Thermo 1 (MEP 261)

Thermodynamics An Engineering Approach

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Sheet 3:Chapter 3

3-26) Complete the table for H_2O:

T, °C	*p*, kPa	*h*, kJ/kg	*v*, m^3/kg	Phase description	***x***
50			4.16		
	200			Saturated vapor	
250	400				
110	600				

Solution

a) T_1 = 50°C, v_1 = 4.16 m3/kg.

From Table A-4, Saturated water, Temperature table

v_f = 0.0001012 m^3/kg, v_g = 12.026 m^3/kg, h_f = 209.34 kJ/kg, h_g = 2591.3 kJ/kg,

As v_f (=0.0001012 m^3/kg) **<** v_1 **(= 4.16** m^3**/kg)<** v_g **(=** 12.026 **m3/kg).**

Hence, State 1 is saturated Liquid-vapor mixture.

$p_1 = p_{sat}$ @ T **= 50**°C = 12.352 kPa.

$x_1 = (v_1 - v_f)/(v_g - v_f)$ **= (4.16 - 0.0001012)/(12.026 - 0.0001012)= 0.3459**

$h_1 = h_f + x_1 (h_g - h_f)$ **=** 209.34 **+0.3459 (**2591.3 **-** 209.34**) = 1033.26** kJ/kg.

b) p_2 **=** 200 kPa, State 2 is saturated vapor. Hence, x_2 = 1.

$T_2 = T_{sat}$ @ p **= 200** kPa = 120.21°C. (from Table A-5)

$v_2 = v_g$ @ p **= 200** kPa = 0.88578 m^3/kg. (from Table A-5)

$h_2 = h_g$ @ p **= 200** kPa = 2706.3 kJ/kg. (from Table A-5)

c) T_3 **= 250**°C, p_3 **= 400 kPa.**

From Table A-5, Saturated water, Pressure table, T_{sat} @ p **= 400** kPa = 143.61°C.

As T_3 **(=** *4***00** °C) > T_{sat} @ p **= 400** kPa = 143.61°C,

Hence, **State 3 is superheated steam.**

From Table A-6, for superheated steam,

For T_3 **= 250**°C, p_3 **= 400 kPa (0.4 MPa),** v_3 **=** 0.59520 m^3/kg, h_3 = 2964.5 kJ/kg.

d) T_4 **= 110**°C, p_4 **= 600 kPa.**

From Table A-5, Saturated water, Pressure table, T_{sat} @ p = 600 kPa = 158.83°C.

As T_4 (= 110 °C) < **T_{sat} @ p = 600** kPa = 158.83°C,

Hence, **State 4 is compressed (subcooled) liquid.**

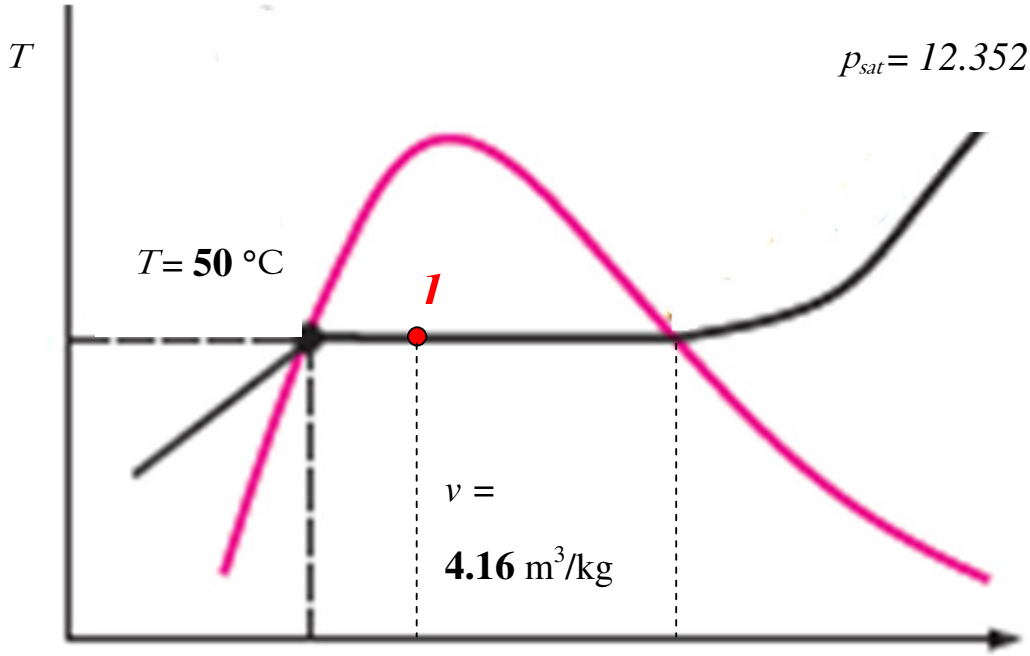
As there is no data for compressed liquid water for p = 600 kPa (= 0.6 MPa) in Table A-7. Hence, by utilizing the approximation:

$v_4 = v_f$ @ T = **110** °C = 0.001052 m^3/kg. (from Table A-4)

$h_4 = h_f$ @ T = **110** °C = 461.42 kJ/kg. (from Table A-4)

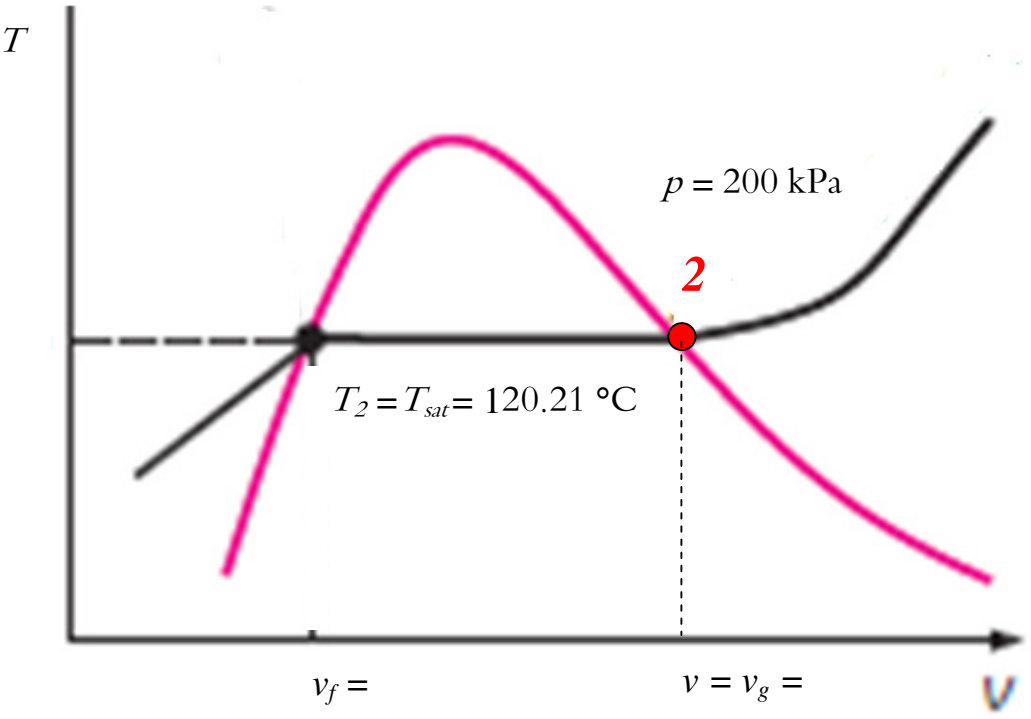
Point	*T,* °C	*p,* kPa	*h*, kJ/kg	*v*, m^3/kg	Phase description	***x***
1	**50**	*12.352*	*1033.26*	**4.16**	*Saturated Liquid-vapor mixture*	*0.3459*
2	*120.21*	**200**	2706.3	0.88578	**Saturated vapor**	1.0
3	**250**	**400**	*2964.5*	*0.5952*	*Superheated steam*	-
4	**110**	**600**	*461.42*	*0.001052*	*Compressed (Subcooled liquid)*	-

State 1



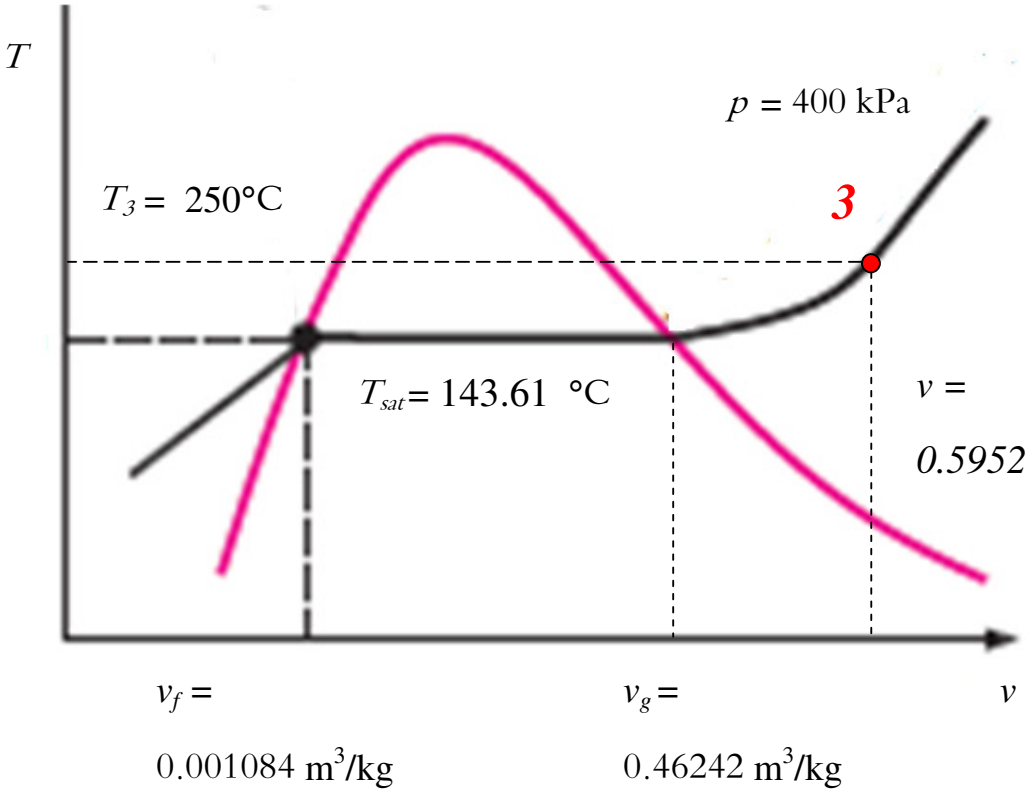
0.0001012 m^3/kg 12.026 m^3/kg

State 2

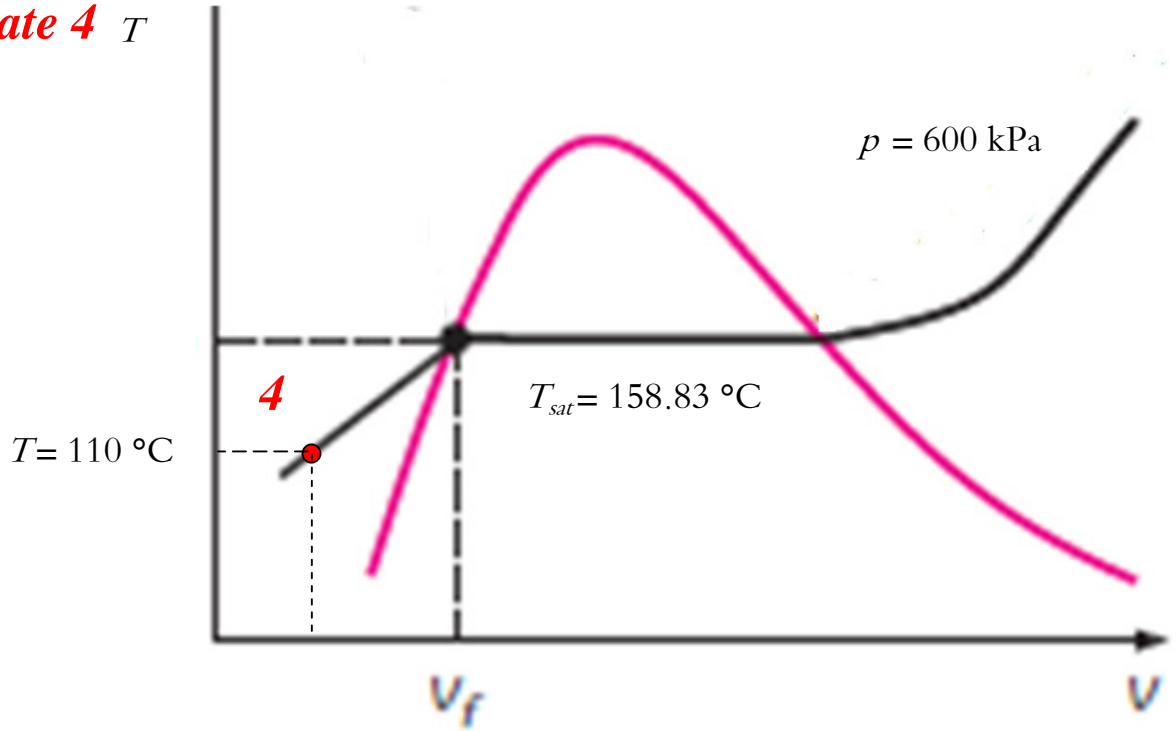


0.0007499 m^3/kg 0.88578 m^3/kg

State 3



State 4



3-30) Complete the table for H_2O:

