Quiz 2
Chemical Engineering Thermodynamics
January 28, 2015

1)

2.2. One mole of an ideal gas ($C_P = 7R/2$) in a closed piston/cylinder is compressed from $T^i = 100$ K, $P^i = 0.1$ MPa to $P^f = 0.7$ MPa by the following pathways. For each pathway, calculate ΔU, ΔH, Q, and W_{EC}: (a) isothermal; (b) constant volume; (c) adiabatic.

2)

2.7. Steam undergoes a state change from 450°C and 3.5 MPa to 150°C and 0.3 MPa. Determine ΔH and ΔU using the following:

b. Ideal gas assumptions. (Be sure to use the ideal gas heat capacity for water.)

R = 8.314 J/(mole °K)

$$\left(\frac{T}{T^i}\right)^{(C_V/R)} = \frac{V^i}{V}$$

$$\left(\frac{T}{T^i}\right)^{(C_P/R)} = \frac{P}{P^i}$$

$$PV^{(C_P/C_V)} = \text{const}$$

Properties of Selected Compounds

Heat capacities are values for ***ideal gas at 298 K*** *and should be used for* ***order of magnitude calculations*** *only. See appendices for temperature-dependent formulas and constants.*

ID	Compound	T_c (K)	P_c (MPa)	ω	ρ g/cm³	MW	C_P^{ig}/R	δ (J/cm³)½	α (J/cm³)½	β (J/cm³)½
902	HYDROGEN	33.3	1.297	−0.215	*0.20*	2	3.507	*2.0*	0	0
905	NITROGEN	126.1	3.394	0.040	*0.88*	28	3.500	5.3	0	0
908	CARBON MONOXIDE	132.9	3.499	0.066	*0.88*	28	3.505	6.3	0	0
909	CARBON DIOXIDE	304.2	7.382	0.228	*1.18*	44	4.456	14.6	1.87	0
Nasty gases										
1922	HYDROGEN SULFIDE	373.5	8.937	0.081	*0.95*	34	4.115	18.0	3.19	3.19
1938	CARBON DISULFIDE	552	7.800	0.115	*1.26*	76	4.109	20.4	0.59	0.33
1904	HYDROGEN CHLORIDE	324.6	8.200	0.120	*1.19*	36.5	3.551	22.0	22.0*	0
1771	HYDROGEN CYANIDE	456.8	5.320	0.407	*0.68*	27	4.330	24.8	3.00	3.00
Miscellaneous compounds										
1051	ACETONE	508.2	4.701	0.306	0.79	58	8.96	19.6	0.00	11.14
1772	ACETONITRILE	545.5	4.833	0.353	0.78	44	6.28	24.1	3.49	8.98
1252	ACETIC ACID	592.7	5.786	0.462	1.04	60	15.01	19.0	24.03	7.50
1911	AMMONIA	406.6	11.270	0.252	0.68	17	4.29	29.2	2.11	8.44
1921	WATER	647.3	22.120	0.344	1.00	18	4.04	47.9	50.13	15.06

References: API Technical Data Book (1988), and Reid, R.C., Prausnitz, J.M., and Sherwood, T.K., The Properties of Liquids and Gases, 3rd Edition, 1977. McGraw-Hill:New York. For a more complete list, see the spreadsheet in props.xlsx or the MATLAB props folder. Italics designate estimated or effective values.

Answers Quiz 2
Chemical Engineering Thermodynamics
January 28, 2016

1)

(2.02) One mole of an ideal gas (T^i = 100 K, P^i = 0.1 MPa)...

a) $\underline{\Delta U = \Delta H = 0}$ since isothermal,
$Q = -W = RT\ln(P_1/P_2) = 8.314(100)\ln(0.1/0.7) = \underline{-1618\ J/mol}$

b) $\underline{W = 0}$, $T_2 = T_1(P_2/P_1) = 100*7 = 700$ K,
$\Delta U = Q = Cv(T_2 - T_1) = 20.79(700\text{-}100) = \underline{12471\ J/mol}$
$\Delta H = Cp(T_2 - T_1) = 29.1(700\text{-}100) = \underline{17459\ J/mol}$

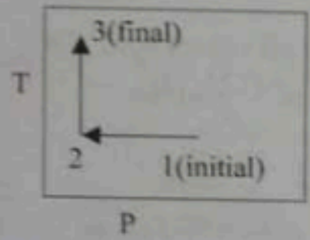
c) $Q = 0$, $T_2 = T_1(P_2/P_1)^{R/Cp} = 100(7)^{2/7} = 174.4K$
$\Delta U = W = Cv(T_2 - T_1) = 20.79(174.4\text{-}100) = \underline{1546\ J/mol}$
$\Delta H = Cp(T_2 - T_1) = 29.1(174.4\text{-}100) = \underline{2164\ J/mol}$

2)

(2.07) Steam under goes a state change from 450 C and 3.5 MPa ...

H^i (450 C, 3.5 MPa) = 3338.0 kJ/kg
U^i (450 C, 3.5 MPa) = 3016.1 kJ/kg
H^f (150 C, 0.3 MPa) = 2761.2 kJ/kg
U^f (150 C, 0.3 MPa) = 2571.0 kJ/kg
Δ H = 2761.2-3338.0 = -576.8 kJ/kg
Δ U = 2571.0-3016.1 = -444.1 kJ/kg

b) Ideal Gas



at intermediate state 2,

$V_2 = \frac{RT_2}{P_2}$ = 8.314*723/0.3 = 20041 cm^3/mol = 0.020041 m^3/mol

Step I: Constant Temperature
$\Delta H_I = 0 \quad \Delta U_I = 0$

Step II: Constant Pressure
Using Cp polynomial
$\Delta H_{II} = \int_{T_2}^{T_3} C_p dT$ =- 10848.769 J/gmol
$\Delta U_{II} = \Delta H_{II} - [(PV)_3 - (PV)_2]$ =- 8353.759 J/gmol

Using the value Cp/R = 4.041 from the back flap of the text:
ΔH = -10,079 J/mol
ΔU = -7589 J/mol

For process,
$\Delta H = \Delta H_I + \Delta H_{II}$ =- 10848.769 kJ/kgmol (-10,079 for Cp constant)
$\Delta U = \Delta U_I + \Delta U_{II}$ =- 8353.759 kJ/kgmol (-7589 for Cp constant)

MW = 18 kg/kgmol
$\therefore \Delta H$ = - 602.709 kJ/kg (-559 for Cp constant)
ΔU = - 464.098 kJ/kg (-421 for Cp constant)