1. Compressed liquid:

In general, a compressed liquid is characterized by:

| Given | Properties Comparison | Tables |
|---|---|---|
| T, P | P > $P_{sat}$. or $T_{given}$ <$T_{sat}$. | From saturated Table or compressed Table. |
| T, or P, and *v* | $v_{given} < v_f$ | From saturated Table or compressed Table. |
| T, or P, and u | $u_{given} < u_f$ | From saturated Table or compressed Table. |
| T, or P, and s | $s_{given} < s_f$ | From saturated Table or compressed Table. |
| T, or P, and h | $h_{given} < h_f$ | From saturated Table or compressed Table. |

2. Superheated vapor:

*In general, a superheated is characterized by:*

| Given | Properties Comparison | Tables |
|---|---|---|
| T, P | P < $P_{sat}$. or $T_{given}$ >Tsat. | From superheated Table. |
| T, or P, and *v* | $v_{given} > v_g$ | From superheated Table. |
| T, or P, and u | $u_{given} > u_g$ | From superheated Table. |
| T, or P, and s | $s_{given} > s_g$ | From superheated Table. |
| T, or P, and h | $h_{given} > h_g$ | From superheated Table. |

3. Saturated liquid (x=0 , v = $v_f$, u = $u_f$,h= $h_f$, and s = $s_f$ at a given saturated temperature or pressure)
4. Saturated vapor (x=1 , v = $v_g$, u = $u_g$, h= $h_g$, and s = $s_g$ at a given saturated temperature or pressure).
5. Saturated liquid-vapor mixture (0< *x* <1) all the properties are between saturated liquid properties and saturated vapor properties: $v_f < v_{given} < v_g, u_f < u_{gievn} < u_g, h_f < h_{given} < h_g, and\ s_f < s_{given} > s_g$.

$$x = \frac{m_g}{m_{total}}, m_{total} = m_g + m_f, V_{total} = V_f + v_g, v = \frac{V_{total}}{m_{total}}, v_f = \frac{V_f}{m_f}, v_g = \frac{V_g}{m_g}$$

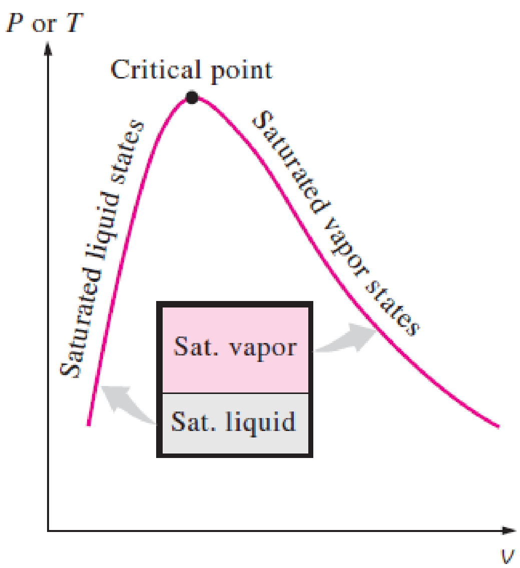
$$h_{fg} = h_g - h_f, u_{fg} = u_g - u_f , v_{fg} = v_g - v_f$$

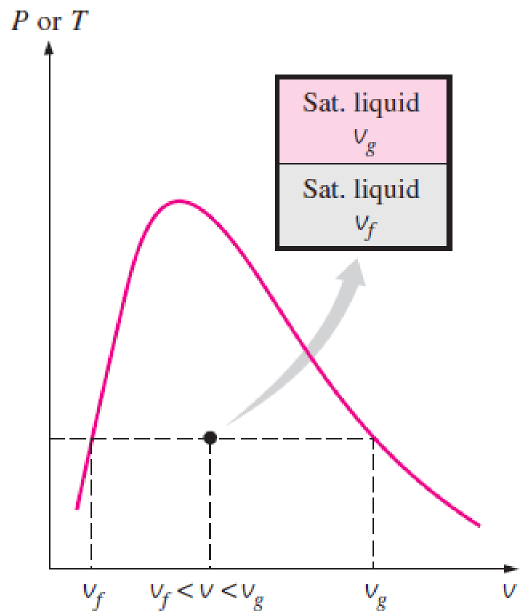
$$m_{total} v = m_f v_f + v_g m_g \to v = \frac{m_f}{m_{total}} v_f + \frac{m_g}{m_{total}} v_g, v = (1 - x) v_f + x v_g$$

