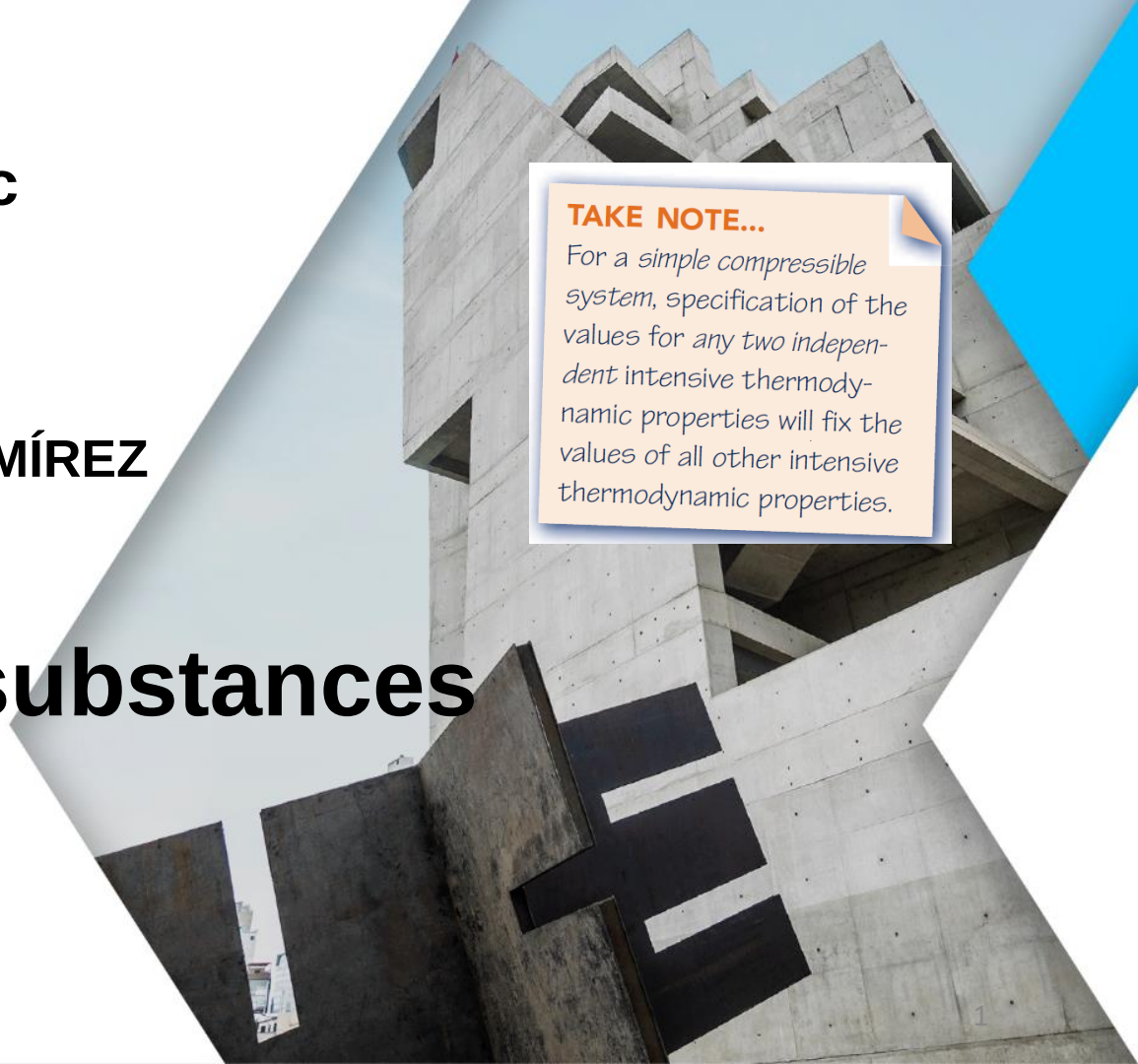
Thermodynamic
2026-1

NEDHER SÁNCHEZ RAMÍREZ
NAUDY LOPEZ

Properties of substances



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Recomendaciones generales:

- Leer antes de clase y entender los conceptos o preguntar si es necesario.
- Practicar bastante:
  - *Ejercicios de clase
  - *Asesorías
  - *Ejercicios del libro resueltos y los de final de capitulo
- Los quizzes virtuales y gradescope úsenlos para aprender de forma honesta (se puede inferir).
- Tengan grupos de estudio y apóyense mutuamente.
- Crear sus propias notas estudio y formulario.
- Son 4 horas de clase en la semana (asistir y ser puntuales, perder alguna es atrasarse mucho)
- Cada hora de clase son 3 horas de estudio por fuera mínimo.
- En la ppt de la semana 1 están todos los links claves para el curso.

Instructores del curso y coordinador

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Guidelines for virtual sessions:

Tiempo aproximado de la sesión 100 minutos

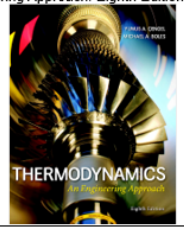
Realizar preguntas a través del chat, habrá un profesor y/o un asistente atento a las dudas planteadas

Levantar la mano si desea hacer uso del micrófono y exponer alguna duda

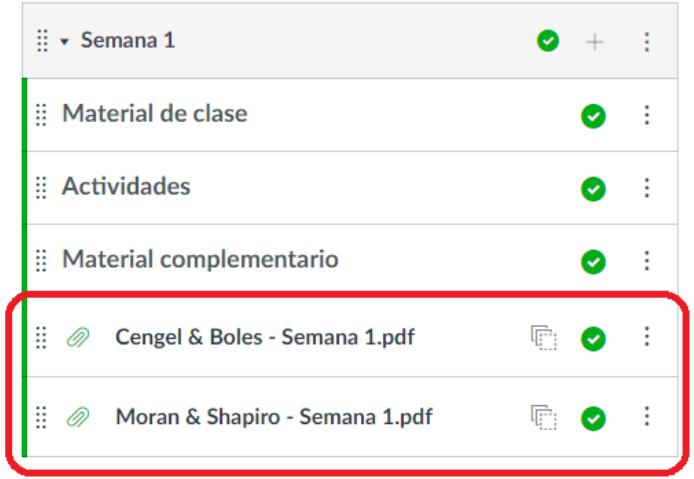
La grabación de la sesión se cargará a Canvas.

Actividades	Inicio		Fin	
	Día	Fecha	Día	Fecha
Inicio de clases UTEC	Lunes 23 de marzo 2026			
Exámenes parciales	Lunes 11 de mayo 2026		Sábado 16 de mayo 2026	
Último día de clases	Sábado 4 de julio 2026			
Exámenes finales	Lunes 6 de julio 2026		Sábado 11 de julio 2026	
Exámenes de rezagados	Jueves 16 de julio 2026		Lunes 20 de julio 2026	

TEMAS SEMANA X SEMANA

Semana	Moran M.J. & Shapiro H.N. (2004). Fundamentos de la termodinámica Técnica. 2da edición (español). 	Cengel, Y.A. & Boles, M.A. (2015). Thermodynamics: An Engineering Approach. Eighth Edition (inglés). 
1	Capítulo 1: secciones 1.1 – 1.6 Ejercicios: 1.1 – 1.28	Capítulo 1: 1.3 – 1.9
2	Capítulo 3: secciones 3.1 – 3.2, 3.3.1 – 3.3.2, 3.3.6 Ejercicios: 3.1 – 3.26	Capítulo 3: 3.1 – 3.5 Capítulo 4: 4.1, 4.5
3	Capítulo 3: 3.3.5, 3.4 – 3.8 Ejercicios: 3.40 – 3.51	Capítulo 3: 3.6 – 3.7 Capítulo 4: 4.4
4	Capítulo 12: 12.1 – 12.4 Ejercicios: 12.1 – 12.6	Capítulo 13: 13.1 – 13.3
5	Capítulo 2: 2.1 – 2.6	Capítulo 2: 2.1 – 2.5
6	Capítulo 3: ejemplos 3.2 – 3.4, 3.8 – 3.11 Ejercicios: 2.1 – 2.10, 2.12 – 2.13, 2.21 – 2.40, 3.27 – 3.39, 3.52 – 3.58, 12.7 – 12.8, 12.10, 12.16 – 12.19	Capítulo 2: 2.6 Capítulo 4: 4.1 – 4.2
7	Capítulo 4: 4.1 – 4.4 Ejercicios: 4.1 – 4.33	Capítulo 5: 5.1 – 5.5
8		
9	Capítulo 5: 5.1 – 5.4 Ejercicios: 5.1 – 5.11, 5.14 – 5.33	Capítulo 6: 6.1 – 6.4, 6.6
10	Capítulo 5: 5.2, 5.6 – 5.7 Ejercicios: 5.14 – 5.33	Capítulo 6: 6.7 – 6.8, 6.10 – 6.11
11	Capítulo 6: 6.1 – 6.5 Ejercicios: 6.1 – 6.31	Capítulo 7: 7.1 – 7.10
12	Capítulo 6: 6.6 Ejercicios: 6.32 – 6.43	Capítulo 7: 7.13
13	Capítulo 6: 6.7 – 6.8 Ejercicios: 6.44 – 6.56	Capítulo 7: 7.12
14		

Importante: Las lecturas señaladas en este documento deben ser leídas antes de la semana indicada, en preparación para la tarea semanal de dicha semana. Ambos libros cubren aproximadamente el mismo contenido, pero con enfoques y niveles de profundidad distintos. Los estudiantes podrán alcanzar la comprensión del curso empleando solo una de las referencias. Sin embargo, se invita a contrastar semanalmente los temas en ambos textos, como método para alcanzar la compresión máxima del contenido. Tener en cuenta que los subcapítulos indicados en esta guía corresponden a las ediciones de los libros especificadas.



Horas de atención - Jhordy Manrique
(Dudas del curso-Tareas - notas)
LUNES 11-1 PM - Oficina P311

Horas de atención - Prof. Naudy Lopez
nlopez@utec.edu.pe
Previa coordinación con el profesor

Horas de atención - Jhordy Manrique
(Dudas del curso-Tareas - notas)
JUEVES 10-12 AM - Oficina P311

Horas de atención - Prof. Nedher Sánchez Ramírez

JUEVES: 9-12 pm….1-2pm - Oficina P311

Horas de asesoría 2026-1

Hora	Lunes	Martes	Miércoles	Jueves	Viernes	Sábado	Hora
7AM - 8AM		Clases		Clases			7AM-8AM
8AM - 9AM		Clases		Clases			8AM - 9AM
9AM - 10AM		Clases	Clases				9AM - 10AM
10AM - 11AM		Clases	Clases				10AM - 11AM
11AM - 12PM			Clases				11AM-12PM
12PM - 1PM			Clases				12PM-1PM
1PM - 2PM			Clases				1PM - 2PM
2PM - 3PM			Clases	CT: https://utec.zoom.us/j/97371427800			2PM - 3PM
3PM - 4PM	Clases					FR: https://utec.zoom.us/j/95953412067	3PM - 4PM
4PM - 5PM	Clases						4PM - 5PM
5PM - 6PM	Clases	Clases	Clases				5PM - 6PM
6PM - 7PM	Clases	Clases	Clases				6PM - 7PM
7PM - 8PM							7PM - 8PM
8PM - 9PM	ASESORÍA DE DUDAS: https://utec.zoom.us/j/97136492520	JG: https://utec.zoom.us/j/92301579107		RV: https://utec.zoom.us/j/92982722393			8PM - 9PM
9PM - 10PM							9PM - 10PM

RV: Rosario Vidal		Todas las sesiones serán grabadas.				
CT: Cristian Tobias		*Varia según disponibilidad				
FR: Franklin Rosas						
JG: Jose Gamero						

Link de WhatsApp de Termodinámica:

https://chat.whatsapp.com/Iu3b3wnWFuY2Zvamn89NNa

Thermodynamics _ Evaluation

COMPONENTE	%
EXAMEN PARCIAL	20
EXAMEN FINAL	30
C	50
APROBACIÓN: 11/20	

EXÁMENES	FECHAS
EXAMEN PARCIAL	(MAYO 8)
EXAMEN FINAL	(JULIO 6)

EXAMEN 1: Todos los temas vistos hasta la semana 6.
EXAMEN 2: Todos los temas vistos hasta la semana 15

Thermodynamics _ Evaluation

COMPONENTE	%
EXAMEN PARCIAL	20
EXAMEN FINAL	30
C	50
APROBACIÓN: 11/20	

EVALUACIÓN CONTINUA (C) :

La evaluación continua vale un 50% de la nota final

-5 % corresponde a **tareas virtuales ..**Son de corrección automática

-10 % corresponde a **tareas individulales** (ejercicios que los alumnos hacen y suben a la plataforma gradescope) …. ..Ver rúbrica

-17 % corresponde a una **tarea grupal** (proyecto)…..Ver rúbrica

-18% restante corresponde **actividades en aula** (quizes de 20 min aprox)..Ver rúbrica

Thermodynamics _ Evaluation

COMPONENTE	%
PARCIAL	20
FINAL	30
C	50
APROBACIÓN: 11/20	

SEMANA 1	TAREA VIRTUAL	SE CALIFICA AUTOMATICO NO NECESITA PROCEDIMIENTO
SEMANA 2	TAREA VIRTUAL	
SEMANA 3	TAREA VIRTUAL	.
SEMANA 4	**TAREA INDIVIDUAL 1** + EVALUACION_ AULA1	TAREA INDIVIDUAL: Esta parte incluye subir un archivo con la solución EVALUACION_ AULA: SEMANAS 1-2
SEMANA 5	TAREA VIRTUAL+ EVALUACION_ AULA2	EVALUACION_ AULA: SEMANAS 1-3
SEMANA 6	TAREA VIRTUAL**+TAREA INDIVIDUAL 2**	
SEMANA 7	TAREA VIRTUAL+ EVALUACION_ AULA3	EVALUACION_ AULA: SEMANAS 1-6
SEMANA 8	**PARCIAL**	
SEMANA 9	EVALUACION_ AULA4+**TAREA INDIVIDUAL 3 +Tarea grupal 1**	EVALUACION_ AULA: SEMANAS 1-8
SEMANA 10	TAREA VIRTUAL	
SEMANA 11	TAREA VIRTUAL	
SEMANA 12	TAREA VIRTUAL+ EVALUACION_ AULA5	EVALUACION_ AULA: SEMANAS 1-11
SEMANA 13	TAREA VIRTUAL**+TAREA INDIVIDUAL 4 + Tarea grupal 2**	
SEMANA 14	TAREA VIRTUAL+EVALUACION_ AULA6	EVALUACION_ AULA : SEMANAS 1-13
SEMANA 15		
SEMANA 16	**FINAL**	

***LAS TAREAS VIRTUALES O LOS GRADESCOPE (TAREA INDIVIDAL) se abren lunes 2pm y se cierran sábado media noche. La tarea virtual se presenta hasta un máximo de 3 veces.**

EVALUACION_ AULA: es un quiz de 20 min aprox. en aula.

