5.2.2020

Thermodynamics → Energy — PE, KE, IE (internal)

Introduction:

work ⇆ Heat

from phase to another [different phase of Energy]

internal Energy → Kinetic energy

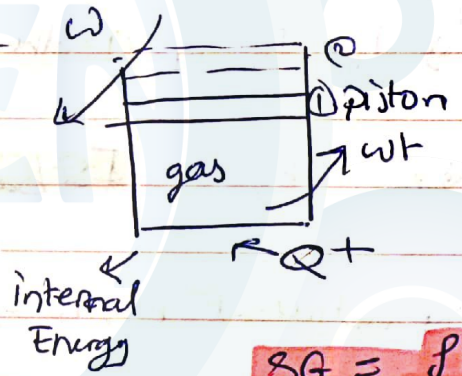
1st law of thermodynamics → Energy conservation

+ energy is property of thermodynamics

$U = Q - W$ [valid in closed systems]

U: internal, Q: heat, W: work

Closed system → there is no mass transfer $\dot{m} = 0$



$SG = \frac{\rho}{\rho_{water}}$

Specific gravity / relative density

$PV = mRT$

properties of sys

extensive → depends on mass of the sys

intensive → does not depend on mass → generalize formulas

e.i (Energy) (V) $\xrightarrow{\div m}$ (specific volume) ν $\rightarrow$ (ρ) D . T . P

$\gamma = \rho . g$

specific weight

$\frac{U}{m} = u$ specific internal Energy

* process: Any change that undergoes from one equilibrium state to another. (sys)

$$E = Q - W$$

$$KE + PE + U = Q - W$$

adiabatic / isolated

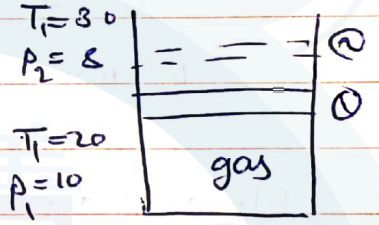
System: closed boundary that contain mass ↓ const.

or

surr ← energy transfer ← Environment

not isolated

properties change ↑ process ↑



* process: State change

↳ $T_1 = T_2$ ⇒ Isothermal process (T const)

↳ $P_1 = P_2$ ⇒ Isobaric process (P is const)

↳ adiabatic process (Q = zero)

↳ polytropic process ⇒ $P_1 V_1^n = P_2 V_2^n = C$

↳ steady-state process ⇒ there is no change in properties with respect to time

$\frac{\partial prop}{\partial t} = 0$

↳ Unsteady- or transient ⇒ prop. changes with time

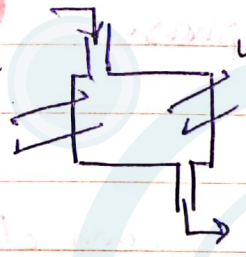
properties

Cycle → processes starts from point and ends from the same point

Open system → mass inside the sys is not const.

$\dot{m} = \frac{VA}{v}$

specific volume



state

① $\dot{m}_1 = \dot{m}_2$

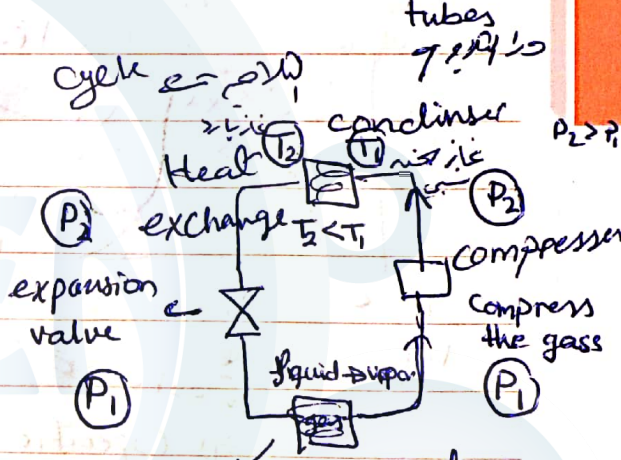
$\dot{m}$ ⇐ mass fluid

② $\dot{m}_1 > \dot{m}_2$ accumalation

③ $\dot{m}_1 < \dot{m}_2$ decomulation'on

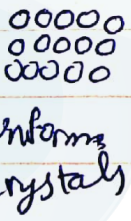
$$KE + PE + \underbrace{(U + PV)}_{H} = Q - W$$

