KATHMANDU UNIVERSITY
End Semester Examination [C]
November/December, 2023

Marks Scored:

Level : B.E./B.Tech.
Year : II
Course : CHEG 201
Semester : I

Exam Roll No. :
Time: 30 mins.
F. M. : 10

Registration No.:
Date : 27 Nov 2023

SECTION "A"
[20 Q. × 0.5 = 10 marks]

Encircle the most appropriate alternative from the given set of choices

1. A semi-batch process differs from an open process in _____
   a. Input b. Output c. Generation d. Consumption

2. Which one is the correct relation?
   a. $C_p + C_v = 0$ b. $C_p = 1 + R / C_v$ c. $C_p = R + C_v$ d. $C_p / C_v = 1$

3. For a mono atomic ideal gas, C_v is
   a. 1.5R b. 2.5R c. 3.5R d. 4.5R

4. Boiling occurs at _____ temperature and _____ pressure, the process appears as a point in ____ diagram.
   a. Constant, constant, P-T
   b. Variable, constant, P-T
   c. Constant, variable, V-T
   d. Variable, variable, V-T

5. Moist air is cooled along the line of constant _____, when it is passed over a cold and drying coil, such that no condensation occurs.
   a. Relative humidity
   b. Enthalpy
   c. Dew point temperature
   d. Wet bulb temperature

6. For heat exchangers, the general energy balance equation reduces to
   a. $\Delta H = 0$ b. $Q = 0$ c. $\Delta E = Q + W$ d. $\Delta E = Q + W - \Delta H$

7. What is the degree of freedom of a system with ice, water and neon?
   a. 1 b. 2 c. 3 d. 4

8. _____ is always endothermic.
   a. Burning b. Boiling c. Condensing d. Freezing

9. A _____ stream is a stream bled off from the process to remove an accumulation of inerts or unwanted material.
   a. Recycle b. Bypass c. Purge d. Mixing

10. The Reynolds number is a dimensionless number given by equation $R = D*v*\rho/\mu$. If D has units of m, v has units of m/s and ρ has units of kg/m^3, what is the unit of μ?
    a. No units b. m/s^2 c. kg.m/s d. kg/m.s

11. Which of the following in **NOT** an intensive variable?
a. Temperature b. Density c. Specific volume d. Volume

12. If the partial pressure of a vapor in equilibrium with a gas mixture containing a single condensable component is equal to the vapor pressure of the pure component at system T, any attempt to increase the partial pressure will lead to _____.
a. Sublimation b. Boiling c. Condensation d. Saturation

13. _____Law is often applied to solutions of non-condensable gases.
a. Raoult's b. Henry's c. Hess's d. Antoine's

14. A solution of dye in water has a specific gravity of 1.05 at 25 C. The concentration of dye is 1 g/L of solution. What is the PPM of dye in solution?
a. 760 b. 820 c. 950 d. 1030

15. For problem described in question 14, what is the mass of water in the solution assuming a basis of 100 g solution?
a. 96.97 b. 97.98 c. 99.90 d. 100

16. 1000 kg of wet solids are to be dried from 30% to 20% moisture by weight. The mass of moisture to be removed in Kg is _____.
a. 125 b. 250 c. 256 d. 320

17. From the definition of relative humidity, as air is cooled, the relative humidity _____ since the partial pressure of the water vapor is _____ while the vapor pressure of water _____with temperature.
a. Increases, constant, decreases b. Decreases, decreases, constant
c. Increases, decreases, constant d. Constant, increases, decreases

18. The standard heat of combustion of ethane (C_2H_6) vapor is -2500 kJ/mol. Assuming reactants and products are all at 25 C, what is the enthalpy change of the combustion reaction if 10 mole/s of CO_2 is produced in the reaction,
a. -5000 kJ/s b. -6250 kJ/s c. -10750 kJ/s d. -12500 kJ/s

19. 100 mol/h of ethane (C_2H_6) is burned with 50% excess air in a combustion reactor. Calculate the stoichiometric amount of air required for the combustion process?
a. 350 mol/h b. 400 mol/h c. 525 mol/h d. 550 mol/h

