ME 40

Thermodynamics

Spring 2009

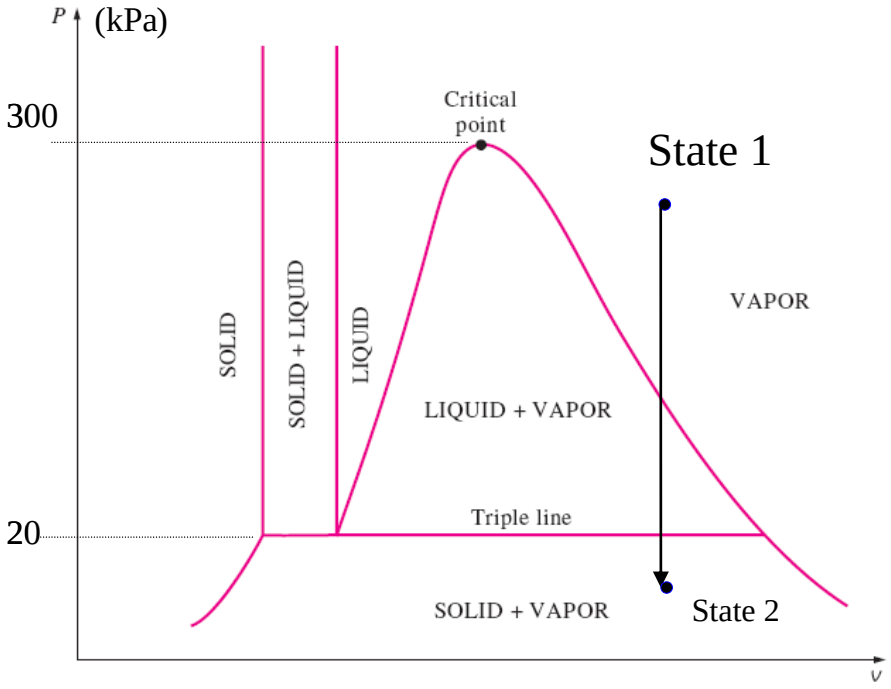
Quiz #1

Solution

February 9, 2009

Name: _____
SID: _____

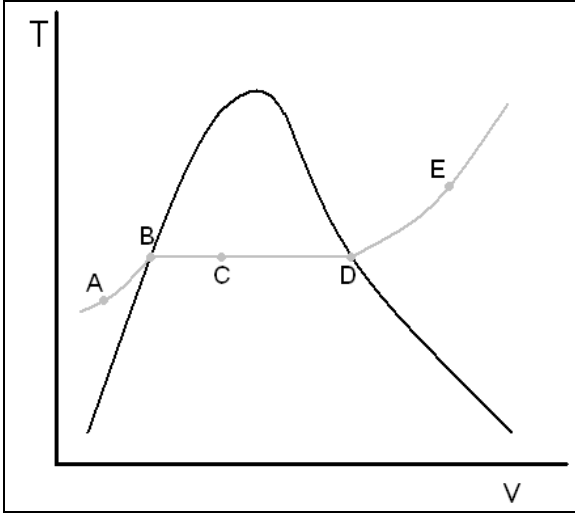
Question 1: [5 points]



A ***rigid*** tank contains a pure substance at State 1 as sketched in the above *(P,v)* diagram. The pressure at State 1 is 285 kPa. Now heat is escaped from the tank and the pressure inside the tank decreases accordingly. At State 2 after reaching equilibrium, the pressure is 10 kPa. Sketch the process on the above *(P,v)* diagram and describe the phase at State 2.

Solution: Since the tank is rigid and of fixed mass, the specific volume doesn't change (hence vertical line) and state 2 exists at 10kPa in the Solid + Vapor region.

Question 2: [5 points]



Referring to the (T,*v*) diagram on the left, determine the quality of State C

$$x = \frac{BC}{BD} = \frac{1-CD}{BD} = \frac{1-.65BD}{BD} = 1 - .65 = .35$$

Note: |CD| = 0.65 |BD| where |CD| is the distance between points C and D, and |BD| is the distance between points B and D. The dark solid line represents the saturated vapor and liquid.

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Question 2: [9 points]

Using the attached tables, complete this chart for H_2O.

	T (ºC)	*P* (kPa)	*h* (kJ/kg)	*x* (quality)	Phase description
i	95		1250.		
ii		300	3486.6		
iii	150	500			

solution

	T (ºC)	*P* (kPa)	*h* (kJ/kg)	*x* (quality)	Phase description
i	95	**(84.609)**	1250.0	**(0.3753)**	**(Saturated liquid-vapor mixture)**
ii	**(500)**	300	3486.6	**(1)**	**(gas or superheated vapor)**
iii	150	500	**(~632.)**	**(0)**	**(compressed liquid)**

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Question 3: [10 Points]

The equation of state for a gas is approximated by $(P + \frac{a}{v^2})v = RT$, where P is pressure, v is specific volume, R gas constant, T temperature, and $a > 0$. At a given state (v,T), the ideal gas law predicts the pressure $P_{ideal} = RT / v$. Determine if the pressure, P, determined by the equation of state is greater or smaller than P_{ideal}.

P= RT/v –a/v2 < P_{ideal}=RT/v as a is positive.

Physical reason: a/v2 represents intermolecular forces (attractive forces).

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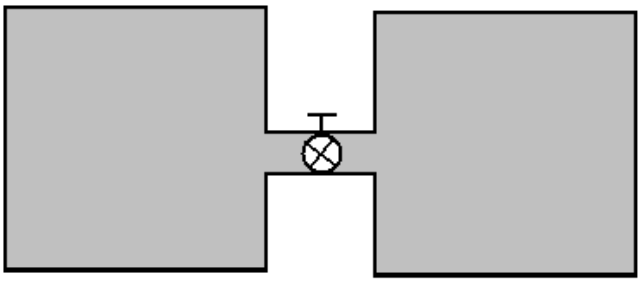
Question 4: [11 points]

Two well-insulated rigid tanks are connected by a valve. Tank A contains 5 kg of superheated *steam* at 800^{o}C and 800kPa. Tank B contains 1 kg of *saturated water mixture* at 150^{o}C and 30% quality. The valve is opened and the two tanks eventually come to thermodynamic equilibrium. Perform a thermodynamics analysis based on conservation of mass and energy to determine if there is any liquid in the final state. (Note that the sizes of the tanks in the sketch are not to the scale.)



Tank A	Tank B
M = 5 kg	M=1 kg
T = 800ºC	T = 150ºC
P = 800 kPa	*x* = 0.3

Solution:

KE=PE=W=Q=0

Conservation of Energy: $E_i-E_f=\Delta E_{sys}=0$

Therefore $E_i=E_f$. This becomes $U_i=U_f$ or $M_A*U_A+M_B*U_B=M_f*U_f$

Tank A: $V_A=M_A*v_A$=5kg x 0.618 m^3/kg =3.09 m^3

U_A = 5kg x 3662.5 kJ/kg =18312.5 kJ

Tank B: $V_B=M_B*v_B$=1kg x(0.3* 0.3924 m^3/kg+0.7* 0.00109 m^3/kg)=0.1184 m^3

U_B = 0.3x 2559.1 kJ/kg +0.7 *631.66 kJ/kg =1209.89 kJ

Total volume at equilibrium = 3.208 m^3

Total mass= 6 kg

Specific volume= 3.208m^3/6kg=0.5346 m^3/kg

Total internal energy= 19522.39 kJ→ specific energy=3253.7 kJ/kg

(v, u) states falls into the superheated regime; there will be no liquid in the final state.