H ⇐ molecules
- internal Energy
- for open systems



Ch:4

* phases → solid, liquid, gas

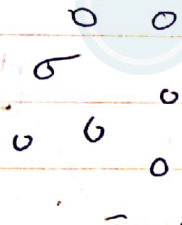


I can form them → Crystals

Compressible or non compressible

const

const



not const

Pure Substances

$u, h, V, T, P \Leftarrow P, T \leftarrow$ State of materials

liq
- compressed liq
- saturated liq

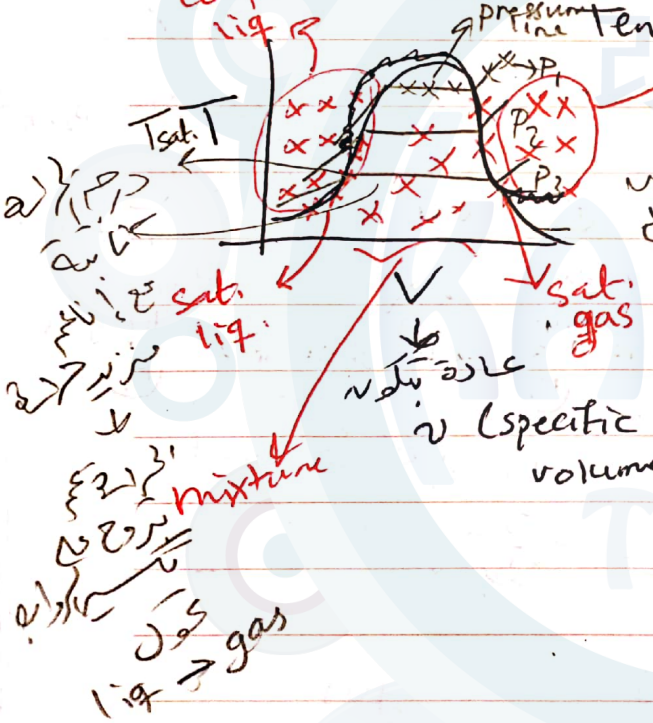
mixture

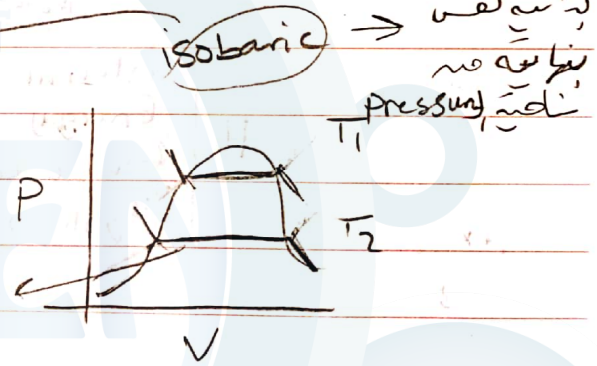
gas
- saturated Vapor
- Syper Heated Vapor

for any material that has many phases

Carbon dioxide → 1 (single) phase

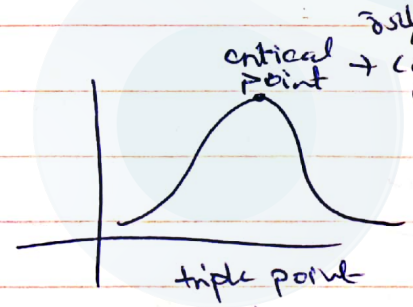
Temp. Vs. Volume





Sensable Heat

Latent Heat → phase change Heat



compressed liq → Syper heated directly

solid → liquid → vapor

فما بدي يعطيني ايها لتحديد الحالة — independent: T, Psat

0.5 kg , water

$T = 20°C$
$P = 200$ kPa] → بدك خاصيتين ما يعتمدوا على بعض عشان تقدر تحدد حالة المادة. independent prop.

