Thermodynamic_2026_1

Second Law_Entropy Control Volume_S12_1

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12_1

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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.

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Thermodynamics _ Evaluation

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

EXÁMENES	FECHAS
EXAMEN PARCIAL	(MAYO 11)
EXAMEN FINAL	(JULIO 6)

EXAMEN PARCIAL : Todos los temas vistos hasta la semana 6.
EXAMEN FINAL: Todos los temas vistos hasta la semana 15

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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	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.

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OBJECTIVE

Session 23-24: Apply the second law of thermodynamics for open, closed and transient systems.

Closed system entropy balance

Seaching by application in processes in addition to cycles!!

In symbols, the closed system entropy balance takes the form:

$$dS = \left(\frac{\delta Q}{T}\right)_b + \delta\sigma$$

[*change* in the amount of entropy contained within the system during some time interval] = [net amount of entropy *transferred in* across the system boundary during the time interval] + [amount of *entropy produced* within the system during the time interval]

$$\underbrace{S_2 - S_1}_{\text{entropy change}} = \underbrace{\int_1^2 \left(\frac{\delta Q}{T}\right)_b}_{\text{entropy transfer}} + \underbrace{\sigma}_{\text{entropy production}}$$

- **ENTROPY CHANGE OF PURE SUBSTANCES**

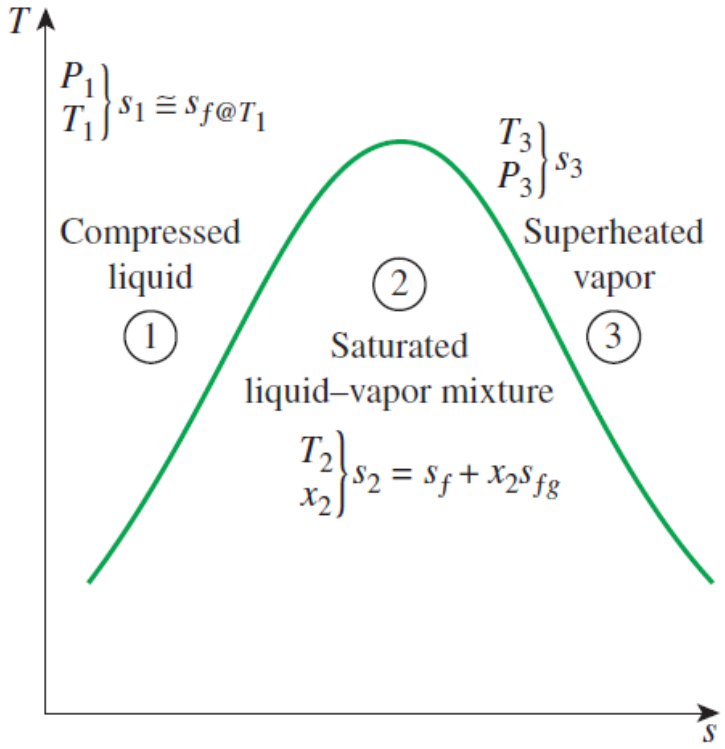


FIGURE The entropy of a pure substance is determined from the tables (like other properties).

TABLE A-17

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

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

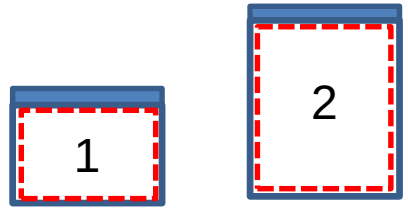
Press. bar	Temp. °C	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g	Press. bar
0.05	−93.28	1.570	6.752	−114.6	326.0	−114.6	474.4	359.8	−0.556	2.081	0.05

TABLE A-18

Properties of Superheated Propane Vapor

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
$p = 0.05$ bar $= 0.005$ MPa ($T_{sat} = -93.28$°C)				
Sat.	6.752	326.0	359.8	2.081

• Ideal gas



- Depends on temperature and pressure
- Tables A-22 and A-23 give s° for temperature

$$s_2 - s_1 = s_2^o - s_1^o - R\ln\frac{p_2}{p_1} \qquad \bar{s}_2 - \bar{s}_1 = \bar{s}_2^o - \bar{s}_1^o - \bar{R}\ln\frac{p_2}{p_1}$$

- Constant specific heat (e.g. helium, neon, or argon)

$$s_2 - s_1 = c_p \ln\frac{T_2}{T_1} - R\ln\frac{p_2}{p_1} \qquad s_2 - s_1 = c_v \ln\frac{T_2}{T_1} + R\ln\frac{v_2}{v_1}$$

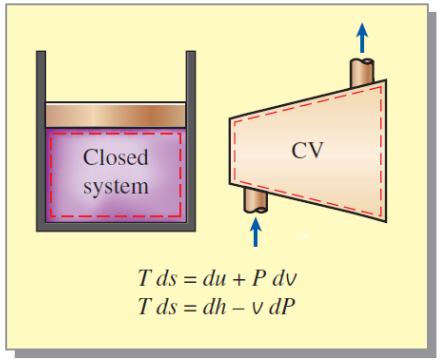


FIGURE 7–27
The *T ds* relations are valid for both reversible and irreversible processes and for both closed and open systems.

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• Entropy Change of an Incompressible Substance

KJ/kg · K

$$s_2 - s_1 = c \ln \frac{T_2}{T_1} \quad \text{(incompressible, constant } c\text{)}$$

▶ FOR EXAMPLE consider a system consisting of liquid water initially at $T_1 = 300$ K, $p_1 = 2$ bar undergoing a process to a final state at $T_2 = 323$ K, $p_2 = 1$ bar. There are two ways to evaluate the change in specific entropy in this case. The first approach is, $s_1 \approx s_f(T_1) = 0.3954$ KJ/kg · K and $s_2 \approx s_f(T_2) = 0.7038$ KJ/kg · K, giving $s_2 - s_1 =$ 0.308 KJ/kg · K.

The second approach is to use the incompressible model.

