GIVEN Piston–Cylinder Assembly w/ NH_3

» 2 states

(1) $T_1 = -20°C$, $x = 50\% = 0.5$, P_1

↓ slowly heated ($\dot{Q}_{in}$)

(2) $p_2 = 6$ bar, $T_2 = 180°C$

» while heated the pressure p varies linearly w/ v ($\frac{m^3}{kg}$)

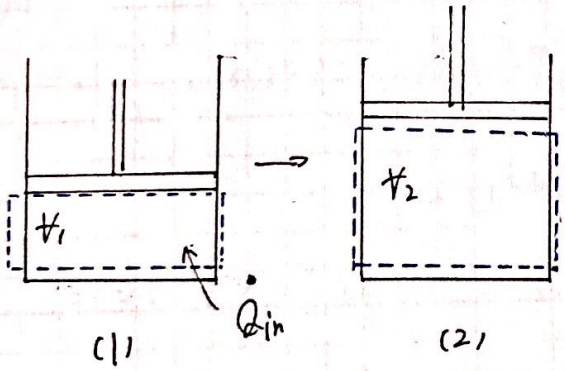
FIND (a) p-v diagram

(b) for NH_3, $\dot{Q}_{in}$ & $\dot{W}_{12}$

ASSUMP
- closed sys.
- Quasi equilibrium
- $\Delta PE = \Delta KE = 0$

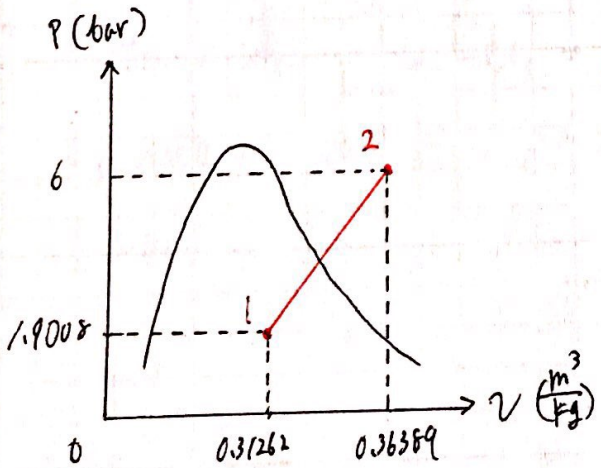
EQN
- $\frac{dm}{dt}_{sys} = \dot{m}_{in} - \dot{m}_{out}$
- $\Delta U = Q - W$
- $W = \int P dV$

FBD



SOLN

(a)



using saturation table @

$T_1 = -20°C$

$\begin{cases} v_f = 0.0015035 \frac{m^3}{kg} \\ v_g = 0.62373 \frac{m^3}{kg} \end{cases}$

thus, from quality, $x = 0.5$

$v = 0.5 v_f + 0.5 v_g$

$\cong 0.31262 \frac{m^3}{kg}$

and

$P_1 = 1.9008$ bar

also $u_1 = 0.5u_{f1} + 0.5u_{g1} = (0.5)(89.095\ \frac{kJ}{kg}) + (0.5)(1299.9\ \frac{kJ}{kg})$

$\simeq 694.5\ \frac{kJ}{kg}$

@ state (2)

T_{sat} for $p_2 = 6$ bar is $T_{sat} = 9.2846\ ^\circ C < T_2 = 180^\circ C$

thus, it is superheated vapor.

from the corresponding table @ $T_2 = 180^\circ C$

$v_2 = 0.36389\ \frac{m^3}{kg}$

and

$u_2 = 1649.4\ \frac{kJ}{kg}$

to calculate $w_{12}\ (\frac{J}{kg})$

w_{12} is the area under the path function of the p-v diagram

therefore

$$w_{12} = [(0.36389 - 0.31262)\tfrac{m^3}{kg}](1.9008 \times 10^5\ Pa) + \frac{1}{2}[(0.36389 - 0.31262)\tfrac{m^3}{kg}][(6 - 1.9008) \times 10^5\ Pa]$$

$\simeq 20254\ J/kg = 20.254\ kJ/kg$

thus,

$q_{12} = \Delta u_{12} + w_{12} = u_2 - u_1 + w_{12}$

$= (1649.4 - 694.5 + 20.254)\ \frac{kJ}{kg}$

$\simeq 975.2\ \frac{kJ}{kg}$

$w_{12} = 20.3\ \frac{kJ}{kg}$

$q_{12} = 975\ \frac{kJ}{kg}$