T03

ENGG 201 –W2012 – Pure Component Examples – Chapter 4

Fall 1990 (Mid-Term)-b

Ammonia (NH_3, M = 17.03 g/mol) is a compound that finds important applications in the fertilizer and refrigeration industries. Its triple-point temperature and pressure are 195.4 K and 6.08 kPa, respectively. Additional *P-V-T* data for NH_3 in the vapor-liquid region are provided below:

		V (cm^3/g)	
T (K)	P, MPa	liquid	vapor
350.0	3.87	1.95	31.73
370.0	5.89	2.15	19.02
390.0	8.61	2.50	10.72
405.6	11.30	4.25	4.25

– critical point

10g

Ten grams of NH_3 is brought to the following sets of conditions. In each case, state whether the NH_3 is a liquid, a vapor, a gas, a solid, or more than one phase. If there is more than one phase, calculate the mass of each phase.

(a) T = 370.0 K; P = 10.0 MPa. – LIQUID
(b) T = 370.0 K; P = 4.0 MPa. – VAPOUR
(c) T = 420.0 K; P = 8.0 MPa. – GAS
(d) T = 380.0 K; P = 5.89 MPa. – VAPOUR
(e) T = 360.0 K; P = 5.89 MPa. – LIQUID
(f) T = 180.0 K; P = 5.89 MPa. – SOLID
(g) T = 370.0 K; volume = 300 cm^3.
(h) T =370.0 K; volume = 21 cm^3.
(i) P = 5.89 MPa; volume = 100 cm^3.

Ans. *(a) L, (b) V, (c) G, (d) V, (e) L, (f) S, (g) V, (h) L, (i) L (5.4g) & V (4.6g).*

1) PHASE(s) – mass of each if more than one

a) $T = 370K$, $P = 10 MPa$ > LIQUID

g) $T = 370K$ $\quad v = 300\ cm^3$

$\left(\frac{cm^3}{g}\right)$ $V = \frac{v}{m} = \frac{300 cm^3}{10\ g} = 30\ cm^3/g$ > VAPOUR

h) $T = 370K$ $\quad v = 21\ cm^3$

$V = \frac{v}{m} = \frac{21 cm^3}{10\ g} = 2.1\ cm^3/g$ > LIQUID

i) $P = 5.89\ MPa$ $\quad v = 100\ cm^3$

$V = \frac{v}{m} = \frac{100 cm^3}{10 g} = 10\ cm^3/g$ > LIQUID + VAPOUR

LIQ	MIX	VAP
2.15	10 cm^3/g	19.02

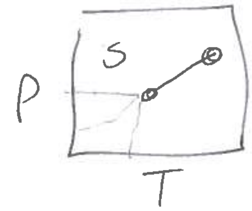
$$\frac{M_{VAP}}{M_{TOT}} = \frac{V_{mix} - V_{LIQ}}{V_{VAP} - V_{LIQ}}$$

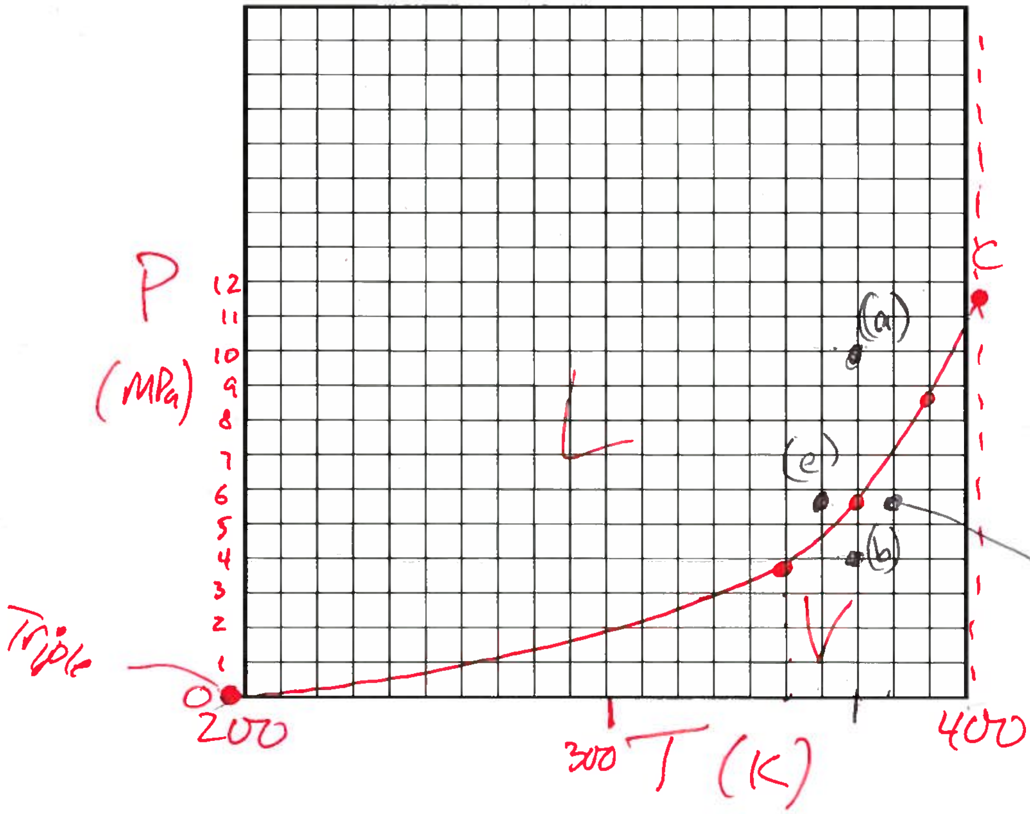
$$\frac{M_V}{M_T} = \frac{10 - 2.15}{19.02 - 2.15}$$

