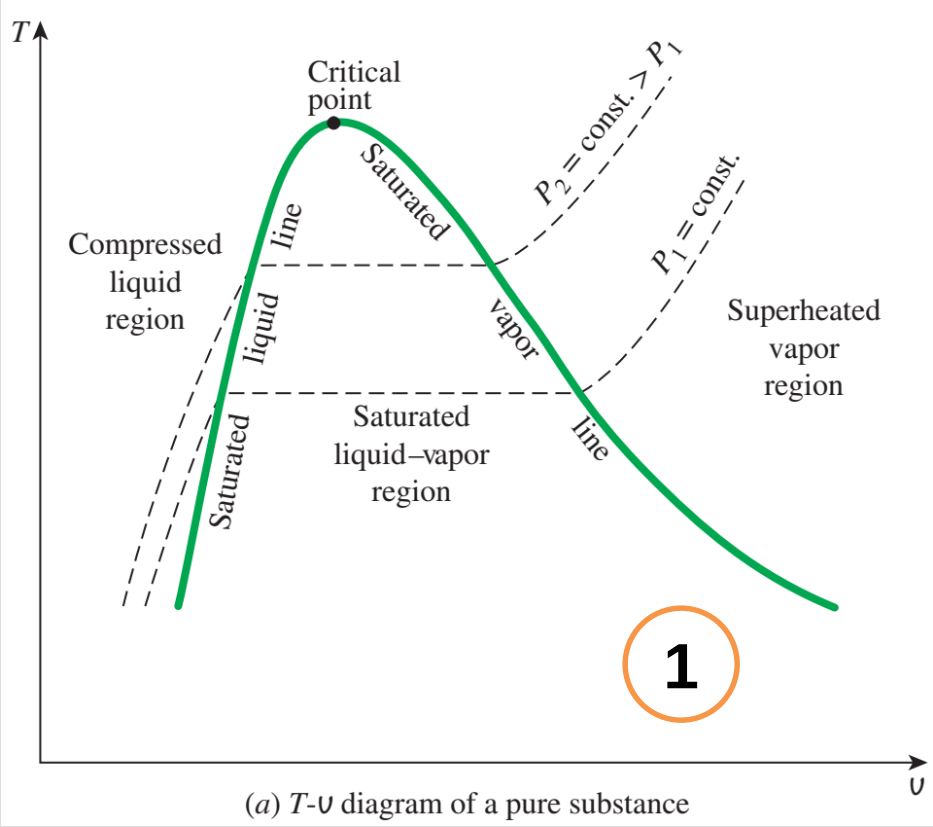
Thermodynamics I

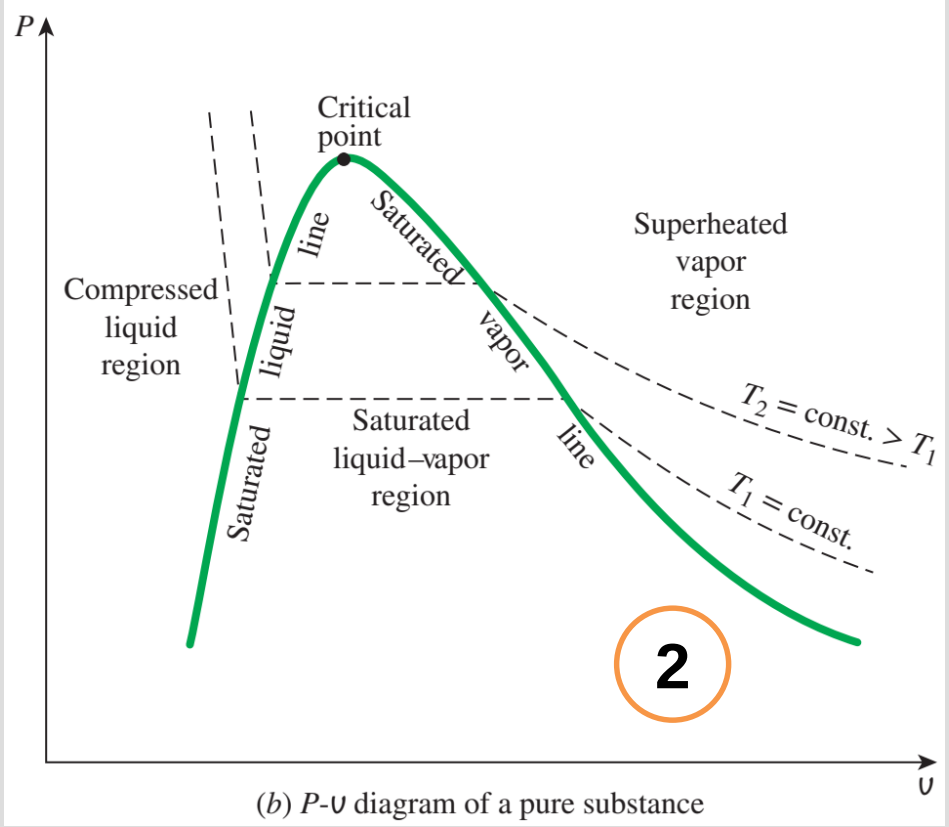
Lecture 12

Property Tables (Ch-3)
(Fixing States on Property Diagrams)