$v = 0.01 \frac{m^3}{g}$ ← (T, P)

v ما بعطيني / P ما بعطيني — internal energy ← Energy change — sys. ال اهم

properties stable

P vs. v diagram

مثلاً بختار ال temp. table

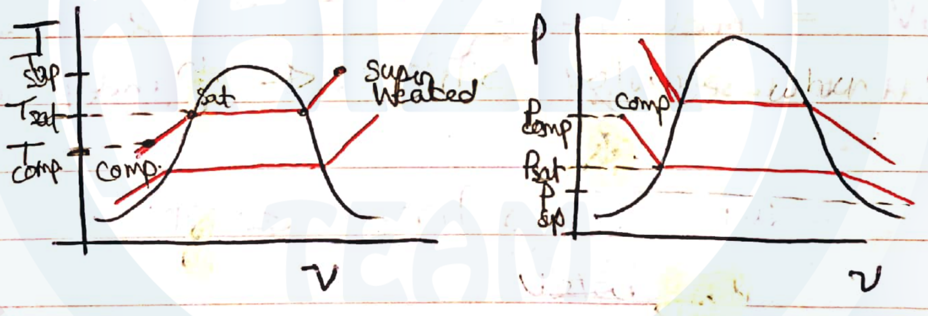
T °C	Psat kPa	v_f	v_g	u_f	u_g
0					
1					
2					
⋮					
20	2.3				

↓ هاي ال pressure الي اعطي

$P_{superheated} < P_{sat} < P_{comp.}$

$200 < 233.9$

Super heated



at sat.
$v = v_g$
$v = v_f$
$u = u_f$
$h = h_f$

$T_{comp.} < T_{sat} < T_{sup.}$ $P_{sup.} < P_{sat} < P_{comp.}$

Compressed (backed) → smaller volume ⇒ $T < T_{sat}$; $P > P_{sat}$;
$v < v_g$; $v < v_f$

mixture ⇒ $v_g < v < v_f$

Super-heated (gas) → bigger volume ⇒ $T > T_{sat}$; $P < P_{sat}$;
$v > v_g$; $v > v_f$

open sys. → h → specific inthalpy
closed sys. → u → specific internal E

v_f → sat. liq

v_g → sat gas

** compressed liquid

but p is less than 5

then we assume that

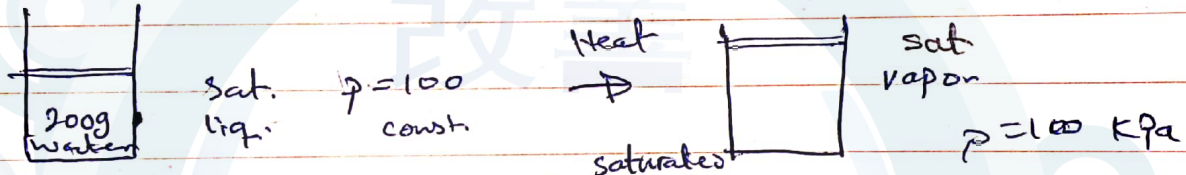
the material state is sat liq.

** interpolation ← 45 لو كانت القيمة

between 40 & 50

Examples 4-3] Volume & energy state change during Evaporating.

given the states



① $\Delta V = m\Delta v = V_2 - V_1$ (0.2 g) $\begin{cases} v_1 = v_f \\ v_2 = v_g \end{cases}$ منين؟ 2 متغيرات independent

② ΔH → closed sys. change of energy Enthalpy

$V_1 = v_f * m$

$V_2 = v_g * m$ → ΔV

① $\Delta V = m (v_g - v_f)$ (m → kg)

$= 0.2 (1.6941 - 0.001043) = 3.38614\ m^3$

② $\Delta H = m (h_g - h_f)$ → h_{fg}

$= 0.2 (2675 - 417.51)$

$= 0.2 (2257.5)$

$= 451.498$

لو كانت الحالة mixture

لازم نجيب منين v_g & v_f

or h_g & h_f

Quality → $x = \frac{\text{mass of vapor}}{\text{total mass}}$ → 0 → 1

0 ↓ sat. liquid — 1 ↓ sat. vapor

$v = v_f + x(v_{fg})$ ← $(v_g - v_f)$

$h = h_f + x\, h_{fg}$

$u = u_f + x\, u_{fg}$

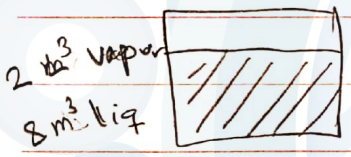
$V \rightarrow V_{avg.} = V_f + V_g$

$v = \frac{V}{m}$

Ex:

rigid tank → volume is const.