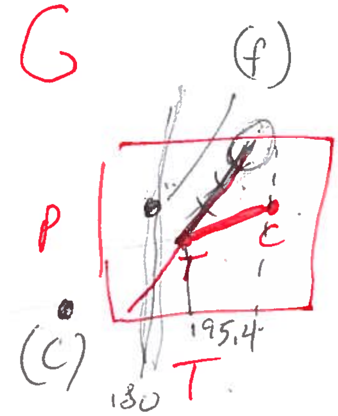
$$\frac{M_V}{M_T} = 0.47$$

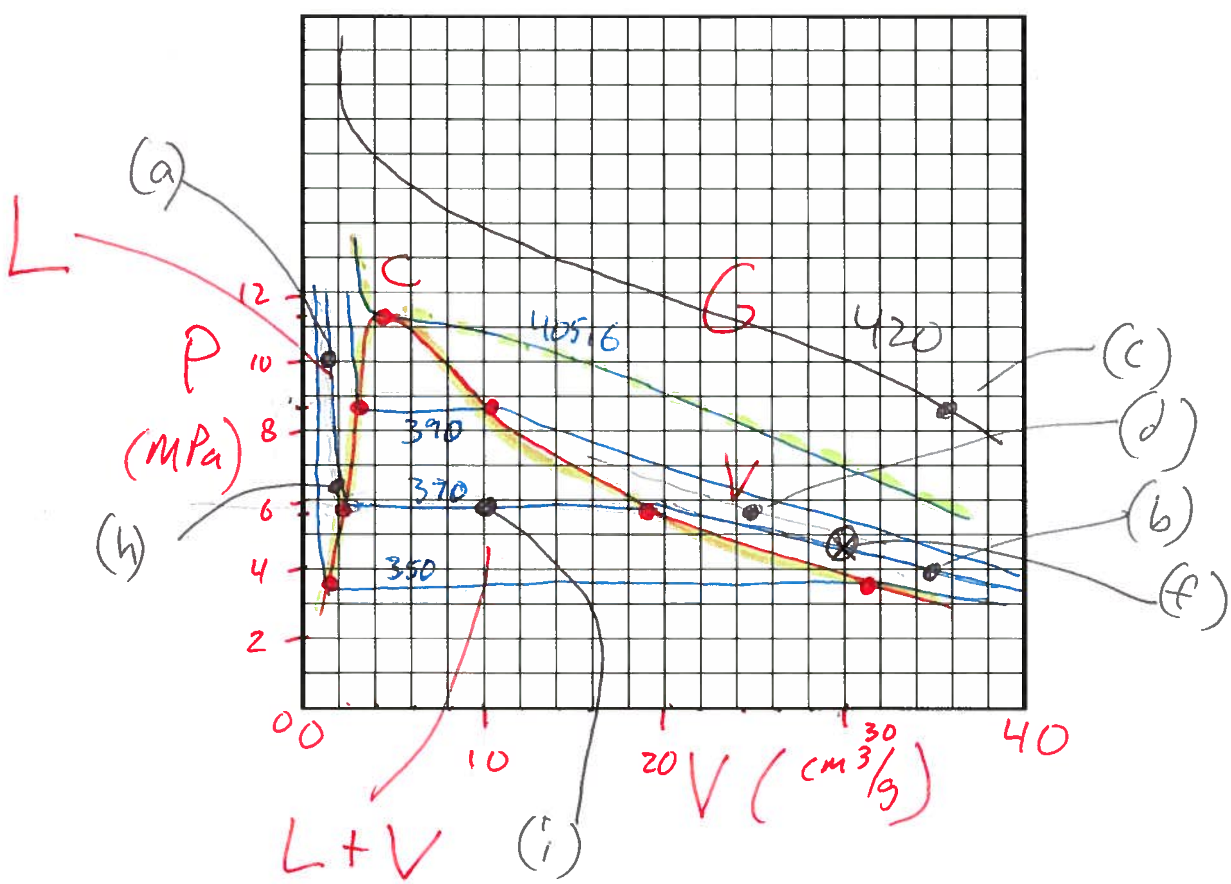
$M_V = 0.47 \times M_T = 0.47 \times 10g = 4.7g$ VAP

$M_L = 10 - 4.7 = 5.3g$ LIQ


S
P
T


P
(MPa)
12
11
10
9
8
7
6
5
4
3
2
1
0
Triple
200
300
T (K)
400
L
V
(a)
(b)
(d)
(e)
C