Dr. Ahmed Rasheed



(*a*) *T*-υ diagram of a pure substance



(*b*) *P*-υ diagram of a pure substance

Superheated Vapor

In the region to the right of the saturated vapor line and at temperatures above the critical point temperature, a substance exists as superheated vapor.

In this region, temperature and pressure are independent properties.

Compared to saturated vapor, superheated vapor is characterized by

Lower pressures ($P < P_{sat}$ at a given T)

Higher tempreatures ($T > T_{sat}$ at a given P)

Higher specific volumes ($v > v_g$ at a given P or T)

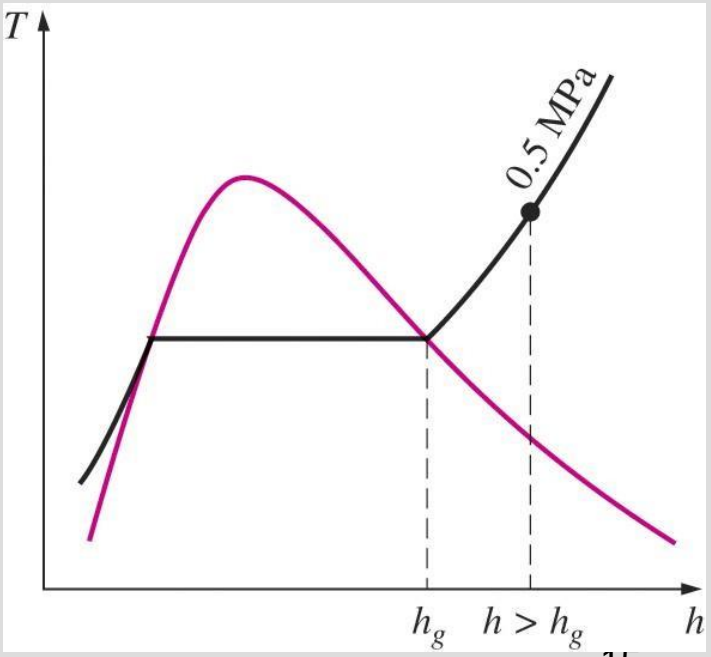
Higher internal energies ($u > u_g$ at a given P or T)

Higher enthalpies ($h > h_g$ at a given P or T)

T, °C	v m³/kg	u kJ/kg	h kJ/kg
	P = 0.1 MPa (99.61°C)		
Sat.	1.6941	2505.6	2675.0
100	1.6959	2506.2	2675.8
150	1.9367	2582.9	2776.6
⋮	⋮	⋮	⋮
1300	7.2605	4687.2	5413.3
	P = 0.5 MPa (151.83°C)		
Sat.	0.37483	2560.7	2748.1
200	0.42503	2643.3	2855.8
250	0.47443	2723.8	2961.0

At a specified P, superheated vapor exists at a higher h than the saturated vapor.

A partial listing of Table A–6.



Exercise Example

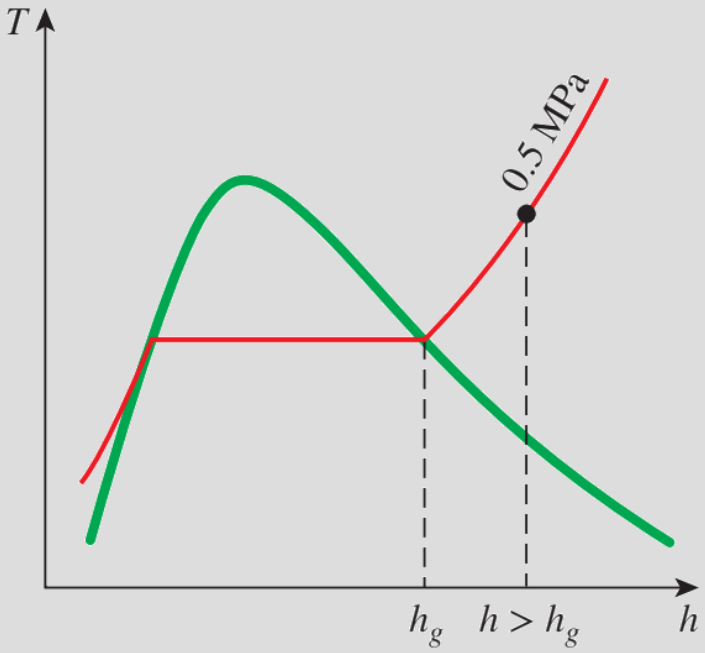
Determine the temperature of water at a state of $P = 0.5$ MPa and $h = 2890$ kJ/kg.