That is, with $c = 4.18$ KJ/kg · K from Table A-19, we get

$$s_2 - s_1 = c \ln \frac{T_2}{T_1} = \left(4.18 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}\right) \ln\left(\frac{323 \text{ K}}{300 \text{ K}}\right) = 0.309 \text{ KJ/kg} \cdot \text{K}$$

Comparing the values obtained for the change in specific entropy using the two approaches considered here, we see they are in agreement. ◀ ◀ ◀ ◀ ◀

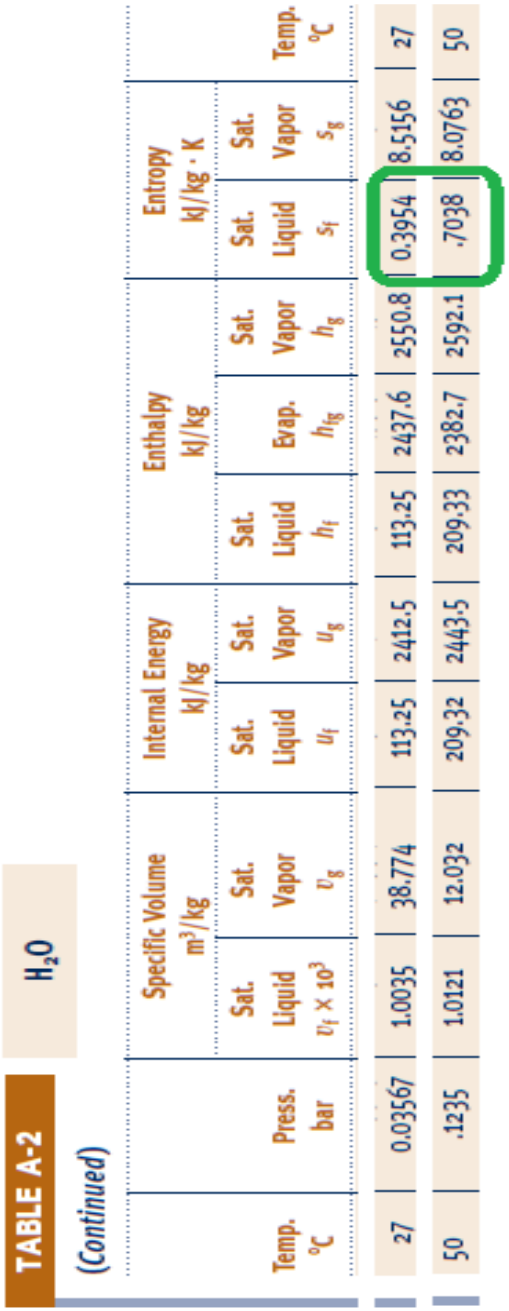

TABLE A-2 (Continued)

H_2O

Temp. °C	Press. bar	Specific Volume m³/kg		Internal Energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/kg · K		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	
27	0.03567	1.0035	38.774	113.25	2412.5		113.25	2437.6	2550.8	0.3954	8.5156	27
50	.1235	1.0121	12.032	209.32	2443.5		209.33	2382.7	2592.1	.7038	8.0763	50

Entropy Balance for Closed Systems

$$\left[\begin{array}{c}\textit{change} \text{ in the amount of} \\ \text{entropy contained} \\ \text{within the system during} \\ \text{some time interval}\end{array}\right] = \left[\begin{array}{c}\text{net amount of} \\ \text{entropy } \textit{transferred in} \\ \text{across the system} \\ \text{boundary during the} \\ \text{time interval}\end{array}\right] + \left[\begin{array}{c}\text{amount of } \textit{entropy} \\ \textit{produced} \text{ within the} \\ \text{system during the time} \\ \text{interval}\end{array}\right]$$

$$\underbrace{S_2 - S_1}_{\substack{\text{entropy} \\ \text{change}}} = \underbrace{\int_1^2 \left(\frac{\delta Q}{T}\right)_b}_{\substack{\text{entropy} \\ \text{transfer}}} + \underbrace{\sigma}_{\substack{\text{entropy} \\ \text{production}}}$$

- Where subscript **b** signals that the integrand is evaluated at the system boundary.
- It is important to highlight that at the end the **σ** allows us to compare two devices, for example, we must choose a temperature (much better constant!) that allows us to easily calculate the entropy that accompanies heat transfer ($\int \frac{\delta Q}{T}$)
- The method of taking average temperatures is an approximation, since we really must solve an integral, so it is preferred to take a slightly more external temperature that is constant during the process.

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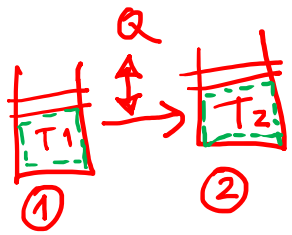
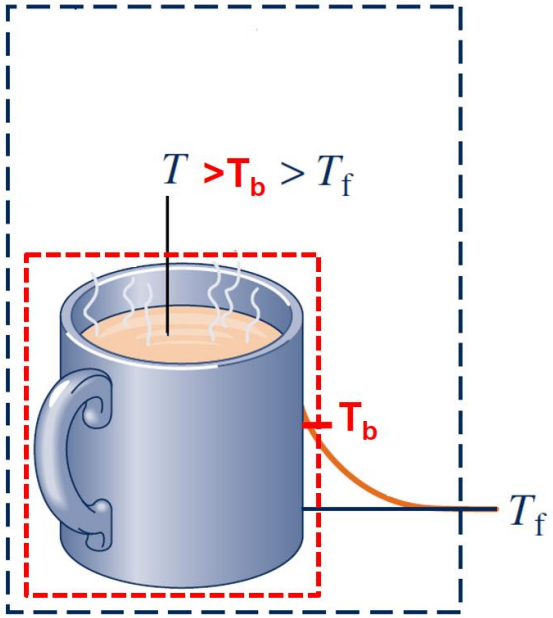


$$\int \frac{\delta Q}{T} + \sigma = S_2 - S_1$$

?

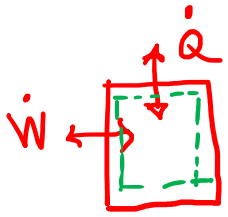
Boundary of enlarged system



Closed System Entropy Balance

If the temperature T_b is constant ⇨ $S_2 - S_1 = \frac{Q}{T_b} + \sigma$

where Q/T_b represents the *amount* of entropy transferred through the portion of the boundary at temperature T_b.



$$\frac{dE}{dt} = \dot{Q} - \dot{W} \quad \left[\frac{kJ}{s}\right] \Leftrightarrow kW$$

$$\frac{dS}{dt} = \frac{\dot{Q}}{T_b} + \dot{\sigma} \quad \left[\frac{kJ}{s \cdot K}\right] \Leftrightarrow \frac{kW}{K}$$