T, °C	*p*, kPa	*h*, kJ/kg	*v*, m^3/kg	***x***	Phase description
	200			0.7	
140		1800			
	950			0.0	
80	500				
	800	3162.2			

Solution

a) $p_1 =$ 200 kPa, $x = 0.7$.

From Table A-5, Saturated water, Pressure table

$T_1 = T_{sat} @ p = 200$ kPa = 120.21°C.

v_f = 0.001061 m^3/kg, v_g = 0.88578 m^3/kg, h_f = 504.71 kJ/kg, h_g = 2706.3 kJ/kg,

As $0 < x_1 (= 0.7) < 1$.

Hence, State 1 is saturated Liquid-vapor mixture.

$v_1 = v_f + x_1 (v_g - v_f) = 0.001061 + 0.7 (0.88578 - 0.001061) = 0.62$ m^3/kg.

$h_1 = h_f + x_1 (h_g - h_f) = 504.71 + 0.7 (2706.3 - 504.71) =$ **2045.8** kJ/kg.

b) $T_2 =$ 140 °C, $h_2 =$ 1800 kJ/kg.

From Table A-4, Saturated water, Temperature table,

v_f = 0.001080 m^3/kg, v_g = 0.50850 m^3/kg, h_f = 589.16 kJ/kg, h_g = 2733.5 kJ/kg,

As h_f (=589.16 kJ/kg **) < h_2 (=**1800 kJ/kg **)< h_g (=** 2733.5 kJ/kg **).**

Hence, State 2 is saturated Liquid-vapor mixture.

$p_2 = p_{sat}$ @ T = 140 °C = 361.53 kPa. (from Table A-4)

$x_2 = (h_2 - h_f)/(h_g - h_f) = (1800 - 589.16)/(2733.5 - 589.16) = 0.565$

$v_2 = v_f + x_2 (v_g - v_f) = 0.001080 + 0.565 (0.50850 - 0.001080) = 0.288$ m^3/kg.

c) x_3 = 0, p_3 = 950 kPa.

***As x_3 = 0, hence,* State 3 is saturated liquid.**

From Table A-5, Saturated water, Pressure table,

$T_3 = T_{sat}$ @ p = 950 kPa = 177.66 °C.

$v_3 = v_f$ = 0.001124 m^3/kg, $h_3 = h_f$ = 752.74 kJ/kg,

d) T_4 = 80°C, p_4 = 500 kPa.

From Table A-5, Saturated water, Pressure table, T_{sat} @ p = 500 kPa = 151.83°C.

***As T_4* (= 80 °C) < T_{sat} @ p = 500** kPa = 151.83°C, ***Hence,* State 4 is compressed (subcooled) liquid.**

As there is no data for compressed liquid water for p = 500 kPa (= 0.5 MPa) in Table A-7. Hence, by utilizing the approximation:

$v_4 = v_f$ @ T = **80** °C = 0.001029 m^3/kg. (from Table A-4)

$h_4 = h_f$ @ T = **80** °C = 461.42 kJ/kg. (from Table A-4)

e) P_5 = **800**kPa, h_5 = **3162.2** kJ/kg.

From Table A-5, Saturated water, Pressure table, h_f @ p = **500** kPa = 720.87 kJ/kg, h_g @ p = **500** kPa = 2770.8 kJ/kg, T_{sat} @ p = **800** kPa = 170.41°C.

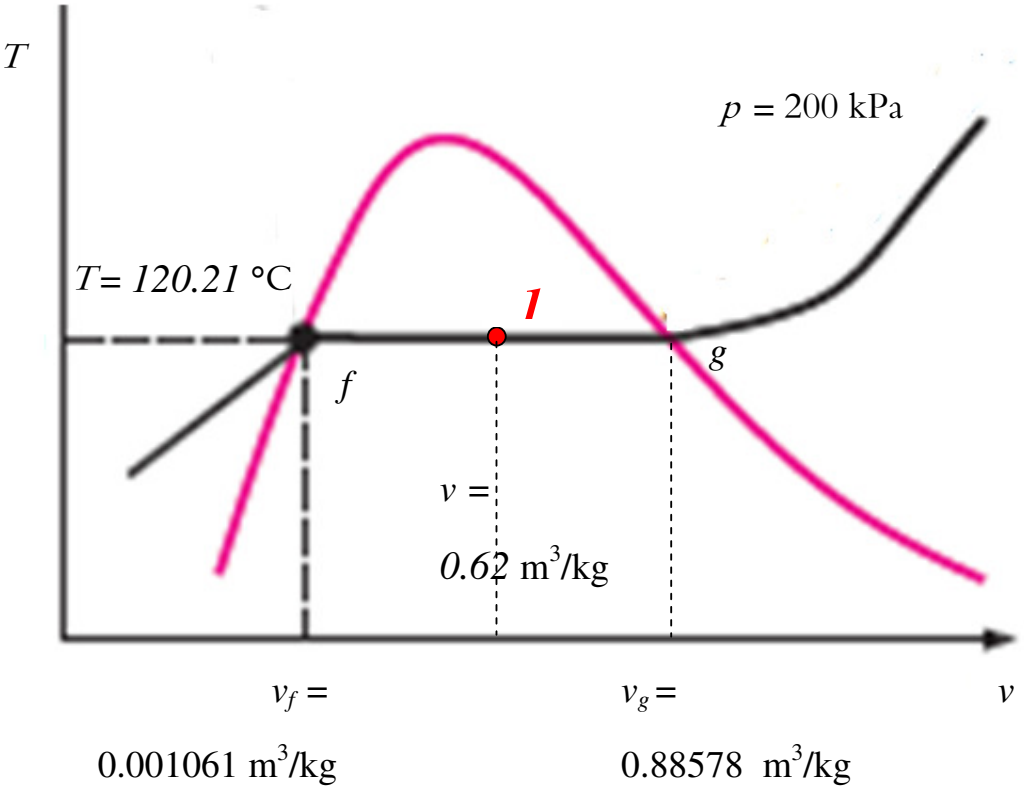
As h_5 (= **3162.2** kJ/kg) > h_g @ p = **500** kPa = 2770.8 kJ/kg, *Hence,* **State 5 is superheated steam.**

From Table A-6, for superheated steam,

For p_5 = **800** kPa =0.8 MPa, h_5 = **3162.2** kJ/kg, T_5 = **350** °C, v_5 = 0.35442 m^3/kg.

Point	*T,* °C	*p,* kPa	*h*, kJ/kg	*v*, m^3/kg	Phase description	***x***
1	*120.21*	**200**	*2045.8*	*0.62*	*Saturated Liquid-vapor mixture*	**0.7**
2	**140**	*361.53*	**1800**	*0.288*	*Saturated Liquid-vapor mixture*	*0.565*
3	*177.66*	**950**	*752.74*	*0.001124*	*Saturated liquid*	**0.0**
4	**80**	**500**	*461.42*	*0.001029*	*Compressed liquid*	-
5	*350*	**800**	**3162.2**	*0.35442*	*Superheated steam*	-