Thermodynamics _ Evaluation

EVALUACIÓN CONTINUA (C) :

COMPONENTE	%
C	50

25 %
- **3 actividades en aula → 9 %**
- **2 tareas individuales → 5 %**
- **½ tareas virtuales → 2.5 %**
- **1ra entrega tarea grupal → 8.5 %**

25 %
- **3 actividades en aula → 9 %**
- **2 tareas individuales → 5 %**
- **½ tareas virtuales → 2.5 %**
- **2da entrega tarea grupal → 8.5 %**

Se subirá al EDU En dos bloques de 25% c/u

Thermodynamics _ Evaluation

Tarea grupal (proyecto).....

La actividad consta del análisis de una sistema, dicho análisis puede requerir elementos de programación.

Fechas de entrega del laboratorio:
1ra entrega - 18/05/2026 a las 9 am (jueves de la semana 9)
2da entrega - 15/06/2026 a las 9am (lunes de la semana 13)

Este ciclo no hay co-evaluación !!!

Link con toda la información de la tarea grupal :

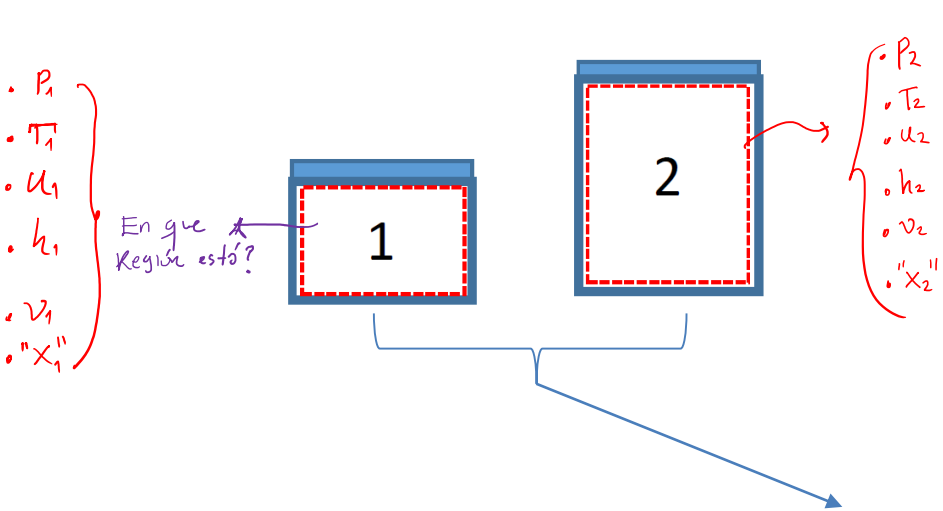
https://docs.google.com/spreadsheets/d/1DMrZjoEaRlHfZPbrFa5q84ha0ElWJQS1zmyLanvjGcw/edit?gid=0#gid=0

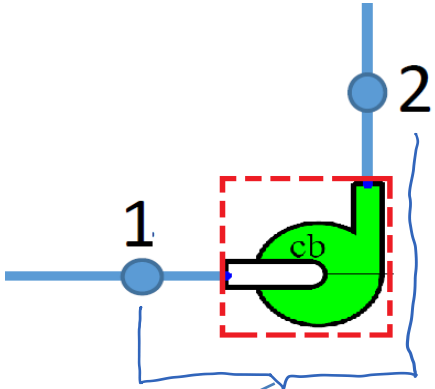
Thermodynamics _ Evaluation

Link con las rubricas de actividad de aula y tarea individual:

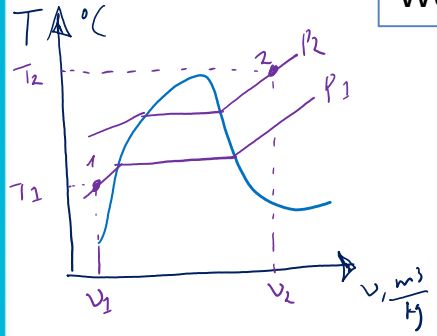
https://docs.google.com/spreadsheets/d/1iLMFoTAZiUBYuD8fGZFW4d0pF0-UBt8f/edit?gid=85594443#gid=85594443

Last week we studied:





We need to do a thermodynamic analysis between any two states ⇔ Q, W



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- ✓ **Session 3-4: Identify and calculate the properties of a pure substance using thermodynamic tables-PVT diagrams.**

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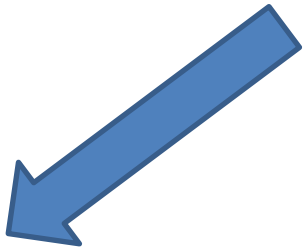
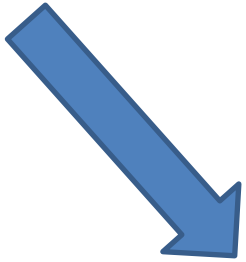
Pure substance in this course





Water, refrigerants…
This week.

Ideal and real gases
Next week.

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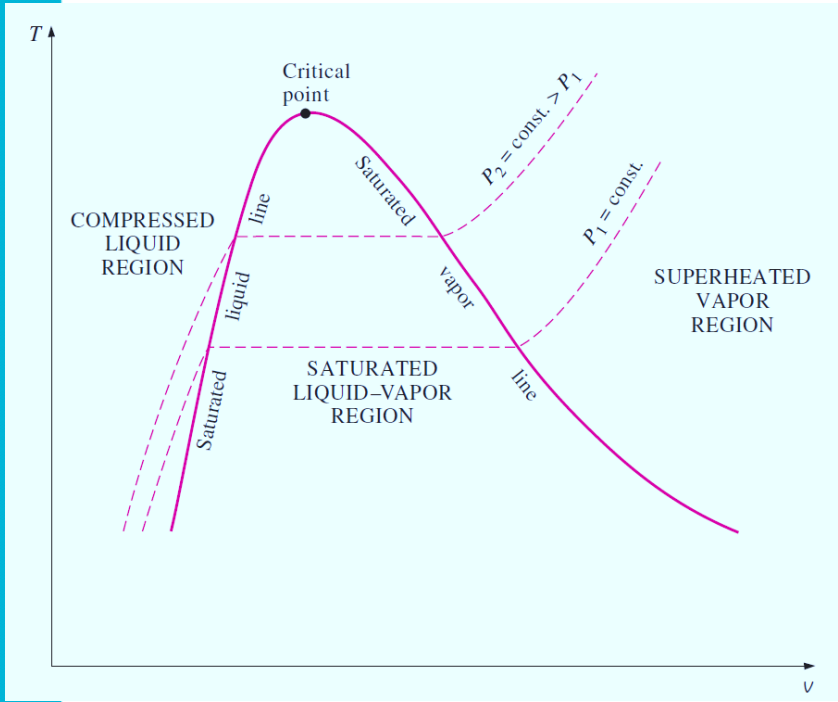
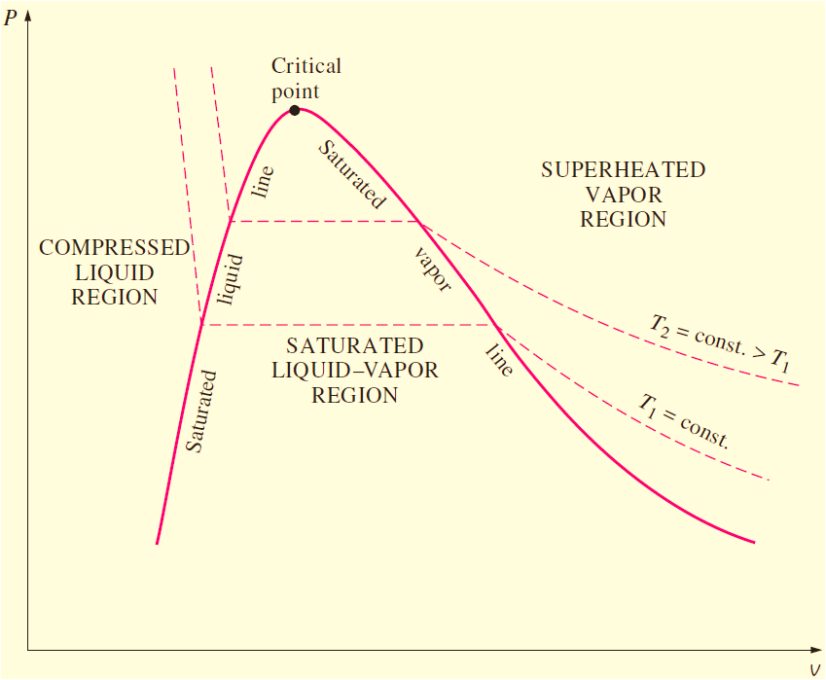
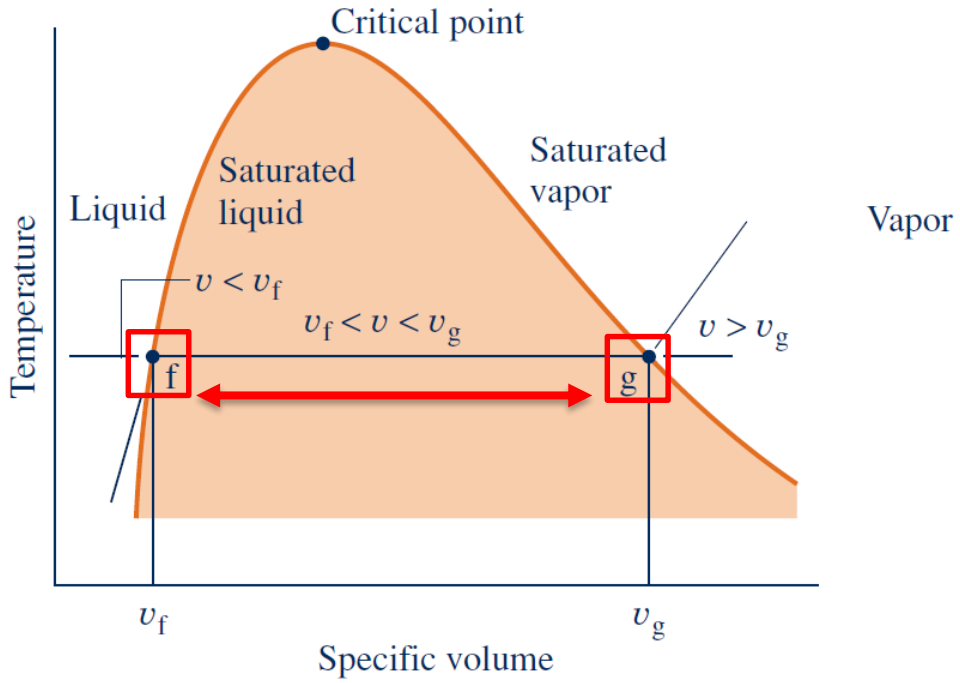
T-v Vs P-v Diagram





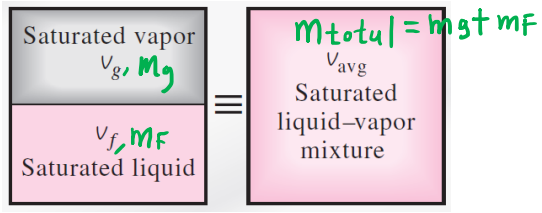
How to use the steam tables (water)?

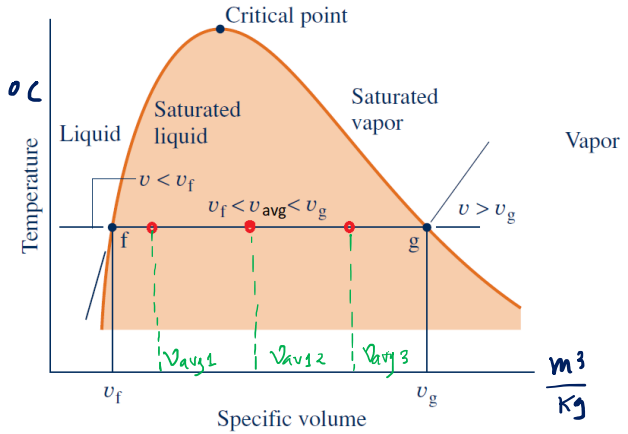
1.a) Saturated Liquid and Saturated Vapor States



1b) Saturated Liquid–Vapor Mixture_Quality

We can suppose that s. liquid and s. vapor form a homogeneous substance with an average volume (v_{avg})





$$v_{avg} = v_f + x(v_g - v_f) \longrightarrow x = \frac{m_{vapor}}{m_{total}} = \frac{m_g}{m_g + m_F}$$

(v_{fg})

1b) Saturated Liquid–Vapor Mixture_ Quality

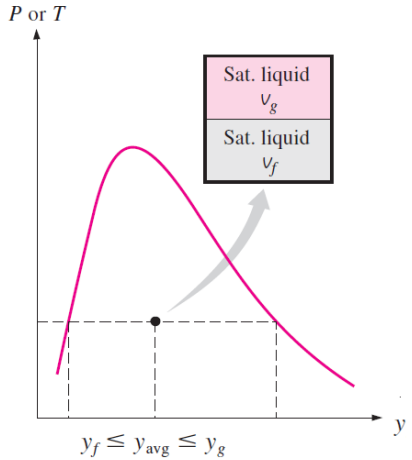
We can this result for the other properties:

$$u_{avg} = u_f + x\,(u_g - u_f) \quad [kJ/kg]$$

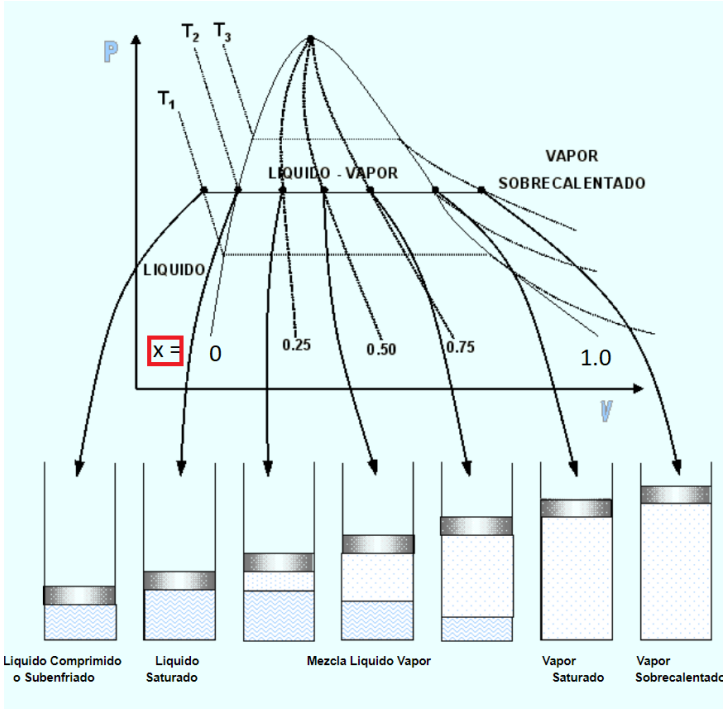
$$h_{avg} = h_f + x\,(h_g - h_f) \quad [kJ/kg]$$