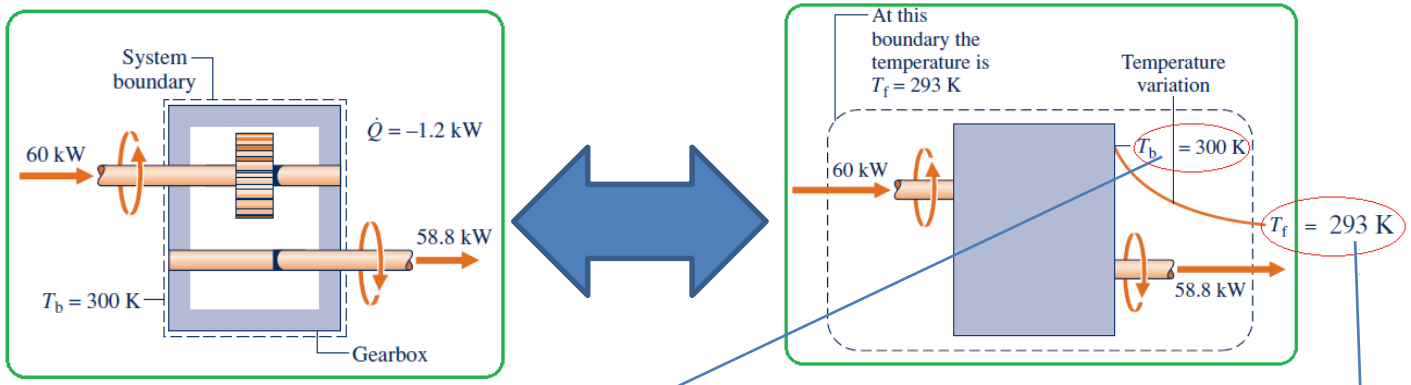
Closed System Entropy Rate Balance

Similarly, the quantity $\dot{Q}/T_j$ represents the *time rate* of entropy transfer through the portion of the boundary whose instantaneous temperature is T_j.

On a time rate basis, the **closed system entropy rate balance** is

$$\frac{dS}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \dot{\sigma}$$

where dS/dt is the time rate of change of entropy of the system. The term $\dot{Q}_j/T_j$ represents the time rate of entropy transfer through the portion of the boundary whose instantaneous temperature is T_j. The term $\dot{\sigma}$ accounts for the time rate of entropy production due to irreversibilities within the system (or extended-Tj)



(a)

$$\frac{dS^0}{dt} = \frac{\dot{Q}}{T_b} + \dot{\sigma}$$

$$\dot{\sigma} = -\frac{\dot{Q}}{T_b}$$

$$\dot{\sigma} = -\frac{(-1.2\ \text{kW})}{(300\ \text{K})} = 4 \times 10^{-3}\ \text{kW/K}$$

(b)

$$\frac{dS^0}{dt} = \frac{\dot{Q}}{T_f} + \dot{\sigma}$$

$$\dot{\sigma} = -\frac{\dot{Q}}{T_f}$$

$$\dot{\sigma} = -\frac{(-1.2\ \text{kW})}{(293\ \text{K})} = 4.1 \times 10^{-3}\ \text{kW/K}$$

The value of the rate of entropy production calculated in part a) measures the importance of the irreversibilities associated with friction and heat transfer within the gearbox. In part (b), an additional source of irreversibility is included in the extended system, namely the irreversibility associated with heat transfer from the outer surface of the gearbox at Tb to the surroundings at Tf. In this case, the irreversibilities within the gearbox are dominant, accounting for about 98% of the total rate of entropy production.

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Example 1:

A rigid tank contains 2 kg of air (ideal gas) at 200 kPa and 20°C. An electrical resistance is connected to the tank, it allows the passage of electrical current, in such a way that 100 kJ of electrical work pass into the interior of the container, until the temperature of the air inside is 80°C. Determine if this process is possible, knowing that the ambient temperature of 293 K.

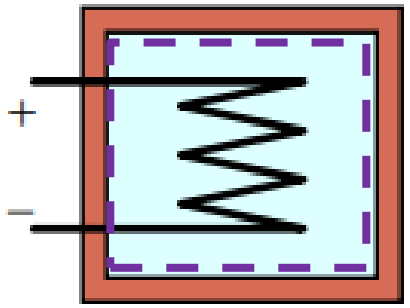
CAMINO 1 →

TABLE A-20

Ideal Gas Specific Heats

Temp. K	c_p Air	c_v Air
250	1.003	0.716
300	1.005	0.718
350	1.008	0.721

Solution:



System: Air inside the tank

Energy Balance: $m(u_2-u_1) = Q_{12} - W_{12}$

Electrical Work: $W_{12} = -100\ kJ$

Entropy Balance:

$$\Delta S = \int \frac{dQ}{T} + \sigma \quad \Leftrightarrow \quad m(\Delta s) = \frac{Q_{12}}{T_{amb}} + \sigma$$

```python
import numpy as np

# Definir los datos conocidos
T1 = 300  # K
T2 = 350  # K
cp1 = 1.005  # kJ/(kg·K)
cp2 = 1.008  # kJ/(kg·K)
cv1 = 0.718  # kJ/(kg·K)
cv2 = 0.721  # kJ/(kg·K)

# Temperatura para la interpolación
T_interpol = ((20+80)/2 )+273.15 # K  = 323,15 K

# Interpolación lineal para cp
cp_interpol = cp1 + ((cp2 - cp1) / (T2 - T1)) * (T_interpol - T1)

# Interpolación lineal para cv
cv_interpol = cv1 + ((cv2 - cv1) / (T2 - T1)) * (T_interpol - T1)

# Imprimir los resultados
print(f"T_interpol: {T_interpol} K")
print(f"cp_interpol: {cp_interpol} kJ/(kg·K)")
print(f"cv_interpol: {cv_interpol} kJ/(kg·K)")
```

```
T_interpol: 323.15 K
cp_interpol: 1.006389 kJ/(kg·K)
cv_interpol: 0.719389 kJ/(kg·K)
```

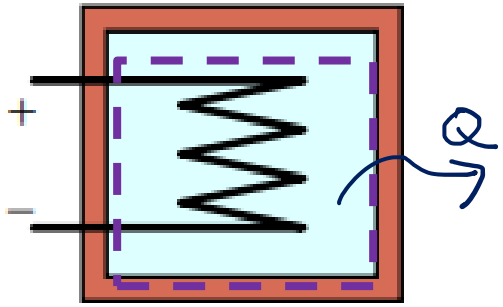
Process: Constant volume and mass so $v_2 = v_1$