G
(f)
P
(C)
T
C
195.4
130
T


L
(a)
P
(MPa)
12
10
8
6
4
2
0
(h)
C
405.6
390
370
350
G
420
V
(c)
(d)
(b)
(f)
0
10
20
30
40
V (cm3/g)
L+V
(i)

Fall 1993 (Mid-Term)-a

The *P-V* diagram, covering the vapour and liquid phase regions, of ethane (C_2H_6; M = 30.1 kg/kmol) is shown below. The critical properties are: P_c =4.9MPa, T_c =305.4K, and V_c =0.14m^3/kmol.

critical point

(a) Identify the state(s) of C_2H_6 at each of the following conditions.
- (i) T=270K, P = 4MPa — LIQUID
- (ii) P=2MPa, V = 1.0m^3/kmol. – VAPOUR
- (iii) T=280K, V=0.4m^3/kmol. – VAPOUR + LIQUID
- (iv) T = 260K, V=1.1m^3/kmol. – VAPOUR
- (v) T = 320K, P = 3MPa. – GAS

$$\rho = \frac{M}{V_m} = \frac{1\ \text{kmol}}{0.14\ m^3} \times \frac{30.1\ \text{kg}}{\text{kmol}}$$

$$\rho = 215\ \frac{\text{kg}}{m^3}$$

(b) What is the density (in kg/m^3) of C_2H_6 at its critical conditions?

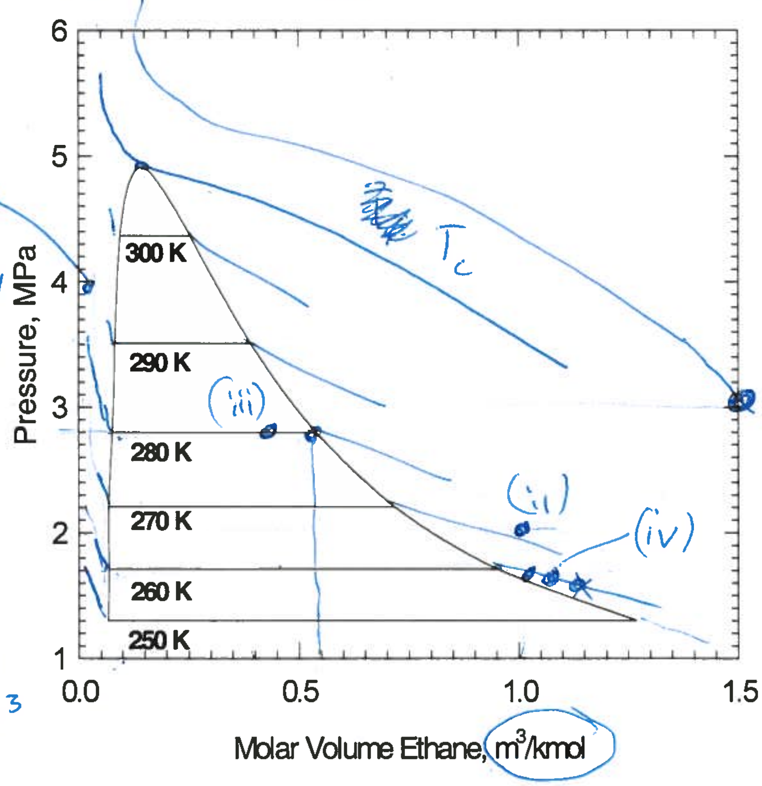
2.8 MPa   2.8 MPa   2.8 MPa

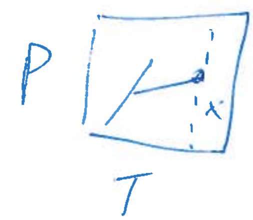
(c) (i)Give the dew point and bubble point pressures and the vapour pressure of C_2H_6 at 280K.
(ii) What is the ratio of the densities of the co-existing liquid and vapour phases at 280K?

(d) (i) Find the mass of the vapour phase in a 100-Litre bottle filled with 3.01 kg of C_2H_6 at 260K.
(ii) What is the volume of the liquid phase in the bottle in Part (d)(i)?

$M_V = 3.01\text{kg}$

$0\ m^3 = 0\ L$





$$\frac{\rho_L}{\rho_V} = \frac{M/V_{mL}}{M/V_{mV}} = \frac{V_{mV}}{V_{mL}} = \frac{0.55\ m^3/\text{kmol}}{0.1\ m^3/\text{kmol}}$$

$$\frac{\rho_L}{\rho_V} = 5.5$$

d) $m_V = ?$

$V = 100\ L = 0.1\ m^3$
$m = 3.01$ kg
$T = 260$ K

$$V_m = \frac{V}{n} = \frac{0.1\ m^3}{0.1\ \text{kmol}} = 1\ m^3/\text{kmol}$$

$\frac{m^3}{\text{kmol}}$

Ans. (a)(i)L, (ii)V,(iii)L+V,(iv)V,(v)G, (b) 215kg/m^3, (c)(i)280K, 2.8MPa,, (ii)7, (d)(i)3.01kg, (ii)0.

$$M = \frac{m}{n} \rightarrow n = \frac{m}{M} = \frac{3.01\ \text{kg}}{30.1\ \text{kg/kmol}} = 0.1\ \text{kmol}$$

Fall 1991 (Mid-Term)-a

The *P-V* diagram for a new industrial material (M = 49 kg/kmol) is provided below. The critical properties of this material are (approximately): T_c = 52°C, P_c = 11.5 MPa, and V_c = 0.34 m^3/kmol. Use the *P-V* diagram to answer the following questions:

(a) What is the state of the material at each of the following conditions?