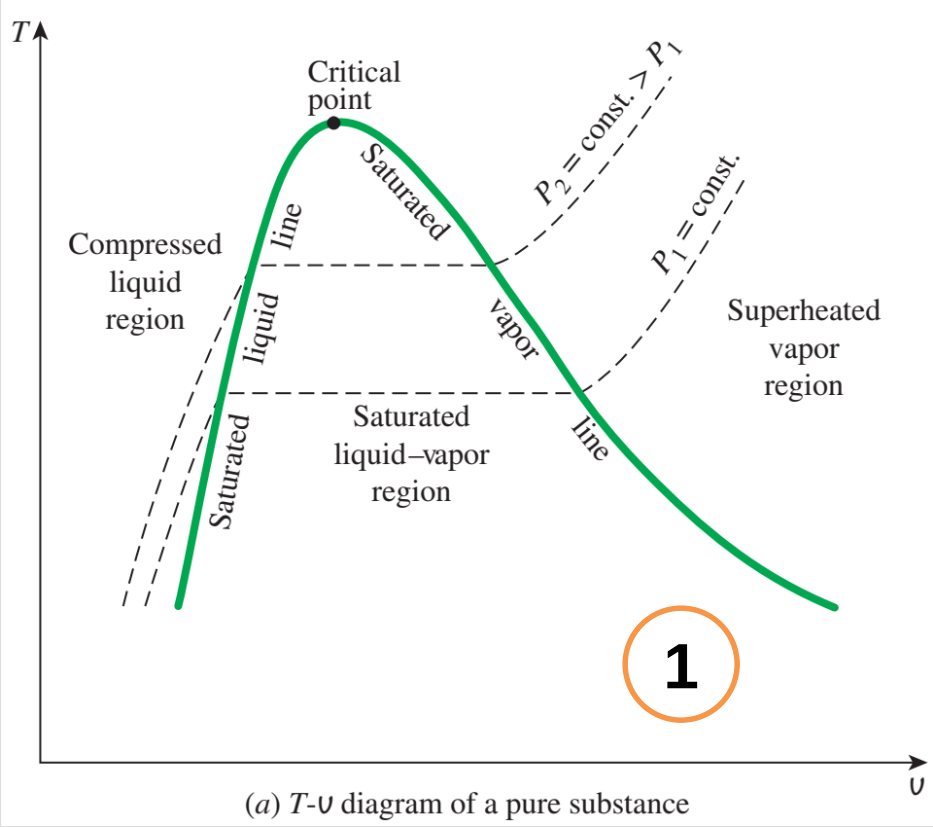
SOLUTION The temperature of water at a specified state is to be determined.

Analysis At 0.5 MPa, the enthalpy of saturated water vapor is $h_g = 2748.1$ kJ/kg. Since $h > h_g$, as shown in Fig. 3–39, we again have superheated vapor. Under 0.5 MPa in Table A–6 we read