Ideal gas, $R = 0.287$ kJ/kg-K

$= \frac{\bar{R}}{M}$

CAMINO 1: c_v, c_p cte { $\Delta u \rightarrow c_v$; $\Delta s \rightarrow c_v, c_p$

CAMINO 2: c_p variable { $\Delta u \rightarrow$ tablas ; $\Delta s \rightarrow s^o \rightarrow$ tablas



Assume constant specific heat then energy equation gives

$m(u_2-u_1) = Q_{12} - W_{12}$

$Q_{12} = m\,C_v\,(T_2-T_1) + W_{12} = 2 \times 0.719\,(80-20) - 100 =$ `-13.72 kJ`

Entropy Balance:

$$s_2 - s_1 = C_v \ln (T_2/T_1) + R \ln \frac{v_2}{v_1}$$

Isochoric Process:

$$v_2 = v_1, \quad \ln \frac{v_2}{v_1} = 0$$

Substituting, we have:

$$s_2 - s_1 = C_v \ln (T_2/T_1) = \texttt{0.1339 kJ/Kg.K}$$

Thus, from the entropy balance we get:

$$\sigma = m(\Delta s) - \frac{Q}{T_{amb}} = 2 \times \texttt{0.1339} + \frac{13.72}{293} = 0.315\ \text{kJ/K} \geq 0,$$

→ −13.72

↳ Irreversible

With this, we can conclude that this process is possible and irreversible.

```python
import math
# Definir las temperaturas
T1 = 20+273.15  # K
T2 = 80+273.15  # K
# Valor interpolado de Cv a 323.15 K
cv_interpol = 0.719  # kJ/(kg·K) (del cálculo de interpol
# Calcular el cambio de entropía
Ds = cv_interpol * math.log(T2 / T1)
# Imprimir el resultado
print(f"El cambio de entropía es {Ds:.4f} kJ/(kg·K)")
```

```
El cambio de entropía es 0.1339 kJ/(kg·K)
```

```python
# Definir los valores proporcionados
m = 2  # kg
delta_s = 0.1339  # kJ/kg.K
Q = 13.72  # kJ
T_amb = 293  # K
# Calcular la tasa de generación de entropía (σ)
sigma = m * delta_s + Q / T_amb
# Imprimir el resultado
print(f"La tasa de generación de entropía (σ) es: {sigma:
```

```
La tasa de generación de entropía (σ) es: 0.315 kJ/K
```

$$m(\Delta s) = \int \frac{dQ}{T} + \sigma =$$

$$s_2 - s_1 = c_v ln \frac{T_2}{T_1} + R ln \frac{v_2}{v_1}$$

```
1 import math
2 Ds= Cv*math.log((T2)/(T1))
3 print(f"el cambio de entropia  es {Ds:.4f} kJ/Kg.K")
```

```
el cambio de entropia  es 0.1339 kJ/Kg.K
```

$$s_2 - s_1 = c_p ln \frac{T_2}{T_1} - R ln \frac{p_2}{p_1}$$

```
1 import math
2 #P2/P1=T2/T1
3 #Cp=Cv+R
4 Ds2= Cp*math.log((T2)/(T1))-R*math.log(T2/T1)
5 print(f"el  de cambio entropia es {Ds2:.4f} kJ/Kg.K")
```

```
el  de cambio entropia es 0.1339 kJ/Kg.K
```

$P_1 V_1 = RT_1$

$P_2 V_2 = RT_2$

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Homework 1: Do it with table A-22 for internal energies and s°

$\Delta U = Q_{12} - W_{12}$

$m(u_2 - u_1) = Q_{12} - W_{12}$

↳ A22

↳ c_p variable

$$m(\Delta s) = \int \frac{dQ}{T} + \sigma$$

$T_1 = 20 + 273.15$

$$s_2 - s_1 = s_2^o - s_1^o - R\ln\frac{p_2}{p_1}$$

$$\bar{s}_2 - \bar{s}_1 = \bar{s}_2^o - \bar{s}_1^o - \bar{R}\ln\frac{p_2}{p_1}$$

