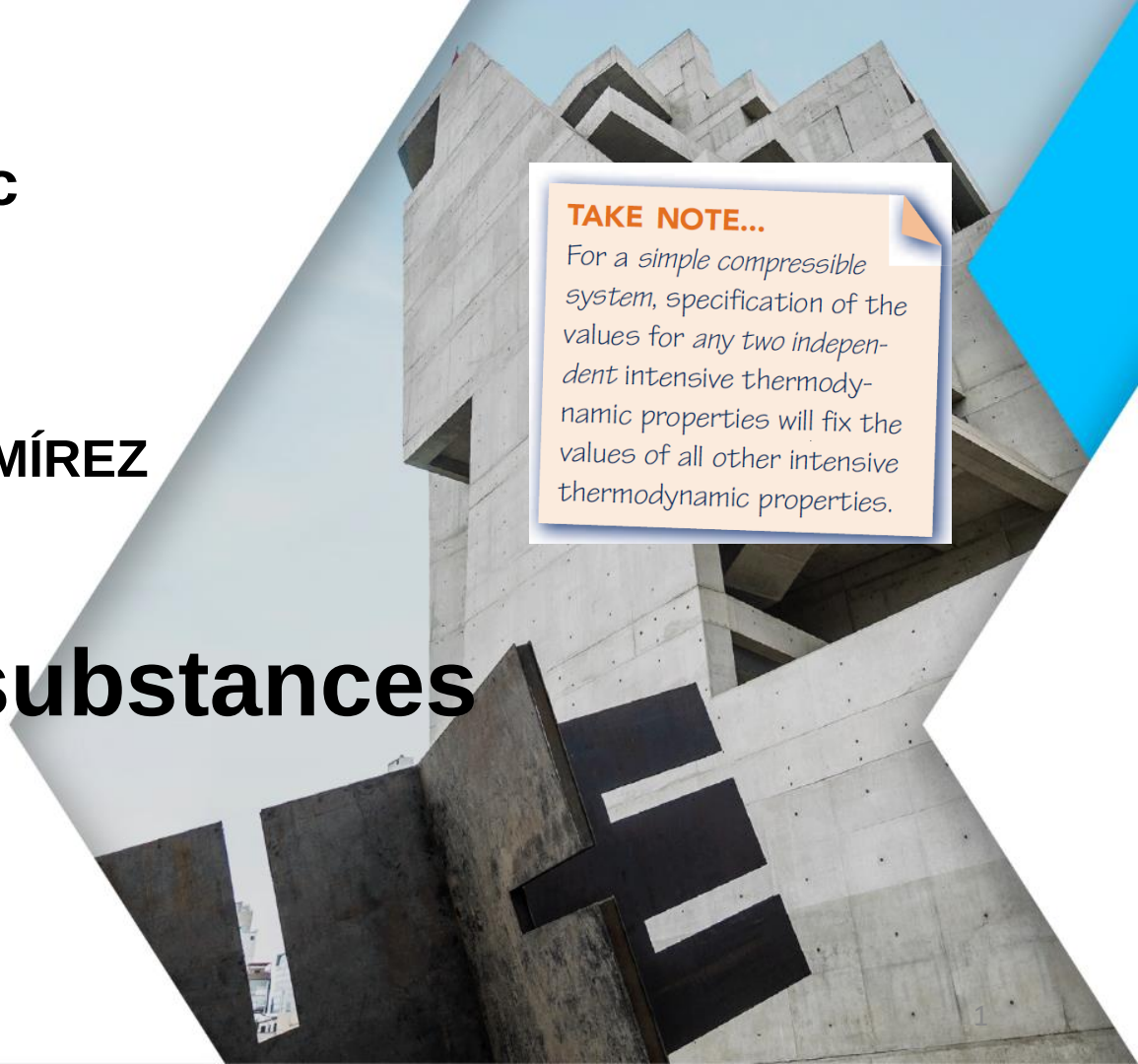
Thermodynamic
2026-1

NEDHER SÁNCHEZ RAMÍREZ
NAUDY LOPEZ

Properties of substances



UTEC
UNIVERSIDAD DE INGENIERÍA Y TECNOLOGÍA

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

hmanrique@utec.edu.pe

nlopez@utec.edu.pe

nsanchezr@utec.edu.pe

squispe@utec.edu.pe

Guidelines for virtual sessions:

Tiempo aproximado de la sesión 100 minutos

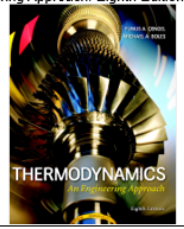
Realizar preguntas a través del chat, habrá un profesor y/o un asistente atento a las dudas planteadas

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

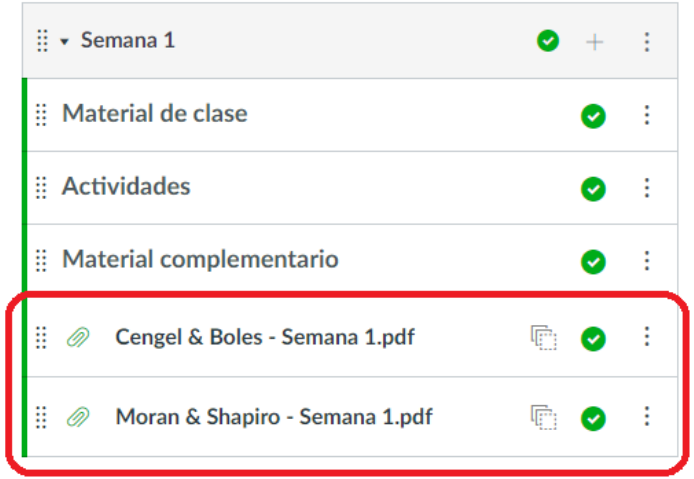
La grabación de la sesión se cargará a Canvas.

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 :

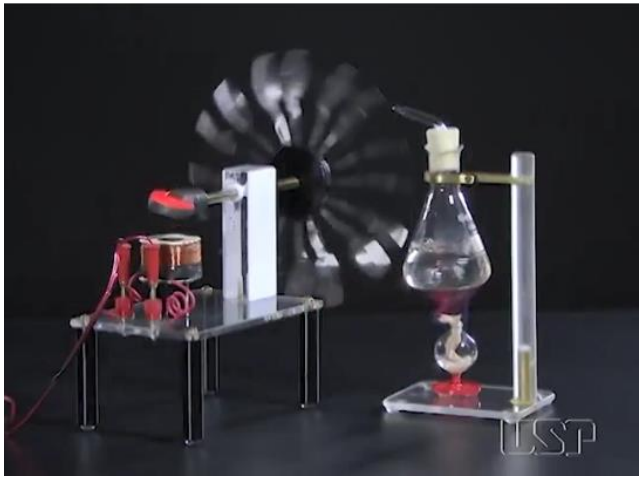
https://docs.google.com/spreadsheets/d/1DMrZjoEaRlHfZPbrFa5q84ha0ElWJQS1zmyLanvjGcw/edit?gid=0#gid=0

Thermodynamics _ Evaluation

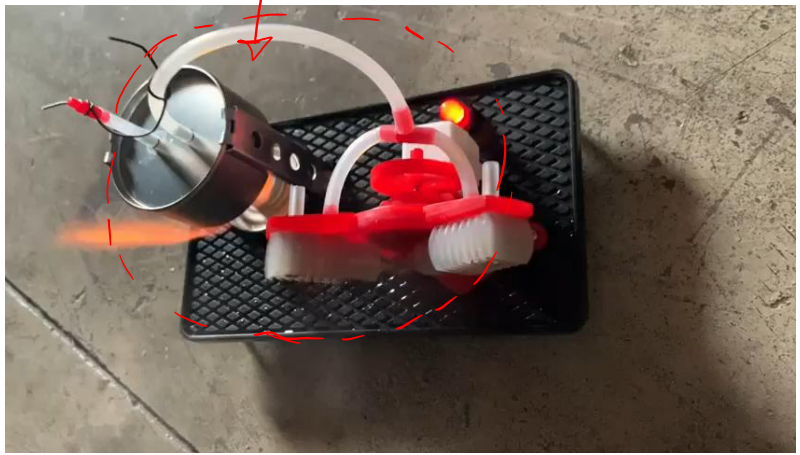
Link con las rubricas de actividad de aula y tarea individual:

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

Why is it important to know the properties of the substances?

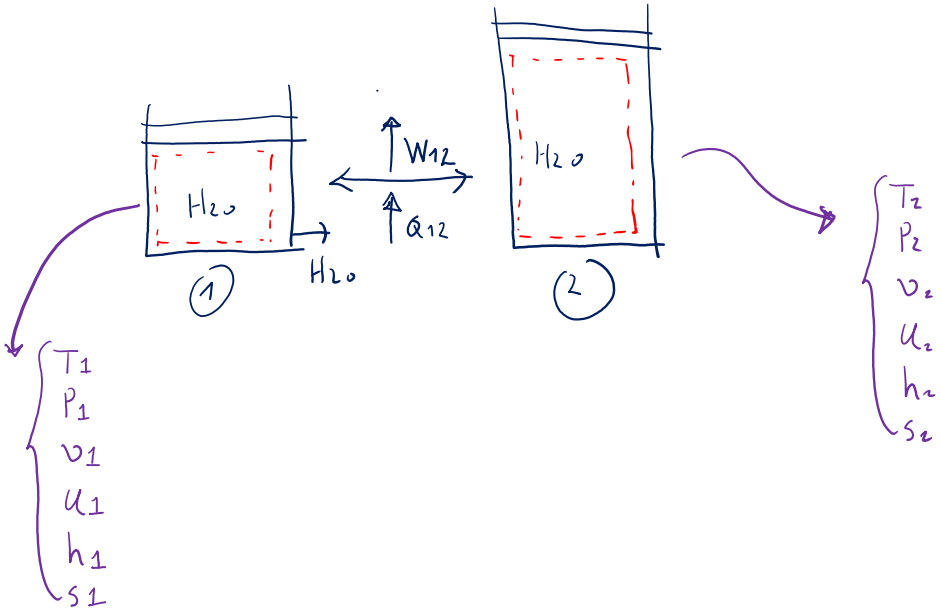


CALOR (Q)?
TRABAJO (W)?



Para evaluar Q, W en un proceso, requiero conocer las propiedades.
↳ Recordar postulado de estado

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA



The State Postulate

The state of a simple compressible system, **the state**, is completely specified by two independent, intensive properties.

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

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

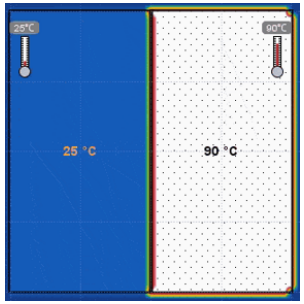
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

TEMPERATURE_STATE PROPERTY

TEMPERATURE_STATE PROPERTY

- ✓ La temperatura es una propiedad intensiva de estado que caracteriza el estado térmico de un sistema y determina la dirección de la transferencia de calor.
- ✓ Microscópicamente, se relaciona con el nivel de agitación de sus partículas, no con toda su energía interna total.

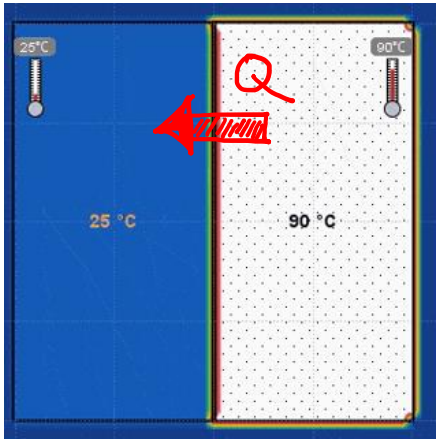
0^{th} Law $\Rightarrow$ Defines Temperature (T)



- ❖ La ley cero dice que debe existir una propiedad que sea igual en todos los sistemas que están en equilibrio térmico. A esa propiedad la llamamos temperatura

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

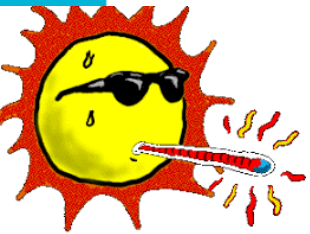
✓ La temperatura es una propiedad intensiva de estado que caracteriza el estado térmico de un sistema y determina la dirección de la transferencia de calor.