20. For the problem described in question 19, what is the flow rate of air fed to the reactor?
a. 1266 mol/h b. 1666 mol/h c. 2499 mol/h d. 3499 mol/h

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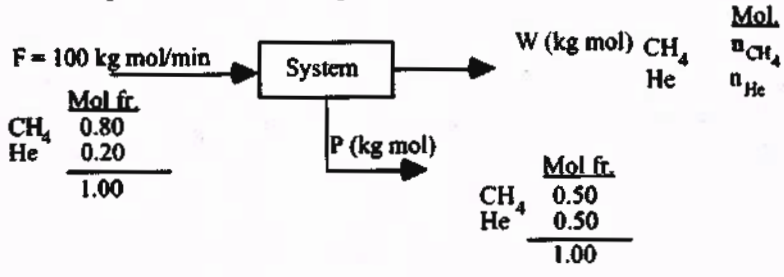
F. M. : 40

SECTION "B"

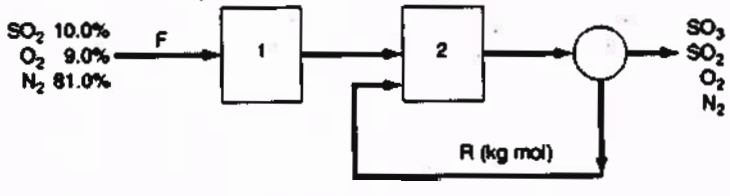
Attempt *ALL* questions

1. From the figure below and assuming P is 20% by weight of F,
   a. Calculate the average molecular weight of F and P. [2]
   b. Calculate P in kg mole. [2]
   c. Calculate the composition of W in kg mole. [2]



2. A gas containing 70% CH_4, 5% C_3H_8, 15% CO, 5%O_2 and 5% N_2 is burned in the flare with air to give flue gas with a composition of 7.73% CO_2, 12.35% H_2O and the balance O_2 and N_2.
   a. Calculate the moles of air sent to the flare and the composition of O_2 and N_2 in the flue gas. [3]
   b. Calculate the percent excess air sent to the flare. [3]

3. The single pass conversion of SO_2 to SO_3 in stage 1 and stage 2 is 75 and 65% respectively. Exit gas is recycled from stage 2 to boost overall SO_2 conversion to 95% as shown in the figure below.
   a. Calculate the composition of the product gas [2]
   b. Calculate the value of the recycle R. [4]



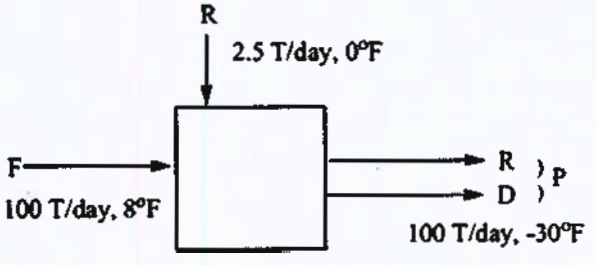
4. Methane and air enter a combustion chamber at 25 °C. 20% excess air is supplied If the product gases exit the chamber at 500 °C,
   a. Calculate the standard heat of reaction for the combustion reaction. [2]
   b. Calculate the total enthalpy change of the process. [4]

5. Air enters a dryer having a dry bulb temperature of 34 °C and a wet-bulb temperature of 17 °C. The moist air flows at the rate of 4500 m^3/hr. The air exits at 34 °C dry bulb and 21 °C wet bulb temperature. In the dryer, wet wood enters at 34 °C with a moisture content of 80% and exits with 50% moisture content.
   a. How much water is evaporated from the wood per hour? [2]
   b. What is the enthalpy change in kJ/hour of the air inlet to exit? [2]
   c. How many kilograms of the entering wet wood are dried per hour? [2]

6. The analysis of a gas mixture showed 30% O_2, 40%N_2, 10% CO_2 and 20% CH_4. The gas mixture is at 8 MPa and 15 °C and flows through a 2 cm diameter pipe at a speed of 3 m/s. Calculate the mass flow rate of the gas. [6]