$T_2 = 80 + 273.15 = 353.15$

TABLE A-22

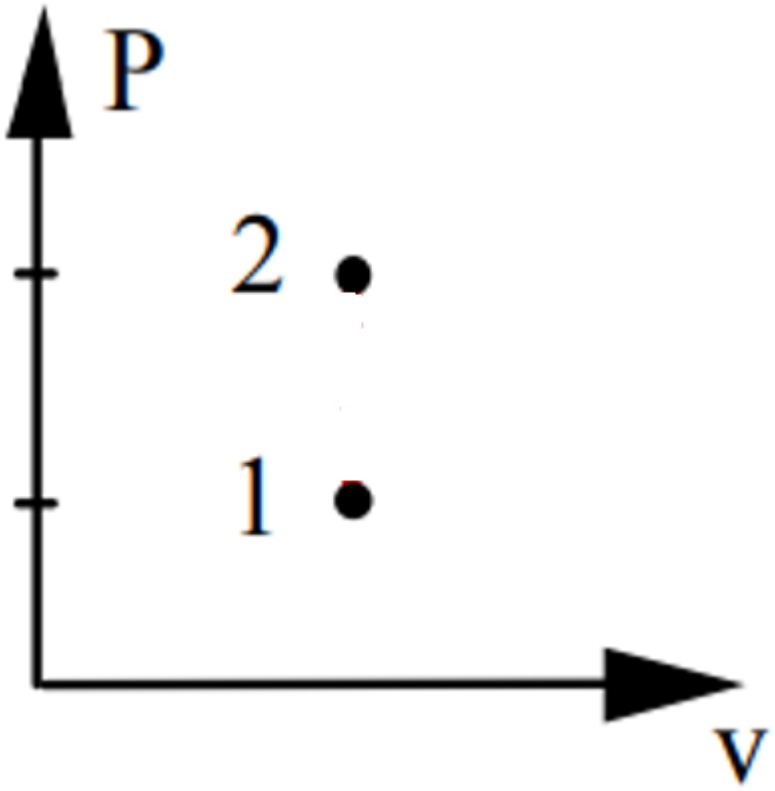
Ideal Gas Properties of Air

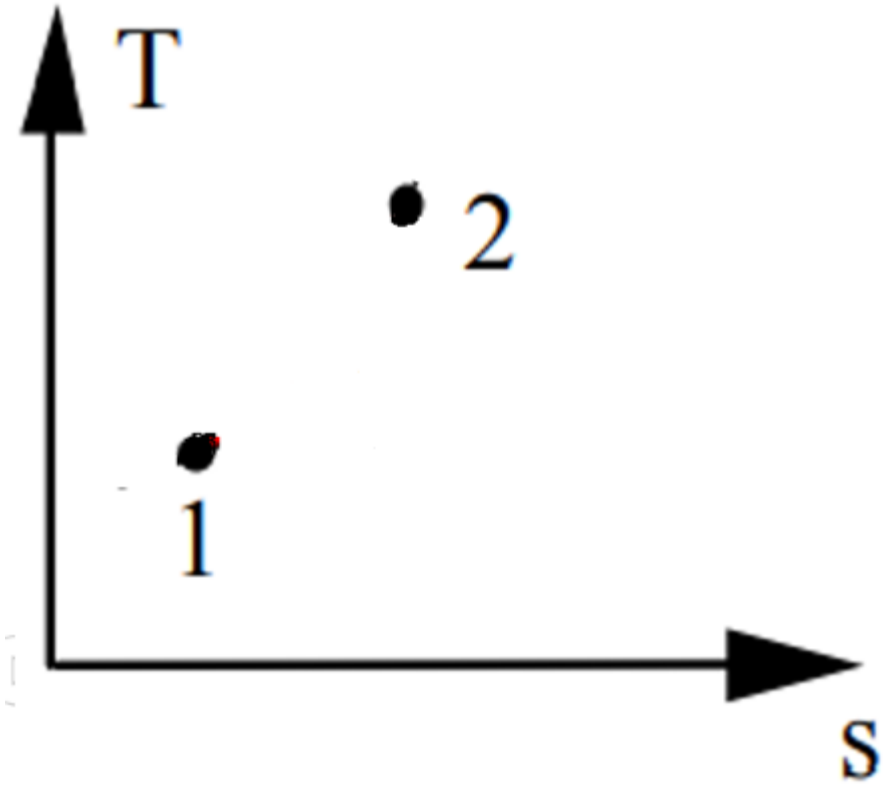
T(K), h and u(kJ/kg), s^o (kJ/kg · K)

				when $\Delta s = 0$[1]			
T	h	u (u_1)	s^o (s^o_1)	p_r	v_r	T	h
290	290.16	206.91	1.66802	1.2311	676.1	550	554.74
295	295.17	210.49	1.68515	1.3068	647.9	560	565.17
300	300.19	214.07	1.70203	1.3860	621.2	570	575.59
350	350.49	250.02	1.85708	2.379	422.2	650	659.84
360	360.58	257.24	1.88543	2.626	393.4	660	670.47

u_2 s^o_2

Homework 2: Complete the graphs with units and the corresponding values.





Second Law – Control Volume

– STATIONARY STATE

$$\frac{dS_{CV}}{dt} = \sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e + \sum \frac{\dot{Q}_j}{T_j} + \dot{\sigma}$$

→ asumiendo $T_{frontera}$ constante

$\dot{m}\, s \Rightarrow \frac{kJ}{sK} \Rightarrow \frac{kW}{K}$

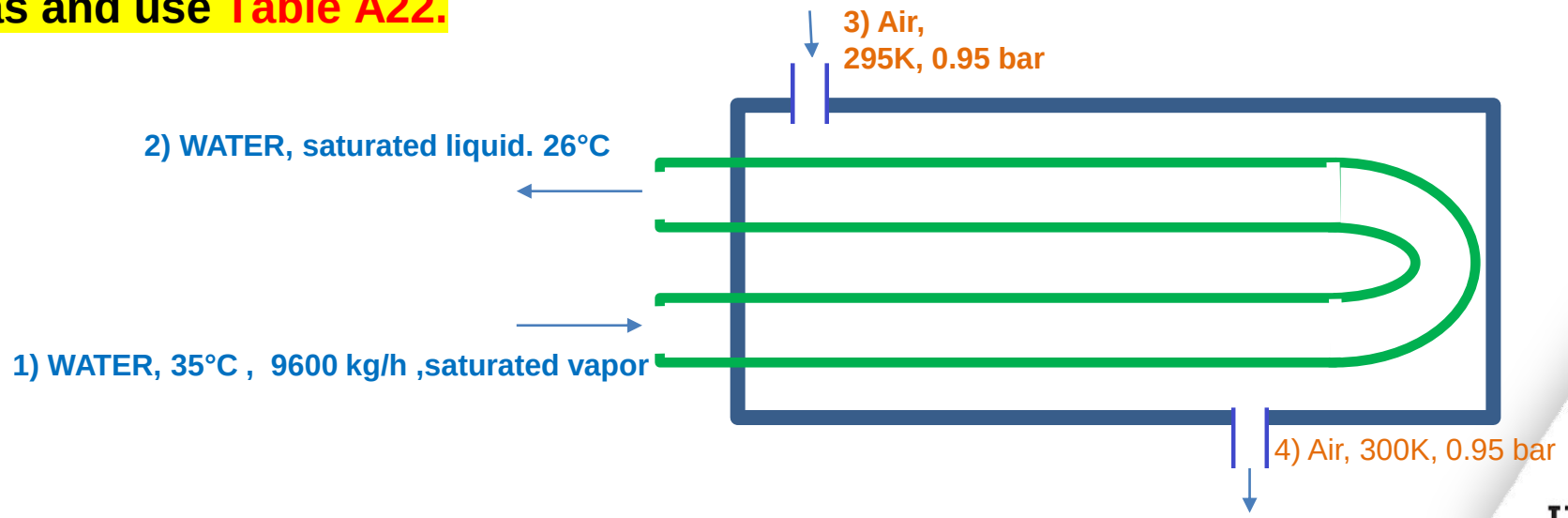
$\frac{kg}{s}$ ↖ ↳ $\frac{kJ}{kg.K}$

Example 2.3:

An air stream is heated in a heat exchanger with adiabatic walls like the one in the figure. For this purpose, saturated water vapor is used, which enters the unit at 35°C at a rate of 9600 kg/h and leaves as a saturated liquid at 26°C. If air enters at 0.95 bar pressure and 295 K, while leaving at 300 K and approximately the same pressure. Determine **a)** the air flow rate (kg/s) $\{\dot{m}_{Air}\}$..**b)** the rate of entropy generation $[kW/K]$ associated with this process.