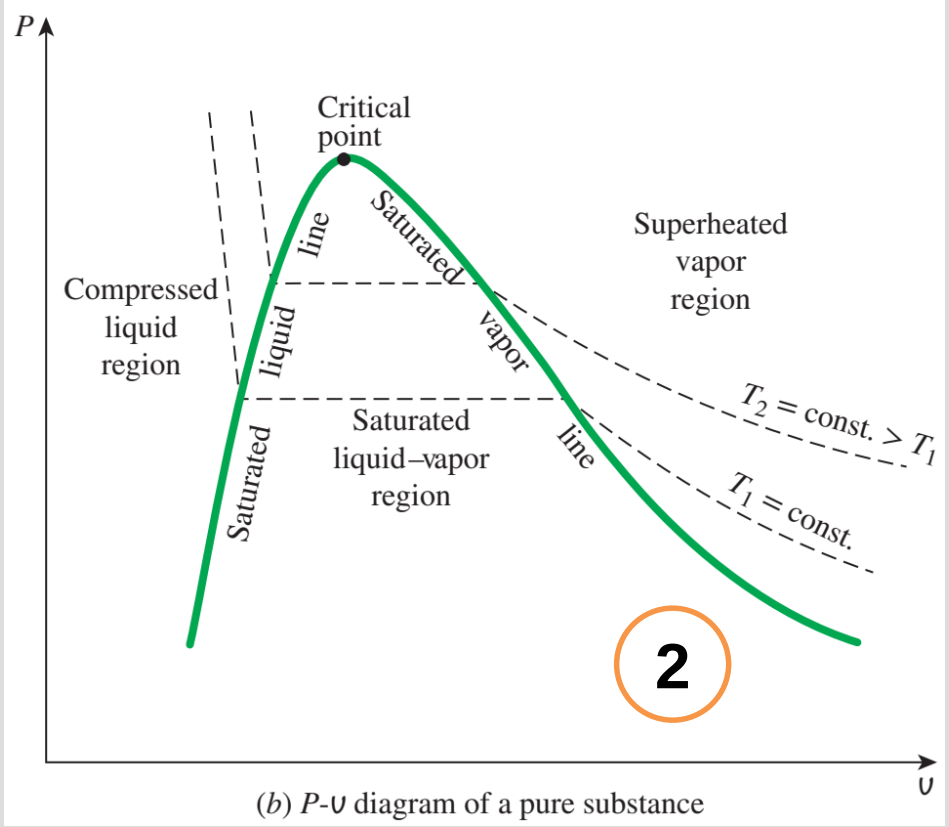
T, °C	h, kJ/kg
200	2855.8
250	2961.0

$$T = 216.3°C$$





(*a*) *T*-υ diagram of a pure substance



(*b*) *P*-υ diagram of a pure substance

Compressed Liquid

The compressed liquid properties depend on temperature much more strongly than they do on pressure.

$y \cong y_{f\,@\,T}$ $\quad y \rightarrow v, u,$ or h

A more accurate relation for h

$$h \cong h_{f\,@\,T} + v_{f\,@\,T}(P - P_{\text{sat}\,@T})$$

Given: P and T

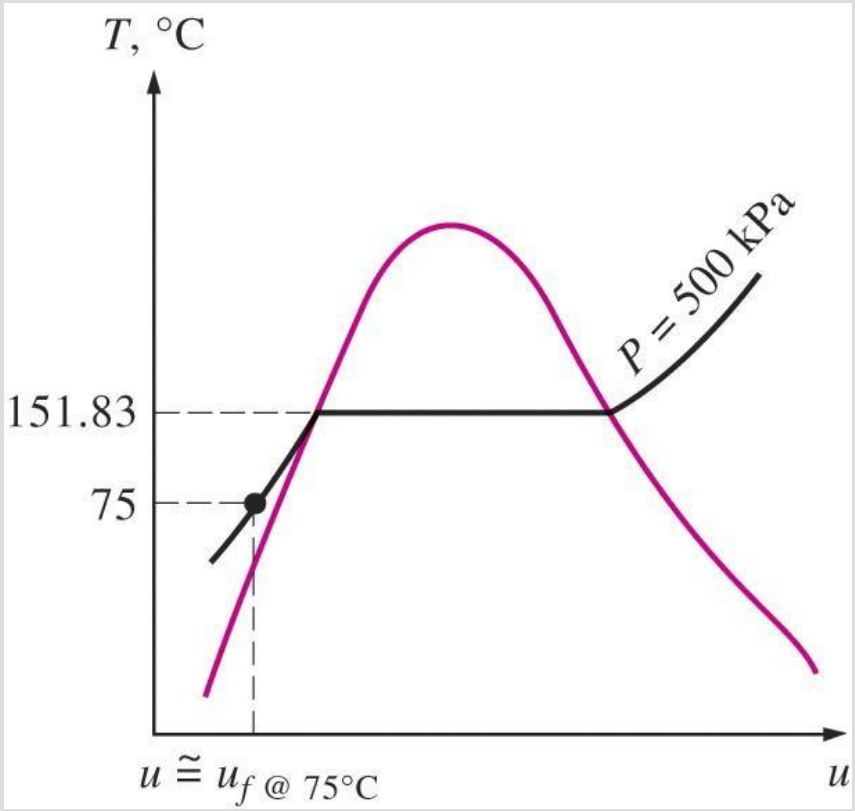
$$v \cong v_{f\,@T}$$
$$u \cong u_{f\,@T}$$
$$h \cong h_{f\,@T}$$

A compressed liquid may be approximated as a saturated liquid at the given temperature.

Compressed liquid is characterized by

Higher pressures ($P > P_{\text{sat}}$ at a given T)
Lower tempreatures ($T < T_{\text{sat}}$ at a given P)
Lower specific volumes ($v < v_f$ at a given P or T)
Lower internal energies ($u < u_f$ at a given P or T)
Lower enthalpies ($h < h_f$ at a given P or T)

At a given P and T, a pure substance will exist as a compressed liquid if $T < T_{\text{sat}\,@\,P}$



Exercise Example

Determine the internal energy of compressed liquid water at 80°C and 5 MPa, using (*a*) data from the compressed liquid table and (*b*) saturated liquid data. What is the error involved in the second case?