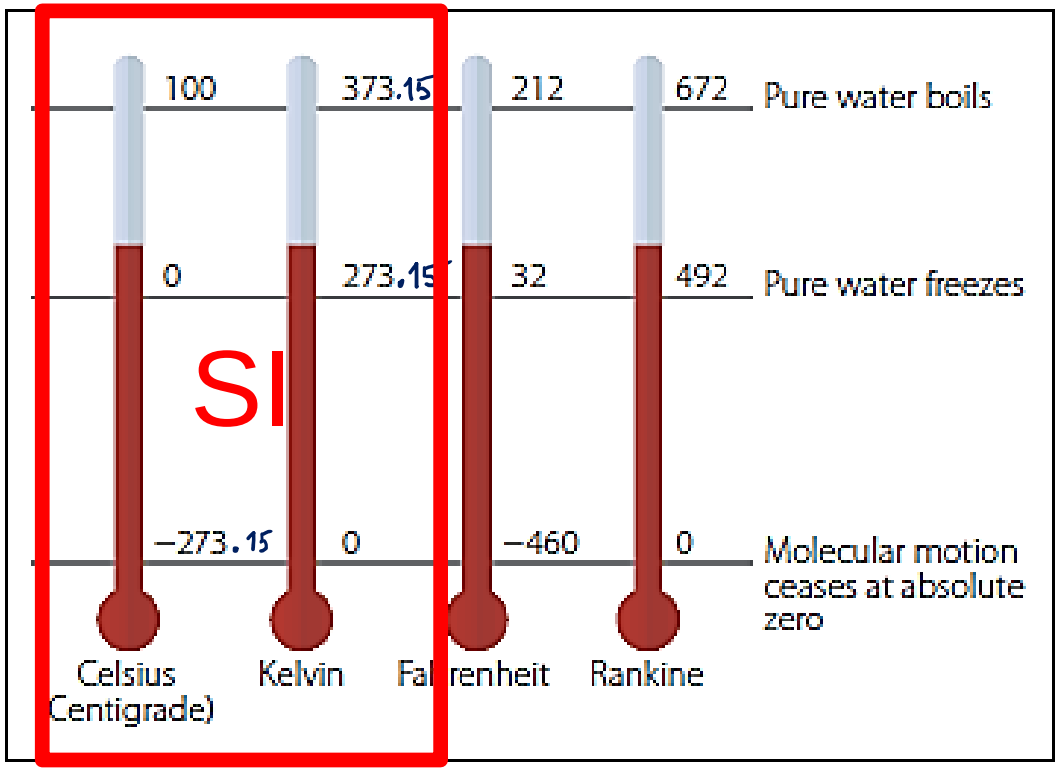


The heat (**Q**) flows until $T_1 = T_2$ ➡ **THERMAL EQUILIBRIUM**

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

How many temperature scales do you know?





K=°C +273.15

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

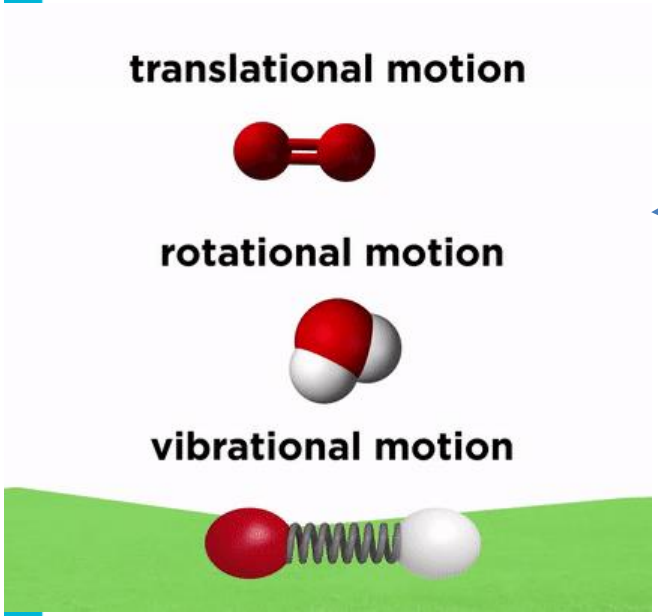
ENERGY_STATE PROPERTY

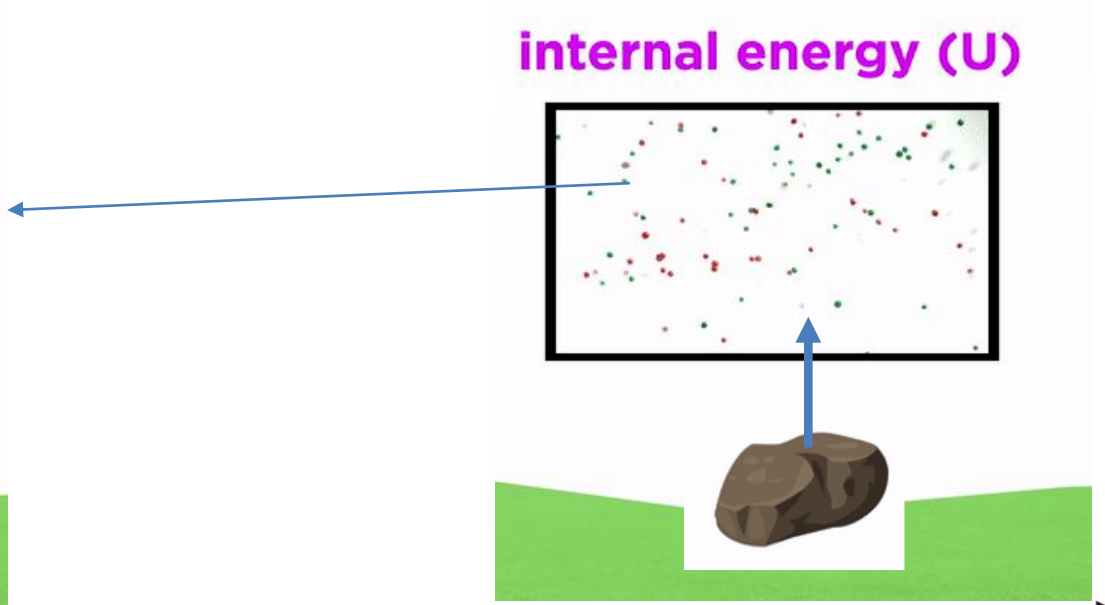
ENERGY

- Since a system is a quantity of matter and it has energy, it is logical to think about quantifying it.

ENERGY

- Since a system is a quantity of matter and it has energy, it is logical to think about quantifying it.





ENERGY

A macroscopic amount of mass can possess energy in the form of **internal energy** inherent in its internal structure, **kinetic energy** in its motion, and **potential energy** associated with external forces acting on the mass (g).

$$E = \text{Internal} + \text{Kinetic} + \text{Potential} = U + \text{KE} + \text{PE}$$

$$e = E/m = u + ke + pe = u + {}^{1}\!/_{2}V^{2} + gz$$

¿What is a phase?

The term phase refers to a quantity of matter that is homogeneous throughout in both chemical composition and physical structure.

Homogeneity in physical structure means that the matter is all solid, or all liquid, or all gas) and same molecular arrangement

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

¿What is a pure substance?

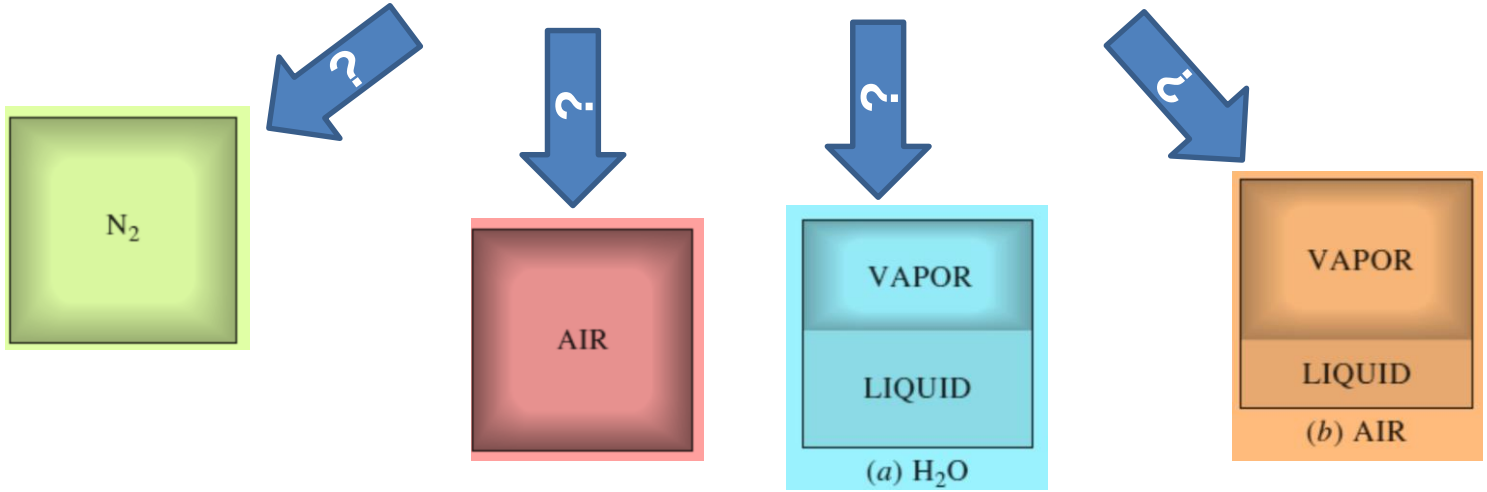
A **pure substance** is one that is uniform and invariable in chemical composition. A pure substance can exist in more than one phase, but its chemical composition must be the same in each phase.

Single chemical element or compound

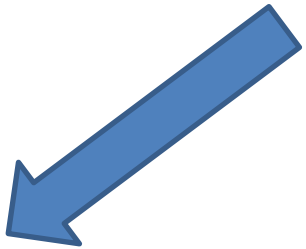
Homogenous mixture of chemical elements or compounds

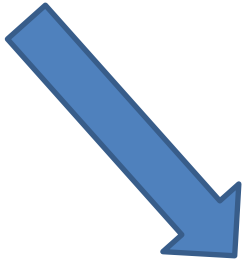
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

¿ What is a pure substance?



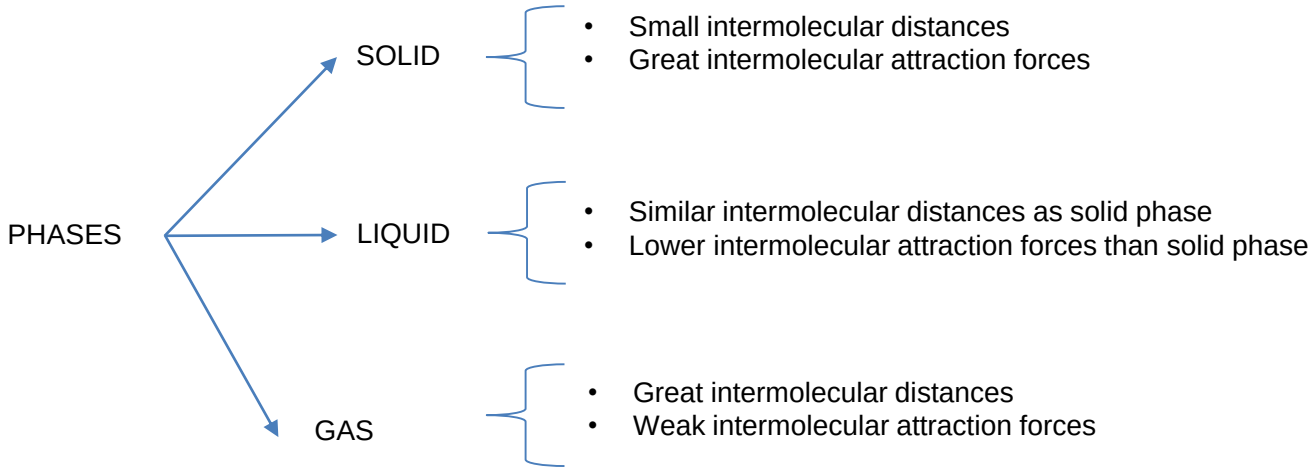
Pure substance in this course





Water, refrigerants…
This week.

Ideal and real gases
Next week.