$$\frac{m_f}{m_{total}} = \left(1 - \frac{m_g}{m_{total}}\right) = 1 - x, v = v_f + x(v_g - v_f) = v_f + x v_{fg}$$

$$h = h_f + x h_{fg}, u = u_f + x u_{fg}$$

Copyright@2016 EngSci Platform




## Problem 1.1 Statement:

Determine the missing properties and the phase descriptions in the following table for water:

| | $T$, °C | $P$, kPa | $u$, kJ/kg | $x$ | Phase description |
|---|---|---|---|---|---|
| (a) | | 200 | | 0.6 | |
| (b) | 125 | | 1600 | | |
| (c) | | 1000 | 2950 | | |
| (d) | 75 | 500 | | | |
| (e) | | 850 | | 0.0 | |

a) Saturated liquid-vapor mixture:

$$u = u_{f_{At\ P=200\ kPa}} + x u_{fg_{At\ P=200\ kPa}}$$

**TABLE A–5**

Saturated water—Pressure table

| | | Specific volume, m³/kg | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | | Entropy, kJ/kg · K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Press., $P$ kPa | Sat. temp., $T_{sat}$ °C | Sat. liquid, $v_f$ | Sat. vapor, $v_g$ | Sat. liquid, $u_f$ | Evap., $u_{fg}$ | Sat. vapor, $u_g$ | Sat. liquid, $h_f$ | Evap., $h_{fg}$ | Sat. vapor, $h_g$ | Sat. liquid, $s_f$ | Evap., $s_{fg}$ | Sat. vapor, $s_g$ |

Copyright@2016 EngSci Platform

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 175 | 116.04 | 0.001057 | 1.0037 | 486.82 | 2037.7 | 2524.5 | 487.01 | 2213.1 | 2700.2 | 1.4850 | 5.6865 | 7.1716 |
| 200 | 120.21 | 0.001061 | 0.88578 | 504.50 | 2024.6 | 2529.1 | 504.71 | 2201.6 | 2706.3 | 1.5302 | 5.5968 | 7.1270 |
| 225 | 123.97 | 0.001064 | 0.79329 | 520.47 | 2012.7 | 2533.2 | 520.71 | 2191.0 | 2711.7 | 1.5706 | 5.5171 | 7.0877 |
| 250 | 127.41 | 0.001067 | 0.71873 | 535.08 | 2001.8 | 2536.8 | 535.35 | 2181.2 | 2716.5 | 1.6072 | 5.4453 | 7.0525 |
| 275 | 130.58 | 0.001070 | 0.65732 | 548.57 | 1991.6 | 2540.1 | 548.86 | 2172.0 | 2720.9 | 1.6408 | 5.3800 | 7.0207 |

$$T = T_{sat} = 120.21^{o}C, u = 504.50 + 0.6 \times 2024.6 = 1719.26 \frac{kJ}{kg}$$

b) $T = 120.21^{o}C \;\; u_g = 2534.3 \frac{kJ}{kg} \quad u_g > u_{given}, and\ u_f < u_{given}$ (Saturated Liquid vapor mixture )