Analysis At 80°C, the saturation pressure of water is 47.416 kPa, and since 5 MPa > P_{sat}, we obviously have compressed liquid, as shown in Fig. 3–41.

(*a*) From the compressed liquid table (Table A–7)

$$\left.\begin{matrix} P = 5 \text{ MPa} \\ T = 80°\text{C} \end{matrix}\right\} \quad u = \mathbf{333.82 \text{ kJ/kg}}$$

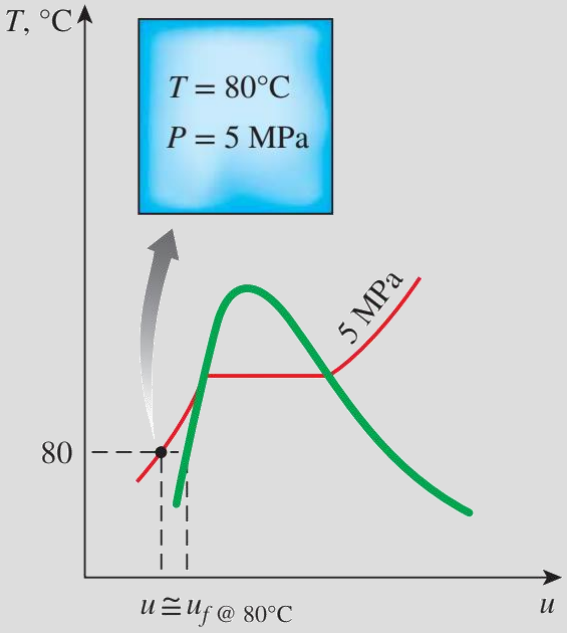
(*b*) From the saturation table (Table A–4), we read

$$u \cong u_{f\,@\,80°\text{C}} = \mathbf{334.97 \text{ kJ/kg}}$$

The error involved is

$$\frac{334.97 - 333.82}{333.82} \times 100 = \mathbf{0.34\%}$$

which is less than 1 percent.

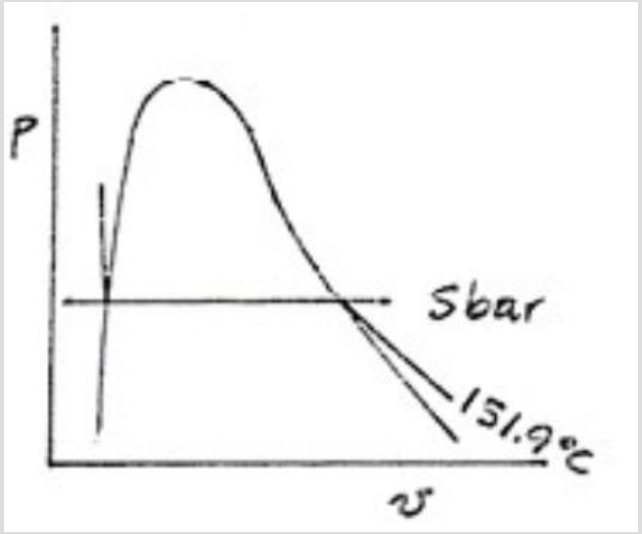


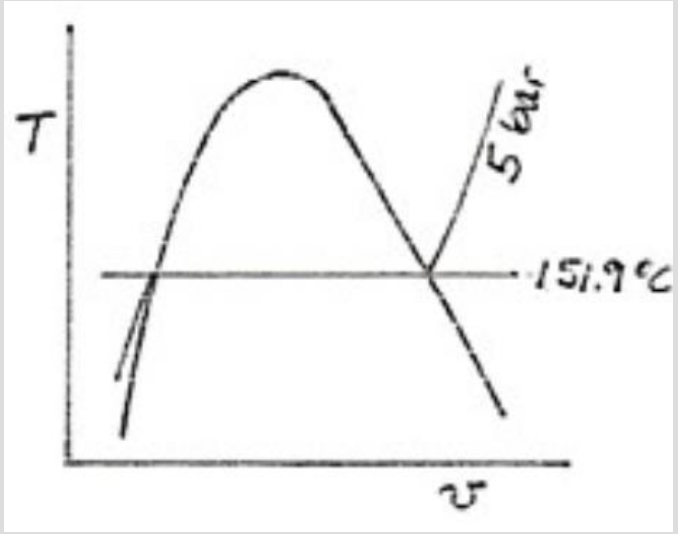
Excercise Problem: P-*v* and T-*v* Diagrams