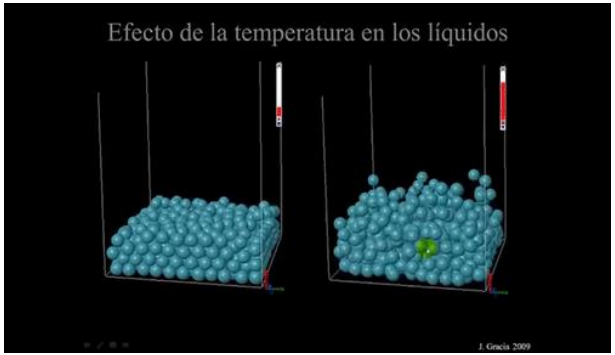


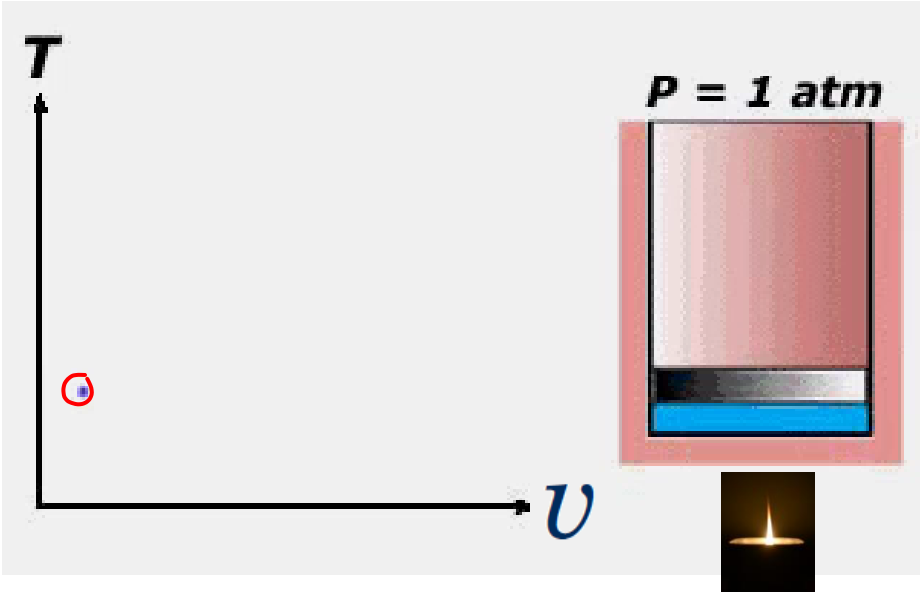
MOLECULE ENERGY IN GAS PHASE > MOLECULE ENERGY IN LIQUID PHASE > MOLECULE ENERGY IN SOLID PHASE

https://www.youtube.com/watch?v=D-jmTj4dsvk

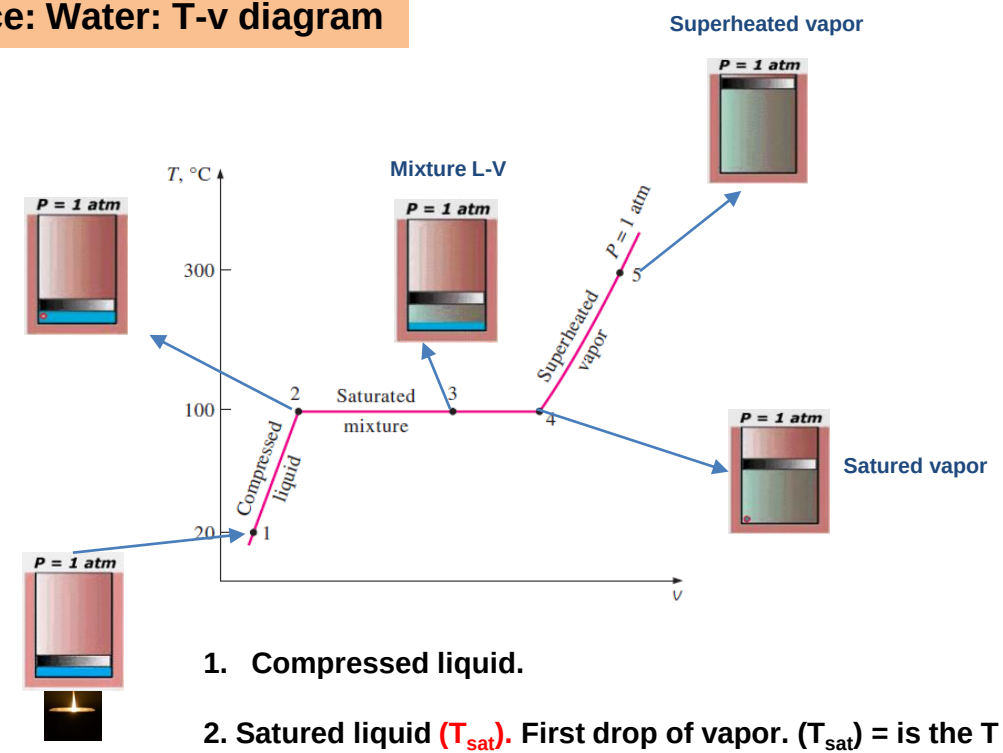
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

T-v diagram for water





Substance: Water: T-v diagram



1. **Compressed liquid.**

2. **Satured liquid (T_{sat}). First drop of vapor. (T_{sat}) = is the T in which a substance change the phase.**

P_{sat_1} = 1 atm = 101.3 kPa↔T_{sat_1} (100 °C).

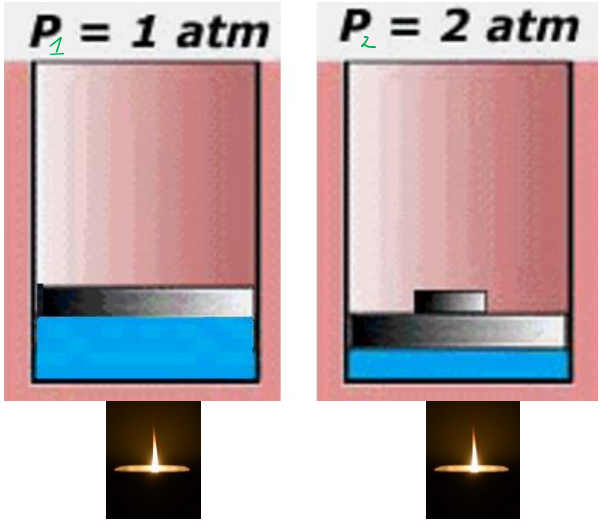
3. **Satured liquid + satured vapor.**

4. **Satured vapor. Last drop of liquid.**

5. **Superheated vapor**

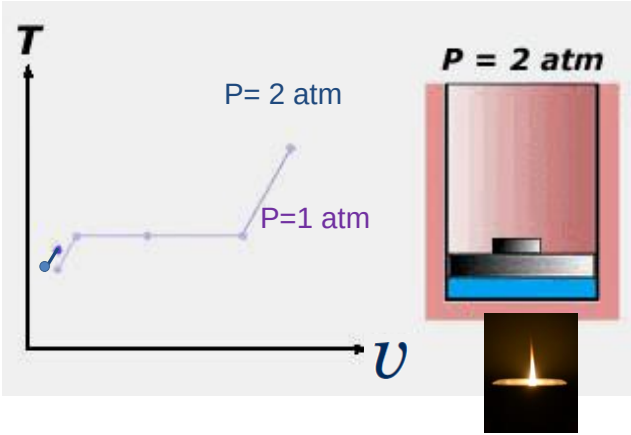
Substance: Water: T-v diagram_$P_2 > P_1$

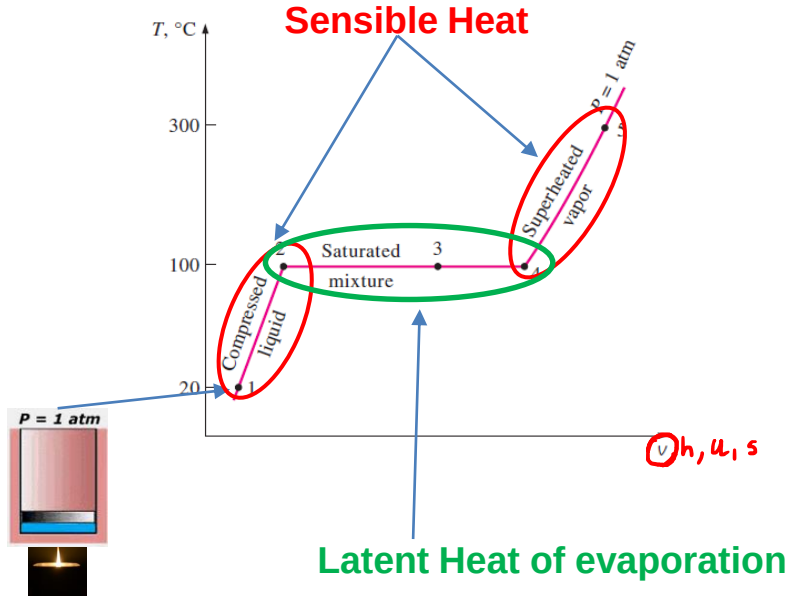
What happens now?

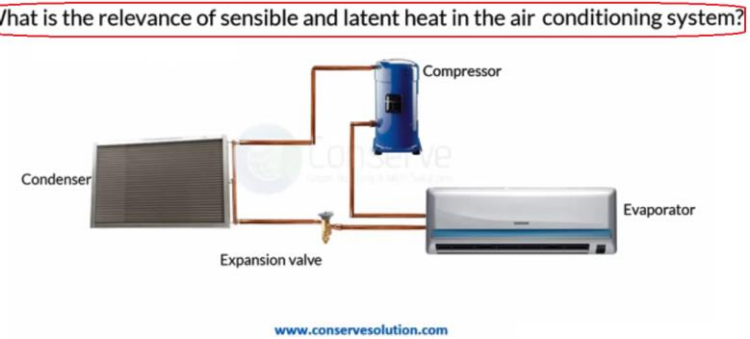


UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

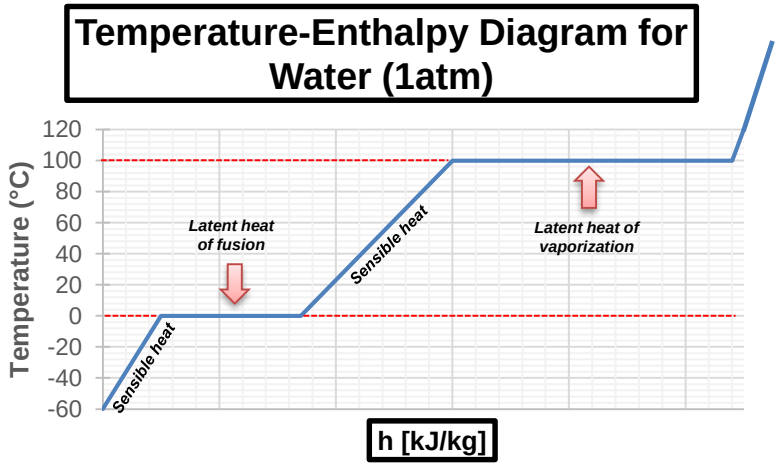
Substance: Water: T-v diagram_P2 > P1
What happens now?