State ? → mixture → x



$T = 90^\circ C$ → pressure → temp. table

50 kg

① $P = ?!$

↓ mixture

@ $V = ?!$

Sat. liquid ، mixture or sat vapor

Line خطوط have the same P

$x = \frac{2}{10} = 0.2$

$P = 70.183$ KPa

$v = v_f + x\, v_{fg}$

$= 0.001036 + 0.2(2.35826) = 0.472688\ m^3/kg$

$V = v \cdot m$

$= 0.472688 \cdot 50$

$= 23.6344\ m^3$

Ex 4-5 Prop. of sat. liquid-vapor mixture

$V = 80\ l$, mass = 4 kg, R = 134a, $P = 160$ KPa

① T = ?! ⇝ pressure table

② X ?! ⇒ mixture quality

③ H ?!

④ V_{vapor} ?!

① $T = -15.6\ ^\circ C$ ⇒ from table A-12

② $v = v_f + X v_{fg}$ $\qquad v = \frac{V}{m} = \frac{80 \times 10^{-3}}{4}$

$\Rightarrow v = \frac{80 \times 10^{-3}\ m^3}{4\ kg} = 0.02\ m^3/kg$

$\Rightarrow x = 0.157 \rightarrow$ liquid > gas.

③ $h = h_f + X h_{fg}$

$= 64.2\ KJ/Kg$

$H = 64.2 * 4 = \ldots$

④ $V_{vapor} \Rightarrow X = \frac{\text{mass of vapor}}{\text{tot. mass}}$

mass of vapor $= 0.157 * 4$

V_{vapor} = mass of vapor $* v_g$

Ex:

$P = 0.5 \text{ MPa} \rightarrow \times 10^3 \rightarrow 500 \text{ KPa}$

$h = 2890 \text{ KJ/Kg}$

$T = ?!$

1) Know the state of material → super heated

2) super heated جداول → $P = 0.5$ MPa; → Inthalpy → h

↓ [illegible] ← interpolation

T	h
200	2855.8
250	2961.0

→ 2890

ايجاد: 216.3

materials with one state

Introduction
Ideal gas law

temp. → Kelvin

$$PV = mRT$$

$$Pv = RT$$

C → K

$$Pv = ZRT$$

$Z = 1$ works as an indecator

كل ما كان اقرب للواحد

[illegible]

Ideal gas

$$Z = \frac{Pv}{RT}$$

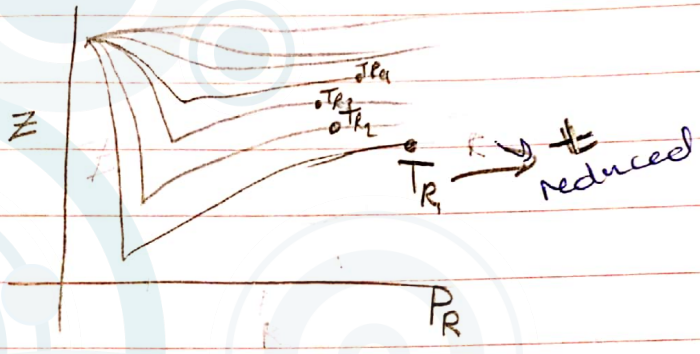
compressability factor

Principle of corresponding state: the Z factor for all gasses is approximately the same at the same Reduced (P & T).

compressibility factor

$$Z = \frac{V_{actual}}{V_{Ideal}}$$

Figure A-28) page: 1012



Range of slight error for Ideal gas: $Z = 0.9 - 1.1$

$$\frac{Pv}{RT} = Z$$

Z ایده‌آل ← T_R و P_R کم

Normalization:-

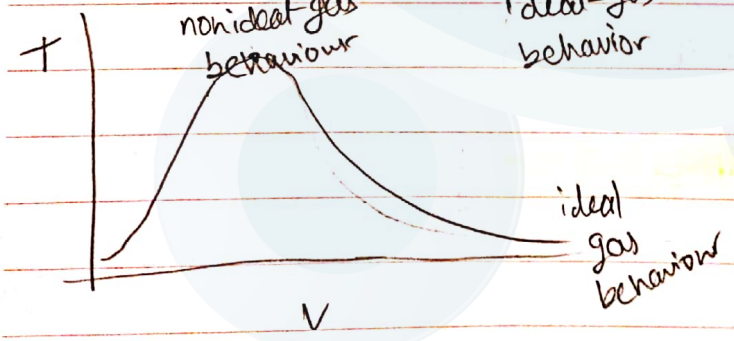
$$T_R = \frac{T_{actual}}{T_{critical}} \quad ; \quad P_R = \frac{P_{act}}{P_{cri}}$$