Components	T_c (K)	P_c (atm)
O_2	154.4	49.7
N_2	126.2	33.5
CO_2	304.2	72.9
CH_4	190.7	45.8

7. A feed of chlorine gas F is sent through an adiabatic heat exchanger to obtain liquid chlorine P (R + D) as shown in the figure below. R is the amount of liquid chlorine vaporized back to gas which is recycled back to heat exchanger at 0 °F instead. The normal boiling point of chlorine is -30 °F. The heat capacity of liquid Cl_2 is 8.1 Btu/ (lb mol.°F). Taking MW of Cl_2 as 71 lb/lbmole.
   a. Determine the energy lost by the feed chlorine gas to turn to liquid chlorine. [2]
   b. If the heat of vaporization is 123.45 Btu/lb Cl_2, determine the heat energy lost or gained in going from -30 °F Cl_2 vapor to 0 °F Cl_2 vapor. [2]



CHEG-201
Table

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These tables and charts are to be provided with the question

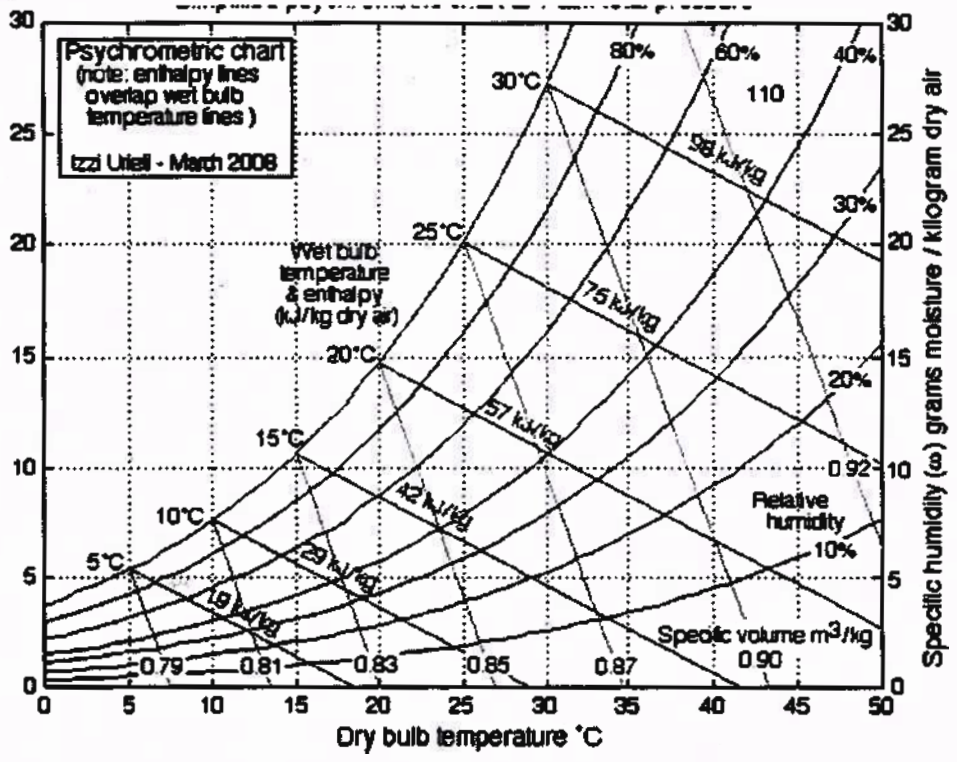

Table C.1: Heat Capacities of Gases in the Ideal-Gas State[a]

Constants in equation $C_p^{ig}/R = A + BT + CT^2 + DT^{-2}$ for T (K) from 298 K to T_{max}