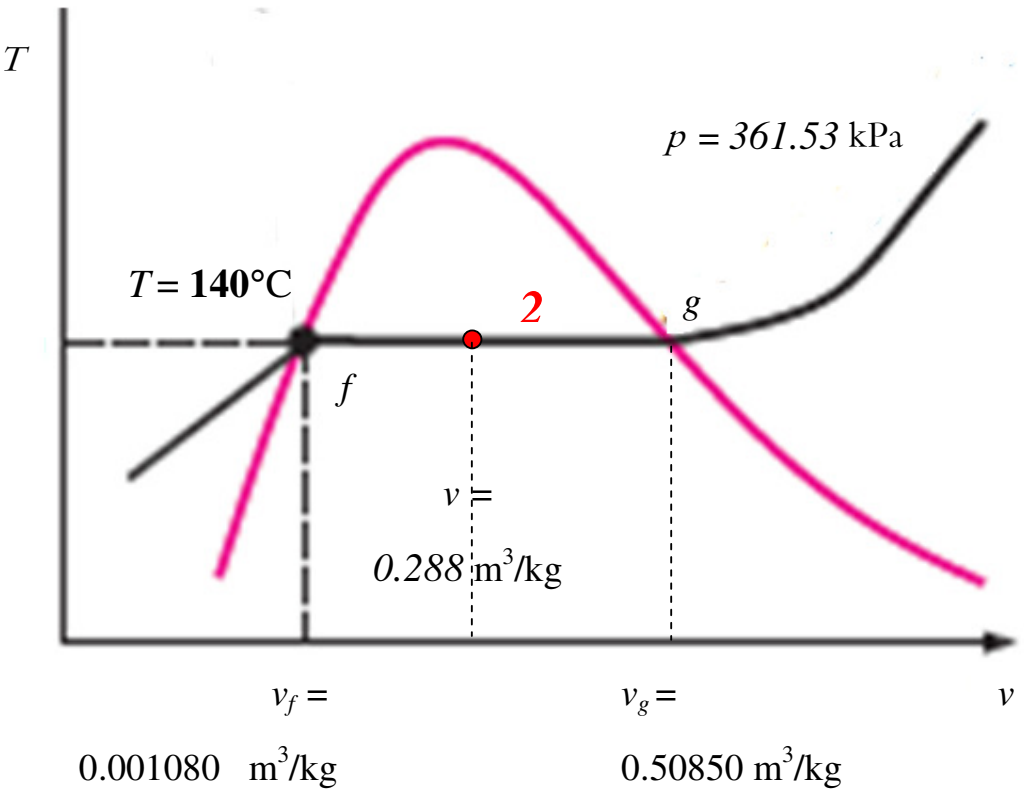
State 1



v_f = 0.001061 m^3/kg

v_g = 0.88578 m^3/kg

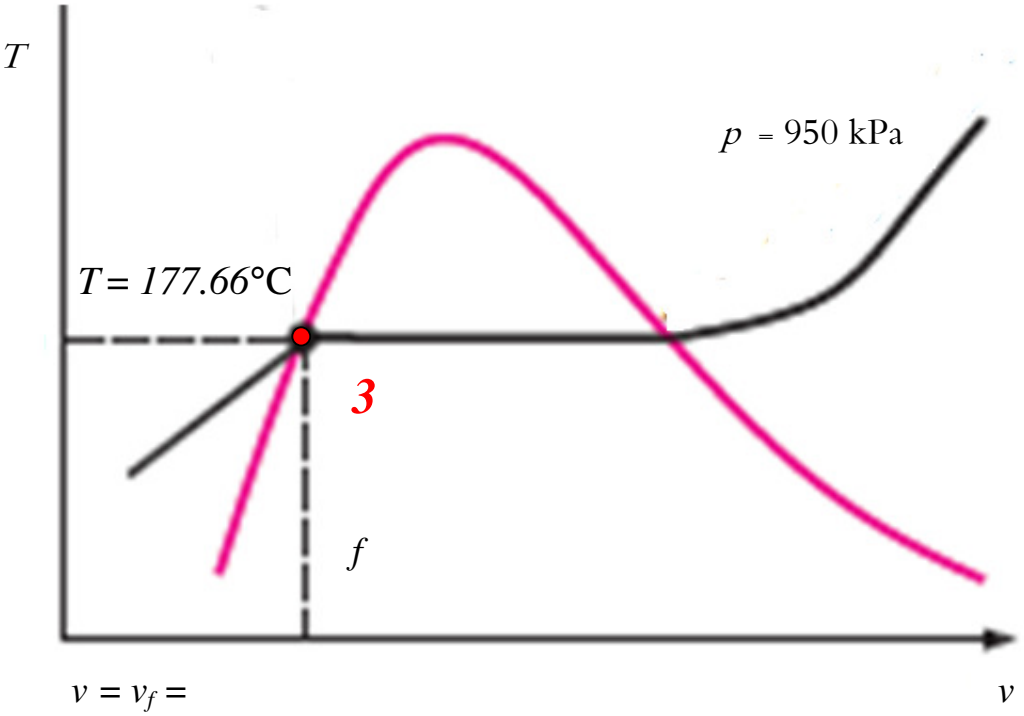
State 2



v_f = 0.001080 m^3/kg

v_g = 0.50850 m^3/kg

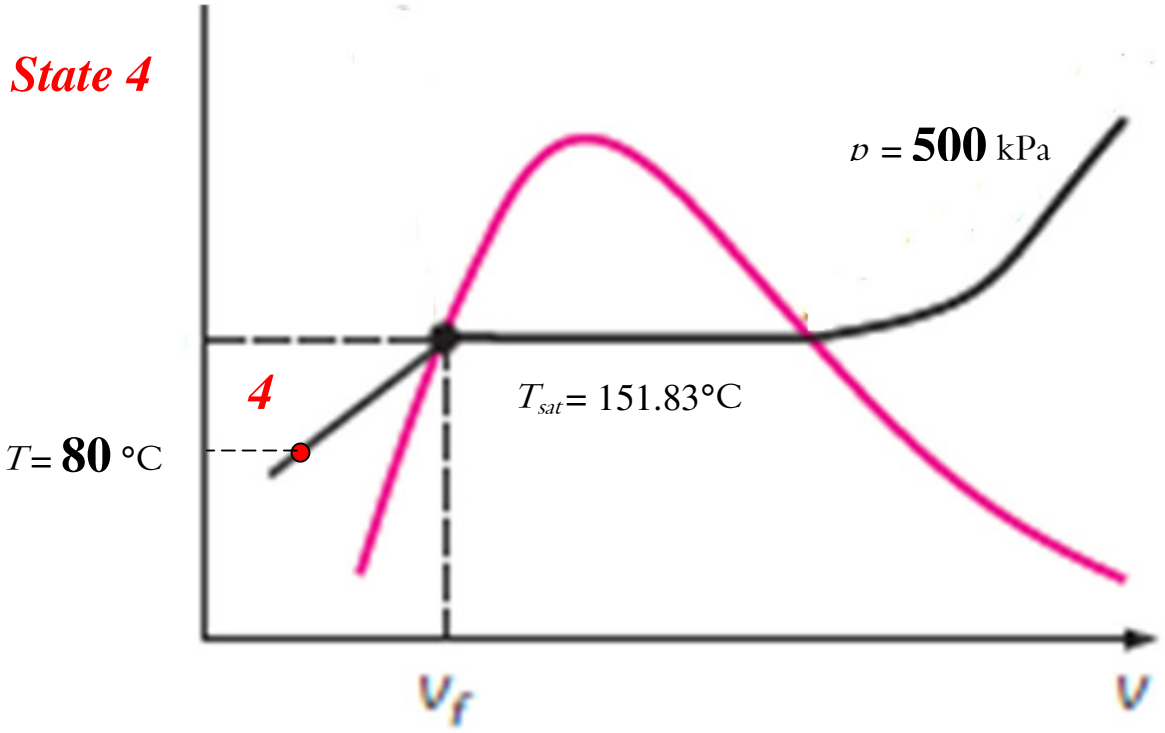
State 3



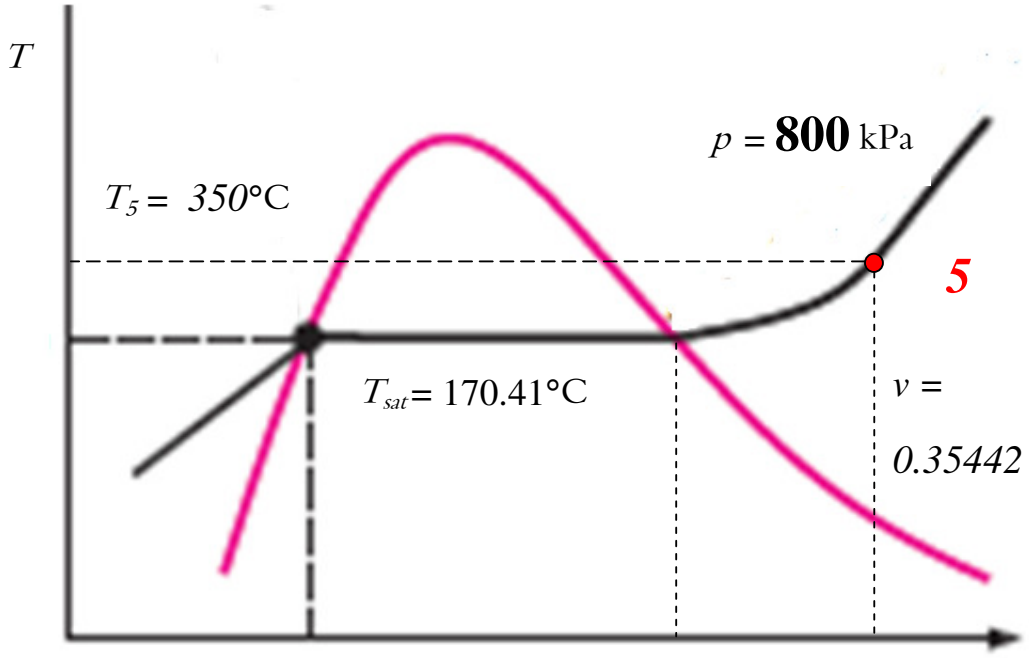
0.001124 m^3/kg

T

State 4



State 5



3-31) Complete the following table for refrigerant–134a:

Point	*T*, °C	*p*, kPa	*u*, kJ/kg	*v*, m^3/kg	***x***	Phase description
1	-8	320				
2	30			0.015		
3		180				Saturated vapor
4	80	600				

Solution

For refrigerant–134a:

State 1: T = –8 °C, p = 320 kPa , From Table A–12 (Saturated **refrigerant–134a** –Pressure table),

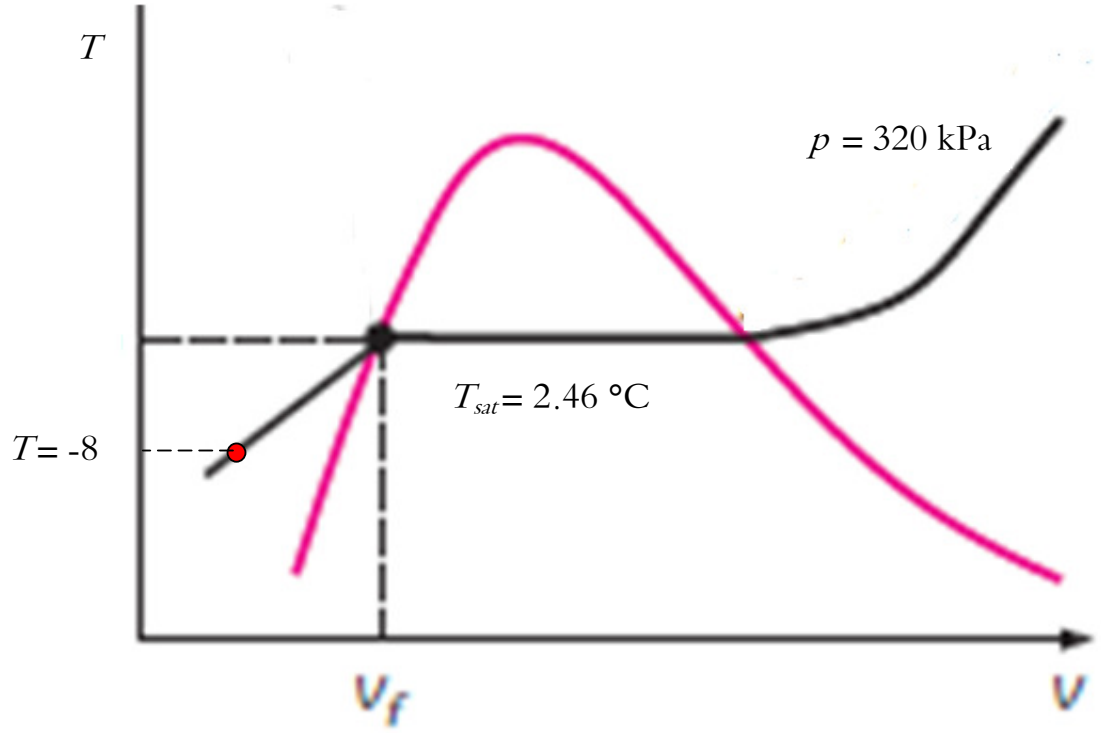
For p = 320 kPa, T_{sat} = 2.46 °C,

As $T < T_{sat}$, Hence, State 1 is compressed (subcooled) liquid,

Hence, conditions are nearly the same as those at Saturated liquid corresponding to T = –8 °C.

Hence, From Table A–11, corresponding to T = –8°C

$v = v_f = 0.0007571$ m^3/kg & $u = u_f = 41.03$ kJ/kg



State 2: T = 30 °C, v = 0.015 m^3/kg, *From Table A-11* (Saturated **refrigerant–134a** -Temperature table)

For T = 30 °C, p_{sat} = 770.64 kPa, v_f = 0.0008421 m^3/kg, v_g = 0.026622 m^3/kg , u_f = 92.93 kJ/kg, u_g = 246.14 kJ/kg.