The values of the average properties of the mixtures are always between the values of the saturated liquid and the saturated vapor properties :

$$y_f \leq y_{avg} \leq y_g$$



1b) Saturated Liquid–Vapor Mixture_ Quality



1c) Superheated Vapor

Unlike what happens in the saturation region, here **P** and **T** are independent, therefore the table is different:

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

TABLE A-4

Properties of Superheated Water Vapor

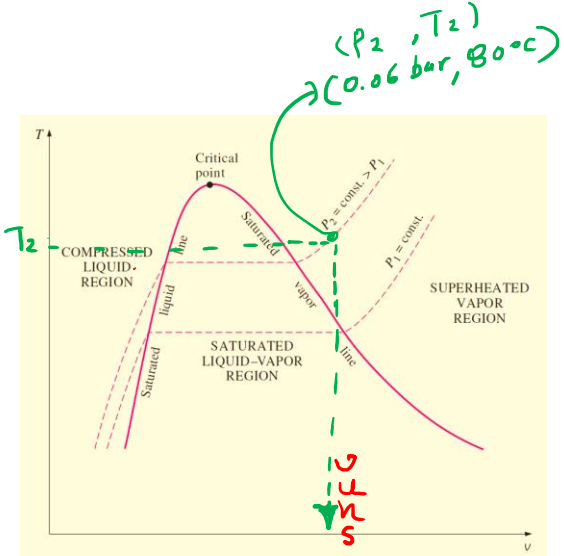
T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 0.06 bar = 0.006 MPa (T_{sat} = 36.16°C)			
Sat.	23.739	2425.0	2567.4	8.3304
80	27.132	2487.3	2650.1	8.5804
120	30.219	2544.7	2726.0	8.7840
160	33.302	2602.7	2802.5	8.9693
200	36.383	2661.4	2879.7	9.1398
240	39.462	2721.0	2957.8	9.2982
280	42.540	2781.5	3036.8	9.4464
320	45.618	2843.0	3116.7	9.5859
360	48.696	2905.5	3197.7	9.7180
400	51.774	2969.0	3279.6	9.8435
440	54.851	3033.5	3362.6	9.9633
500	59.467	3132.3	3489.1	10.1336

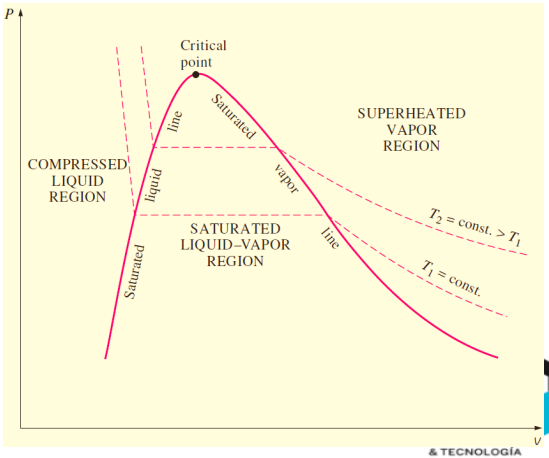
To know that we have superheated steam we use:

Satured vapor as reference:

superheated vapor is characterized by

$$\text{at a given } T \Rightarrow P < P_{sat}$$
$$\text{at a given } P \Rightarrow T > T_{sat}$$
$$\text{at a given } P \text{ or } T \Rightarrow v > v_g$$
$$\text{at a given } P \text{ or } T \Rightarrow u > u_g$$
$$\text{at a given } P \text{ or } T \Rightarrow h > h_g$$





1c) Super heated vapor

EXAMPLE 5.2: Temperature of superheated vapor

5 kg of water at 5 bar is inside a cylinder-piston of 2.0 m^3 of volume. Estimate the temperature and the specific-volume of the water. Sketch T-v diagram.

como referencia, siempre está la saturación

TABLE A-3

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Properties of Saturated Water (Liquid–Vapor): Pressure Table

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Press. bar
5.00	151.9	1.0926	0.3749	639.68	2561.2	640.23	2108.5	2748.7	1.8607	6.8212	5.00

$P = 5bar$

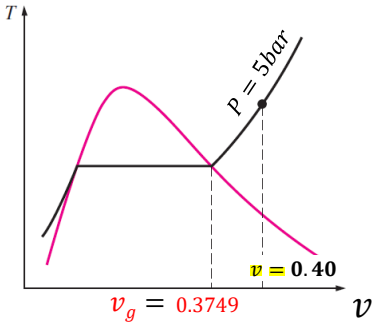
superheated vapor

at a given P or $T \Rightarrow v > v_g$

at a given P or $T \Rightarrow u > u_g$

at a given P or $T \Rightarrow h > h_g$

$$v = \frac{2.0m^3}{5kg} = 0.40m^3/kg > v_g$$



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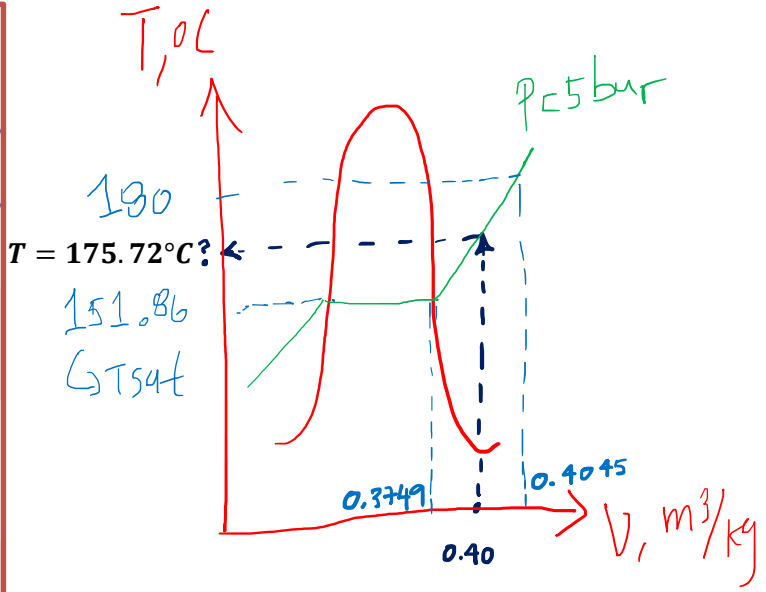
$v = 0.40 m^3/kg$

Temperature should be between 151.86°C and 180°C

TABLE A-4

(Continued)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
		$p = 5.0$ bar $= 0.50$ MPa ($T_{sat} = 151.86°C$)		
Sat.	0.3749	2561.2	2748.7	6.8213
180	0.4045	2609.7	2812.0	6.9656
200	0.4249	2642.9	2855.4	7.0592
240	0.4646	2707.6	2939.9	7.2307
280	0.5034	2771.2	3022.9	7.3865
320	0.5416	2834.7	3105.6	7.5308
360	0.5796	2898.7	3188.4	7.6660
400	0.6173	2963.2	3271.9	7.7938
440	0.6548	3028.6	3356.0	7.9152
500	0.7109	3128.4	3483.9	8.0873
600	0.8041	3299.6	3701.7	8.3522
700	0.8969	3477.5	3925.9	8.5952



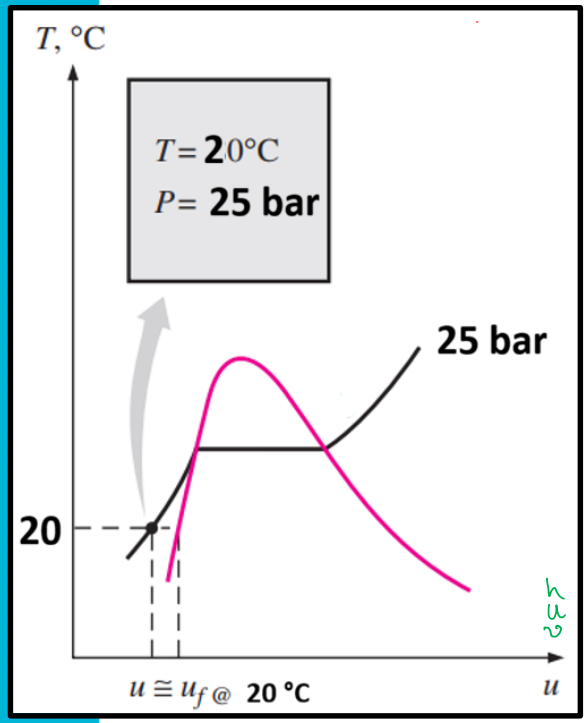
$$y - y_0 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_0)$$

Interpolating: $T = 175.7220\ °C$

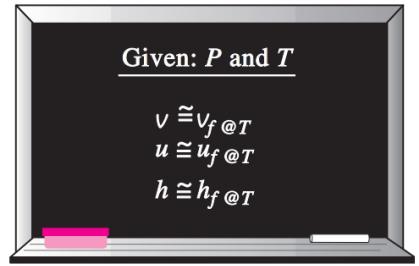
$$\frac{180 - 151.86}{0.4045 - 0.3749} = \frac{T - 151.86}{0.40 - 0.3749}$$

1d) Compressed Liquid

Compressed liquid tables are not as commonly available (only water has a table) , in general we approximate :



$$y \cong y_{f\,@\,T}$$



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

Compressed liquid

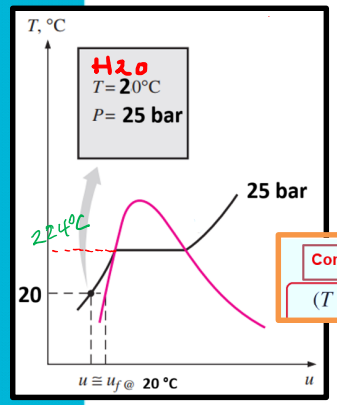
$(P > P_{sat}$ at a given $T)$

$(T < T_{sat}$ at a given $P)$

$(v < v_f$ at a given P or $T)$

$(u < u_f$ at a given P or $T)$

$(h < h_f$ at a given P or $T)$



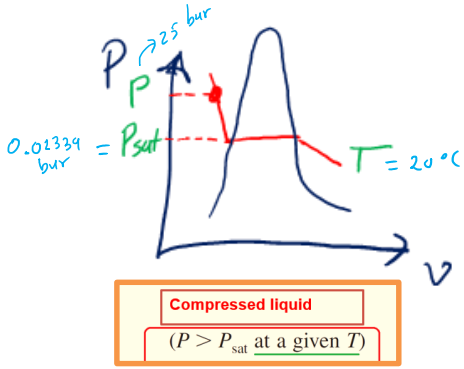


TABLE A-5

Properties of Compressed Liquid Water

T °C	v × 10³ m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 25 bar = 2.5 MPa (T_{sat} = 223.99°C)			
20	1.0006	83.80	86.30	.2961
40	1.0067	167.25	169.77	.5715
80	1.0280	334.29	336.86	1.0737

TABLE A-2

Properties of Saturated Water (Liquid–Vapor): Temperature Table

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g
18	0.02064	1.0014	65.038	75.57	2400.2	75.58	2458.8	2534.4	0.2679	8.7123
19	0.02198	1.0016	61.293	79.76	2401.6	79.77	2456.5	2536.2	0.2823	8.6897
20	0.02339	1.0018	57.791	83.95	2402.9	83.96	2454.1	2538.1	0.2966	8.6672

TABLE A-3

Properties of Saturated Water (Liquid–Vapor): Pressure Table

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

Press. bar	Temp. °C	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g
20.0	212.4	1.1767	0.09963	906.44	2600.3	908.79	1890.7	2799.5	2.4474	6.3409
25.0	224.0	1.1973	0.07998	959.11	2603.1	962.11	1841.0	2803.1	2.5547	6.2575
30.0	233.9	1.2165	0.06668	1004.8	2604.1	1008.4	1795.7	2804.2	2.6457	6.1869

"Como 83.95 es cercano al valor real de 83.80, cuando no se dispone de una tabla de líquido comprimido, o cuando esta es incompleta, es válido aproximar las propiedades usando la tabla de saturación entrando por la misma temperatura."

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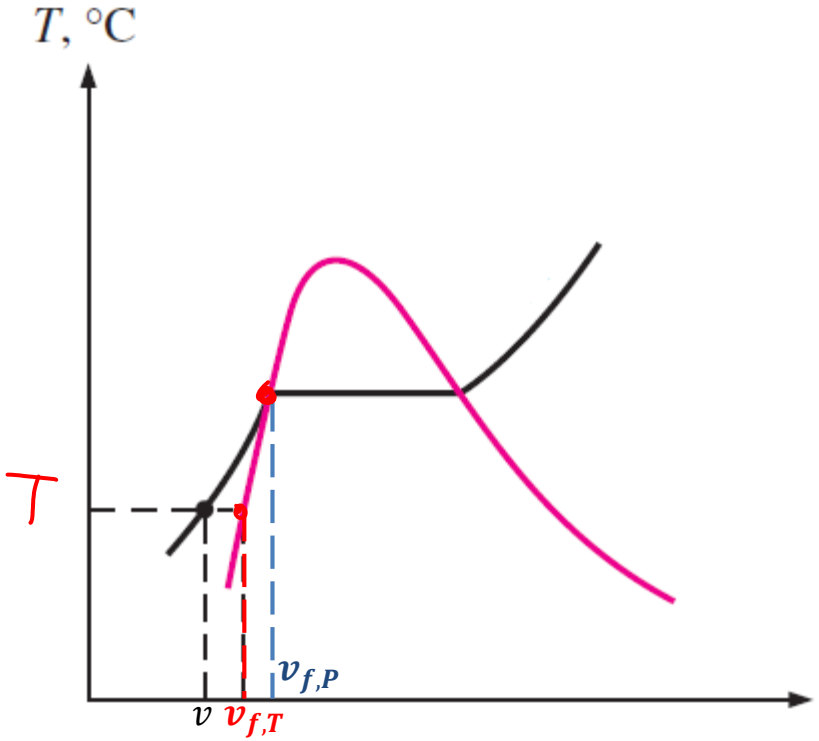