T_R: reduced temp. ; P_R: Reduced Pressure

① $P_R \ll 1$ ⇒ most gasses behavior as an Ideal gas

② $P_R \leq P_{cr}$ ⇒ Ideal gas نیست

③ $T_R > 2$ ⇒ with a good accuricy it's an Ideal gas



Ideal-gas behavior

*Gases Follow The Ideal-gas Eqn:-

① low pressure

② High temp.

17.2.2020

table A-1

$R = 0.043$, $T_{cr} = 374$, $P_{cr} = 4.059$

Ex: 4-11

R-134 → Specific Volume

$P = 1\ MPa$, $T = 50\ ^\circ C$ → $50 + 273.15$ } $0.021796\ \frac{m^3}{kg}$

Ideal gas

percentage of error

① Completely Ideal gas law

$PV = nRT$

$v = \frac{RT}{P}$ (table A-1) $= \frac{0.0813 * (50 + 273)}{1000} = 0.02632\ \frac{m^3}{kg}$

② Z

$R = 0.0815$

$P_{cr} = 4.059\ MPa$

$T_{cr} = 374.2\ K$

$T_R = \frac{T}{T_{cr}}$ → (write)

$P_R = \frac{P}{P_{cr}}$

Figure A-28 ② use the generalized compressibility chart.

$Z = 0.84$ → not Ideal gas

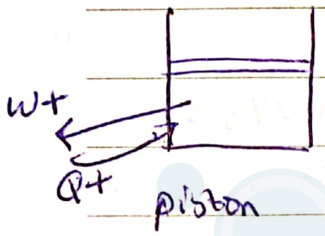
$PV = ZRT$

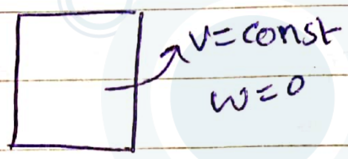
$v = Z\frac{RT}{P} = 0.022113\ \frac{m^3}{kg}$

$v = Z\, v_{ideal}$

Ch:5) Closed system

done on the system -W





$\partial W_b = F ds$
$= P A ds$
$\partial W_b = P dV$

1st law of thermodynamics

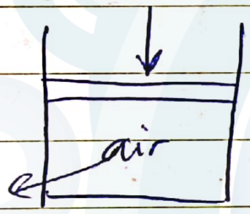
عبارة عن مهملين

$\Delta U + \Delta KE + \Delta PE = Q - W$

$\Delta U = Q - W$

Ex: $V_1 = 0.4\ m^3$ air ; $P_1 = 100$ kPa ; $T_1 = 80°C$

assume **Ideal gas**



$P_1 = 100$ kPa
$V_1 = 0.4\ m^3 \rightarrow V_2 = 0.1\ m^3$
$T_1 = 80 \rightarrow$ const // $T_2 = 80°C$

Find the (work) done on this system.

Isothermal process

const T يعني internal energy اللي بنفقده من ال

lost energy + internal energy ← W

$W = \int_1^2 P \cdot dV = \int \frac{F}{A} \cdot A \cdot ds$

$PV = mRT$ (or mRT_0) — could be replaced

$P_1V_1 = P_2V_2$

$P = \frac{C}{V}$

$W = \int_1^2 \frac{C}{V} \cdot dV = C \ln V_2/V_1$ (could be replaced $\frac{P_2}{P_1}$)