As v_f (= 0.0008421 m^3/kg) < v (= 0.015 m^3/kg) < v_g (= 0.026622 m^3/kg)

Hence, state 2 is saturated liquid-vapor mixture

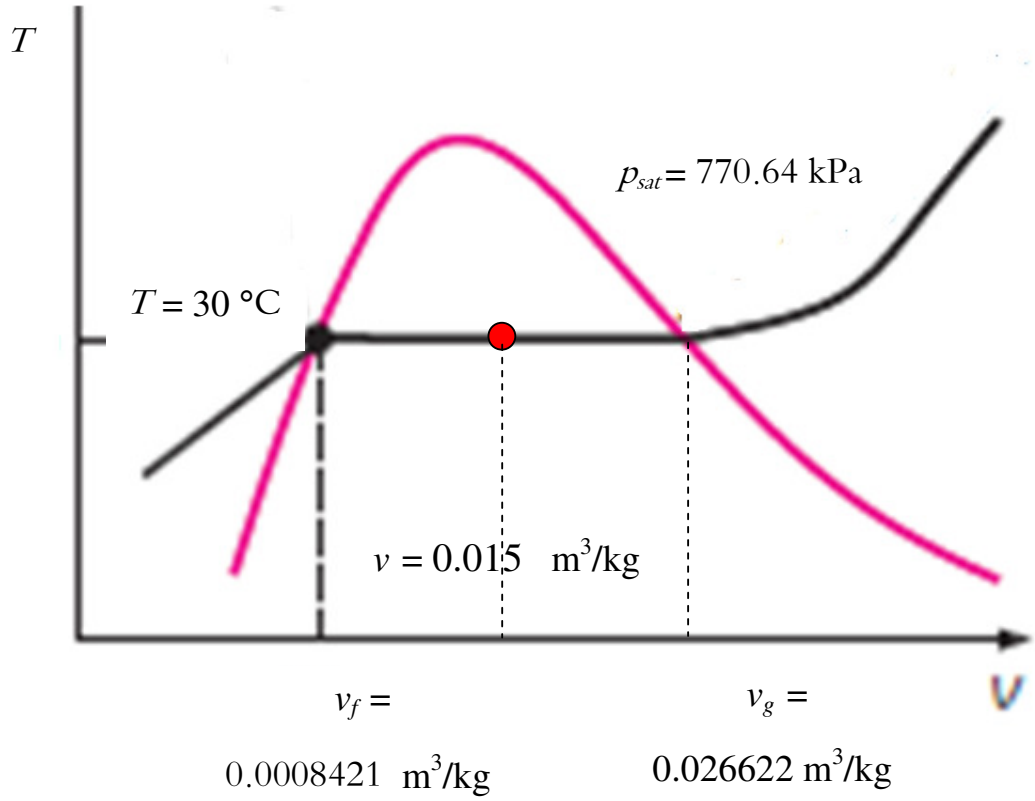
$$\boldsymbol{x} = \frac{\boldsymbol{v} - v_f}{v_g - v_f}$$

Hence,

$$\boldsymbol{x} = \frac{\mathbf{0.015} - 0.0008421}{0.026622 - 0.0008421}$$

Hence, $x = 0.5492$,

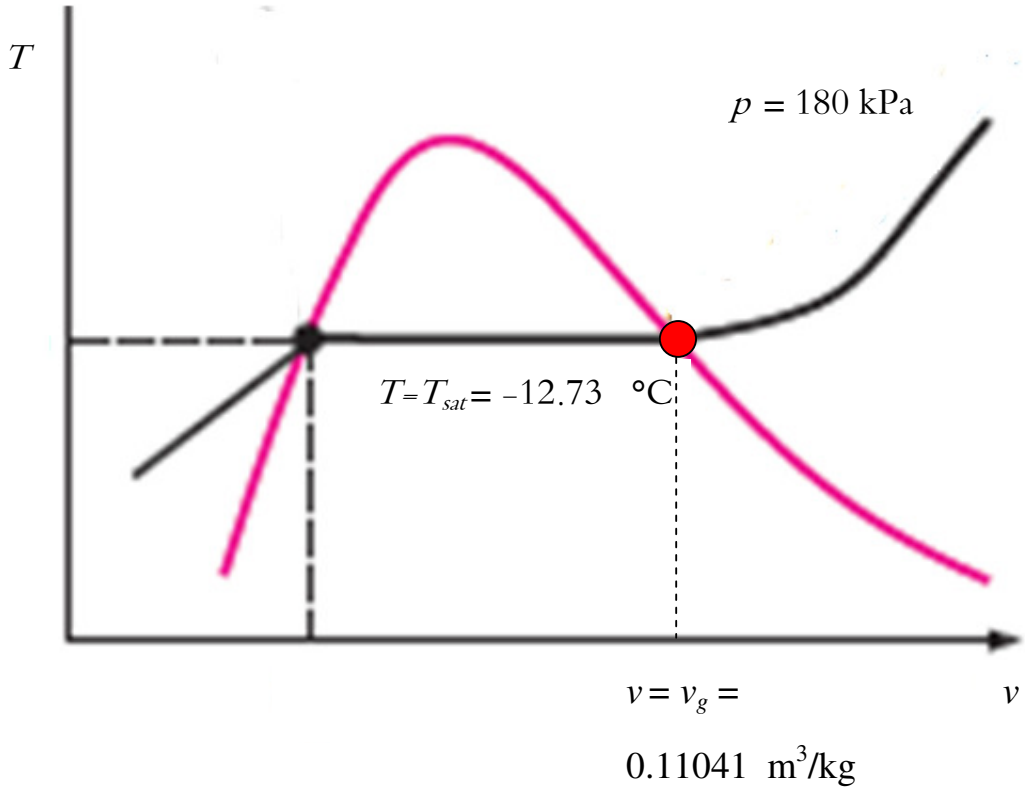
$u = u_f + x(u_g - u_f) = 92.93$ kJ/kg $+0.5492$ (246.14 -92.93) kJ/kg $=$ 177.07 kJ/kg



State 3: $p =$ 180 kPa , *Satureated vapor, x = 1;*

From Table A-12 (Saturated **refrigerant–134a** –Pressure table)**,**

For $p =$ 180 kPa, $T = T_{sat} =$ –12.73 °C, $v = v_g =$ 0.11041 m³/kg , $u = u_g =$ 222.99 kJ/kg.



State 4: T = 80 °C, p = 600 kPa ,

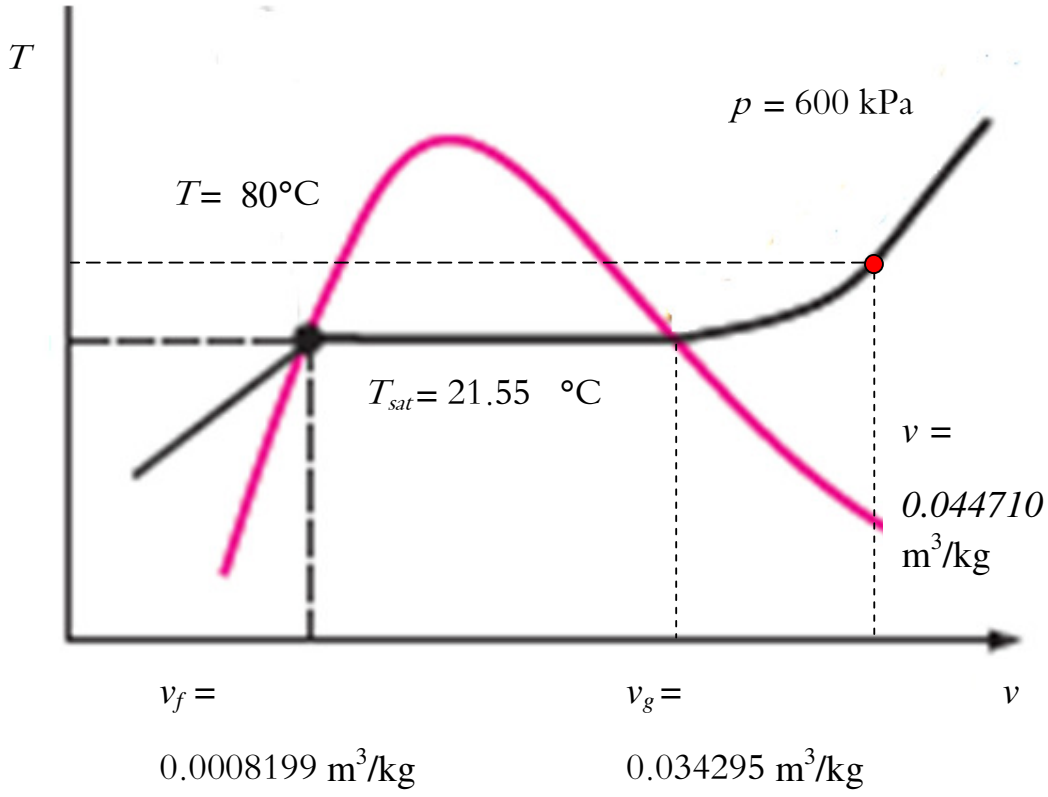
From Table A-12 (Saturated **refrigerant–134a** –Pressure table)**,**

$T_{sat\ at\ p\ =\ 600\ kPa}$ (=21.55 °C),

As T (= 80 °C) > $T_{sat\ at\ p\ =\ 600\ kPa}$ (=21.55 °C), hence state 4 is superheated vapor.

Hence, From Table A–13, Superheated **refrigerant–134a**

For p = 600 kPa (=0.6 MPa), T = 80 °C , *v = 0.044710* m³/kg & *u = 292.73* kJ/kg



Point	*T*, °C	*p*, kPa	*u*, kJ/kg	*v*, m^3/kg	***x***	Phase description
1	**-8**	**320**	*41.03*	*0.0007571*	-	*Compressed liquid*
2	**30**	*770.64*	177.07	**0.015**	*0.5492*	*Saturated liquid-vapor mixture*
3	*-12.73*	**180**	222.99	*0.11041*	*1.0*	**Saturated vapor**
4	**80**	**600**	*292.73*	*0.044710*	-	*Superheated vapor*

3–32: **Complete the table for refrigerant–134a**:

T, °C	*p*, kPa	*u*, kJ/kg	*v*, m^3/kg	Phase description	***x***
20		95			
-12				Saturated liquid	
	400	300			
8	600				

Solution

For refrigerant–134a:

$T = 20$ °C, $u = 95$ kJ/kg, From Table A–11,

For $T = 20$ °C, $p_{sat} = 572.07$ kPa, $u_f = 78.86$ kJ/kg, $u_g = 241.02$ kJ/kg,

$v_f = 0.0008161$ m^3/kg, $v_g = 0.035969$ m^3/kg,

As $u_f < u < u_g$, Hence, State is saturated liquid–vapor mixture,

$$\boldsymbol{x} = \frac{\boldsymbol{u} - u_f}{u_g - u_f} = \frac{95 - 78.86}{241.02 - 78.86} = \mathbf{0.09953}$$