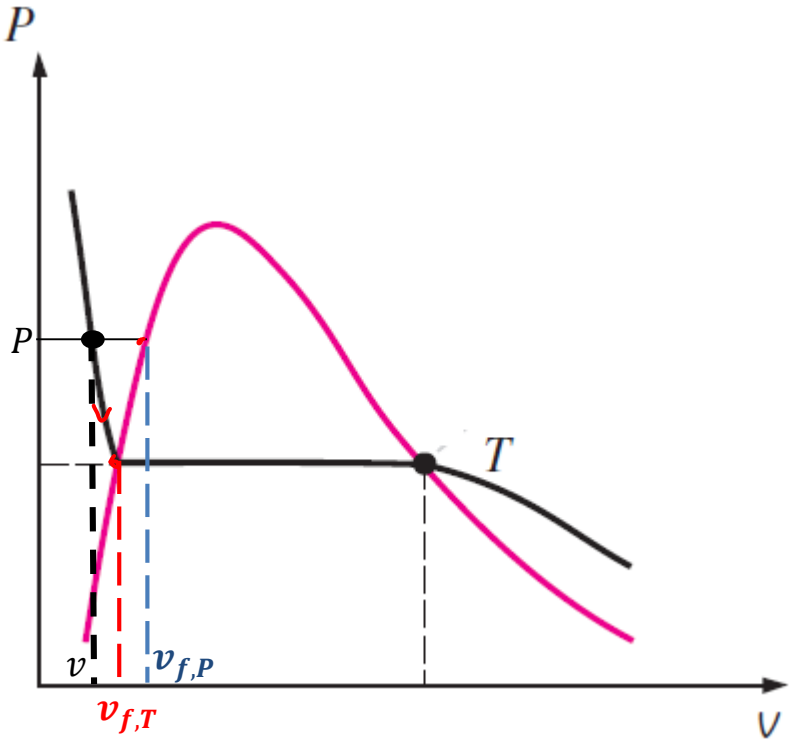

Same T, ignore P

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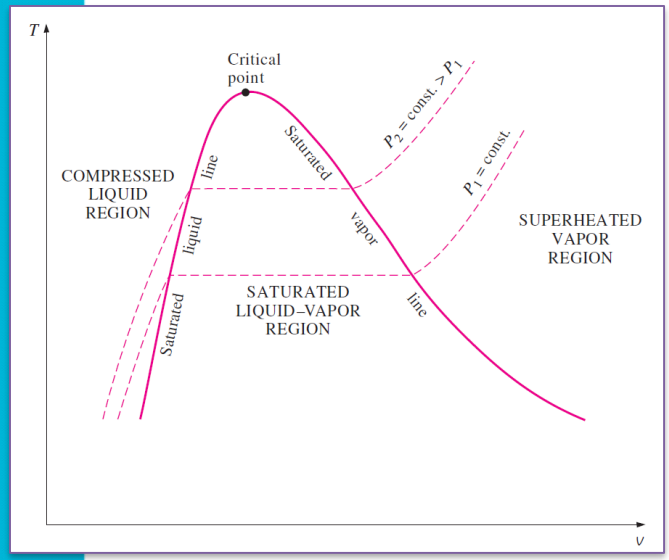
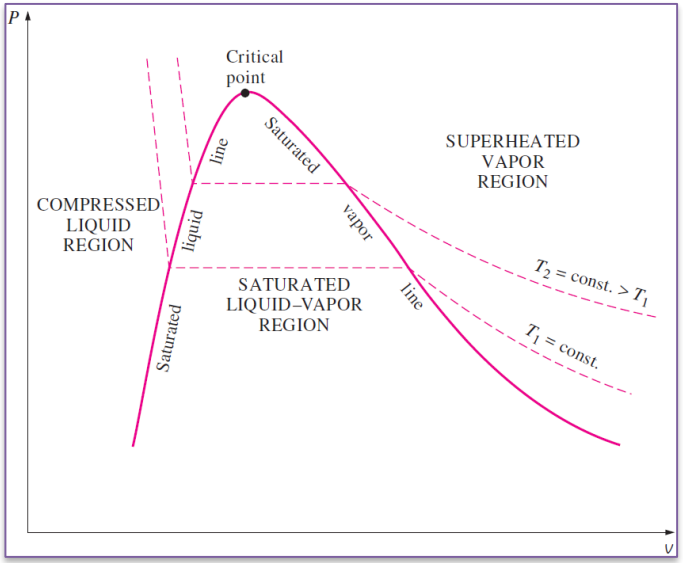
De nuevo debo saber con dos propiedades intensivas, si efectivamente estoy en la región de liquido comprimido, para determinar la región cualquier tabla de saturación sirve.





Compressed liquid

$(P > P_{sat}$ at a given $T)$

$(T < T_{sat}$ at a given $P)$

$(v < v_f$ at a given P or $T)$

$(u < u_f$ at a given P or $T)$

$(h < h_f$ at a given P or $T)$

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EXAMPLE 6.1 : Compressed propane

A 0.10 m^3 rigid tank is full of propane at 8 bar and 12°C. Estimate the mass of propane inside the tank. Sketch **T-v** diagram.

0.10m3
8bar
12°C

TABLE A-16

Properties of Saturated Propane (Liquid–Vapor): Temperature Table

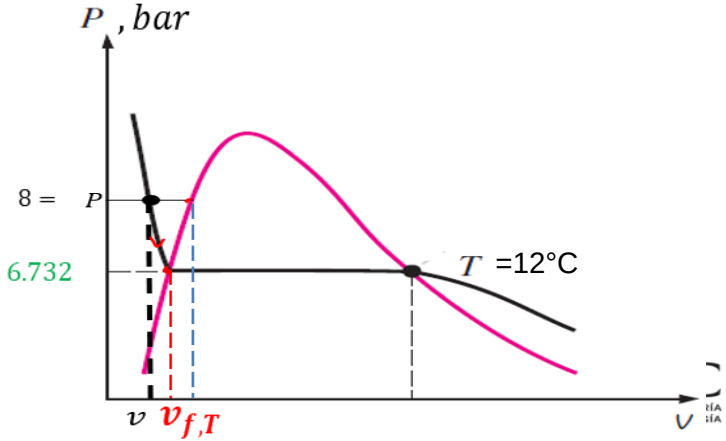
Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Temp. °C	Press. bar	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Temp. °C
0	4.743	1.890	0.09653	94.2	423.8	95.1	374.5	469.6	0.374	1.745	0
4	5.349	1.910	0.08591	104.2	428.1	105.3	368.8	474.1	0.410	1.741	4
8	6.011	1.931	0.07666	114.3	432.3	115.5	362.9	478.4	0.446	1.737	8
12	6.732	1.952	0.06858	124.6	436.5	125.9	356.8	482.7	0.482	1.734	12
16	7.515	1.975	0.06149	135.0	440.7	136.4	350.5	486.9	0.519	1.731	16

$P = 8\ bar > P_{sat@\ 12\ oC}$

L.C. $(P > P_{sat}$ at a given $T)$

Since pressure is higher than saturated pressure at 12°C, propane must exist as compressed liquid



0.10m3
8bar
12°C

As tables for compressed propane at 8bar are not available, **the compressed liquid should be approximate as saturated liquid at the same temperature**

TABLE A-16

Properties of Saturated Propane (Liquid–Vapor): Temperature Table

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g	Temp. °C
0	4.743	1.890	0.09653	94.2	423.8	95.1	374.5	469.6	0.374	1.745	0
4	5.349	1.910	0.08591	104.2	428.1	105.3	368.8	474.1	0.410	1.741	4
8	6.011	1.931	0.07666	114.3	432.3	115.5	362.9	478.4	0.446	1.737	8
12	6.732	1.952	0.06858	124.6	436.5	125.9	356.8	482.7	0.482	1.734	12
16	7.515	1.975	0.06149	135.0	440.7	136.4	350.5	486.9	0.519	1.731	16

$$v = v_{sat@12°C} = 0.001952 m^3/kg$$

The mass is:

$$m = \frac{0.1 m^3}{0.001952 m^3/kg} = \mathbf{51.23 kg}$$

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1d) Compressed liquid

EXAMPLE 6.1 : Compressed propane

A 0.10 m^3 rigid tank is full of propane at 8 bar and 12°C. Estimate the mass of propane inside the tank. Sketch **T-v** diagram.

0.10m3
8bar
12°C

TABLE A-17

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Properties of Saturated Propane (Liquid–Vapor): Pressure Table

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Press. bar
6.00	7.93	1.931	0.07680	114.2	432.2	115.3	363.0	478.3	0.446	1.737	6.00
7.00	13.41	1.960	0.06598	128	438.0	129.6	354.6	484.2	0.495	1.733	7.00
8.00	18.33	1.989	0.05776	141.0	443.1	14[illegible]6	346.7	489.3	0.540	1.729	8.00

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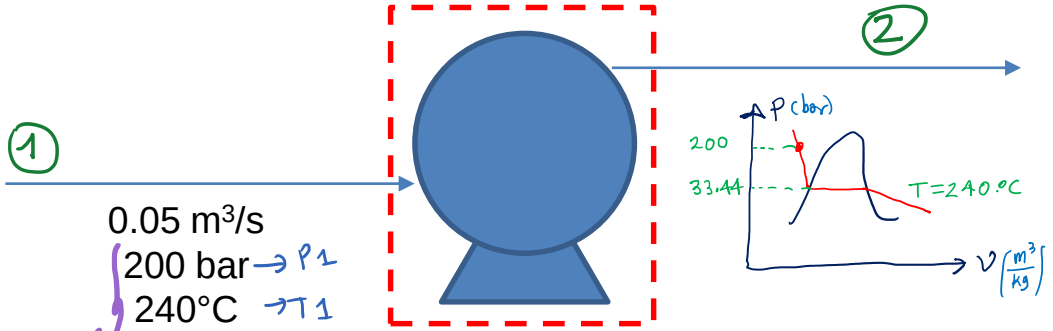
EXAMPLE 9.3:

A volumetric flow rate $\dot{V} = 0.05$ m³/s of water at 240°C and 20 Mpa (200 bar) enters a pump, **a)** What is the mass flow rate [**kg/s**]?

$\dot{m}$



$\dot{m} = \dot{V} / v$ →
- C.L Table (T1, P1)
- saturation table (T1)
- saturation table (P1)

TABLE A-2

Properties of Saturated Water (Liquid–Vapor): Temperature Ta

Pressure Conversions:
1 bar = 0.1 MPa
= 10² kPa

Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Inte Sat. Liqui u_f
240	33.44	1.2291	0.05976	1033.

Compressed liquid

$(P > P_{sat}$ at a given $T)$

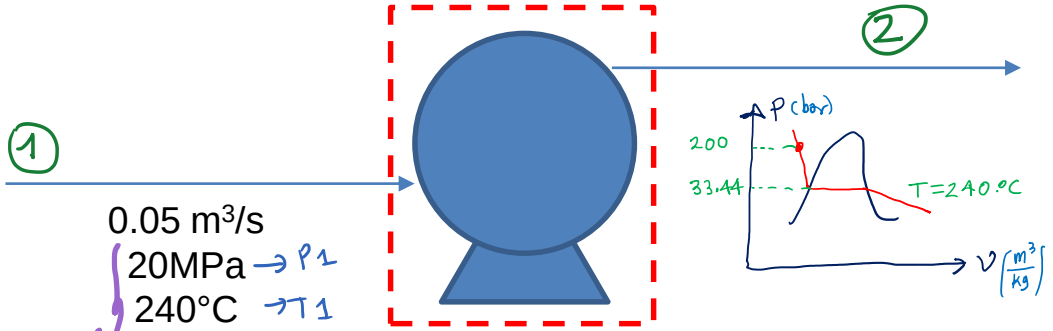
200 > 33.44

EXAMPLE 9.3:

A volumetric flow rate $\dot{V} = 0.05$ m³/s of water at 240°C and 20 Mpa (200 bar) enters a pump, **a)** What is the mass flow rate [**kg/s**]? **b)** What would be the percent error if the properties of the saturated liquid at 240°C were used in the calculation? What if the properties of the saturated liquid at 20 MPa were used?

$\dot{m}$

* **



$\dot{m} = \frac{\dot{V}}{v}$ →

- C. L Table (T1, P1)
- saturation table (T1) *
- saturation table (P1) **

a) Properties of water at 240°C and 20MPa (200 bar) from compressed liquid tables:

TABLE A-5

Properties of Compressed Liquid Water

T °C	$v \times 10^3$ m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
$p = 200$ bar $= 20.0$ MPa ($T_{sat} = 365.81$°C)				
220	1.1693	925.9	949.3	2.4870
260	1.2462	1108.6	1133.5	2.8459

Interpolating, as 240°C is the average of 220°C and 260°C:

$$v = \frac{1.1693 + 1.2462}{2} = 1.2078 \times 10^{-3} \frac{m^3}{kg}$$

$$\dot{m} = \frac{\dot{V}}{v} = \frac{0.05}{1.20775 \times 10^{-3}} = 41.3976 \frac{kg}{s}$$

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b) Properties of water at 240°C from saturated liquid tables:

TABLE A-2

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

(*Continued*)

Temp. °C	Press. bar	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Temp. °C
240	33.44	1.2291	0.05976	1033.2	2604.0	1037.3	1766.5	2803.8	2.7015	6.1437	240

Finding the mass flowrate:

$$v = 1.2291 \times 10^{-3} \frac{m^3}{kg}$$

$$\dot{m} = \frac{\dot{V}}{v} = \frac{0.05}{1.2291 \times 10^{-3}} = 40.6802 \frac{kg}{s}$$

$$\%error = \frac{|40.6802 - 41.3976|}{41.3976} = 0.01733 = 1.733\%$$

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b) Properties of water at 20MPa (200 bar) rom saturated liquid tables:

TABLE A-3

(Continued)

Press. bar	Temp. °C	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g	Press. bar
190.	361.5	1.9243	0.006657	1739.9	2338.1	1776.5	688.0	2464.5	3.9388	5.0228	190.
200.	365.8	2.036	0.005834	1785.6	2293.0	1826.3	583.4	2409.7	4.0139	4.9269	200.

Finding the mass flowrate:

$$v = 2.036 \times 10^{-3} \frac{m^3}{kg}$$

$$\dot{m} = \frac{\dot{V}}{v} = \frac{0.05}{2.036 \times 10^{-3}} = 24.5580 \frac{kg}{s}$$

$$\%error = \frac{|24.5580 - 41.3956|}{41.3956} = 0.4068 = 40.68\ \%$$

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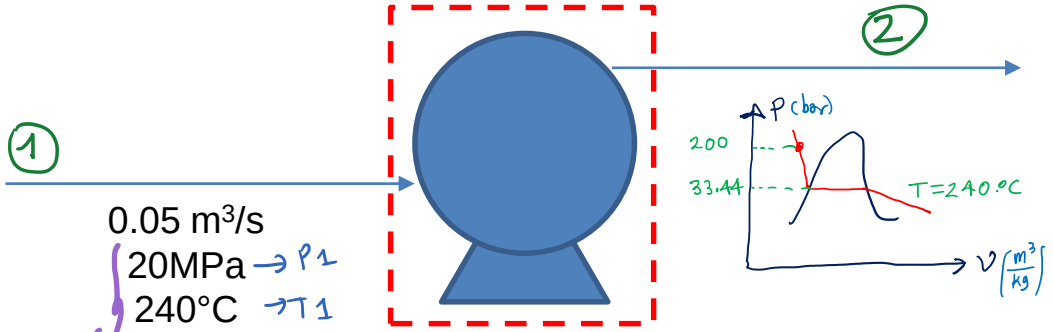
EXAMPLE 9.3:

A volumetric flow rate $\dot{V} = 0.05$ m³/s of water at 240°C and 20 Mpa (200 bar) enters a pump, **a)** What is the mass flow rate [**kg/s**]? **b)** What would be the percent error if the properties of the saturated liquid at 240°C were used in the calculation? What if the properties of the saturated liquid at 20 MPa were used?