Determine the phases or phases in a system consisting of H_2O at the following conditions and sketch p-v and T-v diagrams showing the location of each state

(a) p = 5 bar, T = 151.9 °C
(b) p = 5 bar, T = 200 °C
(c) T = 200 °C, p = 2.5 Mpa
(d) T = 160 °C, p = 4.8 bar

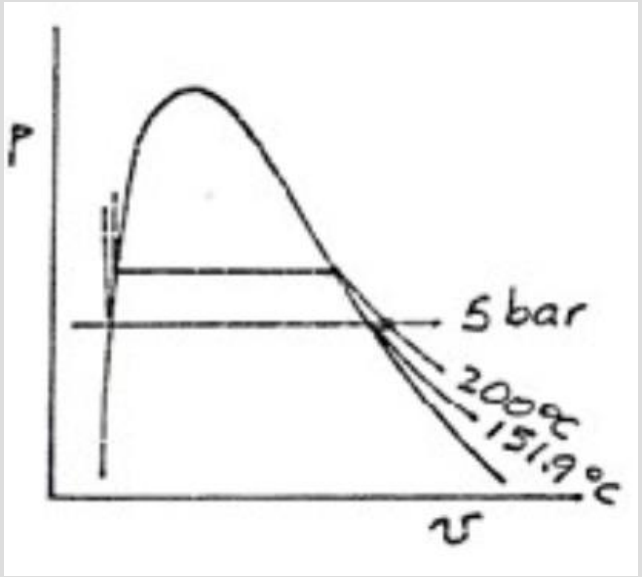
(a) p = 5 bar, T = 151.9 °C

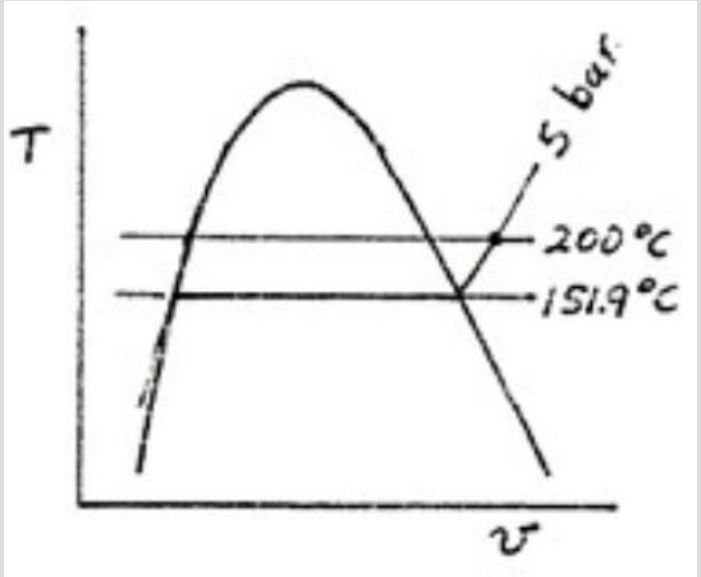




Liquid-Vapor Region

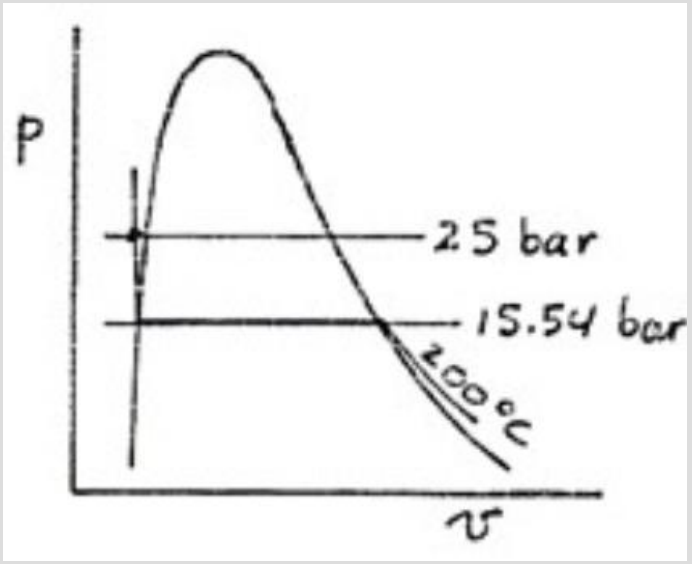
(b) p = 5 bar, T = 200 °C

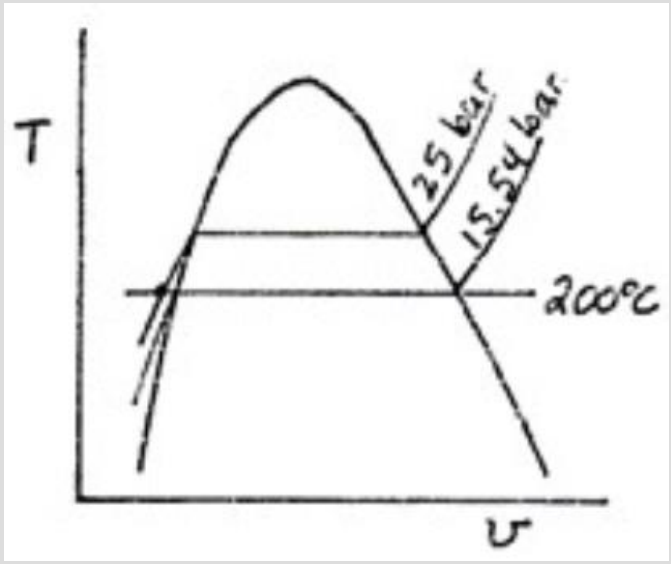