**TABLE A–4**

Saturated water—Temperature table

| | | Specific volume, m³/kg | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | | Entropy, kJ/kg · K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp., $T$ °C | Sat. press., $P_{sat}$ kPa | Sat. liquid, $v_f$ | Sat. vapor, $v_g$ | Sat. liquid, $u_f$ | Evap., $u_{fg}$ | Sat. vapor, $u_g$ | Sat. liquid, $h_f$ | Evap., $h_{fg}$ | Sat. vapor, $h_g$ | Sat. liquid, $s_f$ | Evap., $s_{fg}$ | Sat. vapor, $s_g$ |
| 100 | 101.42 | 0.001043 | 1.6720 | 419.06 | 2087.0 | 2506.0 | 419.17 | 2256.4 | 2675.6 | 1.3072 | 6.0470 | 7.3542 |
| 105 | 120.90 | 0.001047 | 1.4186 | 440.15 | 2071.8 | 2511.9 | 440.28 | 2243.1 | 2683.4 | 1.3634 | 5.9319 | 7.2952 |
| 110 | 143.38 | 0.001052 | 1.2094 | 461.27 | 2056.4 | 2517.7 | 461.42 | 2229.7 | 2691.1 | 1.4188 | 5.8193 | 7.2382 |
| 115 | 169.18 | 0.001056 | 1.0360 | 482.42 | 2040.9 | 2523.3 | 482.59 | 2216.0 | 2698.6 | 1.4737 | 5.7092 | 7.1829 |
| 120 | 198.67 | 0.001060 | 0.89133 | 503.60 | 2025.3 | 2528.9 | 503.81 | 2202.1 | 2706.0 | 1.5279 | 5.6013 | 7.1292 |
| 125 | 232.23 | 0.001065 | 0.77012 | 524.83 | 2009.5 | 2534.3 | 525.07 | 2188.1 | 2713.1 | 1.5816 | 5.4956 | 7.0771 |

$$P = P_{sat_{T=125C}} = 232.23\ kPa, x = \frac{u - u_f}{u_{fg}} = \frac{1600 - 524.83}{2009.5} = 0.535$$

c) $P = 1000\ kPam = 1MPa\ , u = 2950 \frac{kJ}{kg}$

**TABLE A–5**

Saturated water—Pressure table (*Continued*)

| | | Specific volume, m³/kg | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | | Entropy, kJ/kg · K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Press., $P$ kPa | Sat. temp., $T_{sat}$ °C | Sat. liquid, $v_f$ | Sat. vapor, $v_g$ | Sat. liquid, $u_f$ | Evap., $u_{fg}$ | Sat. vapor, $u_g$ | Sat. liquid, $h_f$ | Evap., $h_{fg}$ | Sat. vapor, $h_g$ | Sat. liquid, $s_f$ | Evap., $s_{fg}$ | Sat. vapor, $s_g$ |
| 800 | 170.41 | 0.001115 | 0.24035 | 719.97 | 1856.1 | 2576.0 | 720.87 | 2047.5 | 2768.3 | 2.0457 | 4.6160 | 6.6616 |
| 850 | 172.94 | 0.001118 | 0.22690 | 731.00 | 1846.9 | 2577.9 | 731.95 | 2038.8 | 2770.8 | 2.0705 | 4.5705 | 6.6409 |
| 900 | 175.35 | 0.001121 | 0.21489 | 741.55 | 1838.1 | 2579.6 | 742.56 | 2030.5 | 2773.0 | 2.0941 | 4.5273 | 6.6213 |
| 950 | 177.66 | 0.001124 | 0.20411 | 751.67 | 1829.6 | 2581.3 | 752.74 | 2022.4 | 2775.2 | 2.1166 | 4.4862 | 6.6027 |
| 1000 | 179.88 | 0.001127 | 0.19436 | 761.39 | 1821.4 | 2582.8 | 762.51 | 2014.6 | 2777.1 | 2.1381 | 4.4470 | 6.5850 |

$u_{given} > u_g$ [ Superheated]

From superheated Table:

| T °C | u (kJ/kg) |
|---|---|
| 350 | 2875.7 |
| T=? | 2950 |
| 400 | 2957.9 |

Copyright@2016 EngSci Platform

**TABLE A–6**

Superheated water (*Continued*)