$\dot{m}$

↳ Tabla entrando por T.

↳ Tabla entrando por P.



$\dot{m} = \frac{\dot{V}}{v}$ →

- C. L table (T_1, P_1)
- saturation table (T_1)
- saturation table (P_1)

TABLE A-2

Properties of Saturated Water (Liquid–Vapor): Temperature Ta

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Inte… Sat. Liqui… u_f
240	33.44	1.2291	0.05976	1033.

TABLE A-3 Properties of Saturated Wate…

Press. bar	Temp. °C	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Inte… Sat. Liqui… u_f
200.	365.8	2.036	0.005834	1785.6

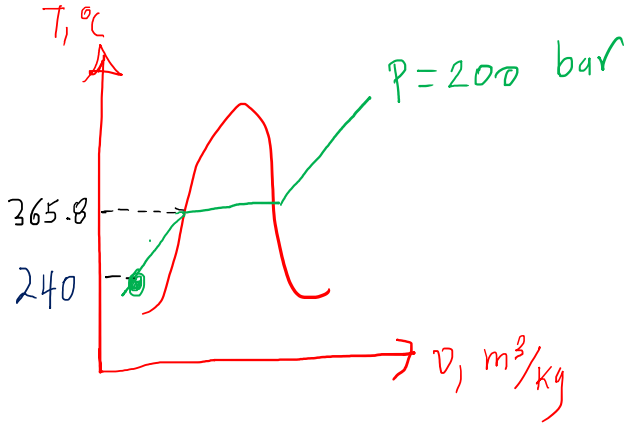
L.C. $(T < T_{sat}$ at a given $P)$

ESTADO 1: 240°C and 20 Mpa (200 bar)

TABLE A-3 Properties of Saturated Water (Liquid–Vapor): Pressure Table

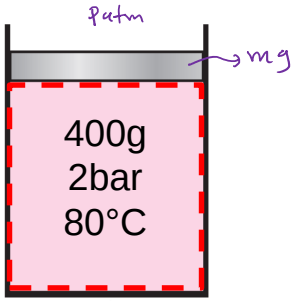
		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy $kJ/kg \cdot K$	
Press. bar	Temp. °C	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g
200.	365.8	2.036	0.005834	1785.6	2293.0	1826.3	583.4	2409.7	4.0139	4.9269

L.C. $(T < T_{sat}$ at a given $P)$

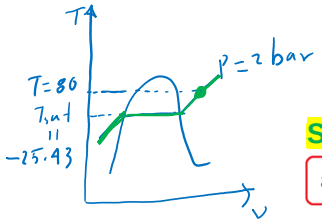


EXAMPLE 7.4:

400 g of Propane initially fill a piston-cylinder (without friction) device at 200 kPa and 80 ^{0}C (**state1**) . The device is then slowly cooled until the temperature is -30 ^{0}C (**state2**). Determine the change in the device´s volume(m^3)(ΔV) as a result of cooling. Sketch T(^{0}C) –v(m^3/kg) diagram.



$T_1 > T_{SAT}$
80°C > -25.43°C



Superheated vapor

at a given $P \Rightarrow T > T_{sat}$

TABLE A-17

Properties of Saturated Propane (Liquid–Vapor): Pressure Table

Press. bar	Temp. °C	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g	Press. bar
2.00	−25.43	1.781	0.2192	33.1	396.6	33.5	406.9	440.4	0.139	1.782	2.00

TABLE A-18

Properties of Superheated Propane Vapor

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 2.0 bar = 0.2 MPa (T_{sat} = −25.43°C)			
Sat.	0.2192	396.6	440.4	1.782
−20	0.2251	404.0	449.0	1.816
−10	0.2358	417.7	464.9	1.877
0	0.2463	431.8	481.1	1.938
10	0.2566	446.3	497.6	1.997
20	0.2669	461.1	514.5	2.056
30	0.2770	476.3	531.7	2.113
40	0.2871	491.9	549.3	2.170
50	0.2970	507.9	567.3	2.227
60	0.3070	524.3	585.7	2.283
70	0.3169	541.1	604.5	2.339
80	0.3267	558.4	623.7	2.394
90	0.3365	576.1	643.4	2.449

state1 :

$P_1 = 200kPa = 2bar$

$T_1 = 80°C$

$\Rightarrow \quad v_1 = 0.3267\, m^3/kg$

The initial volume is:

$V_1 = mv_1 = 0.400 \times 0.3267 = 0.13068m^3$

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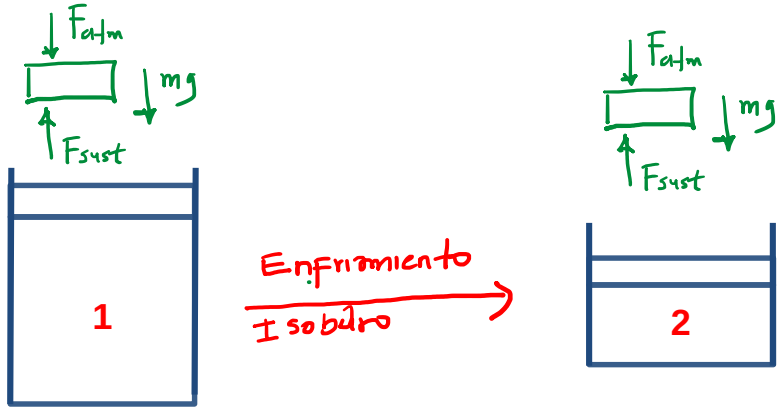
EXAMPLE 7.4:

400 g of Propane initially fill a piston-cylinder (without friction) device at 200 kPa and 80 ^{0}C (**state1**) . The device is then slowly cooled until the temperature is -30 ^{0}C (**state2**). Determine the change in the device´s volume(m^3)(ΔV) as a result of cooling. Sketch T(^{0}C) –v(m^3/kg) diagram.



$$P_{sys} = P_{atm} + \frac{mg}{A}$$

EXAMPLE 7.4:

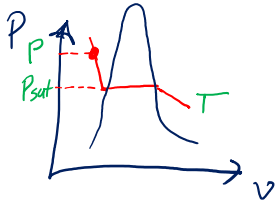
400 g of Propane initially fill a piston-cylinder device at 200 kPa and 80 ^{0}C . The device is then cooled until the temperature is -30 ^{0}C. Determine the change in the device´s volume(m^3) as a result of cooling. Sketch P-v diagram.

state2 :

$T_2 = -30°C$

$P_2 = 200kPa = 2bar$ > 1.677

L.C. $(P > P_{sat}$ at a given $T)$



$v_2 = v_{sat@-30°C} = 1.763 \times 10^{-3}\ m^3/kg$

TABLE A-16

Properties of Saturated Prop

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Temp. °C	Press. bar	Specific Volume m^3/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg: Sat. Vapor v_g
−30	1.677	1.763	0.2585

The final volume is:

$V_2 = mv_2 = 0.400 \times 1.763 \times 10^{-3} = 0.0007052m^3$

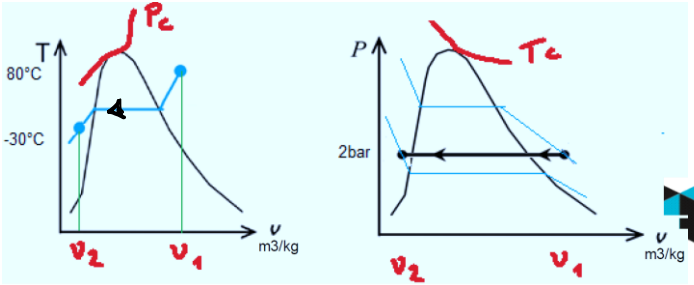
The volume change is:

$V_2 - V_1 = 0.0007052 - 0.13068 = -0.1300m^3$

TABLE A-1

Atomic or Molecular Weights and Critical Properties of Selected Elements and Compounds

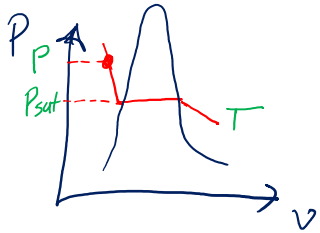
Substance	Chemical Formula	M (kg/kmol)	T_c (K)	p_c (bar)	$Z_c = \frac{p_c v_c}{RT_c}$
Propane	C_3H_8	44.09	370	42.7	0.276



ΔH, ΔU?

Para determinar la región se usa la tabla de saturación como referencia, esta puede ser entrando por Presion o por Temperatura. En particular con P y T como Prop. Intensivas:

state2 :
$T_2 = -30°C$
$P_2 = 200kPa = 2bar$ > 1.677



L.C. $(P > P_{sat}$ at a given $T)$

TABLE A-16

Properties of Saturated Prop

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Temp. °C	Press. bar	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g
−30	1.677	1.763	0.2585

state2 :
$T_2 = -30°C$
$P_2 = 200kPa = 2bar$ < -25.43

L.C. $(T < T_{sat}$ at a given $P)$

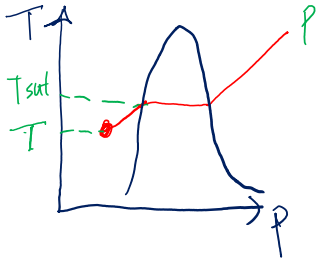


TABLE A-17

Properties of Saturated Pro

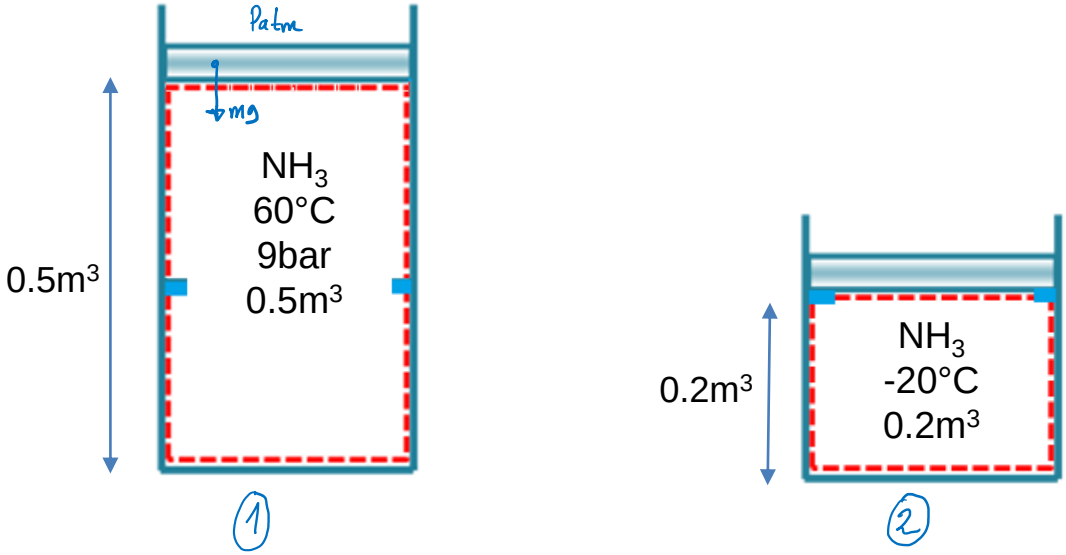
Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g
2.00	−25.43	1.781	0.2192

Analogamente para vapor sobrecalentado

EXAMPLE 8.4:

Ammonia at 60°C is in a piston/cylinder assembly (without friction) with an initial volume of 0.5 m^3. The piston has a mass such that the pressure inside is 900 kPa [state 1]. Now the ammonia is slowly cooled until the piston reaches the stops (at this point the volume is 0.2 m^3), and the final temperature is -20°C [state 2]. Find the final pressure (bar) , quality (if applies) and the force on the stops (N) if the piston has an area of 0.25m^2. Sketch T(^{0}C) –v(m^3/kg) diagram.