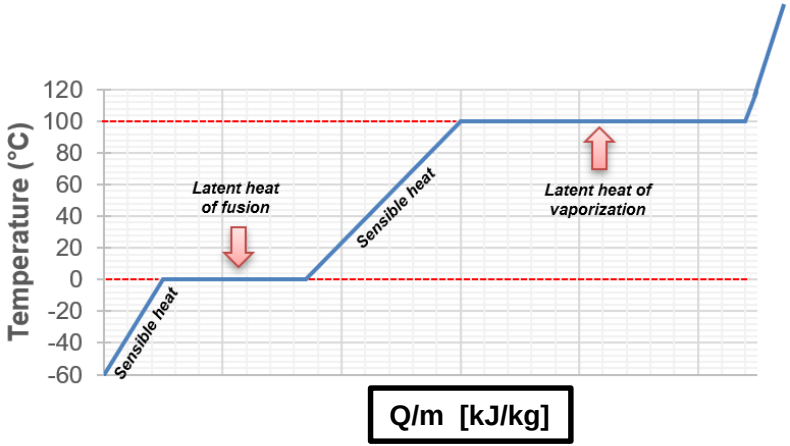



Sensible Heat
T, °C
300
100
20
P = 1 atm
Compressed liquid
Saturated mixture
Superheated vapor
P = 1 atm
1
2
3
4
v
h, u, s
Latent Heat of evaporation


What is the relevance of sensible and latent heat in the air conditioning system?
Compressor
Condenser
Evaporator
Expansion valve
www.conservesolution.com

LATENT HEAT AND SENSIBLE HEAT





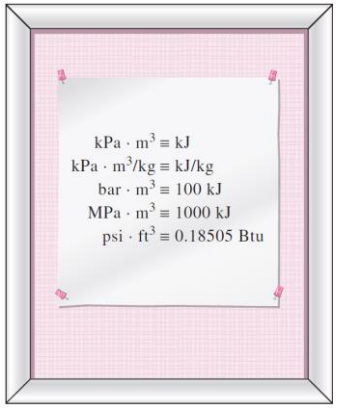
ENTHALPY_STATE PROPERTY

Enthalpy—A Combination Property

- In the analysis of certain types of processes, like **heating** or **cooling** at P = constant, and open system we frequently encounter the combination of properties $u + Pv$. For simplicity and convenience, was define:

$$h = u + Pv \qquad (\text{kJ/kg})$$

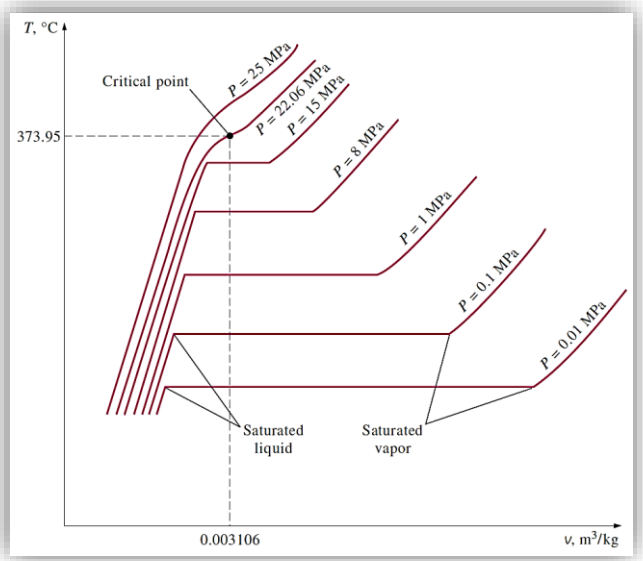
$$H = U + PV \qquad (\text{kJ})$$

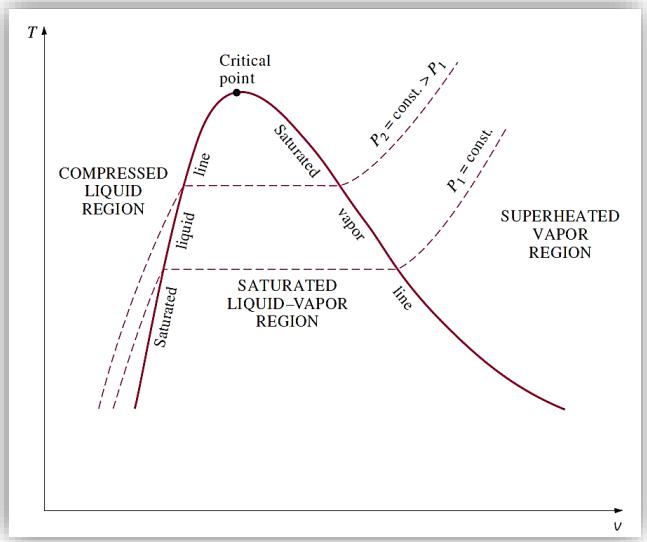


- The enthalpy is also associated with the energy transported by a mass flow (energy balance in open systems), we will see later.

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Substance: Water: T-v diagram

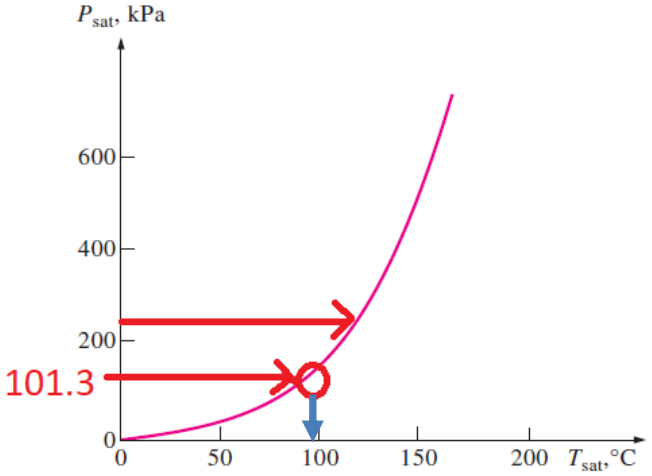




This properties of the critical point for pure substances will be used for the theory of corresponding states in ideal gases. That is why all the critical properties are tabulated.

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Substance: Water: $T_{sat} = f(P_{sat})$



TABLE

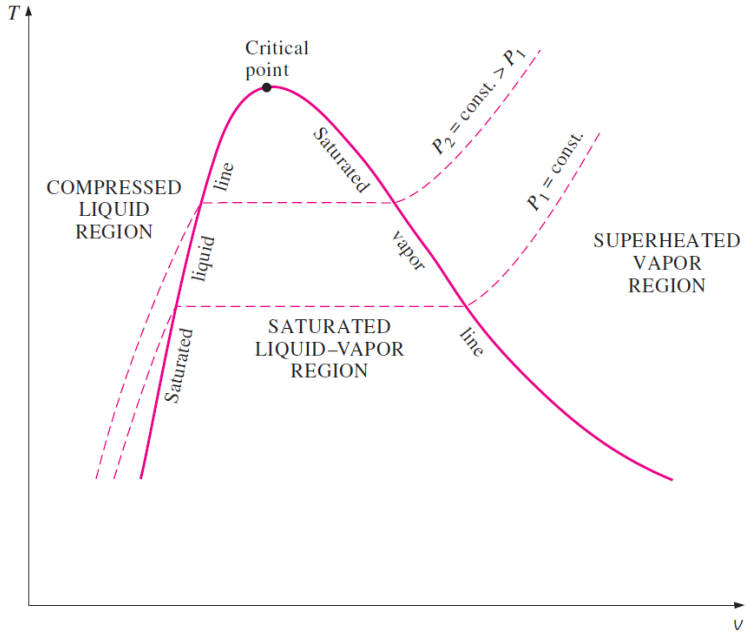
Saturation (boiling) pressure of water at various temperatures

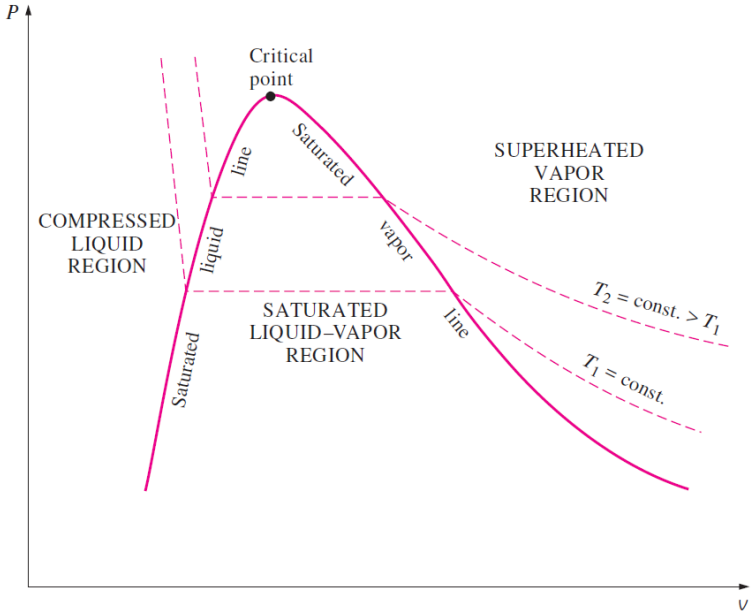
Temperature, T, °C	Saturation pressure, P_{sat}, kPa
−10	0.26
−5	0.40
0	0.61
5	0.87
10	1.23
15	1.71
20	2.34
25	3.17
30	4.25
40	7.39
50	12.35
100	101.3
150	476.2
200	1555
250	3976
300	8588

Consequences of *T*sat and *P*sat Dependence?

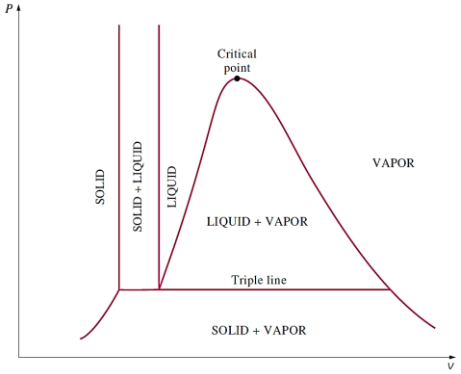
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

T-v Vs P-v Diagram

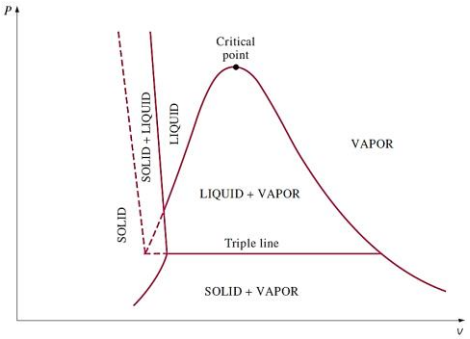




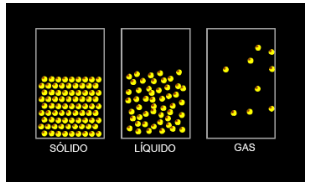
Extending the Diagrams to Include the Solid Phase

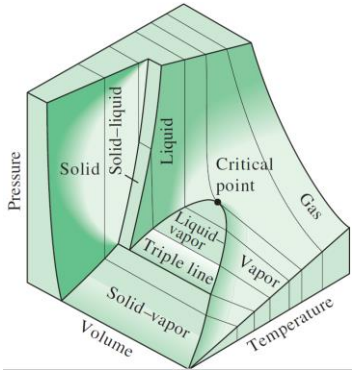


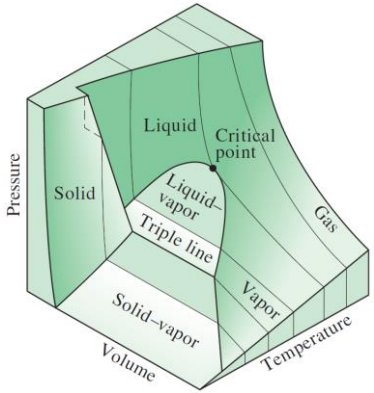
P-v diagram of a substance that contracts on freezing.



P-v diagram of a substance that expands on freezing (such as water).

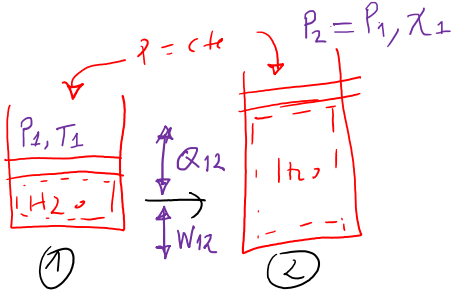


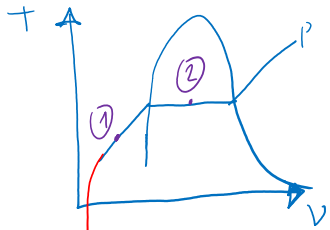




UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Property Tables





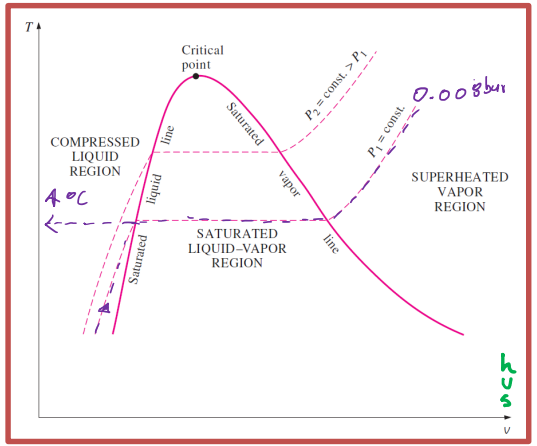
→ L.C. { T, P, u, s, h, v } > En la tabla conociendo 2 Prop. intensivas independientes conozco las otras

Property Tables

- For most substances, the relationships among thermodynamic properties are too complex to be expressed by simple equations. Therefore, properties are frequently presented in the form of tables in a convenient format.