| *T* °C | *v* m³/kg | *u* kJ/kg | *h* kJ/kg | *s* kJ/kg · K |
|---|---|---|---|---|
| | *P* = 1.00 MPa (179.88°C) | | | |
| Sat. | 0.19437 | 2582.8 | 2777.1 | 6.5850 |
| 200 | 0.20602 | 2622.3 | 2828.3 | 6.6956 |
| 250 | 0.23275 | 2710.4 | 2943.1 | 6.9265 |
| 300 | 0.25799 | 2793.7 | 3051.6 | 7.1246 |
| 350 | 0.28250 | 2875.7 | 3158.2 | 7.3029 |
| 400 | 0.30661 | 2957.9 | 3264.5 | 7.4670 |

$$\frac{T-350}{400-350}=\frac{2950-2875.7}{2957.9-2875.7}\rightarrow T=395.2^{o}C$$

d) $T = 75^{o}C\,, P = 500\ kPa \rightarrow T_{given} < T_{sat}@P = 500\ kPa$ [Compressed Liquid]

From the saturated Table using Temperature. i.e.

$$u = u_{f_{T=75C}} = 313.99\,\frac{kJ}{kg}$$

e) P=850 kPa x = 0 (Saturated Liquid)

$$T = T_{sat_{P=850\ kPa}} = 172.9^{o}C, u = u_f = 731\,\frac{kJ}{kg}$$

| | *T*, °C | *P*, kPa | *u*, kJ/kg | *x* | Phase description |
|---|---|---|---|---|---|
| (*a*) | 120.21 | 200 | **1719.26** | 0.6 | Sat. Liquid vapor Mixture |
| (*b*) | 125 | 232.23 | 1600 | 0.535 | Sat. Liquid vapor Mixture |
| (*c*) | 395.2 | 1000 | 2950 | ------- | Superheated |
| (*d*) | 75 | 500 | 313.9 | ------- | Compressed Liquid |
| (*e*) | 172.9 C | 850 | 731 | 0.0 | Sat. Liquid |

## Problem 1.2 Statement:

A refrigerant-134a at 160 kPa and T= 3°C, find the specific volume, internal and enthalpy energy of this state?

Copyright@2016 EngSci Platform

**TABLE A–12**

Saturated refrigerant-134a—Pressure table

| | | Specific volume, $m^3/kg$ | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | | Entropy, kJ/kg · K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Press., $P$ kPa | Sat. temp., $T_{sat}$ °C | Sat. liquid, $v_f$ | Sat. vapor, $v_g$ | Sat. liquid, $u_f$ | Evap., $u_{fg}$ | Sat. vapor, $u_g$ | Sat. liquid, $h_f$ | Evap., $h_{fg}$ | Sat. vapor, $h_g$ | Sat. liquid, $s_f$ | Evap., $s_{fg}$ | Sat. vapor, $s_g$ |
| 60 | −36.95 | 0.0007098 | 0.31121 | 3.798 | 205.32 | 209.12 | 3.841 | 223.95 | 227.79 | 0.01634 | 0.94807 | 0.96441 |
| 70 | −33.87 | 0.0007144 | 0.26929 | 7.680 | 203.20 | 210.88 | 7.730 | 222.00 | 229.73 | 0.03267 | 0.92775 | 0.96042 |
| 80 | −31.13 | 0.0007185 | 0.23753 | 11.15 | 201.30 | 212.46 | 11.21 | 220.25 | 231.46 | 0.04711 | 0.90999 | 0.95710 |
| 90 | −28.65 | 0.0007223 | 0.21263 | 14.31 | 199.57 | 213.88 | 14.37 | 218.65 | 233.02 | 0.06008 | 0.89419 | 0.95427 |
| 100 | −26.37 | 0.0007259 | 0.19254 | 17.21 | 197.98 | 215.19 | 17.28 | 217.16 | 234.44 | 0.07188 | 0.87995 | 0.95183 |
| 120 | −22.32 | 0.0007324 | 0.16212 | 22.40 | 195.11 | 217.51 | 22.49 | 214.48 | 236.97 | 0.09275 | 0.85503 | 0.94779 |
| 140 | −18.77 | 0.0007383 | 0.14014 | 26.98 | 192.57 | 219.54 | 27.08 | 212.08 | 239.16 | 0.11087 | 0.83368 | 0.94456 |
| 160 | −15.60 | 0.0007437 | 0.12348 | 31.09 | 190.27 | 221.35 | 31.21 | 209.90 | 241.11 | 0.12693 | 0.81496 | 0.94190 |

At $P = 160$ kPa $T_{given} > T_{sat}$ , i. e. superheated state.