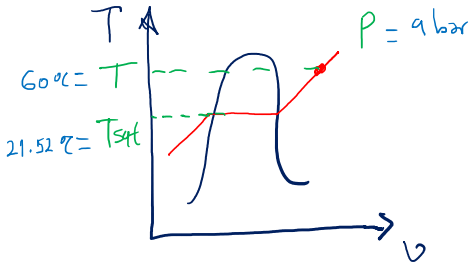


State 1: The properties of ammonia at 60°C and 9bar:

A14 **Properties of Saturated Ammonia (Liquid–Vapor): Pressure Table**

Pressure conversion: 1 bar = 0.1 MPa = 10^2 kPa

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g
9.00	21.52	1.6446	0.1424	280.05	1332.82



Superheated vapor

at a given P ⇨ $T > T_{sat}$

TABLE A-15

(Continued)

T °C	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
		$p = 9.0$ bar $= 0.90$ MPa ($T_{sat} = 21.52$°C)		
60	0.16922	1415.32	1567.61	5.4083

Initial mass of ammonia:

$$m = \frac{V_1}{v_1} = \frac{0.5}{0.16922} = 2.9547\ kg$$

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State 2: The properties of ammonia at -20°C and $V_2 = 0.2\ m^3$:

TABLE A-13

Properties of Saturated Ammonia (Liquid–V

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Temp. °C	Press. bar	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g
−20	1.9019	1.5038	0.6233	88.40	1299.23

$$P_2 = 1.9019 \text{ bar}$$

The specific volume is:

$$v_2 = \frac{V_2}{m} = \frac{0.2}{2.9547} = 0.06769\ m^3/kg$$

$T_2 = -20\ °C$, v_2

As $v_f < v_2 < v_g$ at -20°C, there is a VL mixture:

$$x_2 = \frac{v_2 - v_f}{v_g - v_f} = \frac{0.06769 - 1.5038 \times 10^{-3}}{0.6233 - 1.5038 \times 10^{-3}}$$

$$x_2 = 0.10644$$

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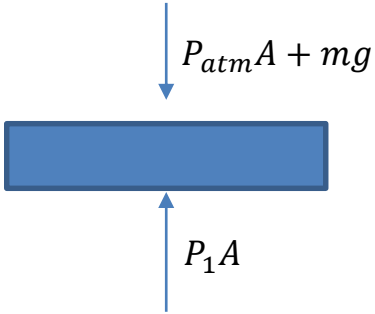
The force on stops can be found by a force balance:

Initially (state 1):

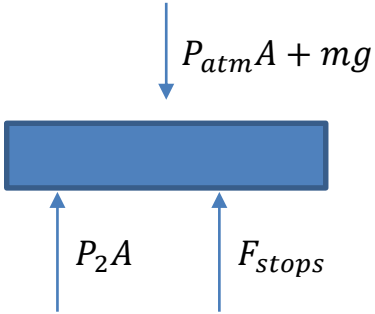


$$P_{atm}A + mg = P_1A$$

$$P_{atm}A + mg = (9bar)A$$

$$P_{atm}A + mg = (900000\ Pa)A$$

When the piston reaches the stops (state 2) :



$$P_{atm}A + mg = P_2A + F_{stops}$$

Pa = $\frac{N}{m^2}$

$$(900000\ Pa)A = (190190\ Pa)A + F_{stops}$$

$$F_{stops} = (709810)A$$

$$F_{stops} = 709810 \times 0.25$$

ΔH, ΔU?

$$\boxed{F_{stops} = 177452.5\ N}$$

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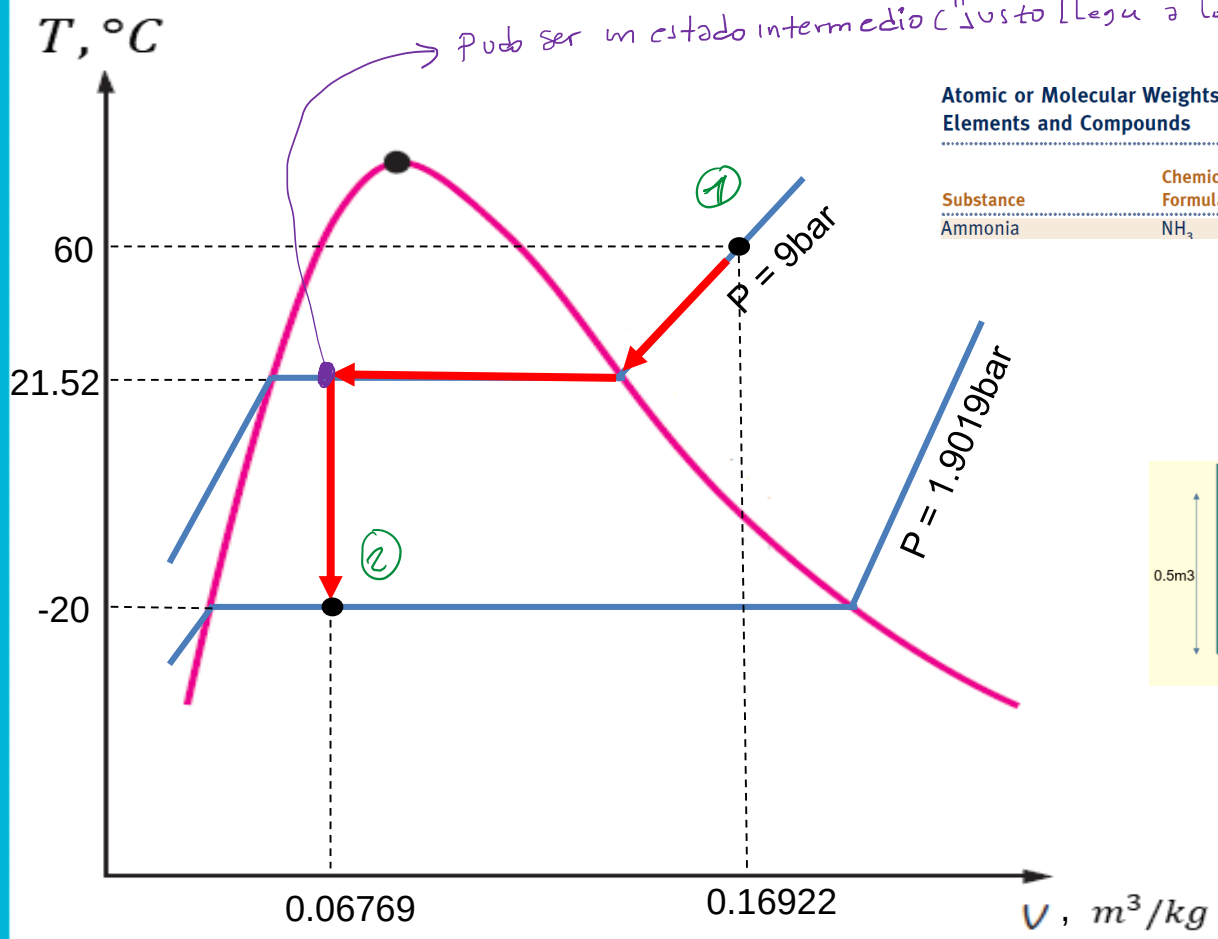
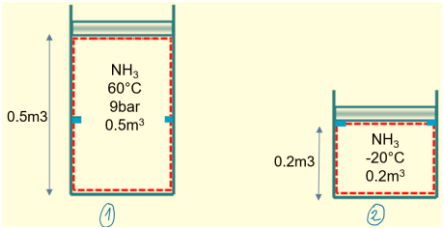


Atomic or Molecular Weights and Critical Properties of Selected Elements and Compounds

Substance	Chemical Formula	M (kg/kmol)	T_c (K)	p_c (bar)	$Z_c = \frac{p_c v_c}{R T_c}$
Ammonia	NH_3	17.03	406	112.8	0.242

↓
~133 °C



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EXAMPLE 8.2: A piston–cylinder device initially contains 50L of R-22 at -36°C and 175 kPa. Heat is transferred to the water at constant pressure until the entire liquid is vaporized (until de last drop of liquid). (*a*) What is the mass of the R-22 (**Kg**)? (*b*) What is the final temperature(**°C**)? (*c*) Determine the total enthalpy change(***kJ***). (*d*) Show the process on a *T[°C]-v[m³/kg]* diagram.

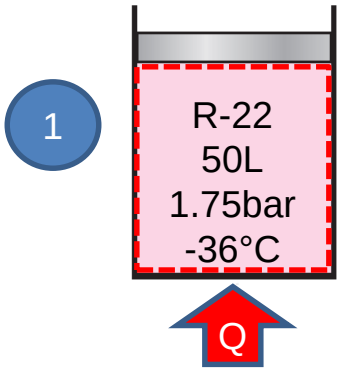

TABLE A-7

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Properties of Saturated Refrigerant 22 (Liquid–Vapor): Temperature Table

Temp. °C	Press. bar	Specific Volume m³/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Temp. °C
−60	0.3749	0.6833	0.5370	−21.57	203.67	−21.55	245.35	223.81	−0.0964	1.0547	−60
−50	0.6451	0.6966	0.3239	−10.89	207.70	−10.85	239.44	228.60	−0.0474	1.0256	−50
−45	0.8290	0.7037	0.2564	−5.50	209.70	−5.44	236.39	230.95	−0.0235	1.0126	−45
−40	1.0522	0.7109	0.2052	−0.07	211.68	0.00	233.27	233.27	0.0000	1.0005	−40
−36	1.2627	0.7169	0.1730	4.29	213.25	4.38	230.71	235.09	0.0186	0.9914	−36
−32	1.5049	0.7231	0.1468	8.68	214.80	8.79	228.10	236.89	0.0369	0.9828	−32

Since the cylinder pressure is larger than saturation pressure at -36°C, R-22 is initially as **compressed liquid**. Its properties can be approximated as a saturated liquid at -36°C:

$v_1 = v_{sat@-36°C} = 0.0007169\ m^3/kg$

$h_1 = h_{sat@-36°C} = 4.38\ kJ/kg$

a) The initial mass is:

$$m = \frac{V}{v_1} = \frac{0.05\ m^3}{0.0007169\ m^3/kg} = 69.7447\ kg$$

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When all the liquid is vaporized, the temperature increases until it reaches the saturated temperature at the given pressure, 175kPa or 1.75bar.

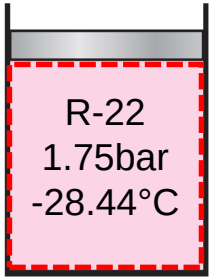


TABLE A-8

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

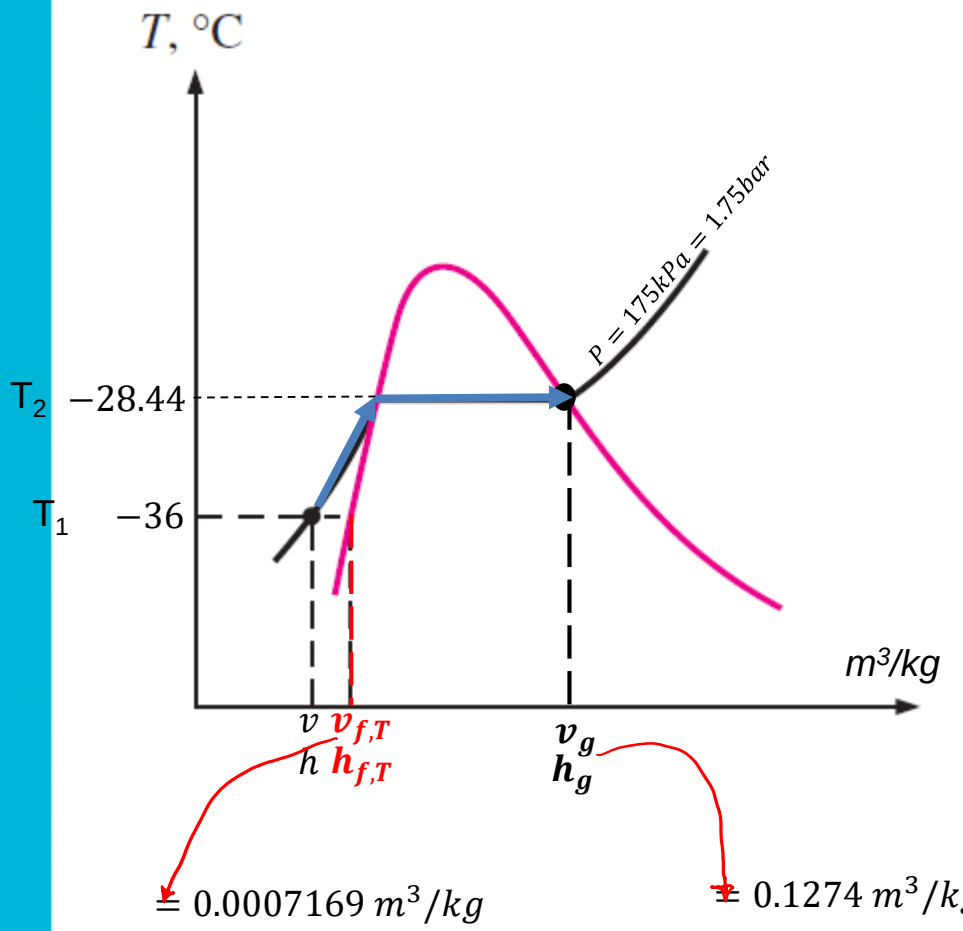
Properties of Saturated Refrigerant 22 (Liquid–Vapor): Pressure Table

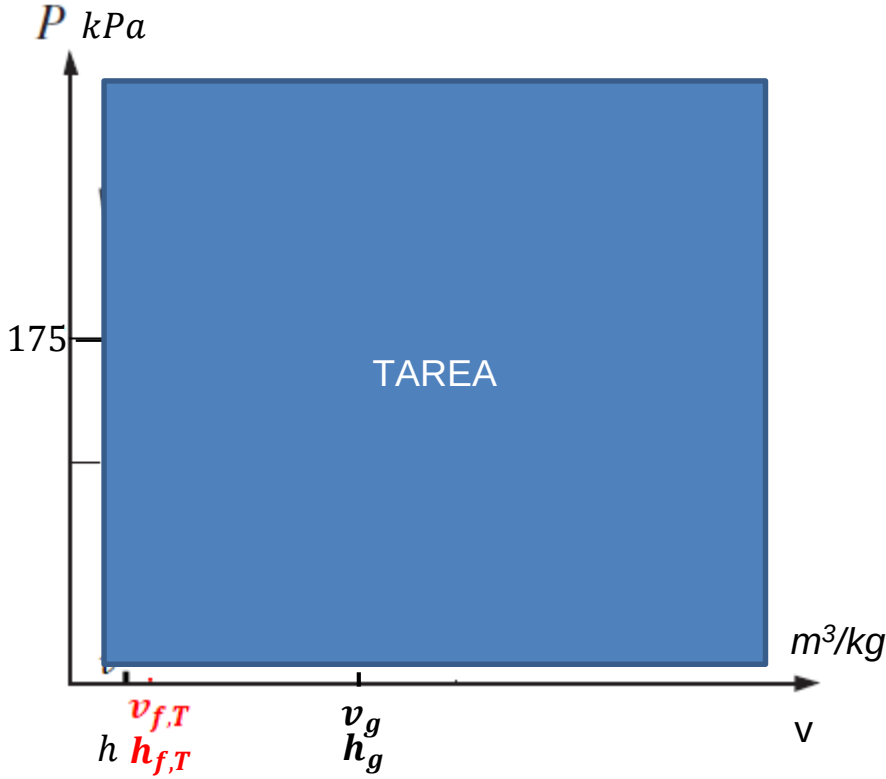
Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Press. bar
1.00	−41.09	0.7093	0.2152	−1.26	211.25	−1.19	233.95	232.77	−0.0051	1.0031	1.00
1.25	−36.23	0.7166	0.1746	4.04	213.16	4.13	230.86	234.99	0.0175	0.9919	1.25
1.50	−32.08	0.7230	0.1472	8.60	214.77	8.70	228.15	236.86	0.0366	0.9830	1.50
1.75	−28.44	0.7287	0.1274	12.61	216.18	12.74	225.73	238.47	0.0531	0.9755	1.75
2.00	−25.18	0.7340	0.1123	16.22	217.42	16.37	223.52	239.88	0.0678	0.9691	2.00

b) The final temperature is Tsat@1.75bar = -28.44°C

c) The total enthalpy change is:

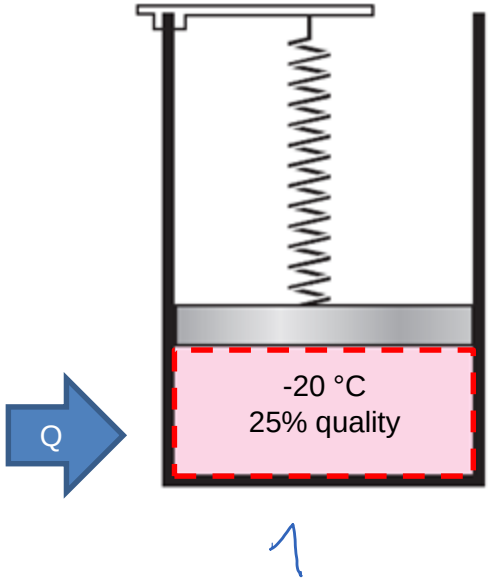
$$\Delta H = H_2 - H_1 = m(h_2 - h_1) = 69.7447 \times (238.47 - 4.38) = 16326.5368 \ kJ$$

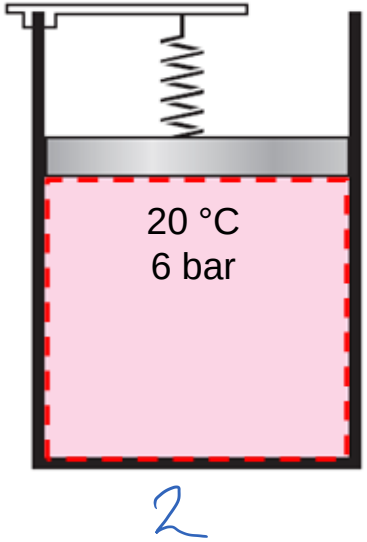

T, °C
$P = 175kPa = 1.75bar$
T_2 −28.44
T_1 −36
m³/kg
v $v_{f,T}$
h $h_{f,T}$
v_g
h_g
$= 0.0007169\ m^3/kg$
$= 0.1274\ m^3/kg$


P kPa
175
TAREA
m³/kg
v
$v_{f,T}$
h $h_{f,T}$
v_g
h_g

EXAMPLE 10.2: 0.5 kg of ammonia is contained in a piston–cylinder assembly, initially at $T_1 = -20°C$ and a quality of 25%. As the ammonia is slowly heated to a final state, where $T_2 = 20°C$, $P_2 = 0.6\,MPa$, its pressure varies linearly with specific volume. For the ammonia, (a) calculate the change in volume (m3) and (b) sketch the process on a P [bar]-v [m3/kg] diagram

If P↑ then v↑ , linear relation….what does it means?