Chemical species		T_{max}	$C_{P_{298}}^{ig}/R$	A	$10^3 B$	$10^6 C$	$10^{-5} D$
Alkanes:							
Methane	CH_4	1500	4.217	1.702	9.081	−2.164	.....
Ethane	C_2H_6	1500	6.369	1.131	19.225	−5.561	.....
Propane	C_3H_8	1500	9.011	1.213	28.785	−8.824	.....
n-Butane	C_4H_{10}	1500	11.928	1.935	36.915	−11.402	.....
iso-Butane	C_4H_{10}	1500	11.901	1.677	37.853	−11.945	.....
n-Pentane	C_5H_{12}	1500	14.731	2.464	45.351	−14.111	.....
n-Hexane	C_6H_{14}	1500	17.550	3.025	53.722	−16.791	.....
n-Heptane	C_7H_{16}	1500	20.361	3.570	62.127	−19.486	.....
n-Octane	C_8H_{18}	1500	23.174	4.108	70.567	−22.208	.....
Miscellaneous inorganics:							
Air		2000	3.509	3.355	0.575	.....	−0.016
Ammonia	NH_3	1800	4.269	3.578	3.020	.....	−0.186
Bromine	Br_2	3000	4.337	4.493	0.056	.....	−0.154
Carbon monoxide	CO	2500	3.507	3.376	0.557	.....	−0.031
Carbon dioxide	CO_2	2000	4.467	5.457	1.045	.....	−1.157
Carbon disulfide	CS_2	1800	5.532	6.311	0.805	.....	−0.906
Chlorine	Cl_2	3000	4.082	4.442	0.089	.....	−0.344
Hydrogen	H_2	3000	3.468	3.249	0.422	.....	0.083
Hydrogen sulfide	H_2S	2300	4.114	3.931	1.490	.....	−0.232
Hydrogen chloride	HCl	2000	3.512	3.156	0.623	.....	0.151
Hydrogen cyanide	HCN	2500	4.326	4.736	1.359	.....	−0.725
Nitrogen	N_2	2000	3.502	3.280	0.593	.....	0.040
Nitrous oxide	N_2O	2000	4.646	5.328	1.214	.....	−0.928
Nitric oxide	NO	2000	3.590	3.387	0.629	.....	0.014
Nitrogen dioxide	NO_2	2000	4.447	4.982	1.195	.....	−0.792
Dinitrogen tetroxide	N_2O_4	2000	9.198	11.660	2.257	.....	−2.787
Oxygen	O_2	2000	3.535	3.639	0.506	.....	−0.227
Sulfur dioxide	SO_2	2000	4.796	5.699	0.801	.....	−1.015
Sulfur trioxide	SO_3	2000	6.094	8.060	1.056	.....	−2.028
Water	H_2O	2000	4.038	3.470	1.450	.....	0.121

Table C.4: Standard Enthalpies and Gibbs Energies of Formation at 298.15 K†

Joules per mole of the substance formed

Chemical species		State (Note 2)	ΔH°_{f298} (Note 1)	ΔG°_{f298} (Note 1)
Alkanes:				
Methane	CH_4	(*g*)	−74,520	−50,460
Ethane	C_2H_6	(*g*)	−83,820	−31,855
Propane	C_3H_8	(*g*)	−104,680	−24,290
n-Butane	C_4H_{10}	(*g*)	−125,790	−16,570
n-Pentane	C_5H_{12}	(*g*)	−146,760	−8,650
n-Hexane	C_6H_{14}	(*g*)	−166,920	150
n-Heptane	C_7H_{16}	(*g*)	−187,780	8,260
n-Octane	C_8H_{18}	(*g*)	−208,750	16,260
1-*Alkenes:*				
Ethylene	C_2H_4	(*g*)	52,510	68,460
Propylene	C_3H_6	(*g*)	19,710	62,205
1-Butene	C_4H_8	(*g*)	−540	70,340
1-Pentene	C_5H_{10}	(*g*)	−21,280	78,410
1-Hexene	C_6H_{12}	(*g*)	−41,950	86,830
1-Heptene	C_7H_{14}	(*g*)	−62,760	
Miscellaneous organics:				
Acetaldehyde	C_2H_4O	(*g*)	−166,190	−128,860
Acetic acid	$C_2H_4O_2$	(*l*)	−484,500	−389,900
Acetylene	C_2H_2	(*g*)	227,480	209,970
Benzene	C_6H_6	(*g*)	82,930	129,665
Benzene	C_6H_6	(*l*)	49,080	124,520
1,3-Butadiene	C_4H_6	(*g*)	109,240	149,795
Cyclohexane	C_6H_{12}	(*g*)	−123,140	31,920
Cyclohexane	C_6H_{12}	(*l*)	−156,230	26,850
1,2-Ethanediol	$C_2H_6O_2$	(*l*)	−454,800	−323,080
Ethanol	C_2H_6O	(*g*)	−235,100	−168,490
Ethanol	C_2H_6O	(*l*)	−277,690	−174,780
Ethylbenzene	C_8H_{10}	(*g*)	29,920	130,890
Ethylene oxide	C_2H_4O	(*g*)	−52,630	−13,010
Formaldehyde	CH_2O	(*g*)	−108,570	−102,530
Methanol	CH_4O	(*g*)	−200,660	−161,960
Methanol	CH_4O	(*l*)	−238,660	−166,270
Methylcyclohexane	C_7H_{14}	(*g*)	−154,770	27,480
Methylcyclohexane	C_7H_{14}	(*l*)	−190,160	20,560
Styrene	C_8H_8	(*g*)	147,360	213,900
Toluene	C_7H_8	(*g*)	50,170	122,050
Toluene	C_7H_8	(*l*)	12,180	113,630