- For each substance, the thermodynamic properties are listed in more than one table. In fact, a separate table is prepared for each region of interest such as the superheated vapor, compressed liquid, and saturated (mixture) regions. Property tables are given in the appendix in both SI and English units.

Property Tables: Saturation tables



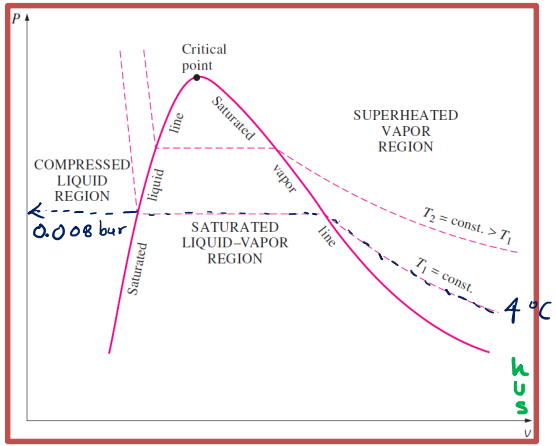


TABLE A-2

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

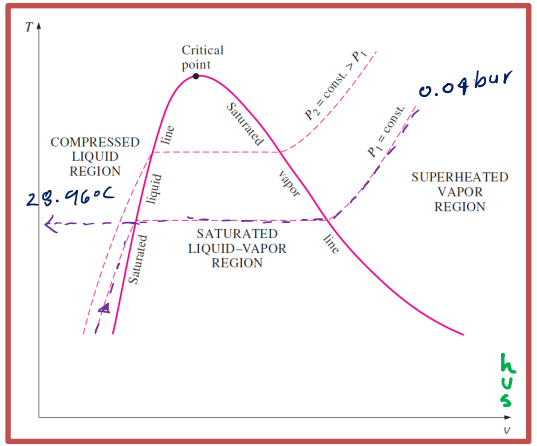
Properties of Saturated Water (Liquid–Vapor): Temperature Table

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
.01	0.00611	1.0002	206.136	0.00	2375.3	0.01	2501.3	2501.4	0.0000	9.1562	.01
4	0.00813	1.0001	157.232	16.77	2380.9	16.78	2491.9	2508.7	0.0610	9.0514	4
5	0.00872	1.0001	147.120	20.97	2382.3	20.98	2489.6	2510.6	0.0761	9.0257	5
6	0.00935	1.0001	137.734	25.19	2383.6	25.20	2487.2	2512.4	0.0912	9.0003	6
8	0.01072	1.0002	120.917	33.59	2386.4	33.60	2482.5	2516.1	0.1212	8.9501	8

H_2O

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

Property Tables: Saturation tables



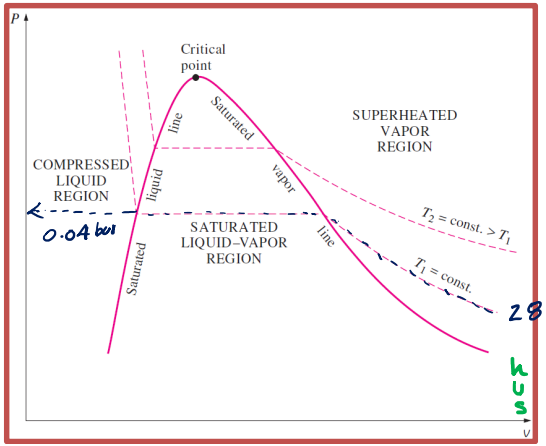


TABLE A-3

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

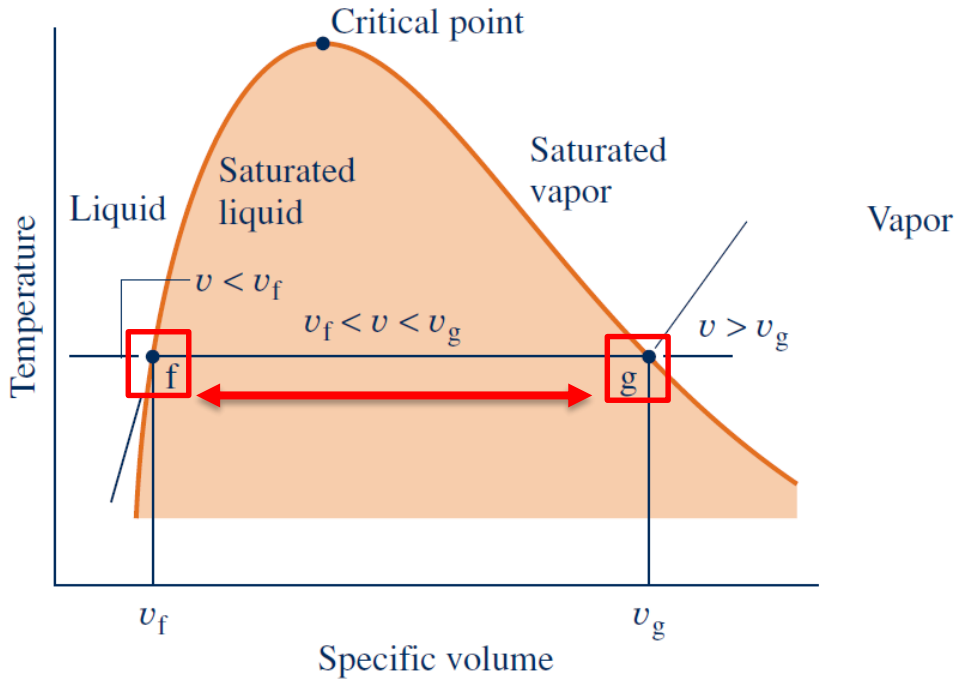
Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

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	Press. bar
0.04	28.96	1.0040	34.800	121.45	2415.2	121.46	2432.9	2554.4	0.4226	8.4746	0.04
0.06	36.16	1.0064	23.739	151.53	2425.0	151.53	2415.9	2567.4	0.5210	8.3304	0.06
0.08	41.51	1.0084	18.103	173.87	2432.2	173.88	2403.1	2577.0	0.5926	8.2287	0.08
0.10	45.81	1.0102	14.674	191.82	2437.9	191.83	2392.8	2584.7	0.6493	8.1502	0.10

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

How to use the steam tables (water)?

1.a) Saturated Liquid and Saturated Vapor States

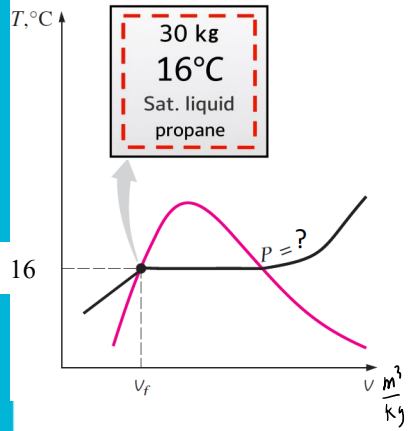


1a) Saturated Liquid and Saturated Vapor States

30 kg
16°C
Sat. liquid
propane

EXAMPLE 1: Pressure and Volume of Saturated Liquid in a Tank

A rigid tank is completely filled with 30 kg of saturated liquid propane at 16°C. Determine:
a) The pressure (**kPa**) in the tank and **b)** the volume (**m³**) of the tank. Sketch the T[**°C**]-v[**m³/kg**] and P[**kPa**]-v[**m³/kg**] diagrams showing the state.



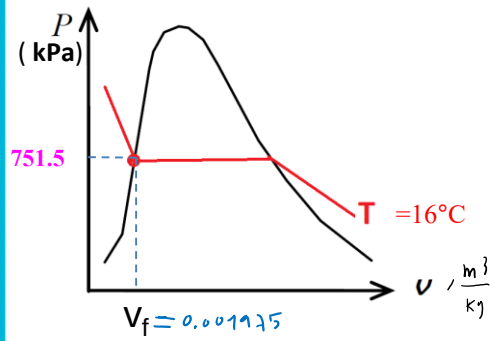


TABLE A-16

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
−100	0.02888	1.553	11.27	−128.4	319.5	−128.4	480.4	352.0	−0.634	2.140	−100
−90	0.06426	1.578	5.345	−107.8	329.3	−107.8	471.4	363.6	−0.519	2.055	−90
−80	0.1301	1.605	2.774	−87.0	339.3	−87.0	462.4	375.4	−0.408	1.986	−80
−70	0.2434	1.633	1.551	−65.8	349.5	−65.8	453.1	387.3	−0.301	1.929	−70
−60	0.4261	1.663	0.9234	−44.4	359.9	−44.3	443.5	399.2	−0.198	1.883	−60
−50	0.7046	1.694	0.5793	−22.5	370.4	−22.4	433.6	411.2	−0.098	1.845	−50
−40	1.110	1.728	0.3798	−0.2	381.0	0.0	423.2	423.2	0.000	1.815	−40
−30	1.677	1.763	0.2585	22.6	391.6	22.9	412.1	435.0	0.096	1.791	−30
−20	2.444	1.802	0.1815	45.9	402.4	46.3	400.5	446.8	0.190	1.772	−20
−10	3.451	1.844	0.1309	69.8	413.2	70.4	388.0	458.4	0.282	1.757	−10
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

a) $P = P_{\text{sat @ 16°C}} = 7.515 \text{ bar} = 751.5 \text{ kPa}$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

1a) Saturated Liquid and Saturated Vapor States

EXAMPLE: **Pressure and b) Volume of Saturated Liquid in a Tank (m^3)**

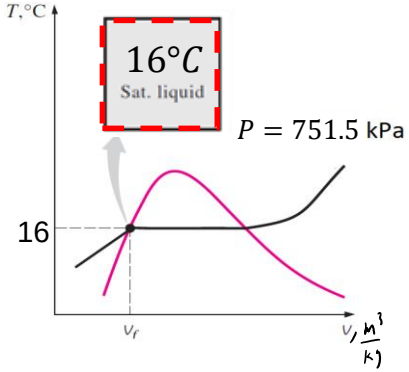


TABLE A-16

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

Properties of Saturated Propane (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
16	7.515	1.975	0.06149	135.0	440.7	136.4	350.5	486.9	0.519	1.731	16

The specific volume of the saturated liquid at 16°C is:

$v_f \times 10^3 = 1.975\ m^3/kg \Rightarrow v_f = 0.001975\ m^3/kg = v_f @\ 16°C$

Then the total volume of the tank becomes:

$V = mv_f = (30\ kg)(0.001975\ m^3/kg) = 0.05925\ m^3$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

1a) Saturated Liquid and Saturated Vapor States

S.V. propane
4 bar
5.2m³

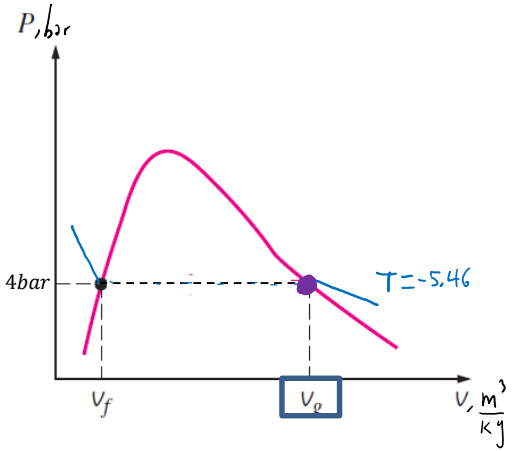
EXAMPLE 2: A 5.2 m³ rigid-tank contains saturated vapor propane at 4bar. Determine the temperature and the mass of vapor inside the tank. Sketch **T[°C]-v[m³/kg]** and **P[bar]-v[m³/kg]** diagram.