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EXAMPLE 10.2: 0.5 kg of ammonia is contained in a piston–cylinder assembly, initially at $T_1 = -20°C$ and a quality of 25%. As the ammonia is slowly heated to a final state, where $T_2 = 20°C$, $P_2 = 0.6\ MPa$, its pressure varies linearly with specific volume. For the ammonia, (a) calculate the change in volume and (b) sketch the process on a P[bar]-v[m³/kg] diagram.

Estado 1

TABLE A-13

Properties of Saturated Ammonia (Liquid–Vapor): Temperature Table

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g
−20	1.9019	1.5038	0.6233	88.40	1299.23	88.68	1329.10	1417.79

The initial specific volume is:

$$v_1 = v_{f1} + x_1 (v_{g1} - v_{f1})$$

$$v_1 = 1.5038 \times 10^{-3} + 0.25 \times \left(0.6233 - 1.5038 \times 10^{-3}\right) = 0.1569\ m^3/kg$$

Estado 2

TABLE A-14 Properties of Saturated Ammonia (Liquid–Vapor): Pressure Table

1 bar = 0.1 MPa = 10^2 kPa

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g
6.00	9.27	1.5982	0.2104	222.37	1324.89	223.32	1227.79	1451.12	0.8649	5.2122

P_2= 600 kPa= 6 bar$\Rightarrow T_2$ =20 °C >T_{sat} = 9.27 °C….sobrecalentado

The final specific volume is $v_2 = 0.22155\ m^3/kg$

TABLE A-15

(*Continued*)

T °C	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 6.0 bar = 0.60 MPa (T_{sat} = 9.27°C)			
Sat.	0.21038	1324.89	1451.12	5.2122
10	0.21115	1326.47	1453.16	5.2195
20	0.22155	1347.62	1480.55	5.3145

The change in volume is: $\Delta V = 0.5 \times (0.22155 - 0.1569) = 0.03232\ m^3$

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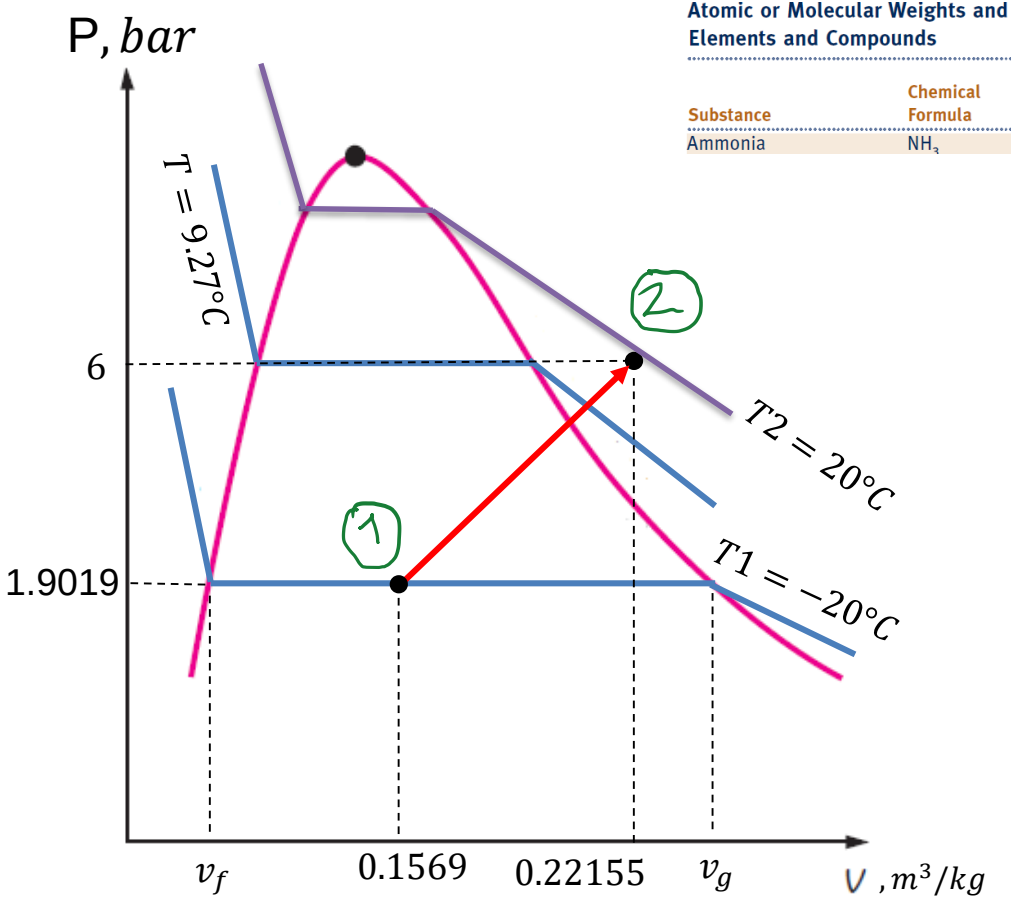

Atomic or Molecular Weights and Critical Properties of Selected Elements and Compounds

Substance	Chemical Formula	M (kg/kmol)	T_c (K)	p_c (bar)	$Z_c = \frac{p_c v_c}{R T_c}$
Ammonia	NH_3	17.03	406	112.8	0.242

≈133 °C

HOMEWORK
ΔH, ΔU?

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Thermodynamics _ Evaluation

SEMANA 1	TAREA VIRTUAL	SE CALIFICA AUTOMATICO NO NECESITA PROCEDIMIENTO
SEMANA 2	TAREA VIRTUAL	
SEMANA 3	TAREA VIRTUAL	.
SEMANA 4	**TAREA INDIVIDUAL 1** + EVALUACION_AULA1	TAREA INDIVIDUAL: Esta parte incluye subir un archivo con la solución EVALUACION_AULA: SEMANAS 1-2

EJERCICIO DESAFÍO SEMANA 2

OBJETIVO: REPASAR TEMAS BÁSICOS DE SEMANAS 1-2

Será resuelto en la asesoría de Franklin el sábado, pero el estudiante debe resolverlo tambien para poder aprender mejor.

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PART 1

A rotating system supports a cylinder with a 30 cm^2 cross-sectional area and 1-m length. The cylinder is equipped with a frictionless piston of unknown mass and has stops located at 26 cm from the base. Initially, the cylinder is in horizontal position ($\theta = 0°$), the piston is placed at 15 cm from the base and is full of R134a with 21% quality **(state 1)**. The system rotates certain angle ($\theta = ?$) until the pressure reaches 1.4bar and the piston is 13 cm from the bottom of the cylinder **(state 2)**. The system continues rotating until it is in vertical position ($\theta = 90°$), and the manometric pressure is 0.6 bar and 15% quality **(state 3)**. Patm = 1bar.

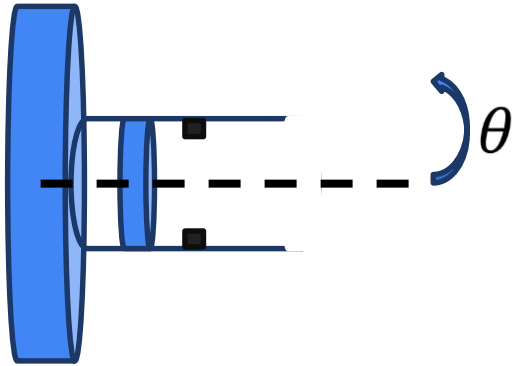


FIGURE 1 - PART 1

Find:

a) Temperature, specific volume and the mass of R134a in state 1.
b) Temperature, specific volume, the piston mass and the distance between the piston and the cylinder base in state 3.
c) Temperature, specific volume, the angle and the quality in state 2 .

PART 2

The cylinder is slowly heated, and the piston starts rising until it **just** gets to the stops **(state 4 – position A)**. The heating continues until the pressure doubles its previous value **(state 5 – position A)**. An instant after that, the stops breaks because of the excessive force and the piston keeps rising following a reversible polytropic path (n = 1.23) until the piston just touches a linear spring and the pressure is 1.8bar **(state 6 – position B).** *To ensure that the process from 5 to 6 follows a reversible polytropic path, an additional weight had to be added to compensate for the refrigerant pressure and then gradually removed until the pressure at state 6 reaches 1.8 bar***.**

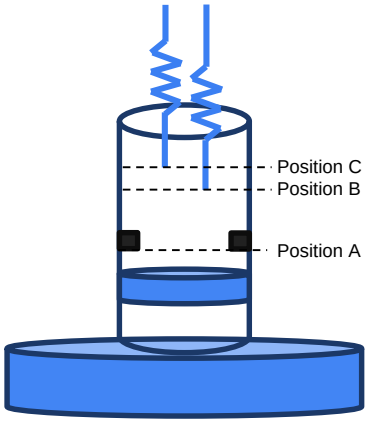


FIGURE 1 - PART 2

Find:

d) Temperature, specific volume and quality (if exists) in state 4.
e) The force on the stops, the temperature and the quality (if exists) in state 5.
f) The specific volume, the temperature, the height respect to cylinder base and the quality (if exists) in state 6.

PART 3

The piston goes up compressing the spring until it **just** gets to position C, moment when the temperature is 80°C and the height is 51.7cm **(state 7 – position C).** The piston keeps going up compressing the second spring (which has the same constant as the first one) until the height of the piston is 95 cm from the base **(state 8)**.

Find:

g) The specific volume, the pressure, the spring constant and the quality (if exists) in state 7.

h) The specific volume, pressure and temperature in state 8.

i) Plot a P (bar) – V (m3) diagram showing all the states previously mentioned, and the processes from state 3 to state 8.

j) Plot a T (°C) – V (m3) diagram showing all the states previously mentioned, and the processes from state 3 to state 8.

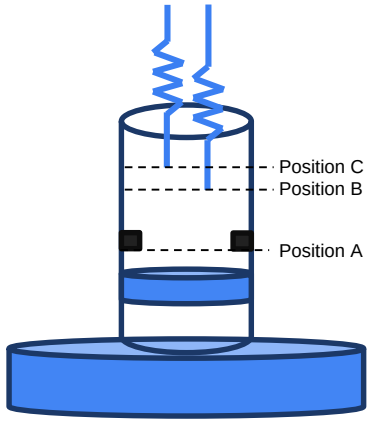
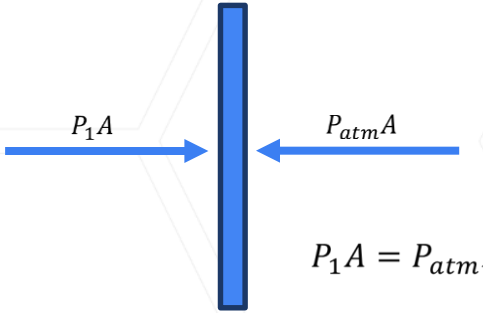


FIGURE 1 - PART 2

a) State 1: FBD for the piston



$$P_1A = P_{atm}A \rightarrow P_1 = P_{atm} = 1bar$$

TABLE A-11

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

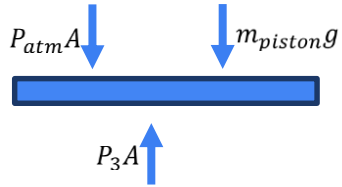
Properties of Saturated

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g
1.0	−26.43	0.7258	0.1917

$$T_1 = T_{sat@1bar} = -26.43°C$$
$$v_1 = 0.7258 \times 10^{-3} + 0.21(0.1917 - 0.7258 \times 10^{-3})$$
$$v_1 = 4.083 \times 10^{-2}\, m^3/kg$$

$$m_{R134} = \frac{Ah_1}{v_1} = \frac{30 \times 15 \times 10^{-6}}{4.083 \times 10^{-2}} = 1.1021 \times 10^{-2} kg$$

b) State 3: FBD for the piston



$$P_3A = P_{atm}A + m_{piston}g \rightarrow 1.6 = 1 + \frac{m_{piston} \times 9.81}{(30 \times 10^{-4}) \times 10^5}$$

$$m_{piston} = 18.3487kg$$

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

Properties of Saturated

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g
1.6	−15.62	0.7435	0.1229

$$T_3 = T_{sat@1.6bar} = -15.62°C$$
$$v_3 = 0.7435 \times 10^{-3} + 0.15(0.1229 - 0.7435 \times 10^{-3})$$
$$v_3 = 1.9067 \times 10^{-2}\, m^3/kg$$

$$h_3 = \frac{v_3 m_{R134}}{A} = \frac{1.9067 \times 10^{-2} \times 1.1021 \times 10^{-2}}{30 \times 10^{-4}}$$
$$h_3 = 0.07m = 7cm$$

c) State 2: FBD for the piston

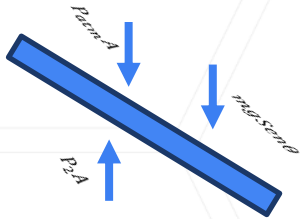


TABLE A-11

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Properties of Saturated

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g
1.4	−18.80	0.7381	0.1395

$$P_2A = P_{atm}A + m_{piston}gSen\theta \rightarrow 1.4 = 1 + \frac{18.3487 \times 9.81 Sen\theta}{(30 \times 10^{-4}) \times 10^5}$$