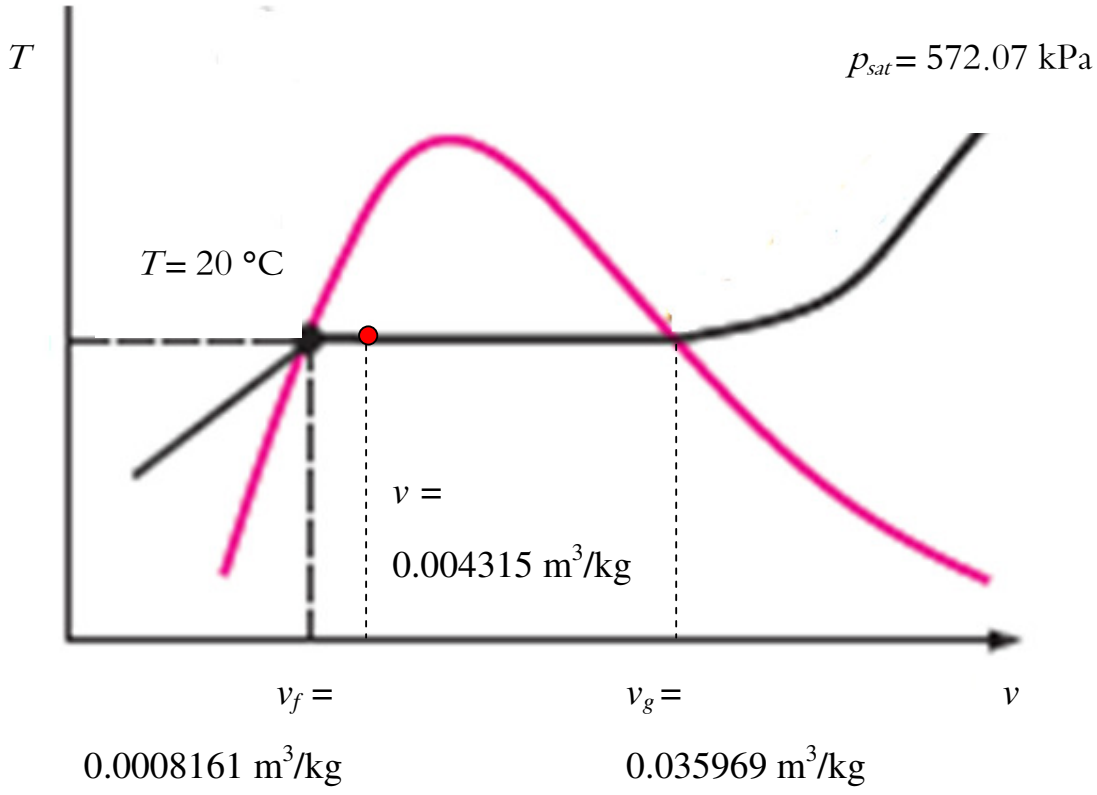
As

$$\boldsymbol{x} = \frac{\boldsymbol{v} - v_f}{v_g - v_f}$$

Hence,

$$\mathbf{0.09953} = \frac{\boldsymbol{v} - 0.0008161}{0.035969 - 0.0008161}$$

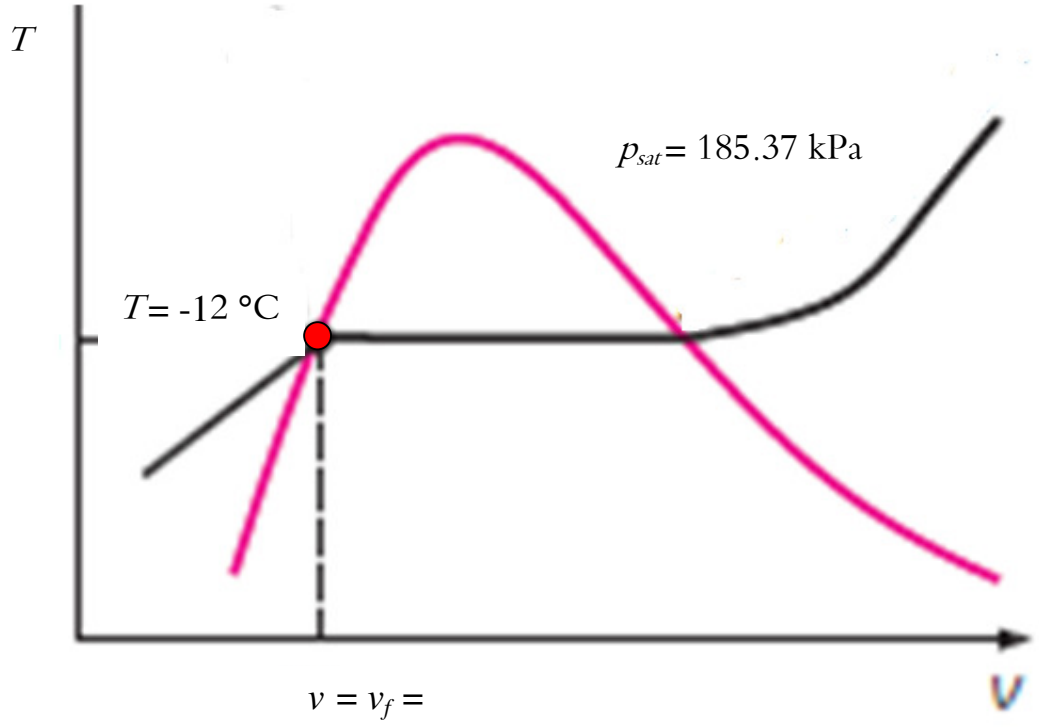
Hence, v = 0.004315 m^3/kg,



b)

T = –12 °C, **Saturated liquid**, From Table A–11,

For T = –12 °C, p_{sat} = 185.37 kPa, $u = u_f$ = 35.78 kJ/kg, $v = v_f$ = 0.0007499 m^3/kg& x = 0.



$v = v_f =$

0.0007499 m^3/kg

c)

$p =$ 400 kPa , $u =$ 300 kJ/kg, From Table A–12,Data *for* $p =$ 400 kPa*;*

p, kPa	*T* , °C	*v* , m^3/kg	*u*, kJ/kg
400	**80**	0.068747	**294.53**
	T	*v*	300
	90	0.071023	**303.32**

Hence,

$$\frac{T - \mathbf{80}}{90 - 80} = \frac{300 - 294.53}{303.32 - 294.53}$$

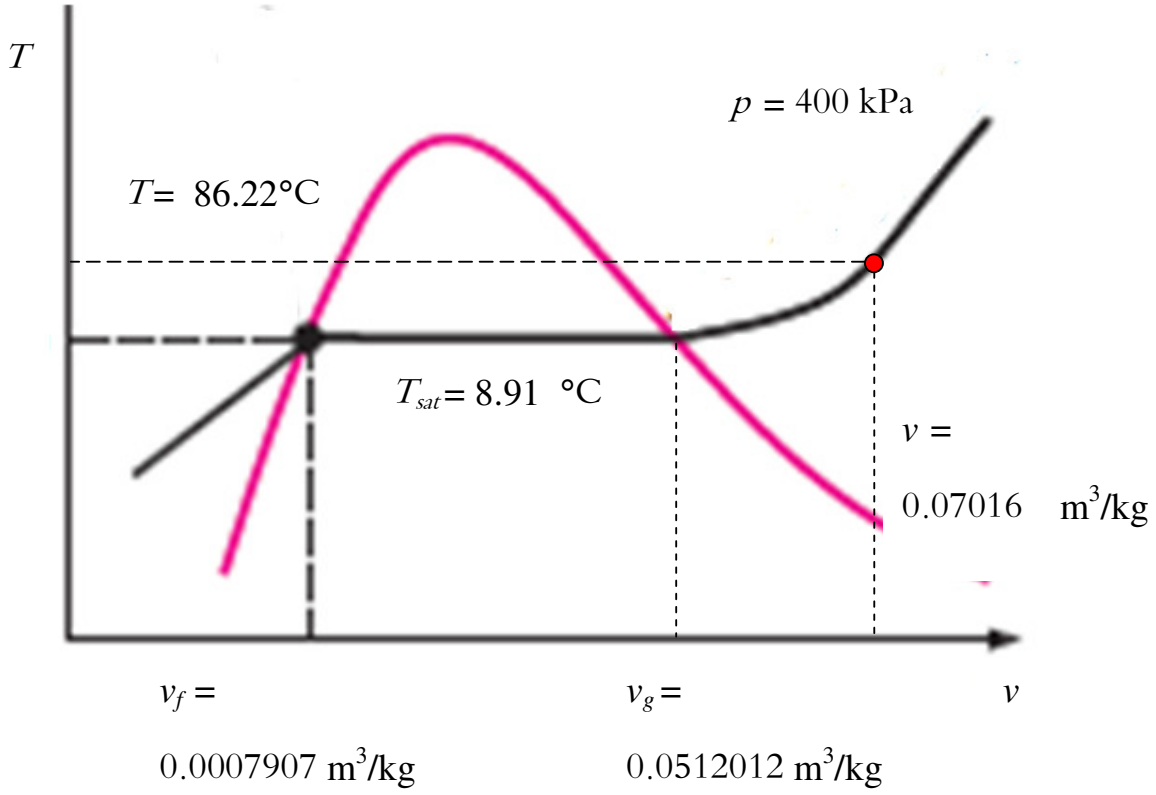
Hence, $T = 86.22$ °C

$$\frac{v - 0.068747}{0.071023 - 0.068747} = \frac{300 - 294.53}{303.32 - 294.53}$$

$v = 0.07016$ m^3/kg,

From Table A-12,

For p = 400 kPa, $T_{sat} = 8.91$ °C, $T_{sat} = 185.37$ kPa, $v_f = 0.0007907$ m^3/kg& $v_g = 0.051201$ m^3/kg.



d)

p = 600 kPa, From Table A-12,

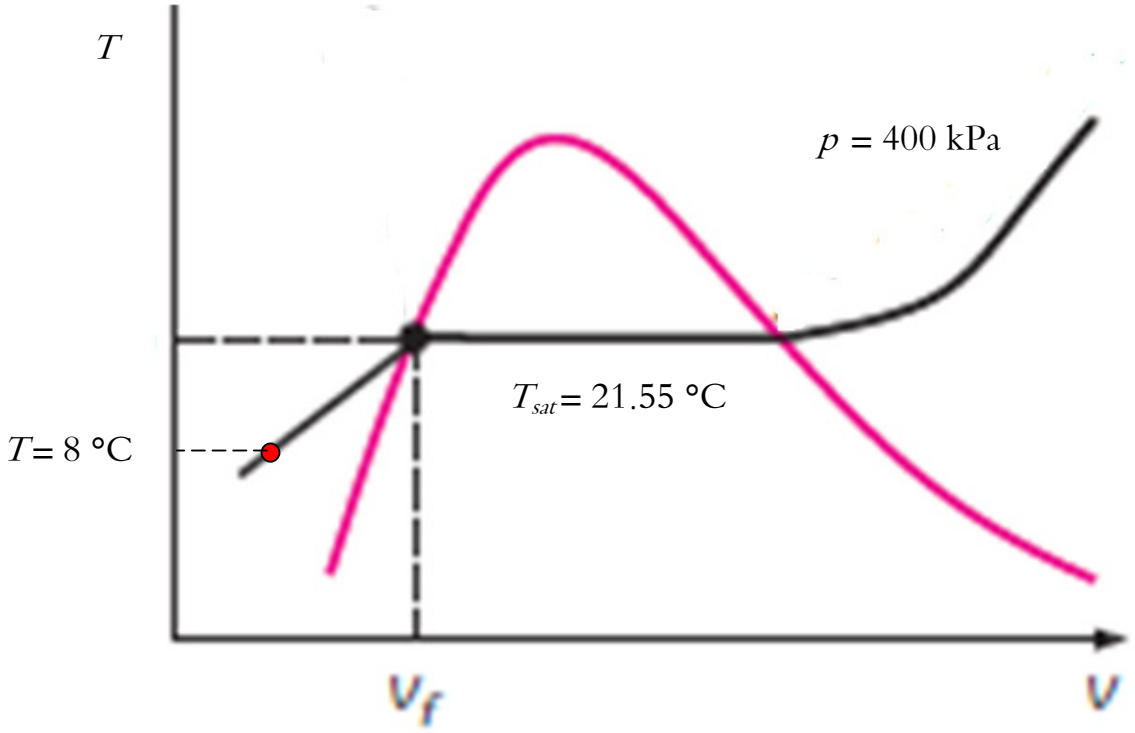
For p = 600 kPa, T_{sat} = 21.55 °C.

As T (= 8 °C) < $T_{sat\ at\ p\ =\ 600\ kPa}$ (=21.55 °C), hence state is sucbcooled (compressed) liquid.

Hence, conditions are nearly the same as those at Saturated liquid corresponding to T = 8 °C.

Hence, From Table A-11, corresponding to T = 8°C

$v = v_f = 0.0007887\ m^3/kg$ & $u = u_f = 62.39\ kJ/kg$



T, °C	*p*, kPa	*u*, kJ/kg	*v*, m^3/kg	Phase description	***x***
20	572.07	**95**	0.004315	Saturated liquid-vapor mixture	0.09953
-12	185.37	35.78	0.0007499	**Saturated liquid**	0
86.22	**400**	**300**	0.07016	Superheated vapor	-
8	**600**	62.39	0.0007887	Sucbcooled (compressed) liquid	-

3–34: **Complete the table for H_2O**:

T, °C	*p*, kPa	*h*, kJ/kg	*v*, m^3/kg	*x*	Phase description
140			**0.05**		
	550				**Saturated liquid**
125	**750**				
500			**0.140**		

Solution

a) $T = 140$ °C, $v = 0.05$ m^3/kg.