Super Heated Region

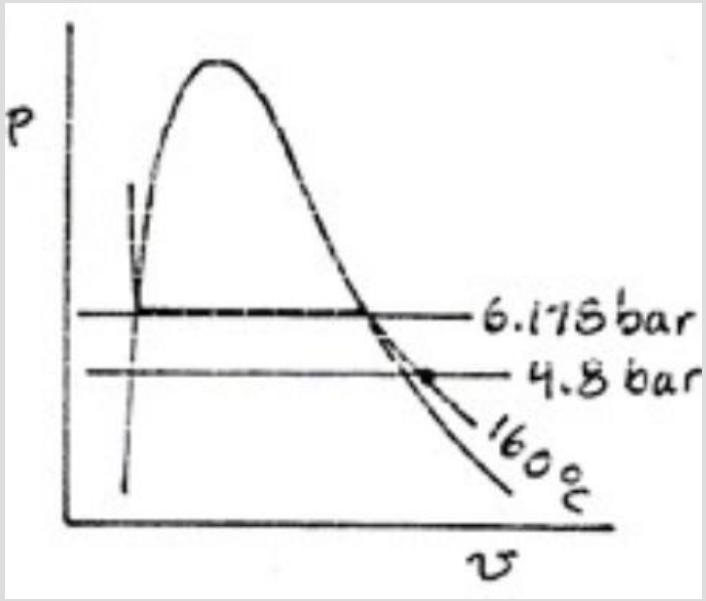
(c) T = 200 °C, p = 2.5 Mpa

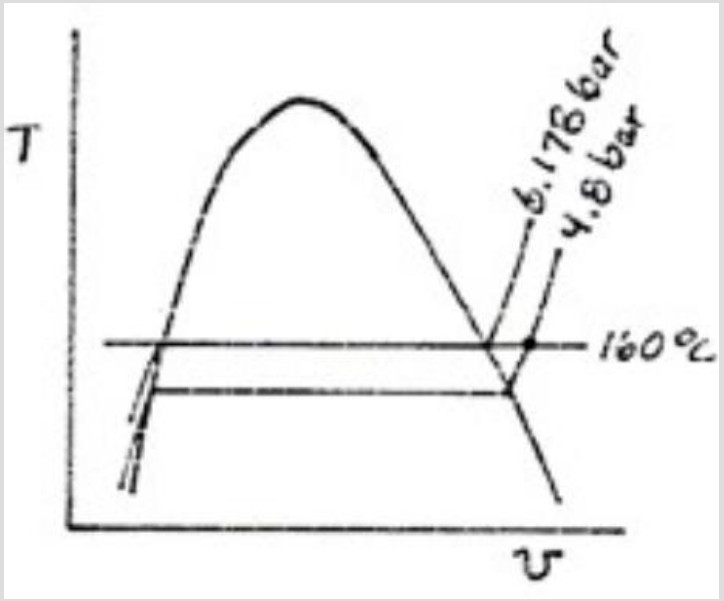




Sub-Cooled Region

(b) p = 5 bar, T = 200 °C





Super Heated Region

Example 3-9: Determine the missing properties and the phase descriptions in the following table for water:

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*)	**120.21**	200	**1719.26**	0.6	**Sat. Liquid-Vapor Mix.**
(*b*)	125		1600		
(*c*)		1000	2950		
(*d*)	75	500			
(*e*)		850		0.0	

