Answers to Lab 5

Example 1: (Exercises with interpolation)

Sometimes property data does not fall on the points given in the table. Under these conditions, we must interpolate between the available data points on the table to find the necessary information. Typically this is done using linear interpolation. This means that the missing data between the available points can be estimated by assuming that the functional relationship is a straight line.

Superheated water vapor, $v = v(P, T)$		
Temperature	Pressure	
	1.5 bars	3.0 bars
200 °C	1.444 m³/kg	0.716 m³/kg
240 °C	1.570 m³/kg	0.781 m³/kg

a) P = 1.5 bars, T = 215 °C (linear) [Answer: 1.491 m³/kg] ***v* = 1.491 m³/kg**

- Using linear interpolation between the given data points at P = 1.5 bars,

$$\frac{\boldsymbol{v} - 1.444}{215 - 200} = \frac{1.570 - 1.444}{240 - 200} \quad \Rightarrow \quad \boxed{\boldsymbol{v} = 1.491\,\text{m}^3/\text{kg}}$$

b) P = 2.0 bars, T = 200 °C (linear) [Answer: 1.201 m³/kg] ***v* = 1.201 m³/kg**

- Using linear interpolation between the given data points at T = 200 °C,

$$\frac{\boldsymbol{v} - 1.444}{2 - 1.5} = \frac{0.716 - 1.444}{3 - 1.5} \quad \Rightarrow \quad \boxed{\boldsymbol{v} = 1.201\,\text{m}^3/\text{kg}}$$

c) P = 2.0 bars, T = 215 °C (bi-linear) [Answer: 1.241 m³/kg] ***v* = 1.241 m³/kg**

- Neither the given pressure nor the given temperature are the tabulated values, a bi-linear interpolation procedure (in both the pressure and temperature axes) is necessary to obtain the desired value.
- Firstly, perform linear interpolation between the given data points at P = 1.5 bars, T = 215 °C,

$$\frac{\boldsymbol{v}_{1.5} - 1.444}{215 - 200} = \frac{1.570 - 1.444}{240 - 200} \quad \Rightarrow \quad \boldsymbol{v}_{1.5} = 1.491\,\text{m}^3/\text{kg}$$

- Secondly, perform linear interpolation between the given data points at P = 3.0 bars, T = 215 °C,

$$\frac{\boldsymbol{v}_{3.0} - 0.716}{215 - 200} = \frac{0.781 - 0.716}{240 - 200} \quad \Rightarrow \quad \boldsymbol{v}_{3.0} = 0.740\,\text{m}^3/\text{kg}$$

- Finally, perform linear interpolation between the given data points at P = 1.5 bars, T = 215 °C and P = 3.0 bars, T = 215 °C,

$$\frac{\boldsymbol{v} - \boldsymbol{v}_{1.5}}{\boldsymbol{v}_{3.0} - \boldsymbol{v}_{1.5}} = \frac{2.0 - 1.5}{3.0 - 1.5} \quad \Rightarrow \quad \boxed{\boldsymbol{v} = 1.241\,\text{m}^3/\text{kg}}$$

d) P = 1.5 bars, v = 1.500 m³/kg (linear) [Answer: 218 °C] ***T* = 218 °C**

- Using linear interpolation between the given data points at P = 1.5 bars,

$$\frac{1.5 - 1.444}{\boldsymbol{T} - 200} = \frac{1.570 - 1.444}{240 - 200} \quad \Rightarrow \quad \boxed{\boldsymbol{T} = 218\,^{\circ}\text{C}}$$

Example 2: (Exercises on property table look-up for water)

a) Provide the information requested (unshaded boxes) in the following table for WATER. Use the following abbreviations when specifying the phases:

CL = compressed (subcooled) liquid
SL = saturated liquid
SM = saturated mixture
SV = saturated vapor
SHV = superheated vapor

Use "NA" for items that are not applicable and "INSUF" for insufficient information at a particular state.

State	Phase	Pressure, P [kPa]	Temperature T [°C]	Quality, x	Specific Volume, v [m^3/kg]	Specific Internal Energy, u [kJ/kg]	Specific Enthalpy, h [kJ/kg]	Specific Entropy, s [kJ/(kg-K]
1	SHV	500	350	NA	0.5701		3167.7	
2	SL	500	151.86		0.00109		640.23	1.8607
3	SM	500	151.86	0.1875	0.07118	1000		
4	SV	500	151.86	1.0		2561.2	2748.7	
5	SM	101.33	100	0.30	0.5026			3.1213
6	SHV	91.17	100	NA	2.0		2677.3	
7	SM	101.33	100	0.7760	1.2984			6.0
8	SL	101.33	100	0.0	0.00104	418.94	419.04	1.3069
9	SL	5000	263.99	0.0	0.00129	1147.81	1154.23	2.9202
10	CL	5000	100	NA	0.00104	417.52	422.72	1.3030

b) States 8 and 9 are approximations of state 10. Which approximation is more accurate? Plot these three states on the *P*-*v* and *T*-*v* diagrams and explain your choice.