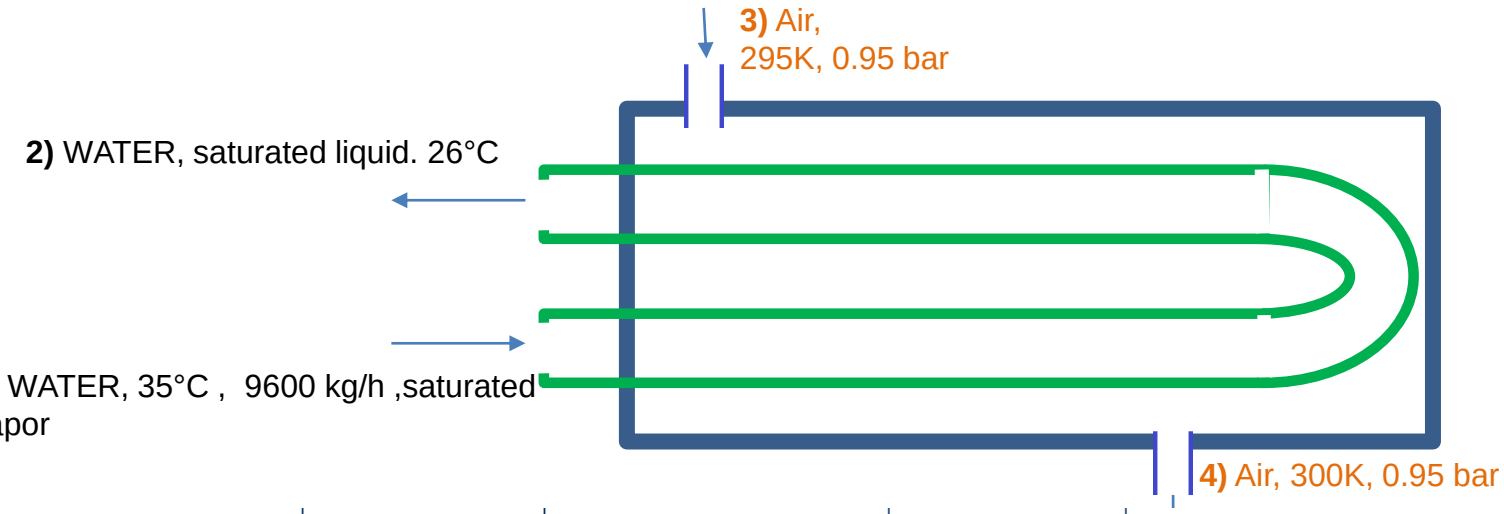
cp variable

Consider air as a ideal gas and use Table A22.



Assumptions **1** Steady operating conditions exist. **2** The heat exchanger is well-insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **3** Changes in the kinetic and potential energies of fluid streams are negligible. **4** Air is an ideal gas **5** The pressure of air remains constant.

Example 2.3:



Water Properties:

T_1= 35°C

Vapor Saturado

h_1= 2565.3 kJ/kg

s_1= 8.3531 kJ/kgK

T_2=26°C

Líquido Saturado

h_2= 109.07 kJ/kg

s_2= 0.3814 kJ/kgK

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
26	0.03363	1.0032	40.994	109.06	2411.1	109.07	2439.9	2549.0	0.3814	8.5367	26
35	0.05628	1.0060	25.216	146.67	2423.4	146.68	2418.6	2565.3	0.5053	8.3531	35

Air Properties:

T_3= 295 K

h3=295.17 kJ/kg

s_3^0 =1.68515 kJ/kgK

T_4= 300 K

h4=300.19 kJ/kg

s_4^0 =1.70203 kJ/kgK

P_3 = P_4= 0.95 bar

TABLE A-22

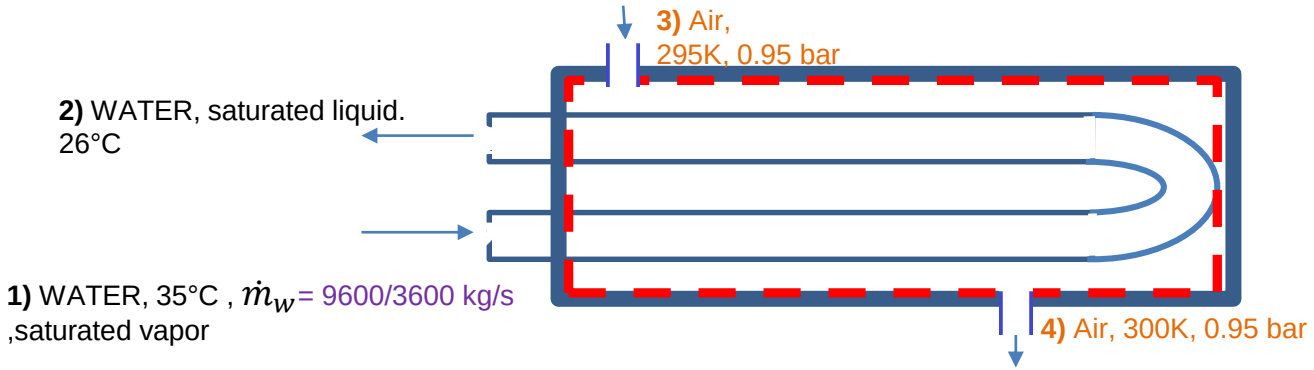
Ideal Gas Properties of Air

T(K), *h* and *u*(kJ/kg), s^o (kJ/kg · K)

T	h	u	s^o	when $\Delta s = o^1$: p_r	v_r
295	295.17	210.49	1.68515	1.3068	647.9
300	300.19	214.07	1.70203	1.3860	621.2

CV: All heat exchanger

Water Properties:
T_1= 35°C
Vapor Saturado
h_1= 2565.3 kJ/kg
s_1= 8.3531 kJ/kgK
T_2=26°C
Líquido Saturado
h_2= 109.07 kJ/kg
s_2= 0.3814 kJ/kgK



Air Properties:
T_3= 295 K
T_4= 300 K
$P_1 = P_2$= 0.95 bar
h3=295.17 kJ/kg
h4=300.19 kJ/kg
s_3^0 =1.68515 kJ/kgK
s_4^0 =1.70203 kJ/kgK

The energy balance stationary: :