From Table A-4, Saturated water, Temperature table, $p_{sat\ at\ T = 140\ °C} = 361.53$ kPa

For T = 140°C.

$v_f = 0.001080$ m^3/kg, $v_g = 0.50850$ m^3/kg, $h_f = 589.16$ kJ/kg, $h_g = 2733.5$ kJ/kg,

As v_f (=0.001080 m^3/kg) **<** v **(=**0.05 m^3/kg**)<** v_g(=0.50850 m^3/kg**).**

Hence, State 1 is saturated Liquid-vapor mixture.

$x_1 = (v_1 - v_f)/(v_g - v_f) = (0.05 - 0.001080) / (0.50850 - 0.001080) = 0.0964$.

$h_1 = h_f + x_1 (h_g - h_f) = 589.16 + 0.0964\ (2733.5 - 589.16) =$ **795.87** kJ/kg.

b) $P_2 =$ 550 kPa, ***Saturated liquid***.

From Table A-5, Saturated water, Pressure table, T_{sat} **@** p **= 550** kPa = 155.46°C.

$v = v_f = 0.001097$ m^3/kg, $h = h_f = 655.77$ kJ/kg.

c) $T_3 =$ 125°C, $p_3 = 750$ **kPa.**

From Table A-5, Saturated water, Pressure table,

T_{sat} **@** p **= 750** kPa = 167.75 °C.

As T_3 **(=** ***125*** °C) < T_{sat} **@** p **= 750** kPa = 167.75°C, ***Hence,*** **State 4 is compressed (subcooled) liquid.**

As there is no data for compressed liquid water for p = 750 kPa (= 0.75 MPa) in Table A-7. Hence, by utilizing the approximation:

$v_3 = v_f$ @ T = **125** °C = 0.001065 m^3/kg. (from Table A-4)

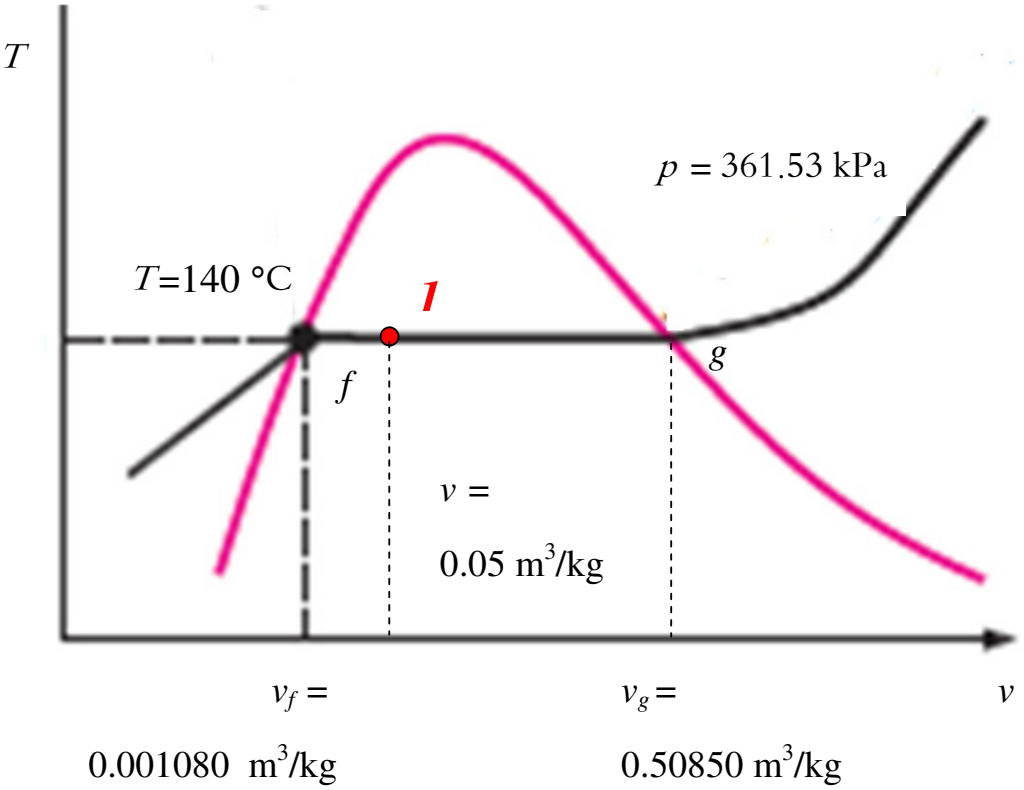
$h_3 = h_f$ @ T = **125** °C = 525.07 kJ/kg. (from Table A-4)

d) T_4 = **500** °C, v_4 =**0.140** m^3/kg**.**

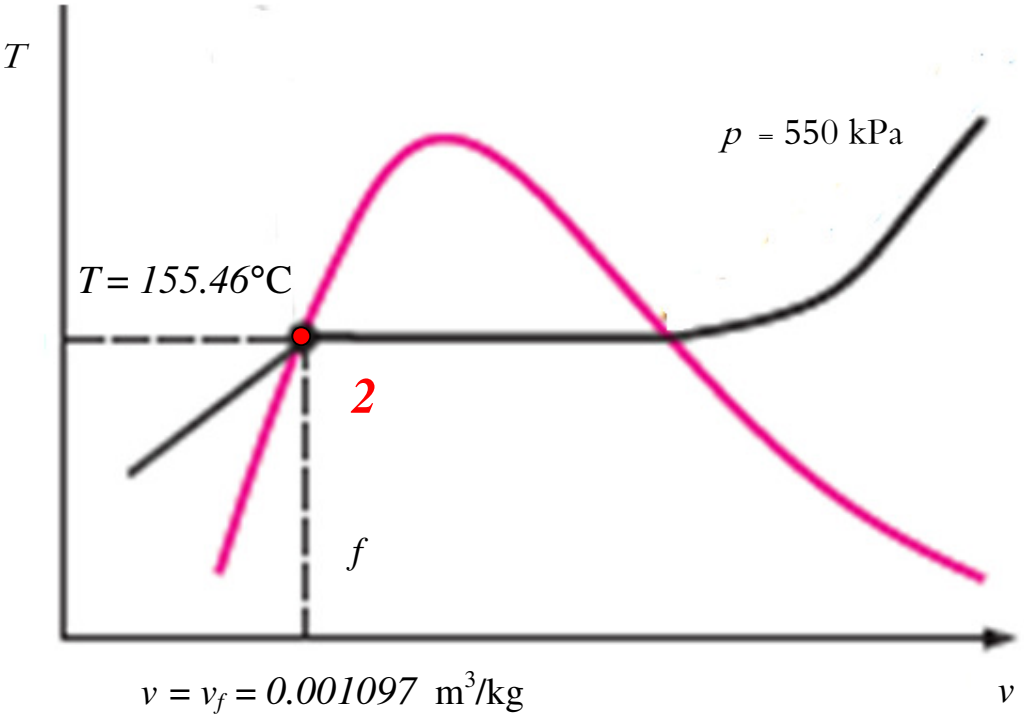
From Table A-6, Superheated steam, T_4 = 500 °C , v_4 **= 0.140** m^3/kg , h_4 = 3462.8 kJ/kg , p_4 = 2.5 MPa.

T, °C	*p,* kPa	*h*, kJ/kg	*v*, m^3/kg	*x*	Phase description
140	*361.53*	*795.87*	**0.05**	*0.0964*	*Saturated liquid-vapor mixture*
155.46	**550**	*655.77*	*0.001097*	*0.0*	**Saturated liquid**
125	**750**	*525.07*	*0.001065*	-	*Compressed (Subcooled) liquid*
500	*2500*	*3462.8*	**0.140**	-	Superheated steam

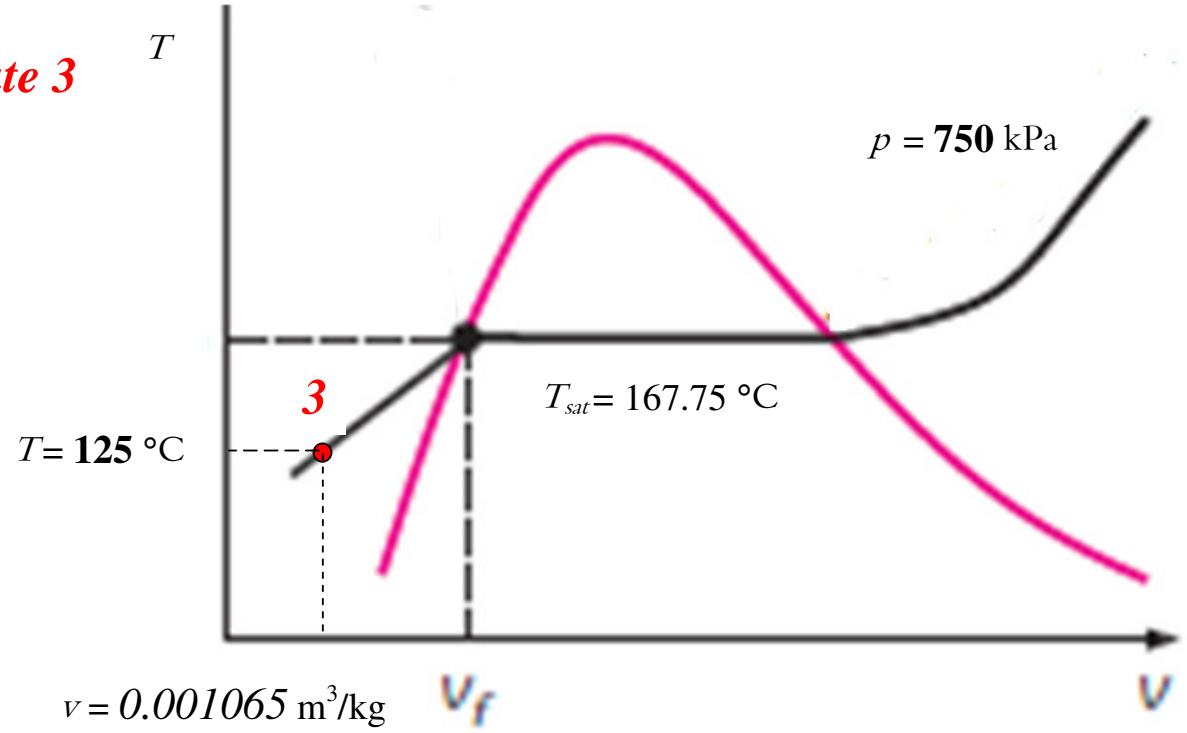
State 1



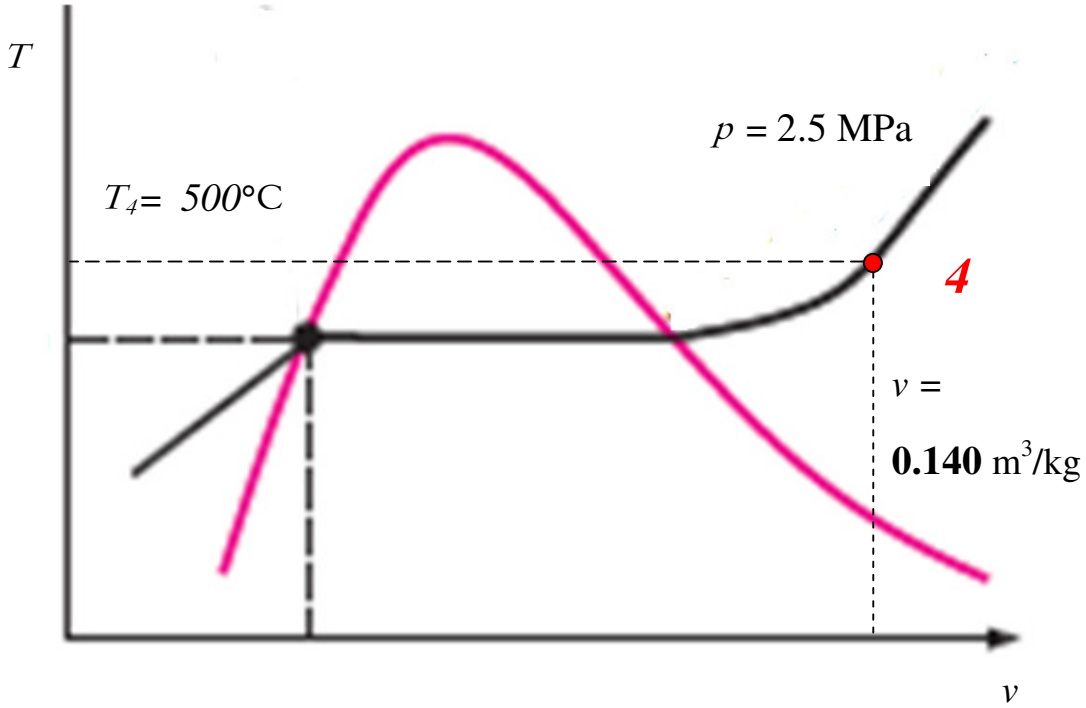
State 2



State 3



State 4



3-35) Complete the following table for H_2O

T, °C	p, kPa	u, kJ/kg	v, m^3/kg	x	Phase description
	400	**1450**			
220					**Saturated vapor**
190	**2500**				
	4000	**3040**			

Solution

a) $\boldsymbol{p}$ = 400 kPa, u = 1450 kJ /kg.