- State 8 is a more accurate approximation of State 10. In the compressed liquid region, the properties are less sensitive to changes in pressure than those in temperature. Hence, the compressed liquid properties can be approximated by:

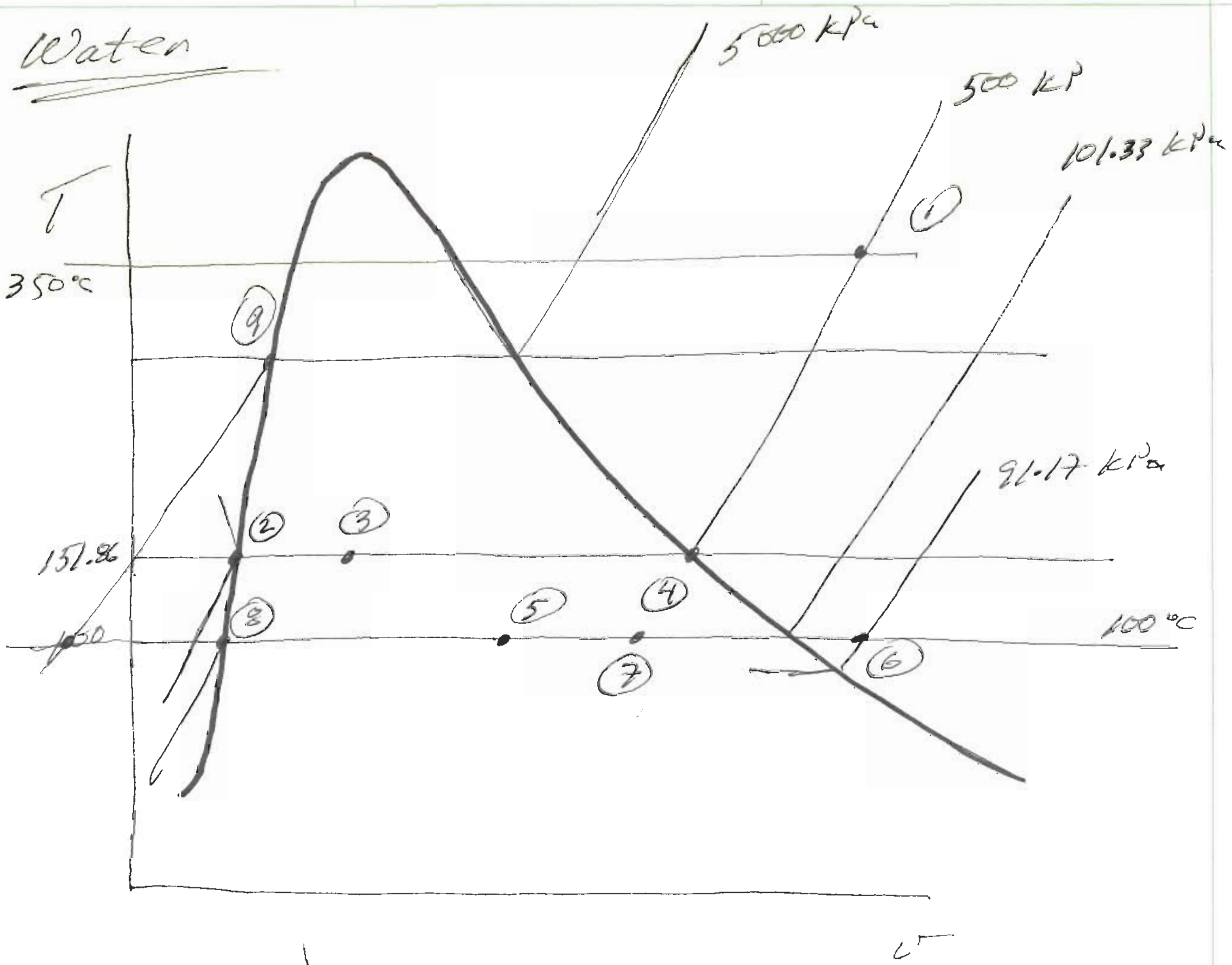