ازا زادت isothermal

$\partial W = F ds = \partial PA \cdot ds$

$\partial W = P \cdot dV$

$W = P_1V_1 \cdot \ln\left(\frac{V_2}{V_1}\right)$

$= 100 \cdot 0.4 \ln\left(\frac{0.1}{0.4}\right) = -55.5$ kJ

when $n=1$

$PV = C \rightarrow$ ideal gas

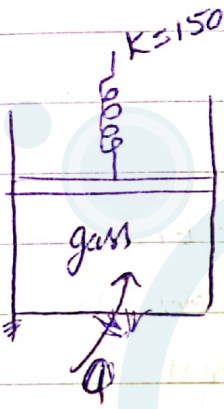
T is const. ↓ isothermal

polytropic $\rightarrow PV^n = C$ $\quad P_1V_1^n = P_2V_2^n$

$$W = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{mR(T_2-T_1)}{1-n} \quad ; \; n \neq 1$$

not because T const.

Ex:



$V_1 = 0.05\ m^3 \rightarrow V_2 = 2V_1$

$P_1 = 200$ KPa

A of piston $= 0.25\ m^2$

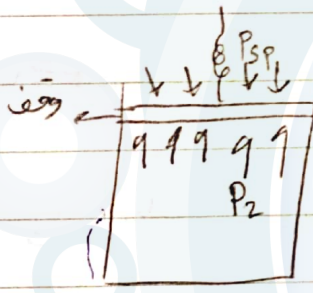
Isobaric ↓ P const

spring is P constant

Find ① Final pressure

② total work done by the gas

③ work done on the spring



$P_{sp} = F/A$ → K. displacement ↓ cylinder

$P_{sp} = 120$ KPa

$P_0 + P_{sp} = P_2$

$P_2 = 120 + P_0$

↓ atm pressure already 200

$P_2 = 320$ KPa

$\frac{\Delta V}{A} = \frac{V_2 - V_1}{A} = \Delta X$

$\Delta X = 0.2$ m

$F_S = 30$ KN

② $W_{sp} = F_{sp} \cdot \Delta X = \frac{1}{2} K (x_2^2 - x_1^2) = 3$ KJ

spring

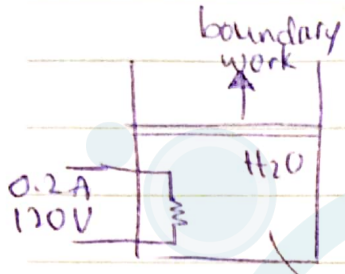
isobatic $W = P_1 \Delta V$

$* W = \frac{P_1 + P_2}{2} (V_2 - V_1) = P_{avg.} \Delta V =$

② $W_{sys\ tot} = W_{on\ piston\ \&\ atm} + W_{on\ spring} = P_1(V_2 - V_1) + \frac{1}{2} K (x_2^2 - x_1^2)$

$= 200(0.05) + \frac{1}{2}(150)(0.2^2 - 0^2) = 10 + 3 = 13$ KJ

Example: 5-5) p: 149 Electric heating of a Gas @ const. P



sat. vapor water

(a) W_b & ΔU in the 1st law can be combined into one term ΔH for a const. P

Prove $\Delta U + W_b = \Delta H$

$Q = -3.7\ J$

$P_1 = P_2 = 300\ kPa$

(b) $T_f = ?$

I $W_b = P\Delta V = PV_2 - PV_1$

$\Delta H = \Delta U + W_b$

$= U_2 - U_1 + PV_2 - PV_1$

$= (U_2 + PV_2) - (U_1 + PV_1)$

$= H_2 - H_1$

Power $= IV \rightarrow W_{elec.} = IV\,t$

$E_{in} - E_{out} = \Delta E_{sys}$

$Q - W_{other} - W_b = \Delta U$

$Q - W_{other} = \Delta U + W_b$

$Q - W_{other} = (U_2 + PV_2) - (U_1 + PV_1)$

$Q - W_{other} = H_2 - H_1$

2] $\Delta U = Q - W$

$U_2 - U_1 = -Q - W_b + W_{elect.}$

isobaric

$m(u_2 - u_1) = -3.7 - W_b + 120(0.2)(5 \times 60) \times \frac{1\ kJ/s}{1000\ VA}$ (5 min → sec)

