

m_2 = m - 0.5 = 4.554 kg

$P_2 = m_2RT_2/V = 4.554 \times 0.2968 \times 375/1 =$ **506.9 kPa**

Problem 3.111

Real gas behavior: P = 1000 kPa from Table B.4.2

Ideal gas constant: $R = \bar{R}/M = 8.31451/72.585 = 0.1146$ kJ/kg K
P = RT/v = 0.1146 × (273.15 + 60) / 0.0347 = 1100 kPa which is 10% too high

Generalized chart Fig D.1 and critical properties from A.2:
Tr = 333.2/(273.15 + 71.3) = 0.967; Pc = 4901 kPa
Assume P = 1000 kPa => Pr = 0.204 => Z ≅ 0.92
v = ZRT/P = 0.92 × 0.1146 × 333.15 /1000 = 0.03512 too high
Assume P = 1050 kPa => Pr = 0.214 => Z ≅ 0.915
v = ZRT/P = 0.915 × 0.1146 × 333.15 / 1050 = 0.03327 too low
P = 1000 + (1050 − 1000) × (0.03470 − 0.03512)/(0.03327 − 0.03512)
P = 1011 kPa   1.1 % high