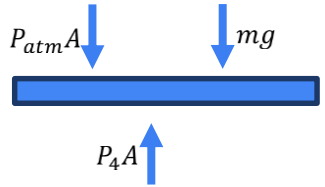
$$Sen\theta = 0.6667 \rightarrow \theta = 41.81°$$

$$v_2 = \frac{(30 \times 10^{-4}) \times (13 \times 10^{-2})}{1.1021 \times 10^{-2}} = 3.5386 \times 10^{-2}\, m^3/kg$$

$$T_2 = T_{sat@1.4bar} = -18.80°C$$

$$x_2 = \frac{3.5386 \times 10^{-2} - 0.7381 \times 10^{-3}}{0.1395 - 0.7381 \times 10^{-3}} = 0.2497 = 24.97\%$$

d) State 4: FBD for the piston



Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Properties of Saturated

Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g
1.6	−15.62	0.7435	0.1229

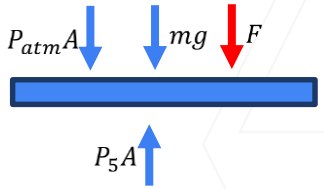
$$P_4A = P_{atm}A + m_{piston}g \rightarrow P_4 = P_3 = 1.6\ bar \quad \textbf{(isobaric)}$$

$$v_4 = \frac{(30 \times 10^{-4}) \times (26 \times 10^{-2})}{1.1021 \times 10^{-2}} = 7.0773 \times 10^{-2}\, m^3/kg$$

$$T_4 = T_{sat@1.6bar} = -15.62°C$$

$$x_4 = \frac{7.0773 \times 10^{-2} - 0.7435 \times 10^{-3}}{0.1229 - 0.7435 \times 10^{-3}} = 0.5733 = 57.33\%$$

e) State 5: FBD for the piston



$$P_5A = \overbrace{P_{atm}A + m_{piston}g}^{P_4A} + F \rightarrow F = (P_5 - P_4)A$$

$$F = (3.2 - 1.6) \times 10^5 \times 30 \times 10^{-4} = 480N$$

TABLE A-12

(Continued)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 3.2 bar = 0.32 MPa (T_{sat} = 2.48°C)			
20	0.06901	242.87	264.95	0.9749
30	0.07214	251.19	274.28	1.0062
40	0.07518	259.61	283.67	1.0367

$$v_5 = v_4 = 7.0773 \times 10^{-2}\, m^3/kg$$

$$T_5 = \frac{30 - 20}{0.07214 - 0.06901}(7.0773 \times 10^{-2} - 0.06901) + 20$$

$$T_5 = 25.63°C$$

f) State 6: Specific volume for a polytropic process

$$P_5 v_5^n = P_6 v_6^n \rightarrow v_6 = \left(\frac{3.2 \times (7.0773 \times 10^{-2})^{1.23}}{1.8}\right)^{1/1.23}$$

$$v_6 = 1.1298 \times 10^{-1}\, m^3/kg$$

Properties of Superheated Refrigerant 134a

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 1.8 bar = 0.18 MPa (T_{sat} = −12.73°C)			
Sat.	0.10983	219.94	239.71	0.9273
−10	0.11135	222.02	242.06	0.9362
0	0.11678	229.67	250.69	0.9684

$$T_6 = \frac{0 - (-10)}{0.11678 - 0.11135}(1.1298 \times 10^{-1} - 0.11135) + (-10)$$

$$T_6 = -6.99°C$$

$$h_6 = \frac{v_6 m_{R134}}{A} = \frac{1.1298 \times 10^{-1} \times 1.1021 \times 10^{-2}}{30 \times 10^{-4}}$$

$$h_6 = 0.41507m = 41.507cm$$

g) State 7: Defining the state with v and T

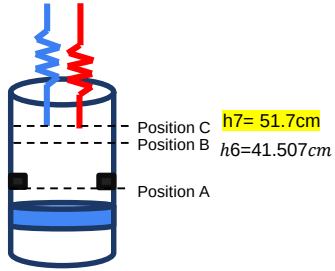
$$v_7 = \frac{Ah_7}{m_{R134}} = \frac{30 \times 10^{-4} \times 51.7 \times 10^{-2}}{1.1021 \times 10^{-2}} = 0.14073\, m^3/kg$$

$$T_7 = 80°C$$

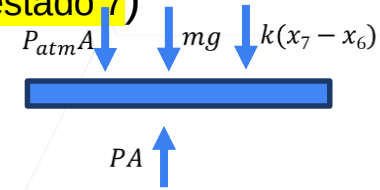
Properties of Superheated Refrigerant 134a Vapor

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
p = 2.0 bar = 0.20 MPa (T_{sat} = −10.09°C)				
70	0.13639	286.74	314.02	1.1661
80	0.14073	295.53	323.68	1.1939
90	0.14504	304.47	333.48	1.2212

$$P_7 = 2bar$$



FBD for the piston to find the constant((estado 7)



$$P_6A = P_{atm}A + m_{piston}g \text{ (estado 6)(1)}$$

$$P_7 = P_{atm} + m_{piston}g + \frac{k(x_7 - x_6)}{A} \times \frac{A}{A} \text{ (estado 7)(2)}$$

$$P_7 = P_{atm} + m_{piston}g + \frac{k(V_7 - V_6)}{A^2}$$

$$(P_7 - P_6) = \frac{k(V_7 - V_6)}{A^2}) \qquad \text{(2)-(1)}$$

The slope:

$$\frac{k}{A^2} = \frac{(P_7 - P_6)}{m_{R134}(v_7 - v_6)}$$

$$\frac{k}{A^2} = \frac{(2 - 1.8) \times 10^5}{1.1021 \times 10^{-2} \times (0.14073 - 1.1298 \times 10^{-1})}$$

$$\frac{k}{(30 \times 10^{-4})^2} = \frac{(2 - 1.8) \times 10^5}{1.1021 \times 10^{-2} \times (0.14073 - 1.1298 \times 10^{-1})}$$

$$k = 588.6364\, N/m$$

h) State 8: Finding first pressure with spring constant

$$v_8 = \frac{Ah_8}{m_{R134}} = \frac{30 \times 10^{-4} \times 95 \times 10^{-7}}{1.1021 \times 10^{-2}} = 2.58592 \times 10^{-1}\, m^3/kg$$

$$\frac{2k}{A^2} = \frac{(P_8 - P_7)}{m_{R134}(v_8 - v_7)} \rightarrow \frac{2 \times 588.6364}{(30 \times 10^{-4})^2} = \frac{(P_8 - 2) \times 10^5}{1.1021 \times 10^{-2} \times (2.58592 \times 10^{-1} - 0.14073)} \rightarrow P_8 = 3.7bar = 370kPa$$

From tables, the specific volume is too large compared to reported values, so it is possible that R134a behaves as ideal gas. Find Z for state 8

Substance	Chemical Formula	M (kg/kmol)	T_c (K)	p_c (bar)	$Z_c = \frac{p_c v_c}{RT_c}$
Refrigerant 134a	CF_3CH_2F	102.03	374	40.7	0.260

$$P_r = \frac{P_8}{P_c} = \frac{3.7}{40.7} = 0.091$$

$$v'_r = \frac{v_8 P_c}{RT_c} = \frac{2.58592 \times 10^{-1} \times 40.7 \times 10^5}{\frac{8314}{102.03} \times 374} = 34.5348$$

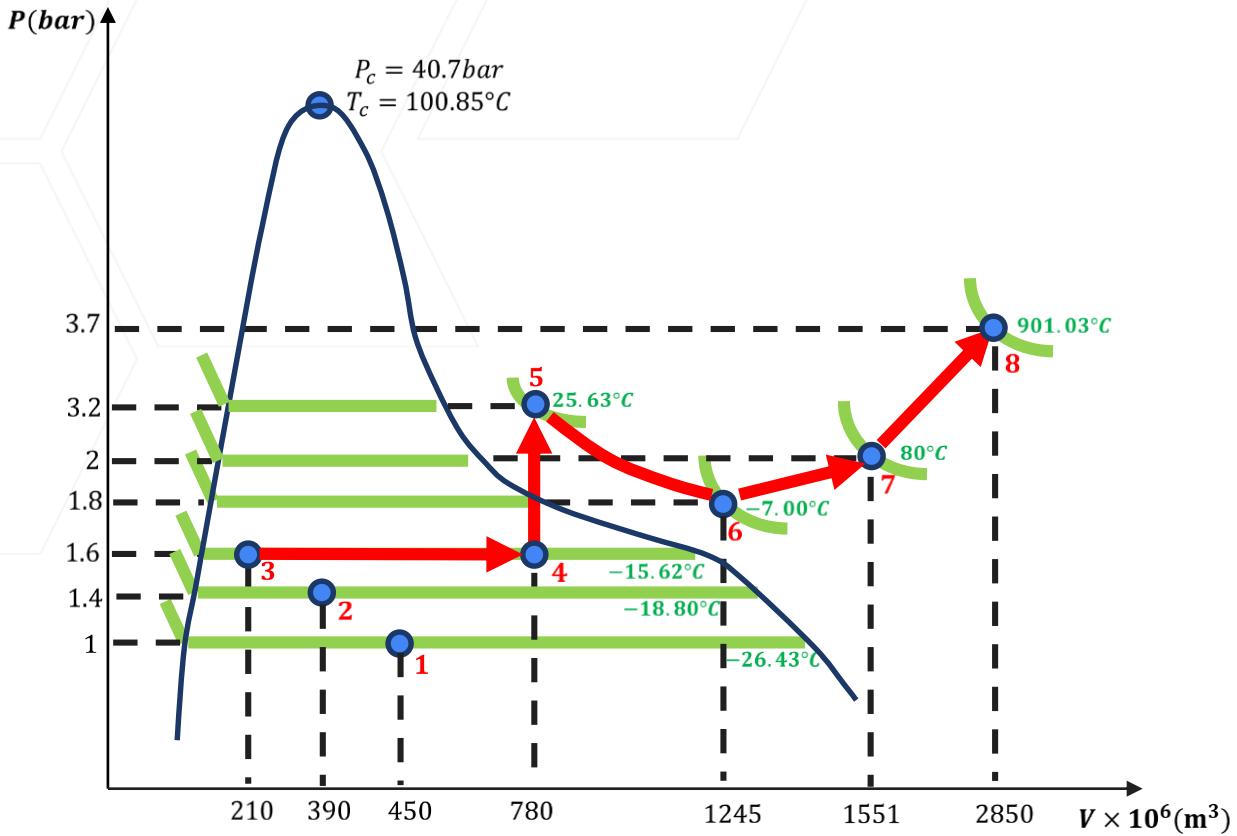
$$Z \approx 1$$

$$P_8 v_8 = RT_8$$

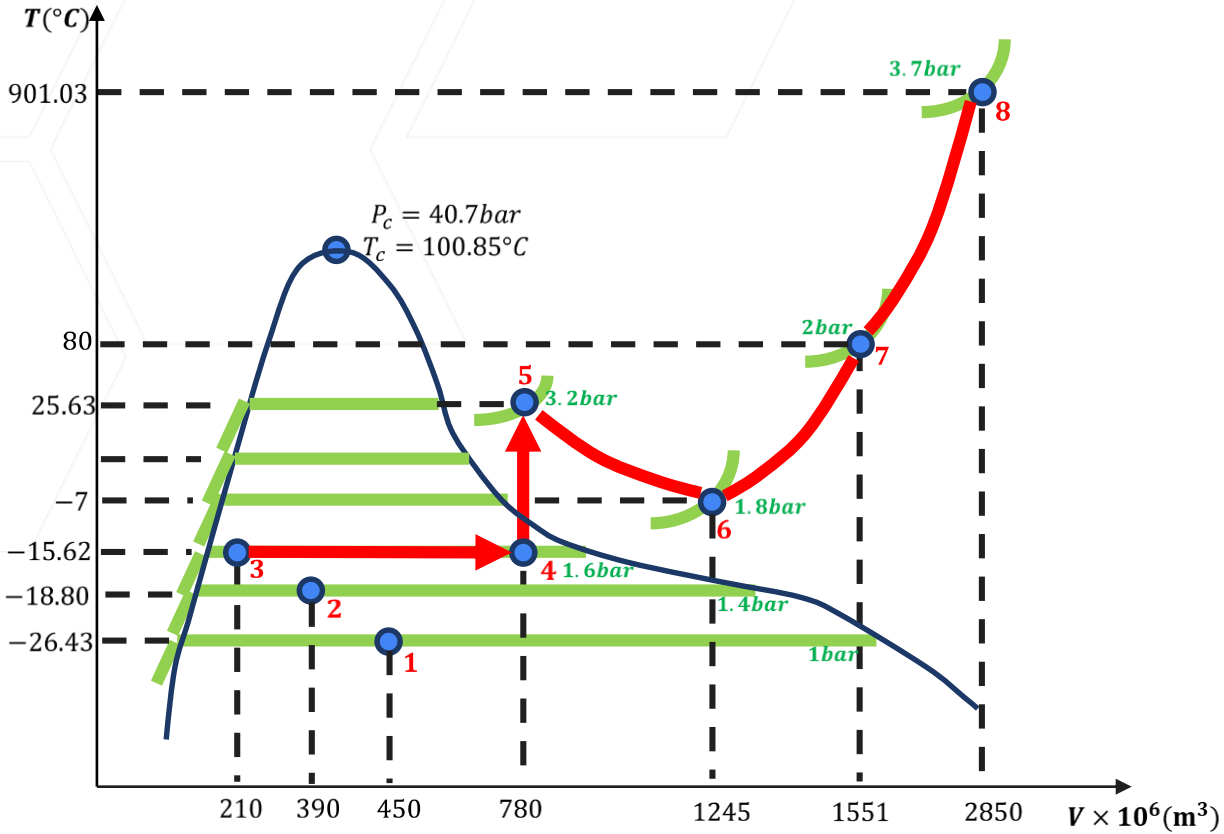
$$370 \times 2.58592 \times 10^{-1} = \frac{8.314}{102.03} \times T_8$$

$$T_8 = 1174.18K = 901.03°C$$

i) Plot a P (bar) – V (m3) diagram showing all the states previously mentioned, and the processes from state 3 to state 8.



j) Plot a T (°C) – V (m3) diagram showing all the states previously mentioned, and the processes from state 3 to state 8.

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Thanks!