From Table A-5, Saturated water, Teperature table, $T_{sat\ at\ p\ =\ 400\ kPa}$ (=143.61°C).

v_f = 0.001084 m^3/kg, v_g = 0.46242 m^3/kg, u_f = 604.22 kJ/kg, u_g = 2553.1 kJ/kg,

As u_f (=604.22 kJ/kg) **<** $\boldsymbol{u}$ **(=**1450 kJ /kg**)<** u_g(=2553.1 kJ/kg).

Hence, State 1 is saturated Liquid-vapor mixture.

$x_1 = (u_1 - u_f)/(u_g - u_f) = (1450 - 604.22) / (2553.1 - 604.22) = 0.44.$

$\boldsymbol{v_1} = v_f + \boldsymbol{x_1}\,(v_g - v_f) = 0.001084 + 0.44\,(0.46242 - 0.001084) =$ **0.2013** m^3/kg.

b) $\boldsymbol{T_2}$ = 220 °C, **Saturated vapor**.

From Table A-4, Saturated water, Tempererature table, $\boldsymbol{p_{sat}}$ **@** $\boldsymbol{T}$ **= 220** °C = 2319.6 kPa.

$v = v_g = 0.078405\ m^3/kg$, $u = u_g = 2602.3$ kJ/kg.

c) T_3 = 190 ℃, p_3 = 2500 kPa.

From Table A-5, Saturated water, Pressure table,

T_{sat} @ p = **2500** kPa = 223.95 °C.

As T_3 (=**190** °C) < T_{sat} @ p = **2500** kPa = 223.95 °C, ***Hence,***
State 3 is compressed (subcooled) liquid.
As there is no data for compressed liquid water for p = 2500 kPa (= 2.5 MPa) in Table A-7. Hence, by utilizing the approximation:
$v_3 = v_f$ @ T = **190** °C = 0.001141 m^3/kg. (from Table A-4)

$u_3 = u_f$ @ T = **190** °C = 806.00 kJ/kg. (from Table A-4)

d) p_4 = 4000 kPa, **u_4 = 3040** kJ/kg.

From Table A-5, Saturated water, Pressure table,

u_f = 1082.4 kJ/kg, u_g = 2601.7 kJ/kg,

As u_4 = **3040** *kJ/kg* > u_g = 2601.7 kJ/kg, hence state 4 is superheated vapor.

From Table A-6, Superheated water,

P_4 = 4000 kPa (4.0 MPa),

T , °C	v , m^3/kg	u , kJ/kg
450	0.08004	3011.0
T_4	v_4	3040
500	0.08644	3100.3

Hence, (T_4-450)/(500-450)=(3040-3011.0)/(3100.3-3011.0)

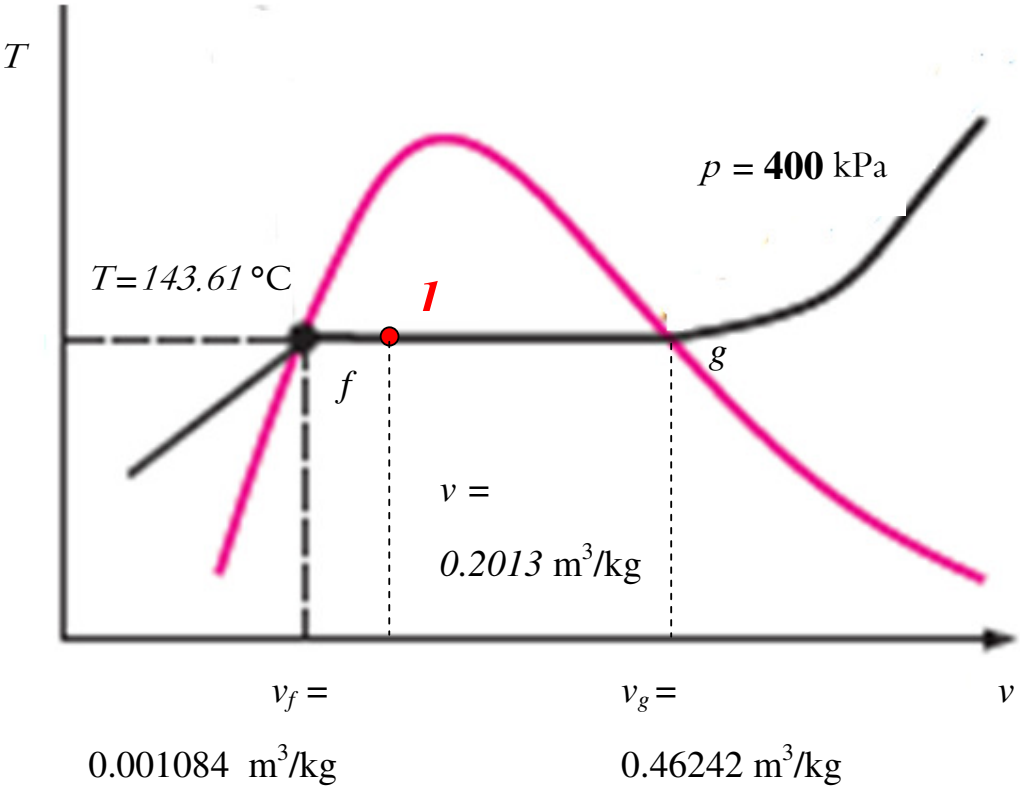
i.e., $T_4 = 466.24$ °C

Similarly, $(v_4-0.08004)/(0.08644-0.08004)=(3040-3011.0)/(3100.3-3011.0)$

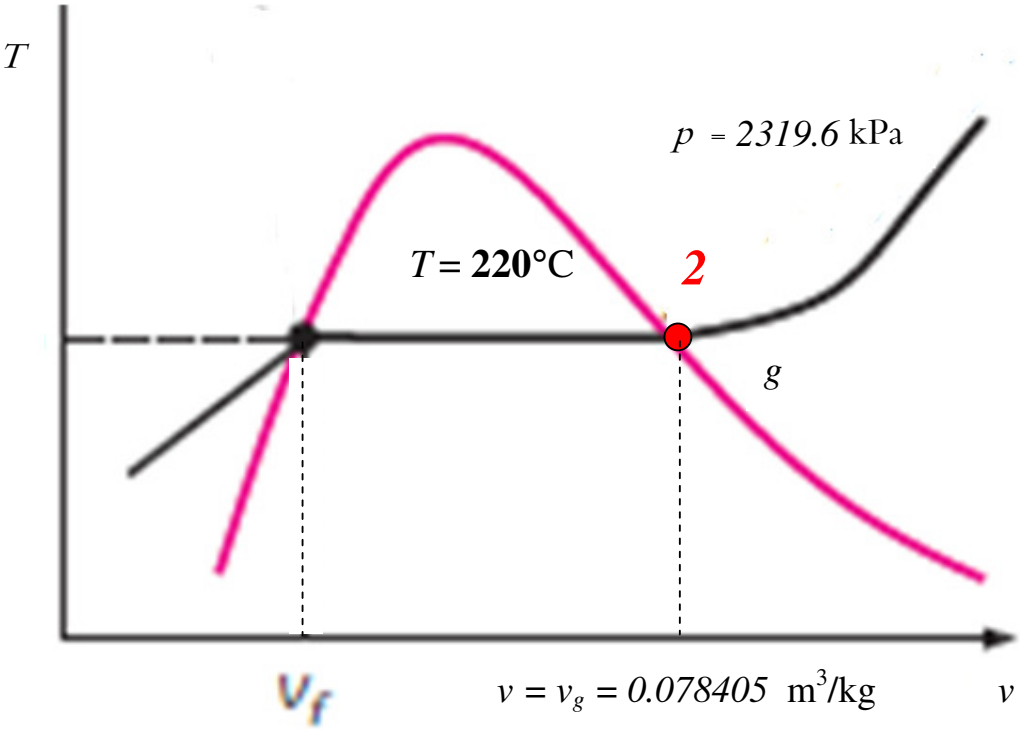
i.e., $v_4 = 0.082118$ m^3/kg

T, °C	*p,* kPa	*u*, kJ/kg	*v*, m^3/kg	*x*	Phase description
143.61	**400**	**1450**	*0.2013*	*0.44*	*Saturated liquid-vapor mixture*
220	*2319.6*	*2602.3*	*0.078405*	*1.0*	**Saturated vapor**
190	**2500**	806.00	0.001141	-	*compressed (subcooled) liquid*
466.24	**4000**	**3040**	*0.082118*	-	Superheated vapor