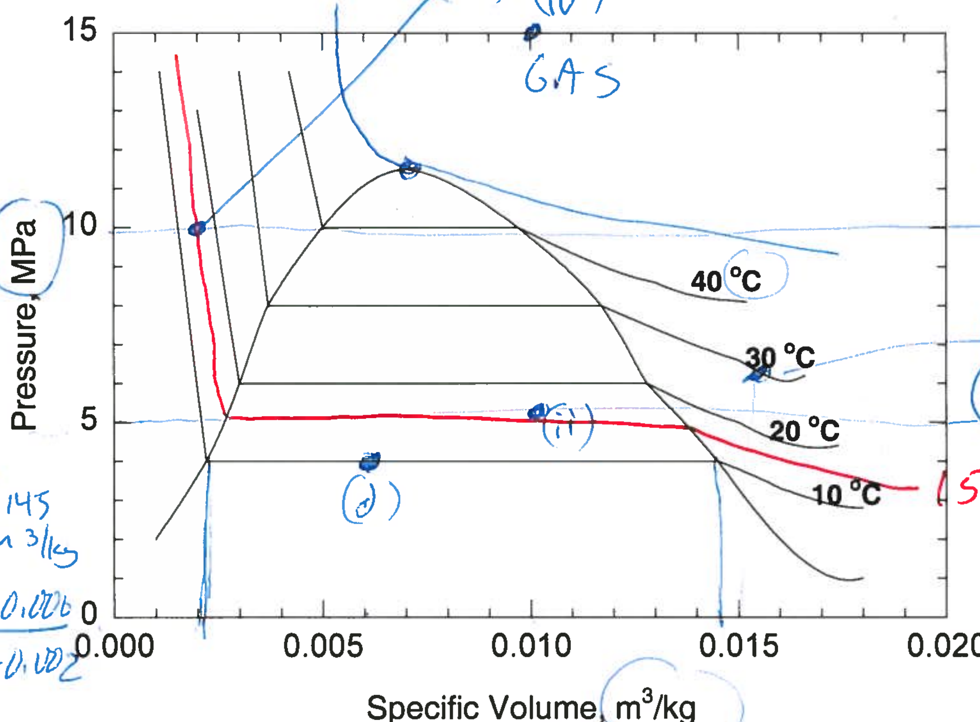
- (i) T = 30°C, V = 0.015 m^3/kg   VAPOUR
- (ii) P = 5 MPa, V = 0.010 m^3/kg   V + L
- (iii) P = 10 MPa, T = 15°C   L
- (iv) V = 0.010 m^3/kg, P = 15 MPa   G

(b) What is the density of the material (in kg/m^3) at its critical conditions? $\rho_c = \frac{M}{V_{mc}} = \frac{49\ \text{kg/kmol}}{0.34\ \frac{m^3}{kmol}}$ 144.12 $\frac{kg}{m^3}$

(c) What is the vapour pressure at 25°C?   7 MPa

(d) What is the density (ρ_L) and mass (m_L) of the liquid phase in a 1 kg sample which occupies a volume of 0.006m^3 at 10°C? $V = \frac{0.006\ m^3}{1\ kg} = 0.006\ m^3/kg$

(e) What are the density and the volume occupied by the vapour phase in Part (d)?



$\rho_L = \frac{1}{V_L}$

$\rho_L = \frac{1}{0.002\ \frac{m^3}{kg}}$

$\rho_L = 500\ \frac{kg}{m^3}$

L — m — V

0.002   0.006   0.0145 m^3/kg

$\frac{m_L}{m_T} = \frac{0.0145 - 0.006}{0.0145 - 0.002}$

$\frac{m_L}{m_T} = 0.68$

$m_L = 0.68\ (1\ kg)$ 0.68 kg LIQ

$V_V = \ ?\ m^3$

$\rho_V = \ ?\ \frac{kg}{m^3}$

$\rho_V = \frac{1}{V_V}$

$= \frac{1}{0.0145\ \frac{m^3}{kg}}$

$\rho_V = 69\ \frac{kg}{m^3}$

Ans. (a) (i)V, (ii)L+V, (iii)L, (iv)G, (b) 144.12kg/m^3, (c) 7MPa, (d) 500kg/m^3, 0.71kg, (e) 69kg/m^3, 4.2liter