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Table C.4 (Continued)

Chemical species		State (Note 2)	$\Delta H^{\circ}_{f,298}$ (Note 1)	$\Delta G^{\circ}_{f,298}$ (Note 1)
Miscellaneous inorganics:				
Ammonia	NH_3	(*g*)	−46,110	−16,400
Ammonia	NH_3	(*aq*)		−26,500
Calcium carbide	CaC_2	(*s*)	−59,800	−64,900
Calcium carbonate	$CaCO_3$	(*s*)	−1,206,920	−1,128,790
Calcium chloride	$CaCl_2$	(*s*)	−795,800	−748,100
Calcium chloride	$CaCl_2$	(*aq*)		−8,101,900
Calcium chloride	$CaCl_2 \cdot 6H_2O$	(*s*)	−2,607,900	
Calcium hydroxide	$Ca(OH)_2$	(*s*)	−986,090	−898,490
Calcium hydroxide	$Ca(OH)_2$	(*aq*)		−868,070
Calcium oxide	CaO	(*s*)	−635,090	−604,030
Carbon dioxide	CO_2	(*g*)	−393,509	−394,359
Carbon monoxide	CO	(*g*)	−110,525	−137,169
Hydrochloric acid	HCl	(*g*)	−92,307	−95,299
Hydrogen cyanide	HCN	(*g*)	135,100	124,700
Hydrogen sulfide	H_2S	(*g*)	−20,630	−33,560
Iron oxide	FeO	(*s*)	−272,000	
Iron oxide (hematite)	Fe_2O_3	(*s*)	−824,200	−742,200
Iron oxide (magnetite)	Fe_3O_4	(*s*)	−1,118,400	−1,015,400
Iron sulfide (pyrite)	FeS_2	(*s*)	−178,200	−166,900
Lithium chloride	$LiCl$	(*s*)	−408,610	
Lithium chloride	$LiCl \cdot H_2O$	(*s*)	−712,580	
Lithium chloride	$LiCl \cdot 2H_2O$	(*s*)	−1,012,650	
Lithium chloride	$LiCl \cdot 3H_2O$	(*s*)	−1,311,300	
Nitric acid	HNO_3	(*l*)	−174,100	−80,710
Nitric acid	HNO_3	(*aq*)		−111,250
Nitrogen oxides	NO	(*g*)	90,250	86,550
	NO_2	(*g*)	33,180	51,310
	N_2O	(*g*)	82,050	104,200
	N_2O_4	(*g*)	9,160	97,540
Sodium carbonate	Na_2CO_3	(*s*)	−1,130,680	−1,044,440
Sodium carbonate	$Na_2CO_3 \cdot 10H_2O$	(*s*)	−4,081,320	
Sodium chloride	$NaCl$	(*s*)	−411,153	−384,138
Sodium chloride	$NaCl$	(*aq*)		−393,133
Sodium hydroxide	$NaOH$	(*s*)	−425,609	−379,494
Sodium hydroxide	$NaOH$	(*aq*)		−419,150
Sulfur dioxide	SO_2	(*g*)	−296,830	−300,194
Sulfur trioxide	SO_3	(*g*)	−395,720	−371,060
Sulfur trioxide	SO_3	(*l*)	−441,040	
Sulfuric acid	H_2SO_4	(*l*)	−813,989	−690,003
Sulfuric acid	H_2SO_4	(*aq*)		−744,530
Water	H_2O	(*g*)	−241,818	−228,572
Water	H_2O	(*l*)	−285,830	−237,129