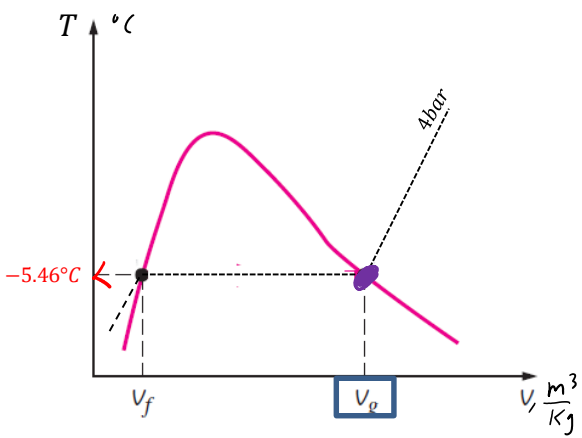
TABLE A-17

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

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

Press. bar	Temp. °C	Specific Volume 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
4.00	−5.46	1.865	0.1137	80.8	418.0	81.5	382.0	463.5	0.324	1.751	4.00





UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

TABLE A-17

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

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

		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · 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	Press. bar
4.00	−5.46	1.865	0.1137	80.8	418.0	81.5	382.0	463.5	0.324	1.751	4.00

Saturated vapor at 4 bar must be at -5.46°C

The specific volume of saturated vapor at 4 bar is 0.1137 m3/kg, therefore the mass of the vapor is:

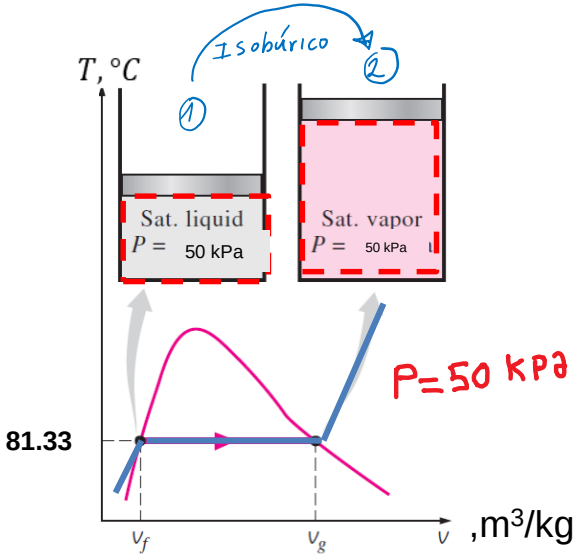
$$\text{mass} = \frac{5.2\text{m}^3}{0.1137\ \frac{\text{m}^3}{\text{kg}}} = 45.7344\ \text{kg}$$

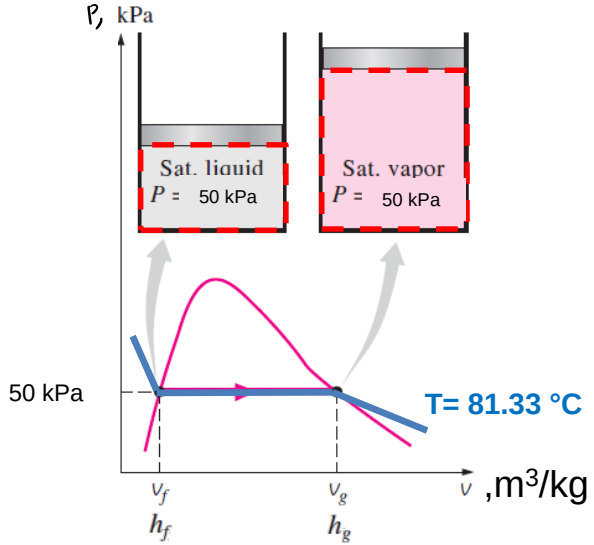
UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

1a) Saturated Liquid and Saturated Vapor States

EXAMPLE 2.4: Volume and Energy Change during Evaporation

A mass of 250 g of saturated liquid water is completely vaporized (to saturated vapor) at a constant pressure of 50 kPa. Determine (*a*) the volume change (**m³**) and (*b*) the amount of energy(heat) transferred to the water (**kJ**). Sketch **T[°C]-v [m³/kg]** and **P[kPa]-v [m³/kg]** diagram.

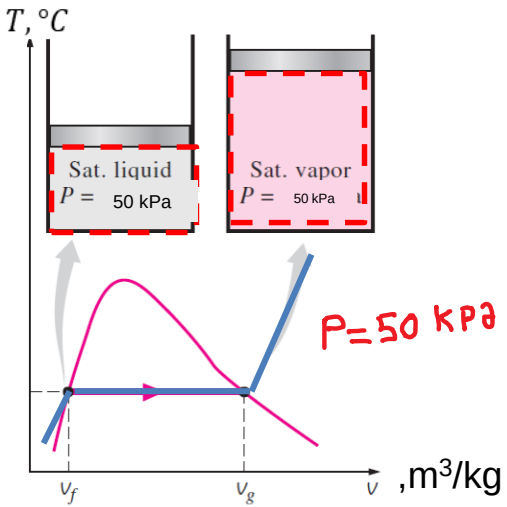




UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

1a) Saturated Liquid and Saturated Vapor States

EXAMPLE 2.4: Volume and Energy Change during Evaporation



1. $v_g - v_f = v_{fg}$?

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 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
0.04	28.96	1.0040	34.800	121.45	2415.2	121.46	2432.9	2554.4	0.4226	8.4746	0.04
0.06	36.16	1.0064	23.739	151.53	2425.0	151.53	2415.9	2567.4	0.5210	8.3304	0.06
0.08	41.51	1.0084	18.103	173.87	2432.2	173.88	2403.1	2577.0	0.5926	8.2287	0.08
0.10	45.81	1.0102	14.674	191.82	2437.9	191.83	2392.8	2584.7	0.6493	8.1502	0.10
0.20	60.06	1.0172	7.649	251.38	2456.7	251.40	2358.3	2609.7	0.8320	7.9085	0.20
0.30	69.10	1.0223	5.229	289.20	2468.4	289.23	2336.1	2625.3	0.9439	7.7686	0.30
0.40	75.87	1.0265	3.993	317.53	2477.0	317.58	2319.2	2636.8	1.0259	7.6700	0.40
0.50	81.33	1.0300	3.240	340.44	2483.9	340.49	2305.4	2645.9	1.0910	7.5939	0.50
0.60	85.94	1.0331	2.732	359.79	2489.6	359.86	2293.6	2653.5	1.1453	7.5320	0.60

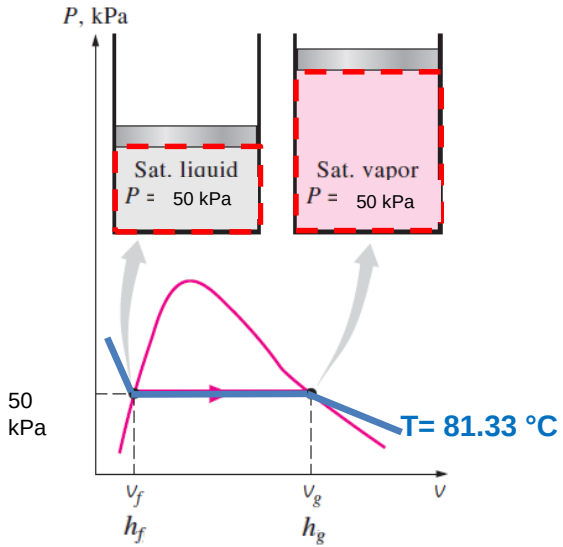
$$v_{fg} = v_g - v_f = 3.240 - 1.0300 \times 10^{-3} = 3.23897\ m^3/kg$$

$$\Delta V = m v_{fg} = 0.250\ kg \times 3.23897\ m^3/kg = 0.8097\ m^3$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

1a) Saturated Liquid and Saturated Vapor States

EXAMPLE 2.4: Volume and Energy Change during Evaporation



1. $h_g - h_f = h_{fg}$?

The amount of energy needed to vaporize a unit mass of a substance at a given pressure is the enthalpy of vaporization at that pressure, which is h_{fg}

TABLE A-3

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

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

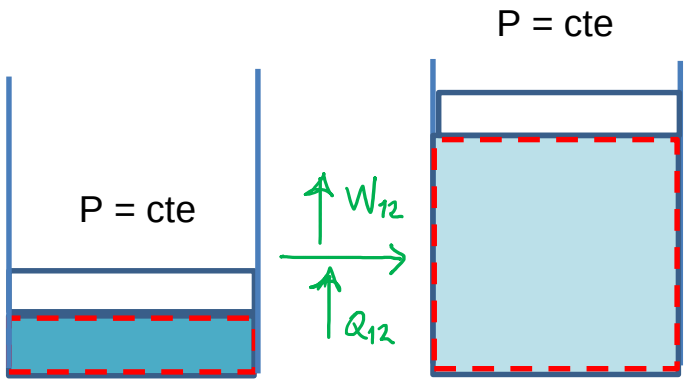
Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Press. bar
0.40	75.87	1.0265	3.993	317.53	2477.0	317.58	2319.2	2636.8	1.0259	7.6700	0.40
0.50	81.33	1.0300	3.240	340.44	2483.9	340.49	2305.4	2645.9	1.0910	7.5939	0.50
0.60	85.94	1.0331	2.732	359.79	2489.6	359.86	2293.6	2653.5	1.1453	7.5320	0.60

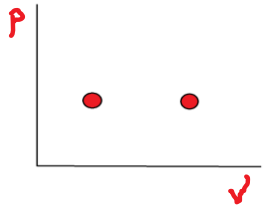
$$h_{fg} = hg - hf = 2305.4\ kJ/kg$$

$$\Delta H = m h_{fg} = 0.250 \times 2305.4 = 576.35\ kJ$$

$$\Delta U = ?$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

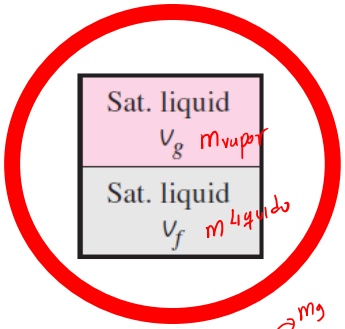




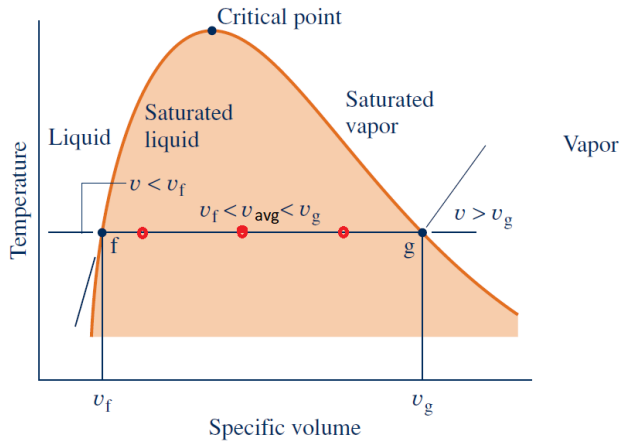
$Q_{12} = \Delta H = m(h_2 - h_1)$

$\Delta U_{12} = Q_{12} - W_{12}$ (ΔH)

1b) Saturated Liquid–Vapor Mixture_Quality



$m_{total} = m_{vapor} + m_{Liquido}$ ($m_{vapor} \rightarrow m_g$, $m_{Liquido} \rightarrow m_f$)

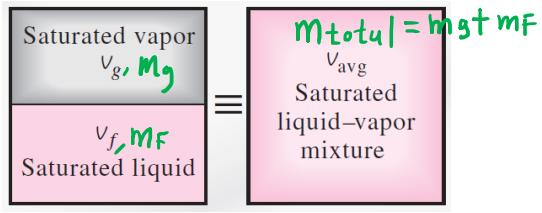


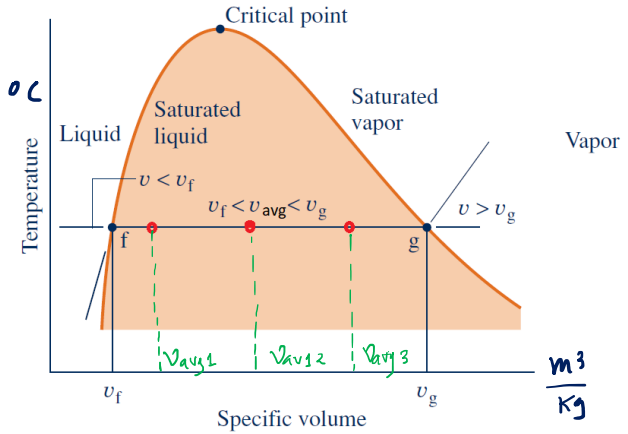
In order to define completely the system we need to know other intensive property = x = quality

$$x = \frac{m_{vapor}}{m_{total}}$$

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})