3 Changes in the kinetic and potential energies of fluid streams are negligible.

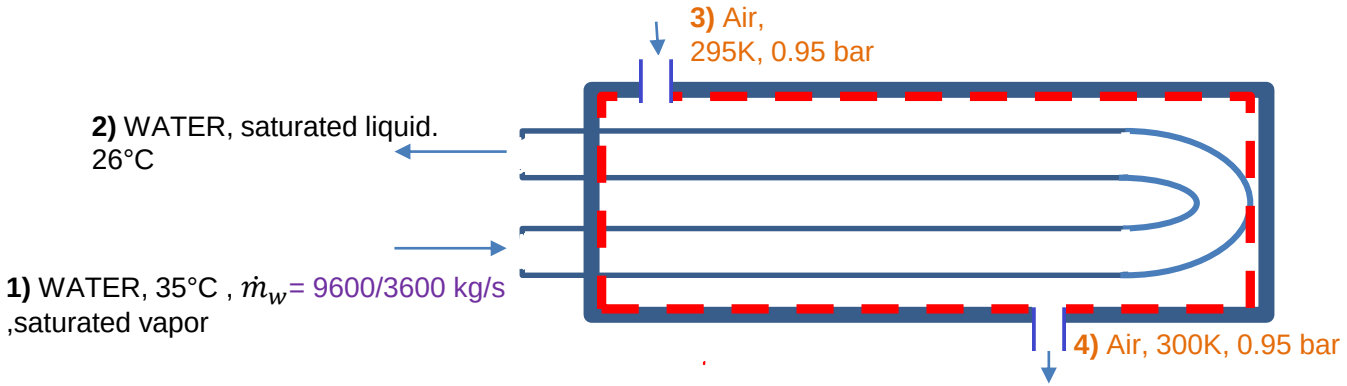
$$\frac{dE}{dt}^{0} = \dot{m}_w(h_1 - h_2) + \dot{m}_{air}^{?}(h_3 - h_4) - \dot{Q} - \dot{W}$$

$$\dot{m}_{air} = 1304.7703 \frac{kg}{s}$$

```
# Definir las propiedades del agua y el aire
h1 = 2565.3   # kJ/kg
h2 = 109.07   # kJ/kg
h3 = 295.17   # kJ/kg
h4 = 300.19   # kJ/kg

# Tasa de flujo másico de agua (convertida a kg/s)
m_dot_w = 9600 / 3600  # kg/s

# Calcular la tasa de flujo másico de aire (m_dot_a)
m_dot_a = -m_dot_w * (h1 - h2) / (h3 - h4)
m_dot_a=round(m_dot_a,4)
# Imprimir los resultados
print(f"Tasa de flujo másico de aire (m_dot_a): {m_dot_a} kg/s")


Tasa de flujo másico de aire (m_dot_a): 1304.7703 kg/s
```

Water Properties:
T_1= 35°C
Vapor Saturado
h_1= 2565.3 kJ/kg
s_1= 8.3531 kJ/kgK
T_2=26°C
Líquido Saturado
h_2= 109.07 kJ/kg
s_2= 0.3814 kJ/kgK

CV: All heat exchanger



Air Properties:
T_3= 295 K
h3=295.17 kJ/kg
s_3^0 =1.68515 kJ/kgK

T_4= 300 K
h4=300.19 kJ/kg
s_4^0 =1.70203 kJ/kgK
P_3 = P_4= 0.95 bar

Entropy balance for open system - stationary:

$$\frac{dS}{dt} = \frac{\dot{Q}}{T} + \dot{m}_w(s_1 - s_2) + \dot{m}_{air}(s_3 - s_4) + \dot{\sigma}$$

$$\left(s_4^0 - s_3^0 - R\ln\frac{P_4}{P_3}\right)$$

$$\dot{\sigma} = \dot{m}_w(s_2 - s_1) + \dot{m}_{air}(s_4 - s_3)$$

$$\dot{\sigma} = 0.7667 \text{ kW/K}$$

```python
import math
import numpy as np

# Propiedades del agua
s1 = 8.3531   # kJ/kg.K
s2 = 0.3814   # kJ/kg.K

# Propiedades del aire
so3 = 1.68515  # kJ/kg.K
so4 = 1.70203  # kJ/kg.K
R   = 0.287    # kJ/kg.K (constante de gas del aire)
P3  = 0.95     # bar
P4  = 0.95     # bar

# Tasa de flujo másico de agua (kg/s)
m_dot_w = 9600 / 3600  # kg/s

# Tasa de flujo másico de aire (kg/s)
m_dot_a = 1304.7703

# Cálculo de la generación de entropía (kW/K)
S_dot_gen = m_dot_w * (s2 - s1) + m_dot_a * (so4 - so3 - R * np.log(P4 / P3))

# Imprimir resultados
print(f"Tasa de generación de entropía (S_dot_gen): {S_dot_gen:.4f} kW/K")
```

```
Tasa de generación de entropía (S_dot_gen): 0.7667 kW/K
```

(A) TAREA: EVALUAR (AIRE) $(s_4 - s_3)$ con C_p y C_v ctes. y $\Delta h = C_p \Delta T$

(B) se podrá escoger otro volumen de control?

Second Law – Control Volume

-TRANSIENT PROCESS

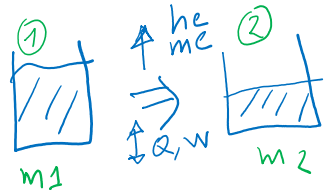
Energy Balance

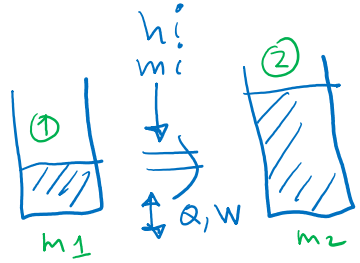
[kW] $\frac{dE}{dt} = \dot{m}(h_1 - h_e) + \dot{Q} - \dot{W}$ → stationary 1 → 2, $\dot{m}_1 = \dot{m}_2$

{transient} Typically the evacuation or filling of a tank

[KJ] $m_2u_2 - m_1u_1 = m_ih_i - m_eh_e + Q_{12} - W_{12}$ (1)

[kg] $m_2 - m_1 = m_i - m_e$ (2)



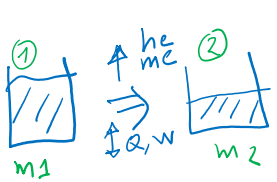


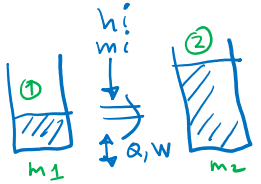
Entropy balance

$\left[\frac{kW}{K}\right]$ $\frac{ds}{dt} = \dot{m}(s_1 - s_2) + \frac{\dot{Q}}{T} + \dot{\sigma}$ → stationary 1 → 2