$P = 0.14$ MPa ($T_{sat} = -18.77$°C)

| T | | | | |
|---|---|---|---|---|
| Sat. | 0.14014 | 219.54 | 239.16 | 0.9446 |
| −20 | | | | |
| −10 | 0.14605 | 225.91 | 246.36 | 0.9724 |
| 0 | 0.15263 | 233.23 | 254.60 | 1.0031 |
| 10 | 0.15908 | 240.66 | 262.93 | 1.0331 |
| 20 | 0.16544 | 248.22 | 271.38 | 1.0624 |
| 30 | 0.17172 | 255.93 | 279.97 | 1.0912 |
| 40 | 0.17794 | 263.79 | 288.70 | 1.1195 |
| 50 | 0.18412 | 271.79 | 297.57 | 1.1474 |
| 60 | 0.19025 | 279.96 | 306.59 | 1.1749 |
| 70 | 0.19635 | 288.28 | 315.77 | 1.2020 |
| 80 | 0.20242 | 296.75 | 325.09 | 1.2288 |
| 90 | 0.20847 | 305.38 | 334.57 | 1.2553 |
| 100 | 0.21449 | 314.17 | 344.20 | 1.2814 |

$P = 0.18$ MPa ($T_{sat} = -12.73$°C)

| T | | | | |
|---|---|---|---|---|
| Sat. | 0.11041 | 222.99 | 242.86 | 0.9397 |
| −10 | 0.11189 | 225.02 | 245.16 | 0.9484 |
| 0 | 0.11722 | 232.48 | 253.58 | 0.9798 |
| 10 | 0.12240 | 240.00 | 262.04 | 1.0102 |
| 20 | 0.12748 | 247.64 | 270.59 | 1.0399 |
| 30 | 0.13248 | 255.41 | 279.25 | 1.0690 |
| 40 | 0.13741 | 263.31 | 288.05 | 1.0975 |
| 50 | 0.14230 | 271.36 | 296.98 | 1.1256 |
| 60 | 0.14715 | 279.56 | 306.05 | 1.1532 |
| 70 | 0.15196 | 287.91 | 315.27 | 1.1805 |
| 80 | 0.15673 | 296.42 | 324.63 | 1.2074 |
| 90 | 0.16149 | 305.07 | 334.14 | 1.2339 |
| 100 | 0.16622 | 313.88 | 343.80 | 1.2602 |

$P = 0.14$ MPa

| T | v [$m^3$/kg] | u [kJ/kg] | h [kJ/kg] |
|---|---|---|---|
| 0 | 0.15263 | 233.23 | 254.60 |
| 3 | v | u | h |
| 10 | 0.15908 | 240.66 | 262.93 |

Copyright@2016 EngSci Platform

$$\frac{3-0}{10-0}=\frac{v-0.15263}{0.15908-0.15263}=\frac{u-233.23}{240.66-233.23}=\frac{h-254.60}{262.93-254.60}$$

$$v=0.154565\frac{m^3}{kg}, u=235.459\frac{kJ}{kg}, \text{and } h=257.099\frac{kJ}{kg}$$

$P = 0.18$ MPa

| T | $v$ [m³/kg] | u [kJ/kg] | h [kJ/kg] |
|---|---|---|---|
| 0 | 0.11722 | 232.48 | 253.58 |
| 3 | v | u | h |
| 10 | 0.12240 | 240.00 | 262.04 |

$$\frac{3-0}{10-0}=\frac{v-0.11722}{0.12240-0.11722}=\frac{u-232.48}{240.0-232.48}=\frac{h-253.58}{262.04-253.58}$$

$$v=0.11874\frac{m^3}{kg}, u=234.74\frac{kJ}{kg}, \text{and } h=256.118\frac{kJ}{kg}$$