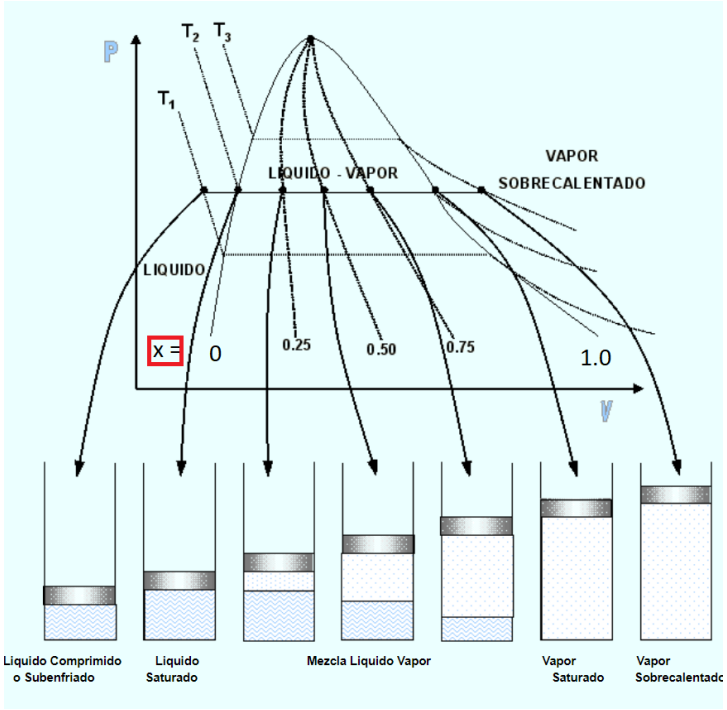




$$v_{avg} = v_f + x(v_g - v_f) \longrightarrow x = \frac{m_{vapor}}{m_{total}} = \frac{m_g}{m_g + m_F}$$

(v_{fg})

1b) Saturated Liquid–Vapor Mixture_ Quality



$$v_{avg} = v_f + x(v_g - v_f)$$

1b) Saturated Liquid–Vapor Mixture_ Quality

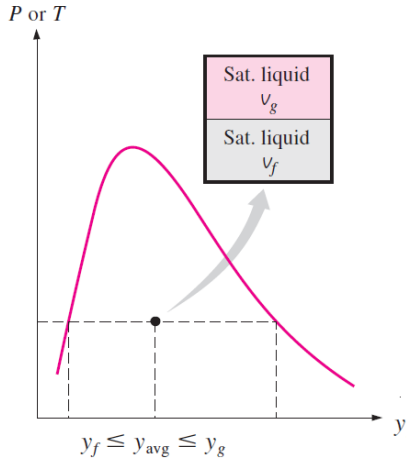
We can this result for the other properties:

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

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

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

EXAMPLE 3.3: Quality of a Mixture

Water in a rigid tank at 400kPa with a quality of 25% has its pressure raises 50kPa on a constant-volume process. What are the new quality and temperature?

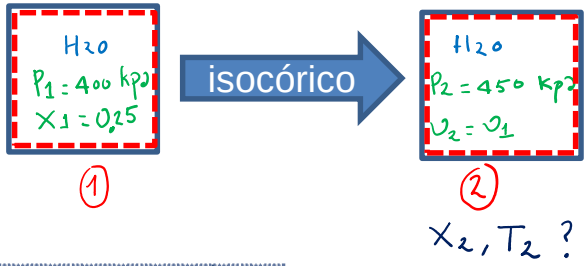


TABLE A-3

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

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

T_{sat} , P_{sat}

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
4.00	143.6	1.0836	0.4625	604.31	2553.6	604.74	2133.8	2738.6	1.7766	6.8959	4.00

State 1: 400kPa (4bar) and 25% quality

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

$$v_1 = 1.0836 \times 10^{-3} + 0.25(0.4625 - 1.0836 \times 10^{-3})$$

$$v_1 = 0.11643 \frac{m^3}{kg}$$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

1b) Saturated Liquid–Vapor Mixture_ Quality

EXAMPLE 3.3: Quality of a Mixture

Water at 400kPa with a quality of 25% has its pressure raises 50kPa on a constant-volume process. What are the new quality and temperature?

TABLE A-3

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

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

T_{sat} , P_{sat}

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
4.00	143.6	1.0836	0.4625	604.31	2553.6	604.74	2133.8	2738.6	1.7766	6.8959	4.00
4.50	147.9	1.0882	0.4140	622.25	2557.6	623.25	2120.7	2743.9	1.8207	6.8565	4.50

State 2: 450kPa (4.5bar) and $v_2 = v_1$ ⟶ $v_2 = v_1 = 0.11643 \frac{m^3}{kg}$

Since $v_{f2} < v_2 < v_{g2}$, it's a mixture,

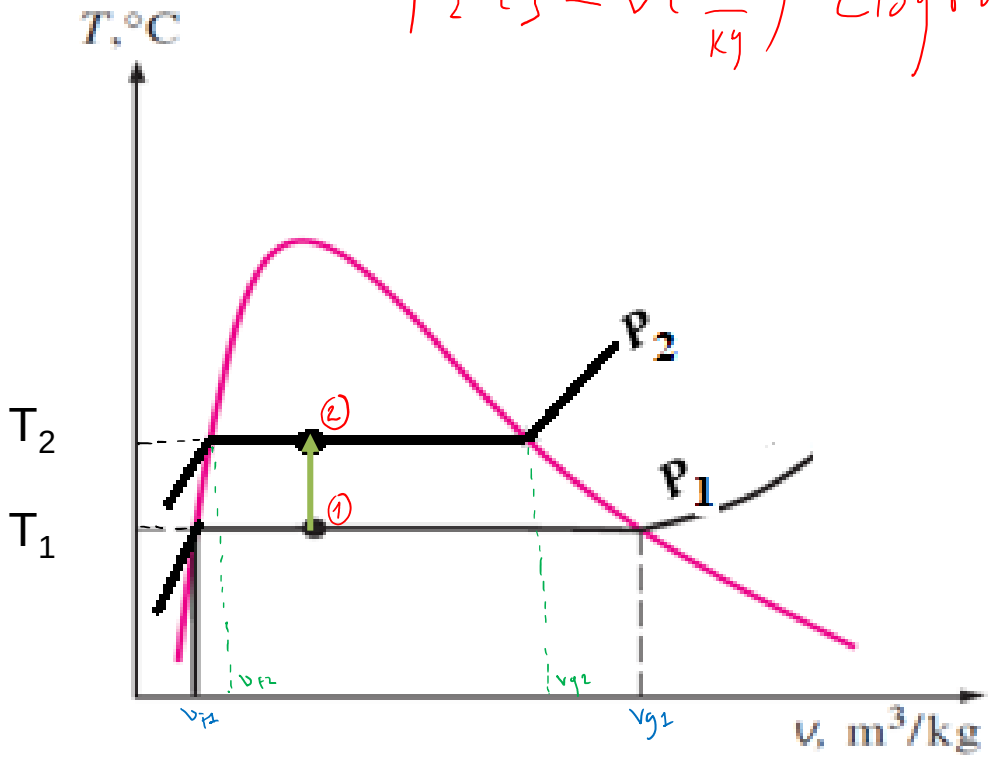
$$x_2 = \frac{v_2 - v_{f2}}{v_{g2} - v_{f2}} = \frac{0.11643 - 1.0882 \times 10^{-3}}{0.4140 - 1.0882 \times 10^{-3}} = 0.2793$$

$T_2 = T_{sat@4.5bar} = 147.9°C$

$\Delta u, \Delta h = ?$

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

$T\,[^\circ C] - v\left(\frac{m^3}{kg}\right)$ diagram ?



1b) Saturated Liquid–Vapor Mixture_ Quality

$V_{vap} = 1.5m^3$

$V_{liq} = 0.5m^3$

EXAMPLE 3.8: Quality of a Mixture

A closed vessel contains 0.5 m^3 of saturated liquid and 1.5 m^3 of saturated vapor in equilibrium of water at 5 bar. Determine the percent vapor on a mass basis.

$V = V_f + V_g$

$V = m_f v_f + m_g v_g$

T_{sat} , P_{sat}

TABLE A-3

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

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

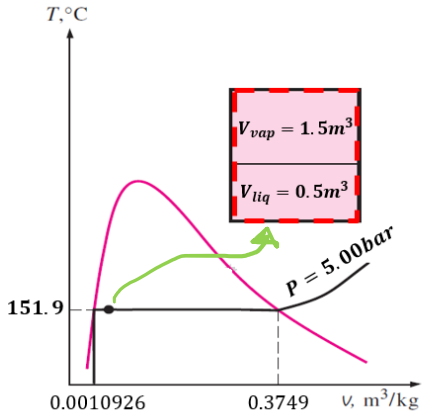
Press. bar	Temp. °C	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid 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

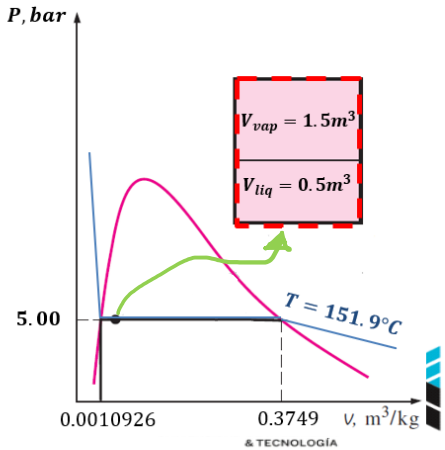
$$V_{liq} = m_{liq} v_f \Rightarrow m_{liq} = \frac{0.5}{0.0010926} = 457.6240\ kg$$

$$V_{vap} = m_{vap} v_g \Rightarrow m_{vap} = \frac{1.5}{0.3749} = 4.0011\ kg$$

$$m_T = m_{liq} + m_{vap} = 457.6240 + 4.0011 = 461.6251\ kg$$

$$x = \frac{m_{vap}}{m_T} = \frac{4.0011}{461.6251} = 8.6667 \times 10^{-3} = 0.8667\ \%$$





The vessel contains 75% vapor by volume but only 0.867% vapor by mass

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

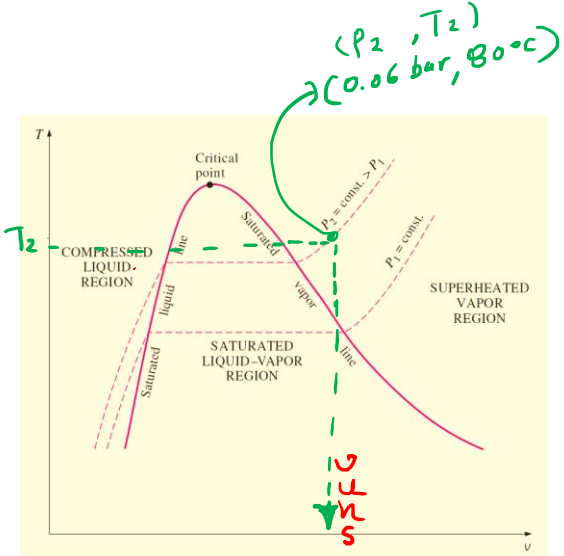
T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 0.06 bar = 0.006 MPa (T_{sat} = 36.16°C)			
Sat.	23.739	2425.0	2567.4	8.3304
80	27.132	2487.3	2650.1	8.5804
120	30.219	2544.7	2726.0	8.7840
160	33.302	2602.7	2802.5	8.9693
200	36.383	2661.4	2879.7	9.1398
240	39.462	2721.0	2957.8	9.2982
280	42.540	2781.5	3036.8	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

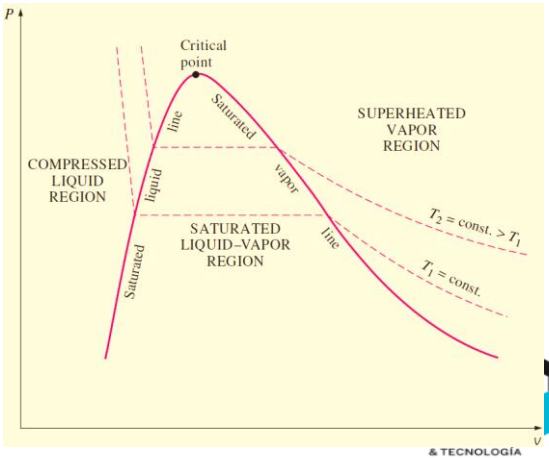
To know that we have superheated steam we use:

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

$P = 5bar$

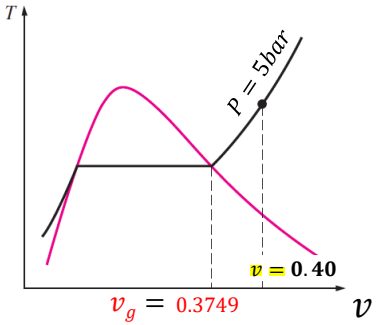
superheated vapor

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

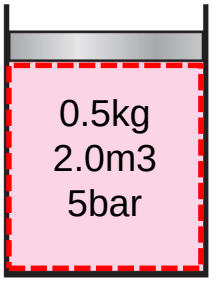
at a given P or $T \Rightarrow u > u_g$

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

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



UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA



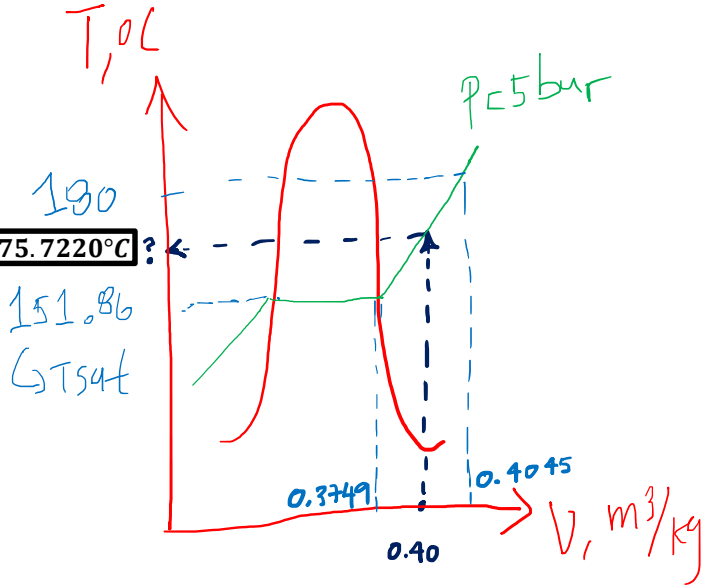
$v = 0.40 m^3/kg$

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



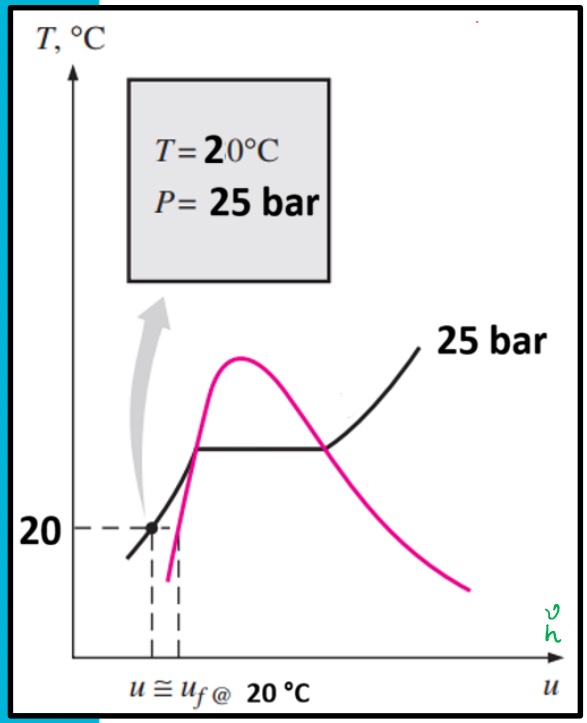
$$y - y_0 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_0)$$

Interpolating: $T = 175.7220\ °C$

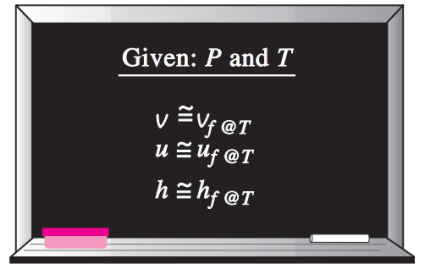
$$\frac{180 - 151.86}{0.4045 - 0.3749} = \frac{T - 151.86}{0.40 - 0.3749}$$

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.

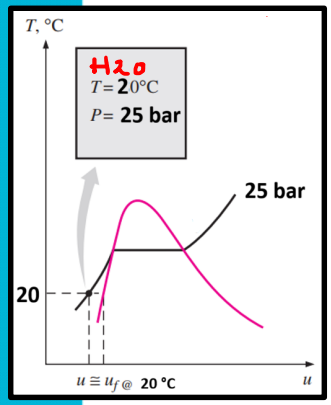


TABLE A-5

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

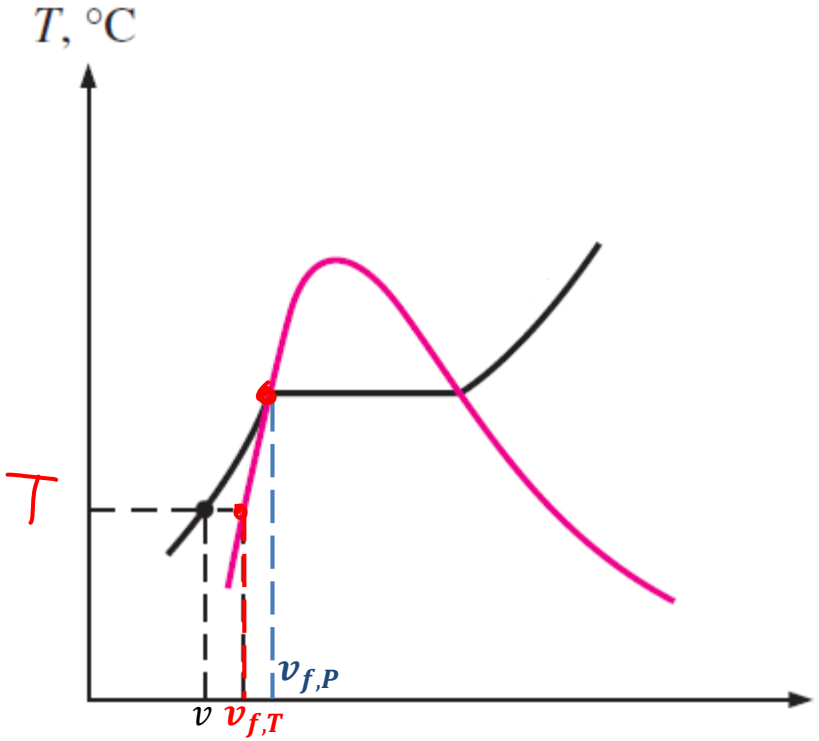
Properties of Saturated Water (Liquid–Vapor): Pressure Table

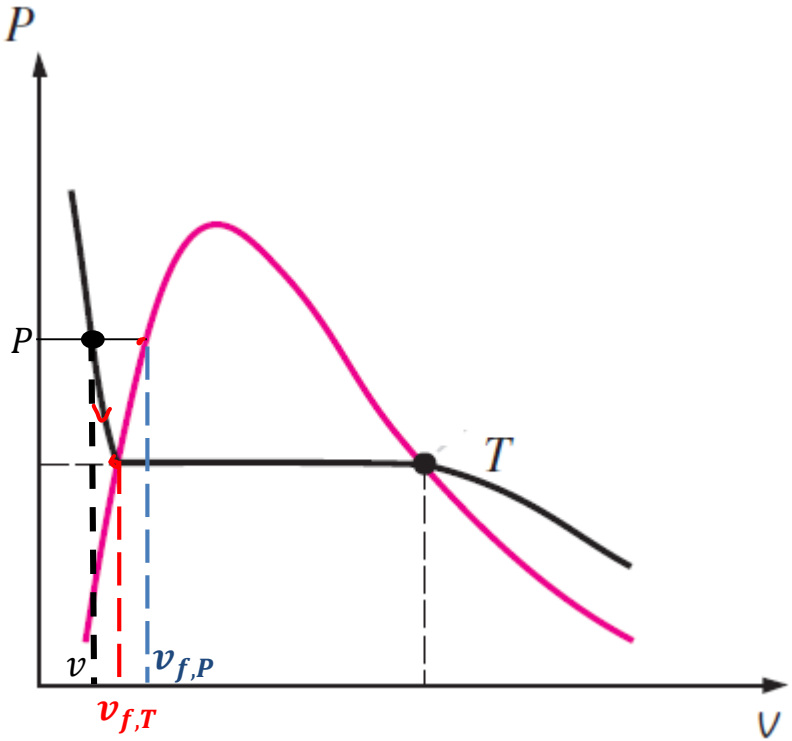
Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

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."

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

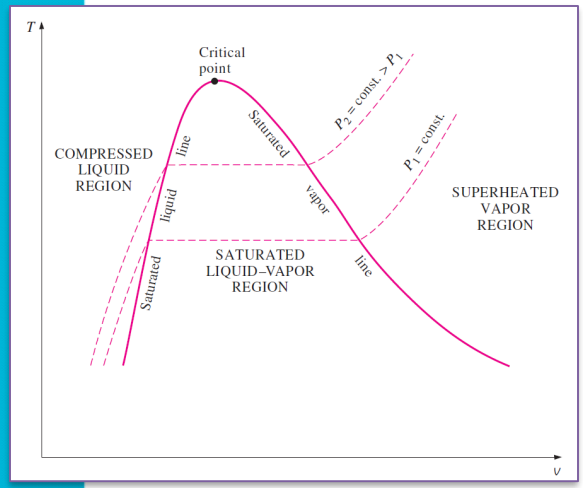


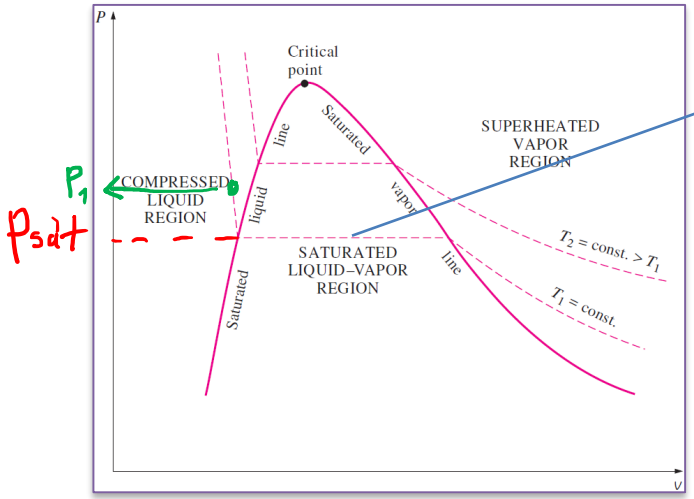


Same T, ignore P

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

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





$(P > P_{sat}$ 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 $T)$

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

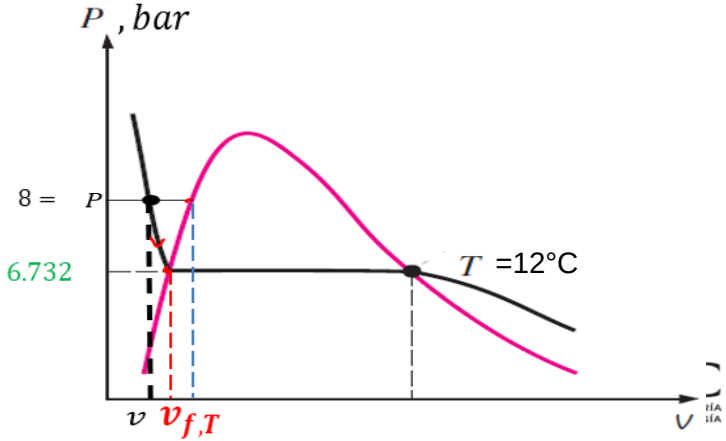
Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

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:

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

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA

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

UTEC
UNIVERSIDAD DE INGENIERÍA & TECNOLOGÍA


UTEC
UNIVERSIDAD DE INGENIERÍA Y TECNOLOGÍA
Thanks!