$V = \frac{v}{m}$

$m_V = m_T - m_L$

$= 1\ kg - 0.68 = 0.32\ kg$ VAP

$\left(0.0145\ \frac{m^3}{kg}\right)(0.32\ kg) =$

0.0046 m^3 VAPOR

TU4

ENGG 201 –W2012 – Pure Component Examples – Chapter 4

Fall 1990 (Mid-Term)-b

TRIPLE POINT

Ammonia (NH_3, M = 17.03 g/mol) is a compound that finds important applications in the fertilizer and refrigeration industries. Its triple-point temperature and pressure are 195.4 K and 6.08 kPa, respectively. Additional *P-V-T* data for NH_3 in the vapor-liquid region are provided below:

T (K)	*P*, MPa	*V* (cm³/g) liquid	*V* (cm³/g) vapor
350.0	3.87	1.95	31.73
370.0	5.89	2.15	19.02
390.0	8.61	2.50	10.72
405.6	11.30	4.25	4.25

10g

CRITICAL PT.

Ten grams of NH_3 is brought to the following sets of conditions. In each case, state whether the NH_3 is a liquid, a vapor, a gas, a solid, or more than one phase. If there is more than one phase, calculate the mass of each phase. (2) (1)

(a) T = 370.0 K; P = 10.0 MPa. – LIQ
(b) T = 370.0 K; P = 4.0 MPa. – VAP
(c) T = 420.0 K; P = 8.0 MPa. – GAS
(d) T = 380.0 K; P = 5.89 MPa. – VAP
(e) T = 360.0 K; P = 5.89 MPa. – LIQ
(f) T = 180.0 K; P = 5.89 MPa. – SOLID $T < T_{TRIP}$, $P > P_{TRIP}$
(g) T = 370.0 K; volume = 300 cm³.
(h) T =370.0 K; volume = 21 cm³.
(i) P = 5.89 MPa; volume = 100 cm³.

Ans. (a) L, (b) V, (c) G, (d) V, (e) L, (f) S, (g) V, (h) L, (i) L (5.4g) & V (4.6g).

(g) $T = 370\text{K}$ $v = 300\text{ cm}^3$

$V = \frac{v}{m} = \frac{300\text{cm}^3}{10\text{g}} = 30\text{ cm}^3/\text{g} = V$ > VAPOUR

(h) $T = 370\text{K}$ $v = 21\text{cm}^3$

$V = \frac{v}{m} = \frac{21\text{cm}^3}{10\text{g}} = 2.1\text{ cm}^3/\text{g} = V$ > LIQUID

(i) $P = 5.89\text{ MPa}$ $v = 100\text{ cm}^3$

$V = \frac{v}{m} = \frac{100\text{cm}^3}{10\text{g}} = 10\text{ cm}^3/\text{g} = V$ > LIQ + VAP

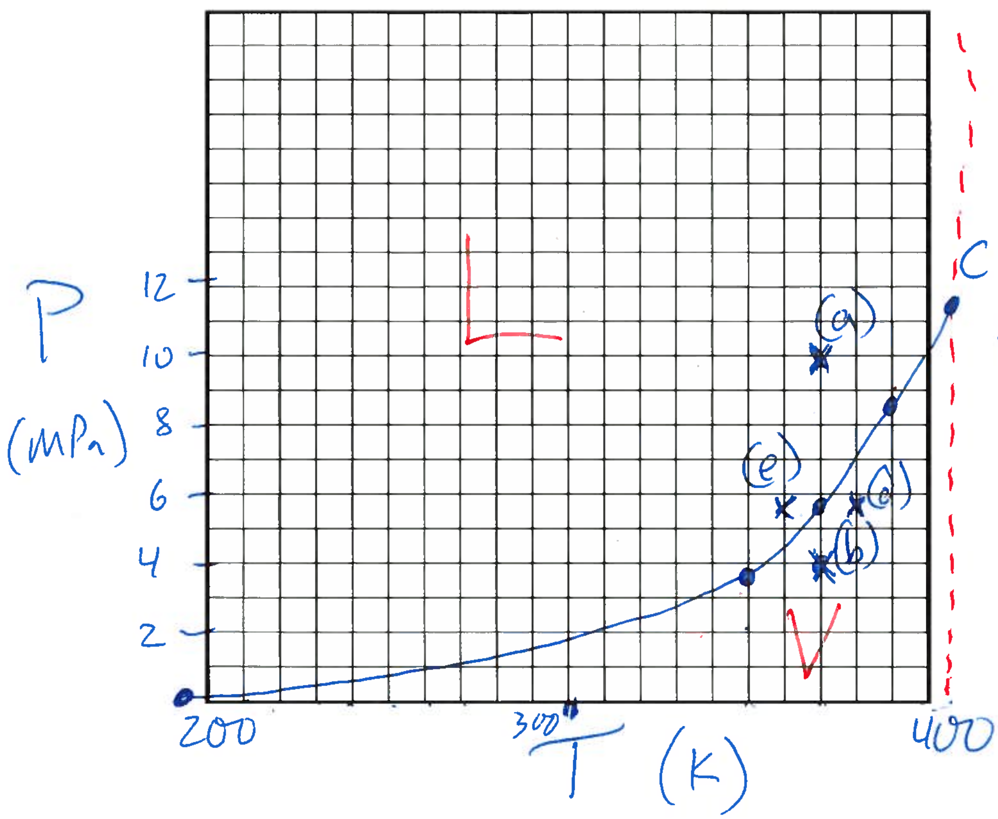
mass = ? mass = ?