$m(h_2 - h_1) = -3.7 + 7.2\ kJ$

$25 \times 10^{-3}\ kg\ \Delta h = \frac{-3.7 + 7.2}{25 \times 10^{-3}\ kg}$

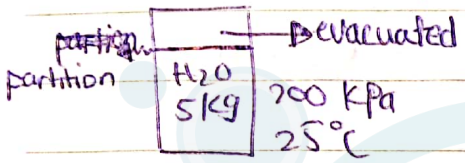
$h_2 - 2724.9 = 140$

$h_2 = 2725.04$

$h_1 = h_{g\ @\ 300\ kPa} = 2724.9\ kJ/kg$

Example 5-6) p:150

Rigid tank ← 2 equal parts



→ remove the partition
- water expanded into the entire tank
- exchange heat with surr
→ $T_f = 25°C$

(a) the Volume of the tank
(b) Final pressure
(c) heat transfer for this process.

25°C, 0.2 MPa → compressed liq. $T_{sat} > T$, $P_{sat} < P$

① $V_1 = (v)_1 m$ → table → sat. liq

$\cong 0.001003 * 5 = 0.005\ m^3$

total Volume $= 2V_1 = 0.01\ m^3$

② 2 independent prop. → to Find the third one

$T_2 = 25°C$

$V_2 = \frac{V_{tot}}{mass} = 0.002\ m^3/kg$

$V_f \leftrightarrow V_2 \leftrightarrow V_g$ @ 25°C

$P_{sat.} = 3.1698$ kPa

0.001003 < 0.002 < 43.34

mixture → sat. liq / sat. gas → Vapor dome

③ Heat transfer Q

$u_{@25°C} = 104.83$ KJ/kg

$Q_{in} = m(u_2 - u_1)$?

mixture — compressed → sat. liq (f)

$u_1 = u_f = 104.83$

u_2 → mixture

$u_2 = u_f + x\, u_{fg}$

$x = \frac{V_2 - V_f}{V_{fg}}$

$x = \frac{0.002 - 0.001}{43.34 - 0.001} = 2.3 \times 10^{-5}$

$u_2 = 104.83 + (2.3 \times 10^{-5})(2304.3)$

$= 104.88$ KJ/KG.

$Q = 5\,(104.88 - 104.83)$

$= 0.25$ KJ

24.2.2020

Specific heat
- C_v → specific heat @ const. volume
- C_p → specific heat @ const pressure

Gas constant = $R = C_p - C_v \Rightarrow \boxed{C_p = R + C_v}$

$\gamma = \frac{C_p}{C_v}$ $\qquad PV = RT$

$C_p(T) = \frac{\partial h}{\partial T}$; $\boxed{C_v(T) = \frac{\partial u}{\partial T}}$

⇒ the change in ~~internal~~ enthalpy ~~energy~~ with temp. @ const. pressure ; = the change in internal energy with temp. @ const volume

$\Delta U = Q - W$

$\Delta h = \int_1^2 C_p(T)\,\partial T = h_2 - h_1$; $\boxed{\Delta u = \int_1^2 C_v(T)\,\partial T = u_2 - u_1}$ (table)

$\Delta h = C_{p_{avg.}} (T_2 - T_1)$; $\Delta u = C_{v_{avg.}} (T_2 - T_1)$

Example 5-1 p:158

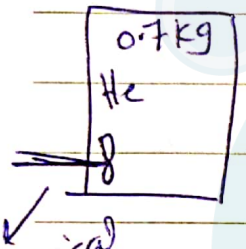
(insolated) isolated → $Q = 0$

rigid → $\Delta V = 0$

Find :-

① $T_2 = ?$

② P_2



Power = 0.015 KW/sec

t = 30 min → 30×60 = 1800 sec

$\Delta U = \cancel{Q}^{0} - W$ → done on the sys → negative

$m(u_2 - u_1) = -(-0.015 \times 1800)$

$0.7(u_2 - u_1) = 27$

table

$u_2 =$

T_2 (table)

or $\Delta U = 27 = C_{v\ avg.} (T_2 - T_1)$

T_1 بدل

C_v بدل

$= 0.7\ (3.11)\ (T_2 - 27)$

$T_2 = 39.4$

trial 2 ← نعوض

② $PV = mRT$

$PV = RT$; $V_1 = V_2$ isobaric

$$\frac{R_1 T_1}{P_1} = \frac{R_2 T_2}{P_2}$$ → Kelvin