Remember:

$$\upsilon_{avg} = \upsilon_f + x\upsilon_{fg} \quad (\mathrm{m^3/kg})$$

$$u_{avg} = u_f + xu_{fg} \quad (\mathrm{kJ/kg})$$

$$h_{avg} = h_f + xh_{fg} \quad (\mathrm{kJ/kg})$$

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(a)	120.21	200	1719.26	0.6	Sat. Liquid-Vapor Mix.
(b)	125	232.23	1600	0.535	Sat. Liquid-Vapor Mix.
(c)		1000	2950		
(d)	75	500			
(e)		850		0.0	

Remember:

if $u < u_f$ we have *compressed liquid*

if $u_f \le u \le u_g$ we have *saturated mixture*

if $u > u_g$ we have *superheated vapor*

$$u_{\text{avg}} = u_f + x u_{fg} \qquad \text{(kJ/kg)}$$

Example 3-9: Determine the missing properties and the phase descriptions in the following table for water:

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)	120.21	200	1719.26	0.6	Sat. Liquid-Vapor Mix.
(b)	125	232.23	1600	0.535	Sat. Liquid-Vapor Mix.
(c)	395.2	1000	2950	N/A	Superheated Vapor
(d)	75	500			
(e)		850		0.0	

Application of interpolation method

Remember:

if $u < u_f$ we have *compressed liquid*

if $u_f \le u \le u_g$ we have *saturated mixture*

if $u > u_g$ we have *superheated vapor*

Example 3-9: Determine the missing properties and the phase descriptions in the following table for water:

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(b)	125	**232.23**	1600	**0.535**	**Sat. Liquid-Vapor Mix.**
(c)	**395.2**	1000	2950	**N/A**	**Superheated Vapor**
(d)	75	500	$u \cong u_{f\,@\,75°C} = 313.99$	**N/A**	**Compressed Liquid**
(e)		850		0.0	

Let's look for the saturation temperature at given pressure

Remember:

if $T < T_{\text{sat @ given } P}$ we have *compressed liquid*

if $T = T_{\text{sat @ given } P}$ we have *saturated mixture*

if $T > T_{\text{sat @ given } P}$ we have *superheated vapor*

A compressed liquid may be approximated as a saturated liquid at the given temperature.

Given: P and T

$$v \cong v_{f\,@T}$$
$$u \cong u_{f\,@T}$$
$$h \cong h_{f\,@T}$$

Example 3-9: Determine the missing properties and the phase descriptions in the following table for water:

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(a)	**120.21**	200	**1719.26**	0.6	**Sat. Liquid-Vapor Mix.**
(b)	125	**232.23**	1600	**0.535**	**Sat. Liquid-Vapor Mix.**
(c)	**395.2**	1000	2950	**N/A**	**Superheated Vapor**
(d)	75	500	$u \cong u_{f\,@\,75°C} = 313.99$	**N/A**	**Compressed Liquid**
(e)	**172.94**	850	**731.00**	0.0	**Saturated Liquid**

$T_{\text{sat @ 850 kPa}}$

u_f @ 850 kPa

Exercise 3-23: Determine the missing properties and the phase descriptions in the following table for water:

T, °C	P, kPa	v, m³/kg	Phase description
50	**12.352**	4.16	**Sat. Liquid-Vapor Mix.**
120.21	200	**0.8858**	Saturated vapor
250	400	**0.5952**	**Superheated Vapor**
110	600	**0.001052**	**Compressed Liquid**

Exercise 3-25

Complete the following table for H_2O

T, °C	*P*, kPa	*h*, kJ/kg	*x*	Phase description
	200		0.7	
140		1800		
	950		0.0	
80	500			
	800	3162.2		

Solution:

T, °C	P, kPa	*h*, kJ / kg	*x*	Phase description
120.21	200	***2045.8***	0.7	***Saturated mixture***
140	***361.53***	1800	***0.565***	***Saturated mixture***
177.66	950	***752.74***	0.0	***Saturated liquid***
80	500	***335.37***	- - -	***Compressed liquid***
350.0	800	3162.2	- - -	***Superheated vapor***

Exercise 3-27

Complete the following table for Refrigerant – 134a

T, °C	*P*, kPa	*u*, kJ/kg	Phase description
20	**572.07**	95	**Sat. Liquid-Vapor Mix.**
−12	**185.37**	**35.78**	Saturated liquid
86.24	400	300	**Super-heated Vapor**
8	600	**62.37**	**Compressed Liquid**

Self-Exercise

Complete the following table for Refrigerant – 134a

T, °C	P, kPa	*h*, kJ /kg	*x*	Phase description
21.55	600	180	*0.545*	*Saturated mixture*
-10	*200.74*	*162.13*	0.6	*Saturated mixture*
-14	500	*33.40*	- - -	*Compressed liquid*
70	1200	300.61	- - -	*Superheated vapor*
44	*1131*	*272.95*	1.0	*Saturated vapor*