LIQ — MIX — VAP
2.15 — 10 cm³/g — 19.02

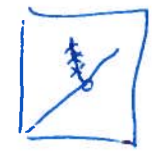
$$\frac{m_L}{m_T} = \frac{19.02 - 10}{19.02 - 2.15} = \cancel{0.534}\ 0.535$$

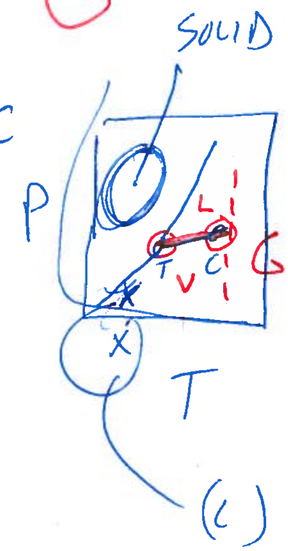
$$m_L = 0.535\, m_T = 0.535(10\text{g}) = \boxed{5.35\text{g LIQ}}$$

$$m_V = m_T - m_L = 10 - 5.35 = \boxed{4.65\text{ g VAP}}$$

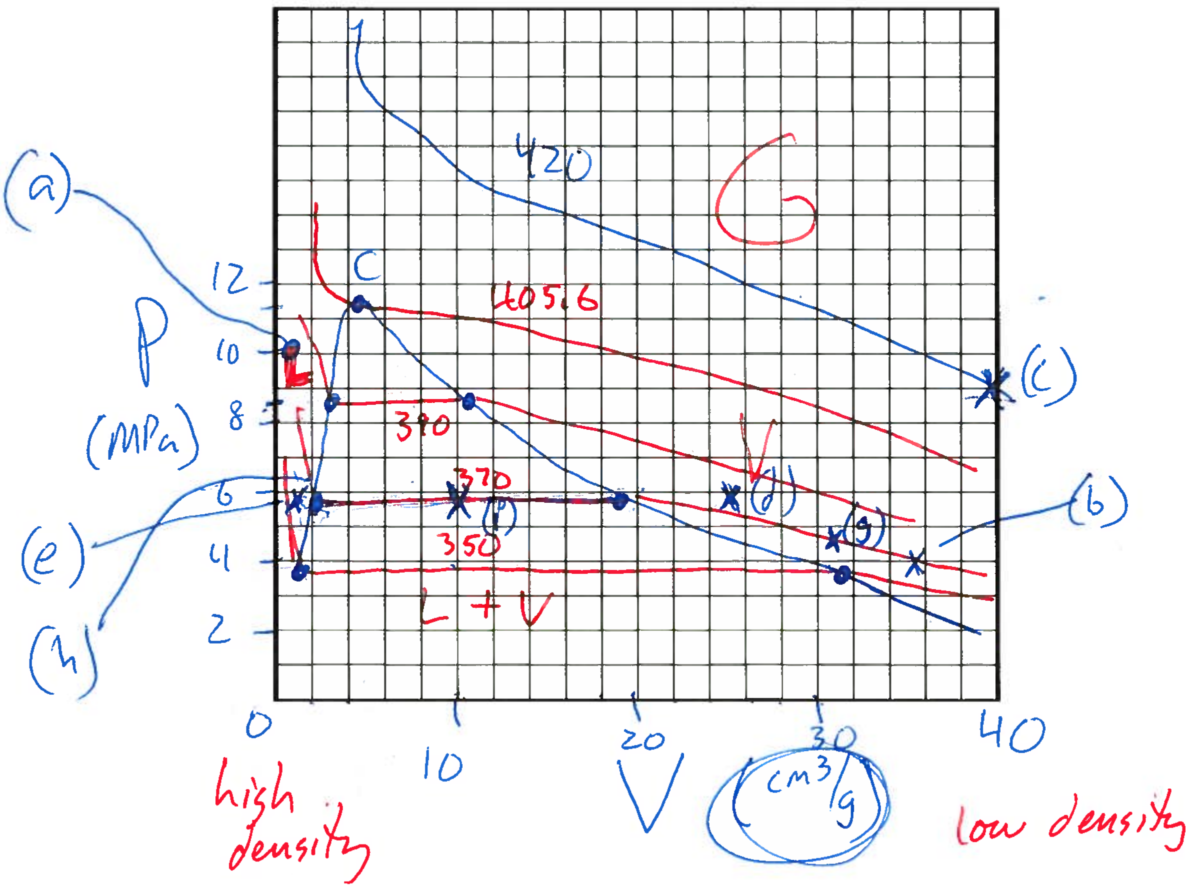


P
(MPa)
12
10
8
6
4
2
200
300
400
T (K)
L
V
G
C
(a)
(b)
(d)
(e)





SOLID
P
T
L
V
G
C
X
(c)



(a)
P
(MPa)
12
10
8
6
4
2
0
10
20
30
40
V
(cm3/g)
high density
low density
420
405.6
390
370
350
G
L
C
V
L + V
(b)
(c)
(d)
(e)
(f)
(g)
(h)

Fall 1993 (Mid-Term)-a

The *P-V* diagram, covering the vapour and liquid phase regions, of ethane (C_2H_6; M = 30.1 kg/kmol) is shown below. The critical properties are: P_c =4.9MPa, T_c =305.4K, and V_c =0.14m³/kmol.