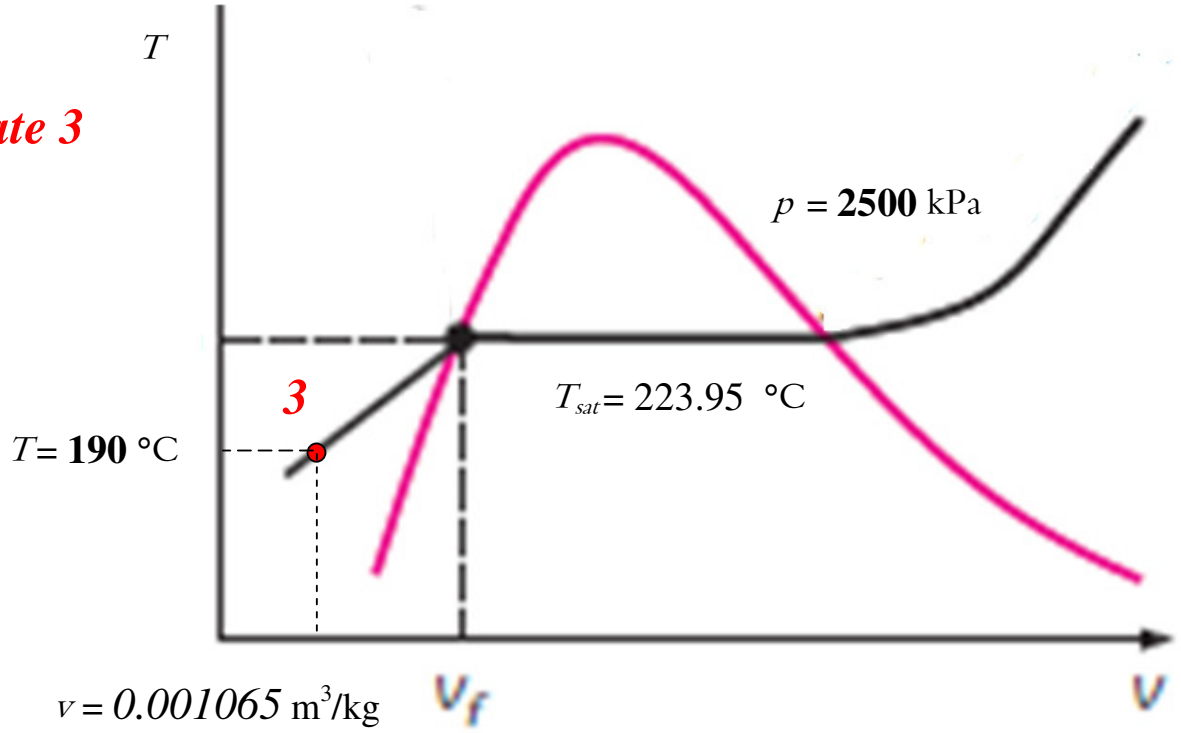
State 1



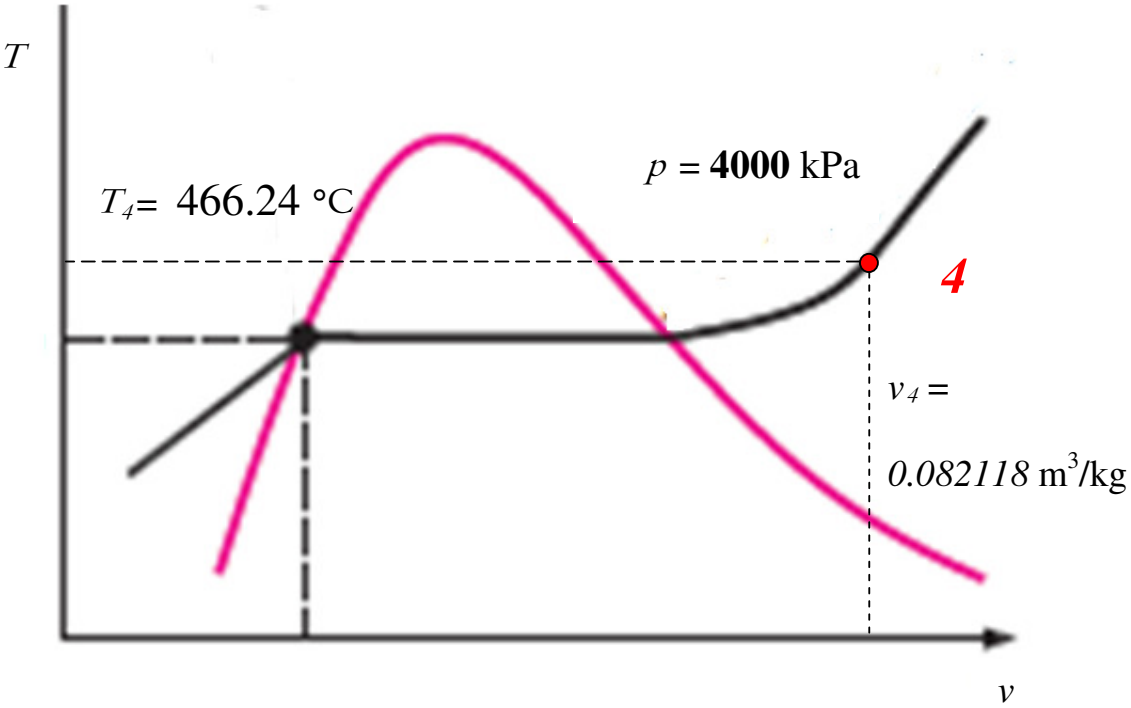
State 2



State 3



State 4



3–36 A 1.8-m^3 rigid tank contains steam at 220°C. One-third of the volume is in the liquid phase and the rest is in the vapor form. Determine (*a*) the pressure of the steam, (*b*) the quality of the saturated mixture, and (*c*) the density of the mixture.

FIGURE P3–36

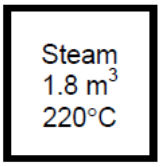
Solution A rigid tank contains steam at a specified state. The pressure, quality, and density of steam are to be determined.

Properties At 220°C $v_f = 0.001190$ m^3/kg and $v_g = 0.08609$ m^3/kg (Table A-4).

Analysis (*a*) Two phases coexist in equilibrium, thus we have a saturated liquid-vapor mixture. If the pressure of the steam is the saturation pressure at the given temperature, then the pressure in the tank must be the saturation pressure at the specified temperature,

$$P = T_{\text{sat@220°C}} = \mathbf{2320\ kPa}$$

(*b*) The total mass and the quality are determined as



$$m_f = \frac{V_f}{v_f} = \frac{1/3 \times (1.8\ \text{m}^3)}{0.001190\ \text{m}^3/\text{kg}} = 504.2\ \text{kg}$$

$$m_g = \frac{V_g}{v_g} = \frac{2/3 \times (1.8\ \text{m}^3)}{0.08609\ \text{m}^3/\text{kg}} = 13.94\ \text{kg}$$

$$m_t = m_f + m_g = 504.2 + 13.94 = 518.1\ \text{kg}$$

$$x = \frac{m_g}{m_t} = \frac{13.94}{518.1} = \mathbf{0.0269}$$

(*c*) The density is determined from

$$v = v_f + x(v_g - v_f) = 0.001190 + (0.0269)(0.08609) = 0.003474\ \text{m}^3/\text{kg}$$

$$\rho = \frac{1}{v} = \frac{1}{0.003474} = \mathbf{287.8\ kg/m^3}$$

3–37 A piston–cylinder device contains 0.85 kg of refrigerant-134a at −10°C. The piston that is free to move has a mass of 12 kg and a diameter of 25 cm. The local atmospheric pressure is 88 kPa. Now, heat is transferred to refrigerant-134a

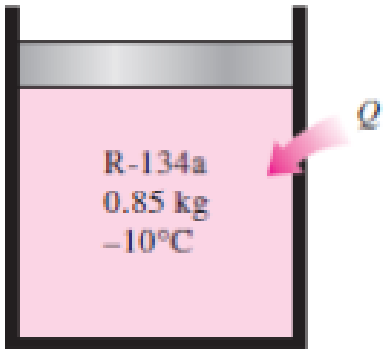


FIGURE P3–37

Solution A piston-cylinder device contains R-134a at a specified state. Heat is transferred to R-134a. The final pressure, the volume change of the cylinder, and the enthalpy change are to be determined.

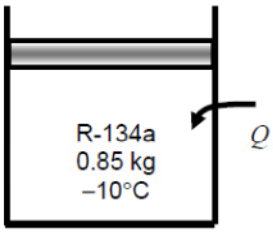
Analysis (a) The final pressure is equal to the initial pressure, which is determined from

$$P_2 = P_1 = P_{atm} + \frac{m_p g}{\pi D^2/4} = 88\ \text{kPa} + \frac{(12\ \text{kg})(9.81\ \text{m/s}^2)}{\pi(0.25\ \text{m})^2/4}\left(\frac{1\ \text{kN}}{1000\ \text{kg.m/s}^2}\right) = \mathbf{90.4\ kPa}$$

(b) The specific volume and enthalpy of R-134a at the initial state of 90.4 kPa and −10°C and at the final state of 90.4 kPa and 15°C are (from EES)

$v_1 = 0.2302\ \text{m}^3/\text{kg}$ $\quad h_1 = 247.76\ \text{kJ/kg}$

$v_2 = 0.2544\ \text{m}^3/\text{kg}$ $\quad h_2 = 268.16\ \text{kJ/kg}$



The initial and the final volumes and the volume change are

$$V_1 = mv_1 = (0.85\ \text{kg})(0.2302\ \text{m}^3/\text{kg}) = 0.1957\ \text{m}^3$$

$$V_2 = mv_2 = (0.85\ \text{kg})(0.2544\ \text{m}^3/\text{kg}) = 0.2162\ \text{m}^3$$

$$\Delta V = 0.2162 - 0.1957 = \mathbf{0.0205\ m^3}$$

(c) The total enthalpy change is determined from

$$\Delta H = m(h_2 - h_1) = (0.85\ \text{kg})(268.16 - 247.76)\ \text{kJ/kg} = \mathbf{17.4\ kJ/kg}$$

3–77 The pressure gage on a 2.5-m^3 oxygen tank reads 500 kPa. Determine the amount of oxygen in the tank if the temperature is 28°C and the atmospheric pressure is 97 kPa.

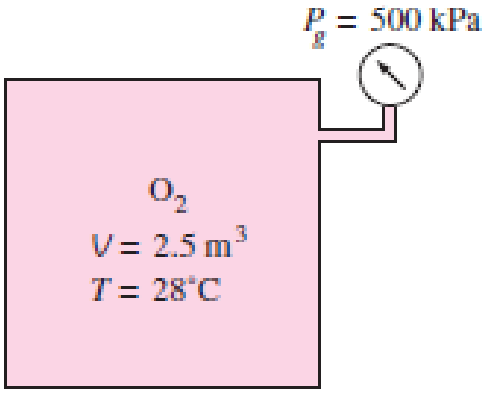


FIGURE P3–77

Solution The pressure and temperature of oxygen gas in a storage tank are given. The mass of oxygen in the tank is to be determined.

Assumption At specified conditions, oxygen behaves as an ideal gas.

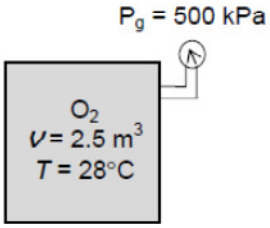
Properties The gas constant of oxygen is $R = 0.2598$ kPa.m^3/kg.K (Table A-1).

Analysis The absolute pressure of O_2 is

$$P = P_g + P_{atm} = 500 + 97 = 597 \text{ kPa}$$

Treating O_2 as an ideal gas, the mass of O_2 in tank is determined to be

$$m = \frac{PV}{RT} = \frac{(597 \text{ kPa})(2.5 \text{ m}^3)}{(0.2598 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(28+273)\text{K}} = \mathbf{19.08 \text{ kg}}$$



3–80 A 1-m^3 tank containing air at 25°C and 500 kPa is connected through a valve to another tank containing 5 kg of air at 35°C and 200 kPa. Now the valve is opened, and the entire system is allowed to reach thermal equilibrium with the surroundings, which are at 20°C. Determine the volume of the second tank and the final equilibrium pressure of air.

Answers: 2.21 m^3, 284.1 kPa

Solution Two rigid tanks connected by a valve to each other contain air at specified conditions. The volume of the second tank and the final equilibrium pressure when the valve is opened are to be determined.

Assumptions At specified conditions, air behaves as an ideal gas.

Properties The gas constant of air is $R = 0.287$ kPa.m^3/kg.K (Table A-1).

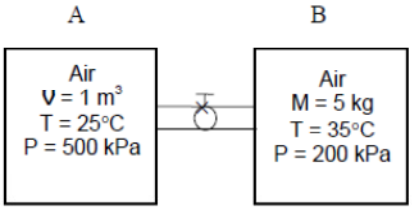
Analysis Let's call the first and the second tanks A and B. Treating air as an ideal gas, the volume of the second tank and the mass of air in the first tank are determined to be

$$V_B = \left(\frac{m_1 R T_1}{P_1}\right)_B = \frac{(5\ \text{kg})(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(308\ \text{K})}{200\ \text{kPa}} = \mathbf{2.21\ m^3}$$

$$m_A = \left(\frac{P_1 V}{R T_1}\right)_A = \frac{(500\ \text{kPa})(1.0\ \text{m}^3)}{(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(298\ \text{K})} = 5.846\ \text{kg}$$

Thus,

$$V = V_A + V_B = 1.0 + 2.21 = 3.21\ \text{m}^3$$
$$m = m_A + m_B = 5.846 + 5.0 = 10.846\ \text{kg}$$



Then the final equilibrium pressure becomes

$$P_2 = \frac{mRT_2}{V} = \frac{(10.846\ \text{kg})(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(293\ \text{K})}{3.21\ \text{m}^3} = \mathbf{284.1\ kPa}$$