$$u(P,T) \cong u_f(T)$$

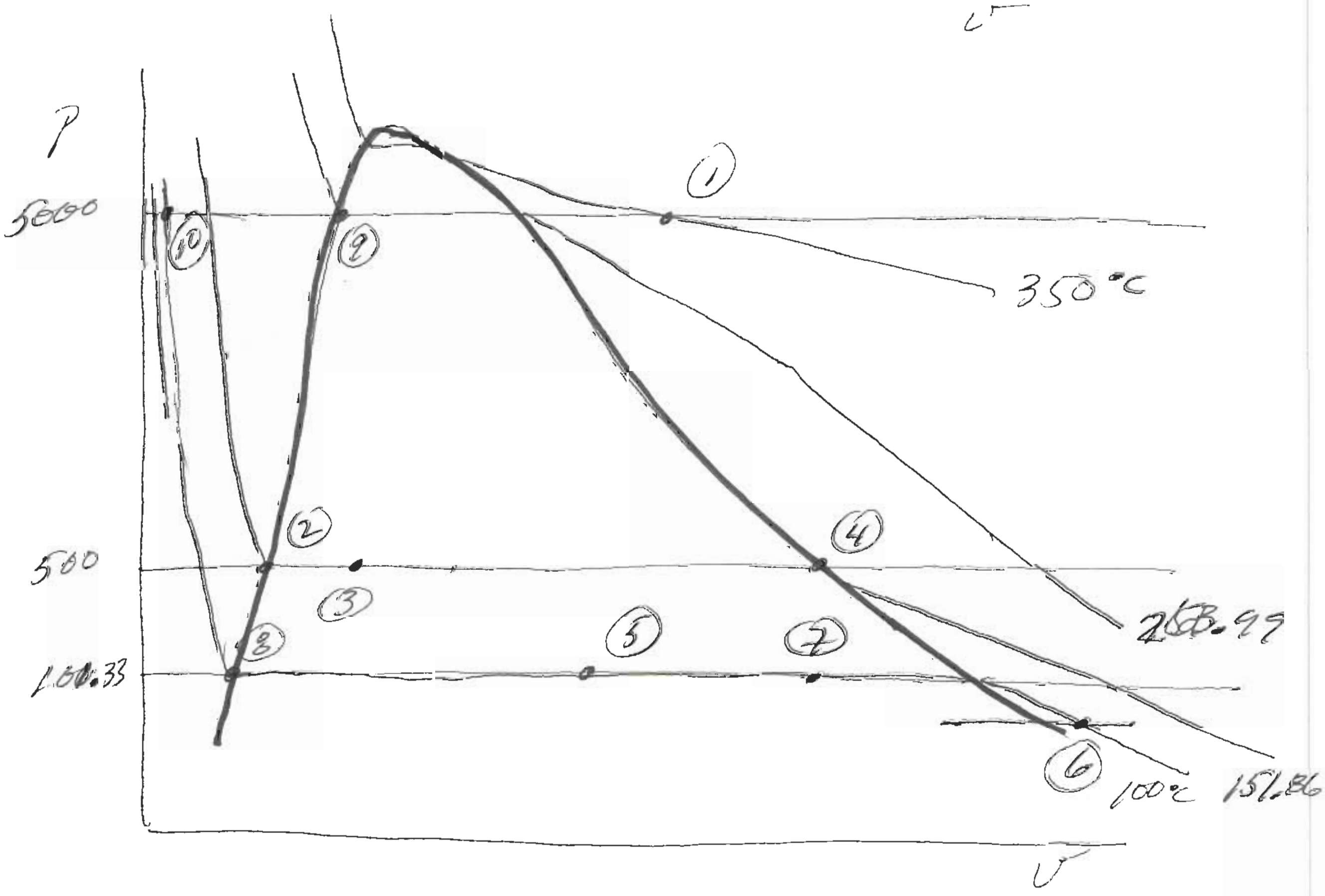
$$v(P,T) \cong v_f(T)$$

$$s(P,T) \cong s_f(T)$$

$$h(P,T) \cong h_f(T) + [P - P_{sat}(T)]v_f(T)$$

Water


T
350°C
151.86
100
5000 kPa
500 kP
101.33 kPa
91.17 kPa
100°C
1
2
3
4
5
6
7
8
9
v