(a) Identify the state(s) of C_2H_6 at each of the following conditions.
 (i) T=270K, P = 4MPa — LIQUID
 (ii) P=2MPa, V = 1.0m³/kmol. — VAPOUR
 (iii) T=280K, V=0.4m³/kmol. — LIQ + VAP
 (iv) T = 260K, V=1.1m³/kmol. — VAP
 (v) T = 320K, P = 3MPa. — GAS

$\rho_c = \frac{M}{V_{mc}} = \frac{30.1 \text{ kg/kmol}}{0.14 \text{ m}^3\text{/kmol}}$

$\boxed{\rho_c = 215 \text{ kg/m}^3}$

(b) What is the density (in kg/m³) of C_2H_6 at its critical conditions?

(c) (i)Give the dew point and bubble point pressures and the vapour pressure of C_2H_6 at 280K.
 2.8 MPa   2.8 MPa   2.8 MPa
 (ii) What is the ratio of the densities of the co-existing liquid and vapour phases at 280K?

(d) (i) Find the mass of the vapour phase in a 100-Litre bottle filled with 3.01 kg of C_2H_6 at 260K.
 m_v v m T
 (ii) What is the volume of the liquid phase in the bottle in Part (d)(i)?

$M = m/n$

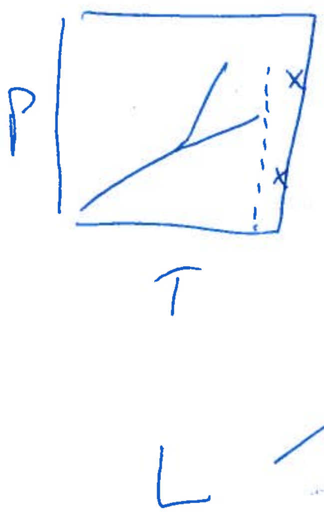
$V_m = \frac{v}{n} = \frac{0.1 \text{ m}^3}{0.1 \text{ kmol}} = 1 \frac{\text{m}^3}{\text{kmol}}$

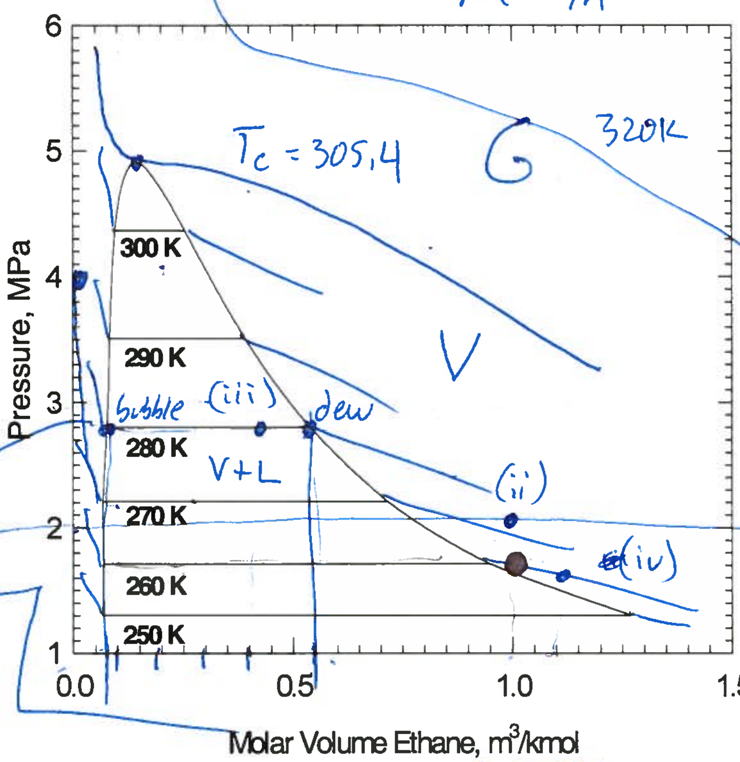
$v = 100L = 0.1 \text{ m}^3$

$n = \frac{m}{M} = \frac{3.01 \text{ kg}}{30.1 \text{ kg/kmol}} = 0.1 \text{ kmol}$

$m_v = 3.01 \text{ kg}$

$V_L = 0 \text{ m}^3$





$\frac{\rho_L}{\rho_V} = \frac{m/V_L}{m/V_V} = \frac{V_V}{V_L}$

$\frac{\rho_L}{\rho_V} = \frac{V_V}{V_L} = \frac{0.55 \text{ m}^3\text{/kmol}}{0.075 \text{ m}^3\text{/kmol}} = 7.33$