$R = 8.314\ J\ mol^{-1}\ K^{-1}$
$= 0.082\ 05\ L\ atm\ mol^{-1}\ K^{-1}$
$= 8.205\ 73\ m^3\ atm\ mol^{-1}\ K^{-1}$
$= 1.987\ cal\ mol^{-1}\ K^{-1}$
$= 62.363\ mmHg\ L\ mol^{-1}\ K^{-1}$
$= 1\ 545.348\ ft\ lb_f\ lbmol^{-1}\ K^{-1}$
$= 1.985\ Btu\ lbmol^{-1}\ R^{-1}$
$= 10.731\ ft^3\ psi\ lbmol^{-1}\ R^{-1}$

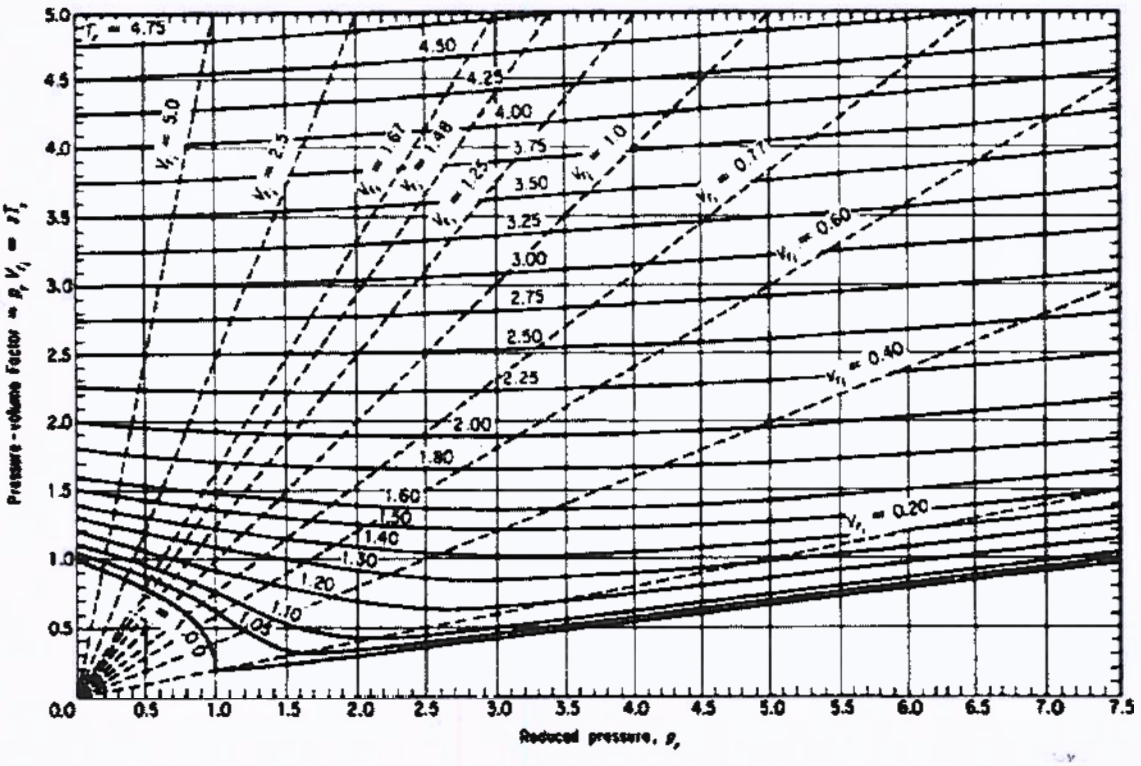

Figure 7.8b. Generalized compressibility chart for higher values of p_r