{transient} Typically the evacuation or filling of a tank

$\left[\frac{KJ}{K}\right]$ $m_2s_2 - m_1s_1 = m_is_i - m_es_e + \frac{Q}{T_b} + \sigma$

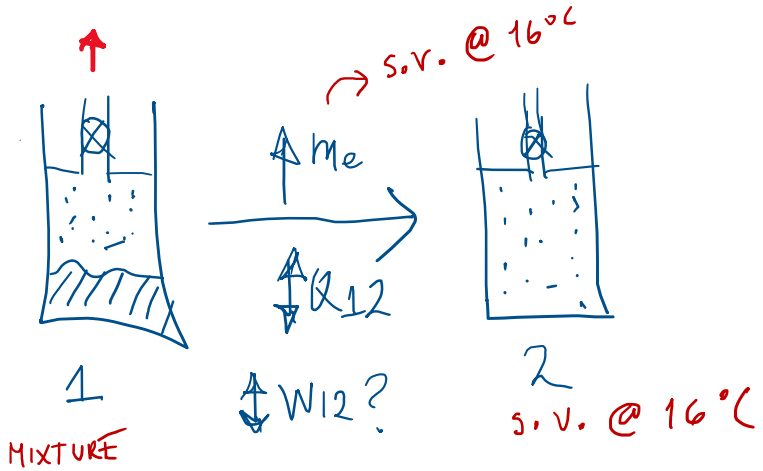




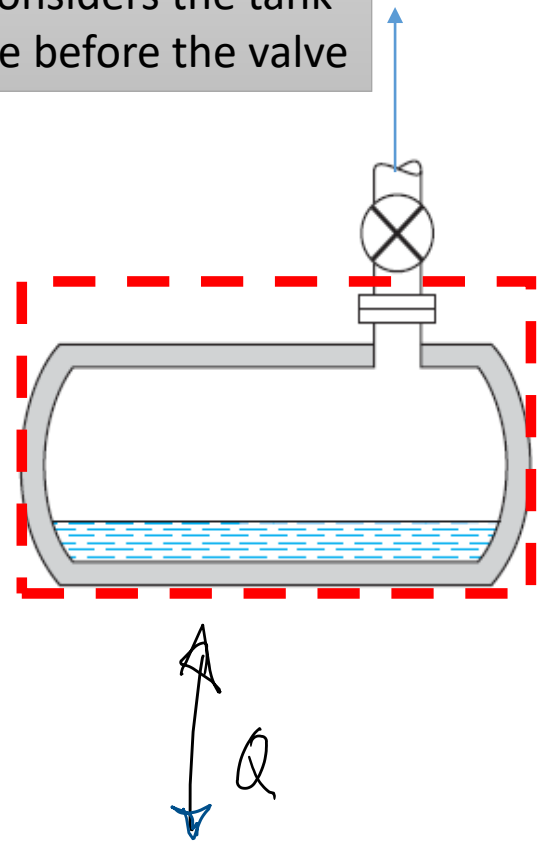
EXAMPLE 3 – TRANSIENT PROCESS

1-m^3 rigid tank contains 100 kg R-22 at a temperature of 16°C, as shown in figure. A valve on top of the tank is opened, and saturated vapor is throttled to ambient pressure of 100 kPa and flows to a collector system. During the process, the temperature inside the tank remains at 16°C by heat transfer from the 20°C ambient. The valve is closed when no more liquid remains inside (only saturated vapor remains). Calculate the heat transfer to the tank and total entropy generation in the process.

state 1 $\begin{cases} T_1 = 16^oC \\ v_1 = \frac{1m^3}{100kg} = 0,01 \frac{m^3}{kg} \end{cases}$ > MIXTURE



The selected CONTROL VOLUME considers the tank and the pipe before the valve



Mass balance for a transient process

$$m_2 - m_1 = m_i - m_e$$

Energy balance for a transient process

$$m_2 u_2 - m_1 u_1 = Q - W + m_i h_i - m_e h_e$$

Defining the states:

Initial (1) = R22 at 16°C and $v = \frac{1}{100} = 0.01 \frac{m^3}{kg}$ MIXTURE

Final (2) = R22 at 16°C as saturated vapor

Mass leaving (s) = R22 at 16°C as saturated vapor

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 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
16	8.1268	0.8162	0.0291	63.53	231.59	64.19	191.02	255.21	0.2442	0.9048	16

Initial (1) = R22 at T_1= 16°C and $v_1 = \frac{1}{100} = 0.01\ \frac{m^3}{kg}$

$x_1 = \frac{0.01 - 0.8162\times10^{-3}}{0.0291 - 0.8162\times10^{-3}} = \mathbf{0.3247}$, $u_1 = 63.53 + 0.3247 \times (231.59 - 63.53) = \mathbf{118.0991\ kJ/kg}$

$s_1 = 0.2442 + 0.3247 \times (0.9048 - 0.2442) = \mathbf{0.4587\ kJ/kgK}$

Final (2) = R22 at 16°C as saturated vapor

$m_2 = \frac{1\ m^3}{0.0291} = 34.3643\ kg$, $u_2 = 231.59\ kJ/kg$, $s_2 = 0.9048\ kJ/kgK$

Mass leaving (s) = R22 at 16°C as saturated vapor

$m_e = m_1 - m_2 = 100 - 34.3643 = 65.6357\ kg$, $h_e = 255.21\ kJ/kg$, $s_e = 0.9048\ kJ/kgK$

Energy balance for transient process :

$$m_2 u_2 - m_1 u_1 = Q - m_e h_e$$

$$34.3643 \times 231.59 - 100 \times 118.0991 = Q - 65.6357 \times 255.21$$

$$\boxed{Q = 12899.4092\ kJ}$$

Entropy balance for transient process:

$$m_2 s_2 - m_1 s_1 = \sum \frac{Q}{T_0} + \sum m_i s_i - \sum m_e s_e + \sigma$$

$$m_2 s_2 - m_1 s_1 = \frac{Q}{T_0} - m_e s_e + \sigma$$

$$34.3643 \times 0.9048 - 100 \times 0.4587 = \frac{12899.4092}{20 + 273.15} - 65.6357 \times 0.9048 + \sigma$$

$$\boxed{\sigma = 0.6073\ kJ/K}$$

TAREA GRUPAL_ULTIMO HORARIO ANTES DE LA ENTREGA

Horas de atención - Jhordy Manrique

Horas de atención - Jhordy Manrique

Thanks!

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