P
5000
500
101.33
350°C
263.99
100°C
151.86
1
2
3
4
5
6
7
8
9
10
v

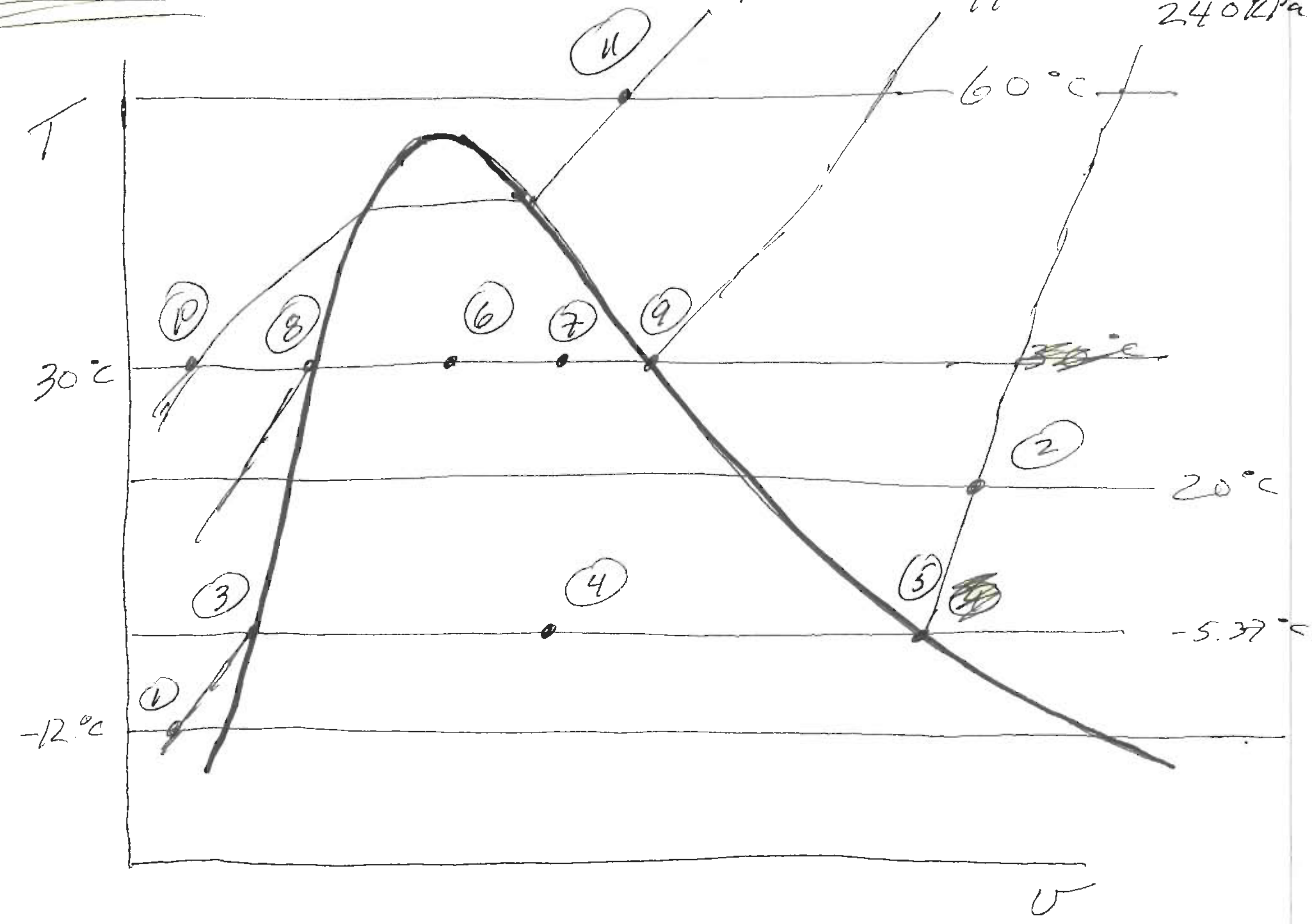
Example 3: (More exercise with property lookup for Refrigerant 134a)
Provide the information requested in the following table for Refrigerant 134a. Use the following abbreviations when specifying the phases:

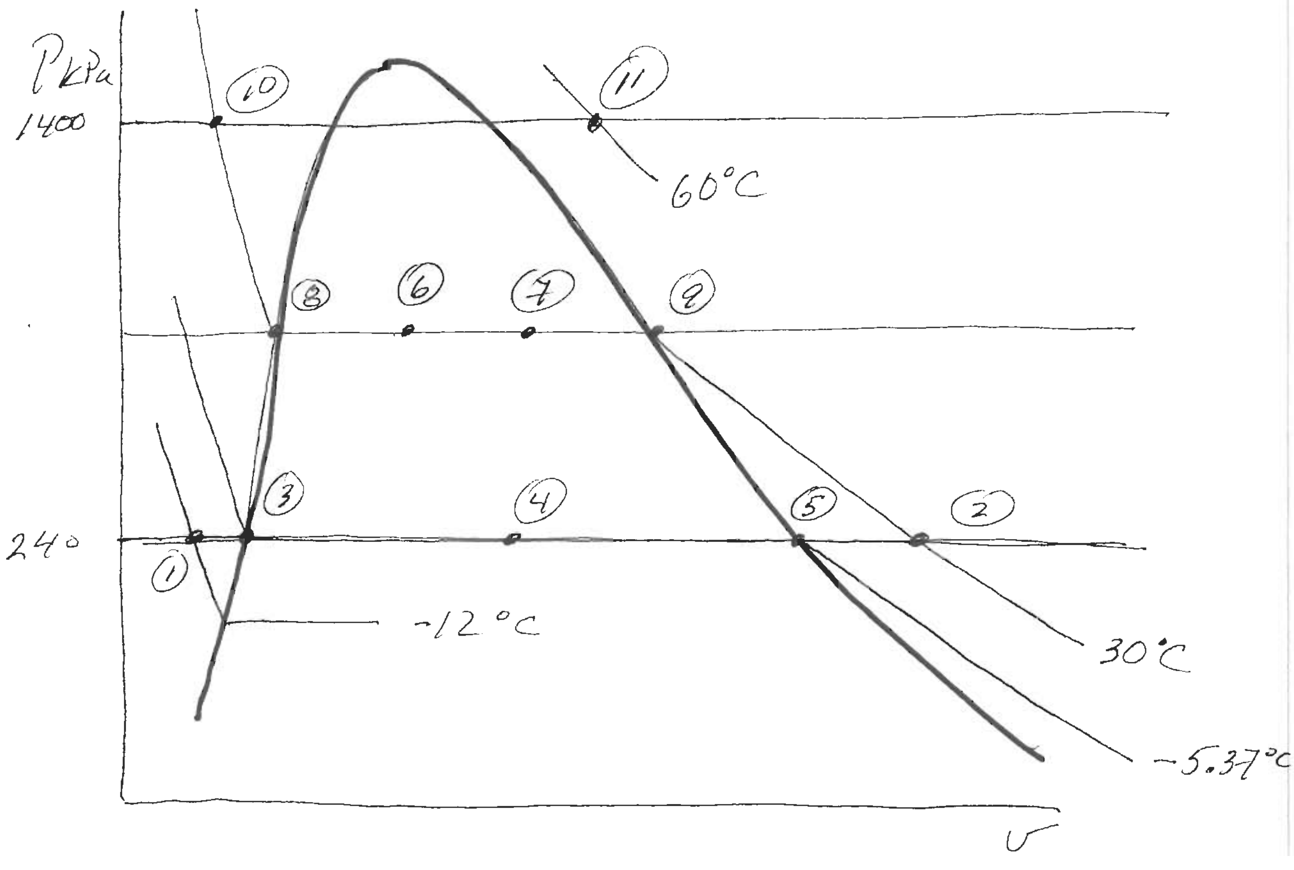
CL = compressed (subcooled) liquid
SL = saturated liquid
SM = saturated mixture
SV = saturated vapor
SHV = superheated vapor

NA = not applicable
INSUF = insufficient information

State	Phase	Pressure, *P* (kPa)	Temperature *T* (°C)	Specific Volume, *v* (m^3/kg)	Specific Internal Energy, *u* (kJ/kg)	Specific Enthalpy, *h* (kJ/kg)	Specific Entropy, *s* (kJ/kg-K)	Quality, *x*
1	CL	240	-12	.000750			0.1388	NA
2	SHV	240	20	.09339		266.85		NA
3	SL	240	-5.37		42.77		0.1710	0.0
4	SM	240	-5.37		139.26	150		0.5322
5	SV	240	-5.37	0.0834		244.09		
6	SM	770.06	30	0.01111		160.29		0.4
7	SM	770.06	30	0.0188			0.7367	0.6999
8	SL	770.06	30		90.84		0.3396	0.0
9	SV	770.06	30	0.0265	243.1	263.5	0.9070	1.0
10	CL	1400	30		90.84	92.02		NA
11	SHV	1400	60	0.01495		283.1		NA

R-134a


1400 kPa
770.06 kPa
240 kPa
T
60 °C
30 °C
20 °C
-5.37 °C
-12 °C
1
2
3
4
5
6
7
8
9
10
11
v


P kPa
1400
240
10
11
60°C
8
6
7
8
3
4
5
2
1
-12 °C
30°C
-5.37°C
v