For $P = 0.16$ MPa at T= 3°C

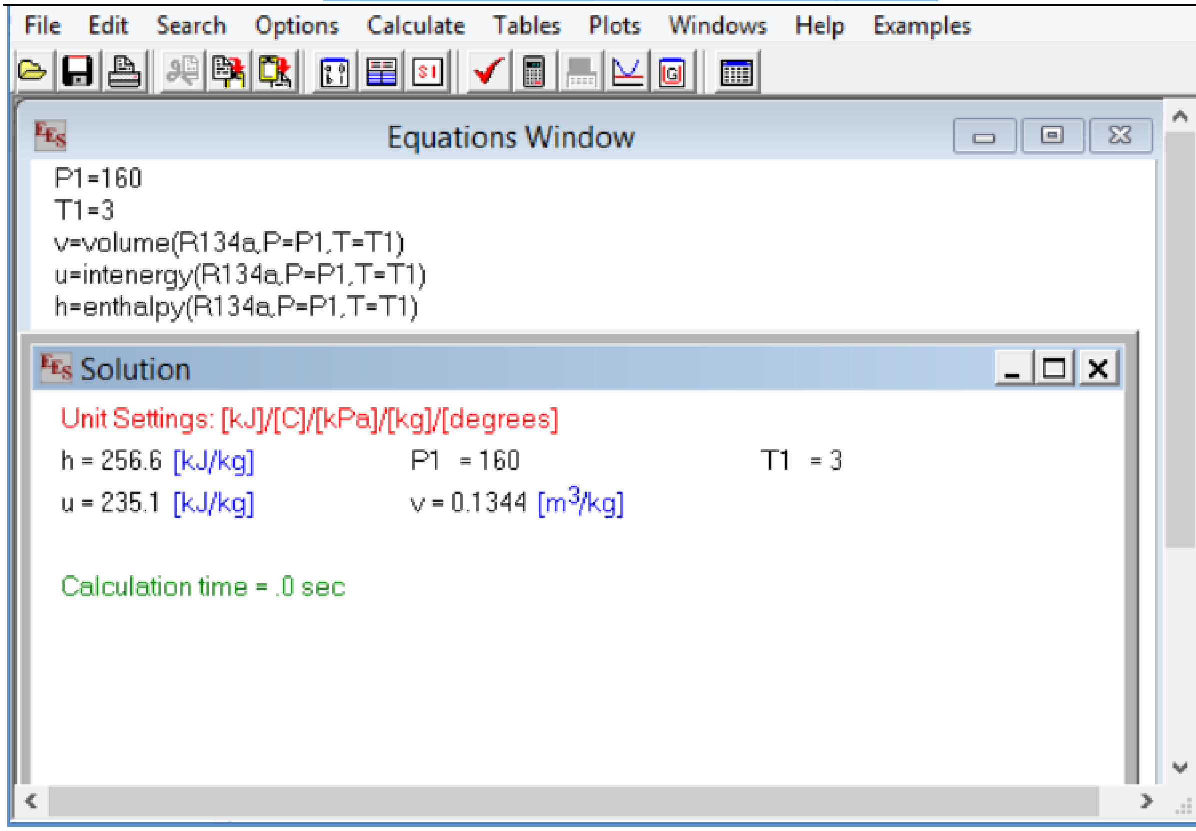
| P [ MPa] | $v$ [m³/kg] | u [kJ/kg] | h [kJ/kg] |
|---|---|---|---|
| 0.14 | 0.154565 | 235.459 | 257.099 |
| 0.16 | v | u | h |
| 0.18 | 0.11874 | 234.74 | 256.118 |

$$\frac{0.16-0.14}{0.18-0.14}=\frac{v-0.154565}{0.11874-0.154565}=\frac{u-235.459}{234.74-235.459}=\frac{h-257.099}{256.118-257.099}$$

$$v=0.1366525\frac{m^3}{kg}, u=235.0995\frac{kJ}{kg}, \text{and } h=256.6085\frac{kJ}{kg}$$

For checking purposes, we employ the Engineering Equation Solver……as

Copyright@2016 EngSci Platform




Copyright@2016 EngSci Platform