Ans. *(a)(i)L, (ii)V,(iii)L+V,(iv)V,(v)G, (b) 215kg/m³, (c)(i)280K, 2.8MPa,, (ii)7, (d)(i)3.01kg, (ii)0.*

ish

Fall 1991 (Mid-Term)-a

The *P-V* diagram for a new industrial material (M = 49 kg/kmol) is provided below. The critical properties of this material are (approximately): T_c = 52°C, P_c = 11.5 MPa, and V_c = 0.34 m^3/kmol. Use the *P-V* diagram to answer the following questions:

CRITICAL

(a) What is the state of the material at each of the following conditions?

- (i) T = 30°C, V = 0.015 m^3/kg VAP
- (ii) P = 5 MPa, V = 0.010 m^3/kg VAP + LIQ
- (iii) P = 10 MPa, T = 15°C — LIQ
- (iv) V = 0.010 m^3/kg, P = 15 MPa – GAS

$\rho_c = 144.12$ kg/m^3

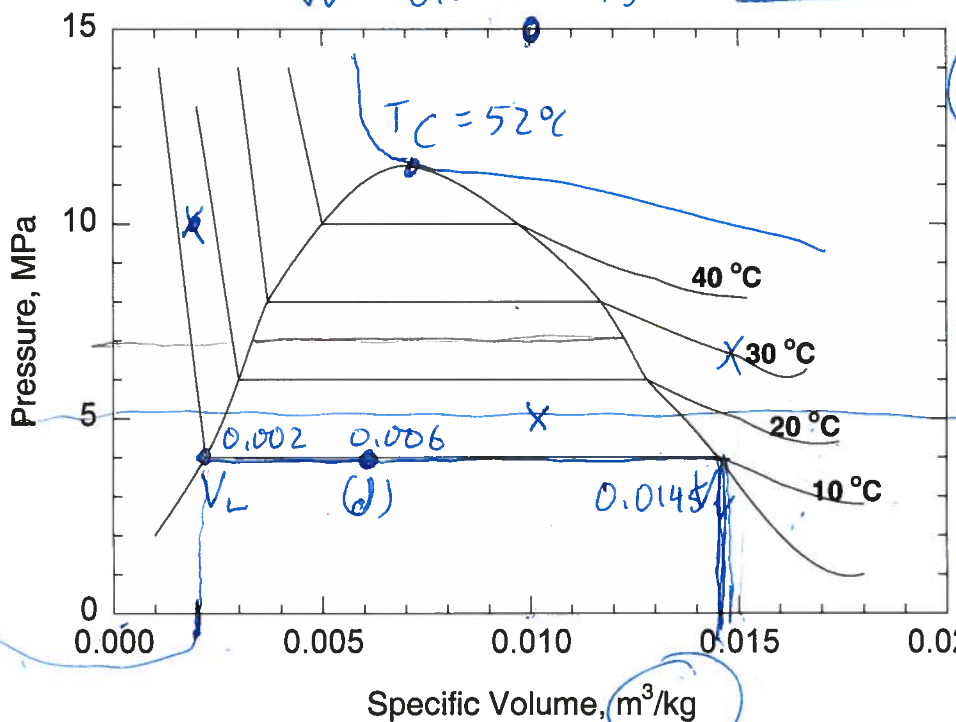
(b) What is the density of the material (in kg/m^3) at its critical conditions? $\rho_c = \frac{M}{V_{mc}} = \frac{49 \text{ kg/kmol}}{0.34 \text{ m}^3\text{/kmol}}$

(c) What is the vapour pressure at 25°C? 7 MPa

(d) What is the density and mass of the liquid phase in a 1 kg sample which occupies a volume of 0.006m^3 at 10°C? $V = \frac{V}{m} = \frac{0.006 \text{ m}^3}{1 \text{ kg}} = 0.006$ m^3/kg

(e) What are the density and the volume occupied by the vapour phase in Part (d)?

$\rho_V = \frac{1}{V_V} = \frac{1}{0.0145 \text{ m}^3\text{/kg}} = 68.96$ kg/m^3



$V_V = ?$

$V_V = \frac{V_V}{M_V}$

$(0.0145 \frac{m^3}{kg})(0.32 kg)$

$= 4.64 \times 10^{-3}$ m^3 VAP

$V_L = 0.002$ m^3/kg

$\rho_L = \frac{1}{V_L} = 500 \frac{kg}{m^3}$

Ans. (a) (i)V, (ii)L+V, (iii)L, (iv)G, (b) 144.12kg/m^3, (c) 7MPa, (d) 500kg/m^3, 0.71kg, (e) 69kg/m^3, 4.2liter

$\frac{M_L}{M_T} = \frac{0.0145 - 0.006}{0.0145 - 0.002} = 0.68$

$M_L = (1 \text{ kg})(0.68) = 0.68$ kg LIQ $\longrightarrow 1 - 0.68 = 0.32$ kg $= M_V$ VAP