KATHMANDU UNIVERSITY
End Semester Examination [C]
June/July, 2023

Marks Scored:

Level : B.Tech.
Year : II

Course : ENVE 204
Semester : I

Exam Roll No. :

Time: 30 mins.

F. M. : 10

Registration No.:

Date : 30 JUN 2023

SECTION "A"
[20Q. × 0.5 = 10 marks]

Encircle the most appropriate answer.

1. Convert 0.01 gmol/mL.min to its equivalent in lbmol/.L.day.
   a. 0.75 b. 8.82 c. 12.12 d. 31.72

2. How many significant figures does the number 0.00035 have?
   a. 1 b. 2 c. 3 d. 4

3. Consider the equation D (ft) = 2exp (-3t), where t is time. What is the dimension of the constant 3?
   a. 1/time b. Time c. Length/time d. Mass

4. What is the volume occupied by 100 kg of blood? The specific gravity of blood is 1.06?
   a. 0.011 b. 0.017 c. 0.094 d. 0.18

5. How many moles of oxygen atom are present in the 10 gm of CO?
   a. 0.36 b. 1.37 c. 0.84 d. 2.55

6. A liquid that is almost entirely water is reported to contain 200 ppm of blue dye. What is the mass fraction of water in the liquid?
   a. 1.99×10^{-4} b. 1.99×10^{-6} c. 0.9299 d. 0.9998

7. In _____ processes, the feed is charged into a vessel at the beginning of the process and the vessel contents are removed sometime later?
   a. Batch b. Semi batch c. Continuous d. Semi continuous

8. Suppose 2 kg/min of benzene, 1 kg/min of toluene and 2 kg/min of water are mixed. What is the mass fraction of benzene in the output?
   a. 0.25 b. 0.5 c. 0.4 d. 1

9. 100 mol/h of methane is burned with 1000 mol/h of air in a combustion reactor. Calculate the % excess air used in the combustion process?
   a. 5% b. 10% c. 7% d. 15%

10. For the problem described in question 9, what is the stoichiometric amount of oxygen needed for the combustion reaction?
    a. 166 mol/h b. 260 mol/h c. 200 mol/h d. 450 mol/h

11. 1 g-mol of ideal gas occupies _____ at standard temperature and pressure?
    a. 22.415 m^3 b. 22.415 L c. 359.05 ft^3 d. 380 ft^3

12. In one process, the off gas analyzes 10% CO_2, 10% O_2 and 80% N_2. If the temperature and pressure are 25 C and 101 kPa respectively, what is the partial pressure of oxygen?
a. 10.1 mm Hg b. 10.1 kPa c. 80.8 kPa d. 7.65 atm

13. Which of the following is **NOT** an equation of state?
a. Peng-Robinson
b. Benedict-Webb-Rubin
c. Soave-Redlich-Kwong
d. Soave-Watson-Schrodinger

14. Gibbs phase rule is concerned with _____
a. Intensive properties of the system
b. Extensive properties of the system
c. Both intensive and extensive properties of the system
d. Non equilibrium systems

15. At bubble point, the _____ of the vapor is equal to the _____ of the volatile liquid.
a. Boiling point, condensation point
b. Bubble point, dew point
c. Partial pressure, vapor pressure
d. Partial pressure, bubble pressure

16. 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

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

18. Which of the following is an extensive variable?
a. Pressure b. Volume c. Density d. Specific volume

19. 120 kg of wet solids are to be dried from 20% to 10% moisture by weight. The mass of moisture to be removed in kg is _____.
a. 8.88 b. 10.00 c. 10.67 d. 15.45

20. The higher the vapor pressure at a given temperature, the greater the _____ of the species at that temperature.
a. Critical temperature
b. Triple point
c. Volatility
d. Latent heat

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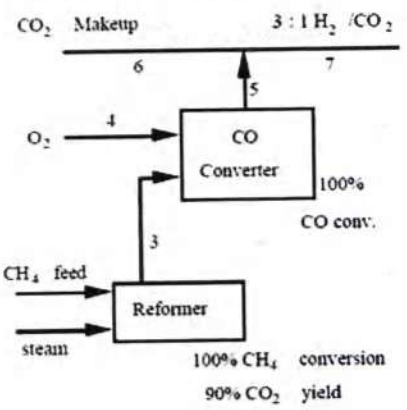
SECTION "B"

Attempt *ALL* questions.

1. Methane is burned with air in a continuous steady state combustion reactor to yield a mixture of CO_2, CO and H_2O. The feed to the reactor contains 7.8 mole% CH_4, 19.4% O_2 and 72.8% N_2. The percentage conversion of methane is 90% and the gas leaving the reactor contains 8 mole CO_2/mol CO.
   a. Write the balanced chemical reactions for the process. [1]
   b. Calculate the molar composition of the product stream. [3]
   c. Calculate the extent of reactions for both the reactions. [2]

2. A process for natural gas reforming is shown below. The chemical reactions involved are:

$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$ (main reformer reaction)
$CH_4 + H_2O \rightarrow CO + 3H_2$ (side reformer reaction)
$2CO + O_2 \rightarrow 2CO_2$ (CO converter reaction)



20% excess steam based on the first reaction is sent to the reformer. The CH_4 feed contains 2% nitrogen as an impurity. Find
   a. Moles of H_2O sent to the reformer [1]
   b. The composition of stream 3 [3]
   c. Amount of makeup CO_2 [2]

3. Liquid propane (C_3H_8) enters a combustion chamber at 25°C at a rate of 0.05 kg/min where it is mixed and burned with 50 percent excess air that enters the combustion chamber at 7°C. An analysis of the combustion gases reveals that all the hydrogen in the fuel burns to H_2O but only 90 percent of the carbon burns to CO_2, with the remaining 10 percent forming CO. If the exit temperature of the combustion gases is 1500 K, determine
   a. the mass flow rate of air [2]
   b. ΔH of the reaction [4]

The following data table is provided.

Species	H_f (kJ/kmol)	$H_{280\,K}$ (kJ/kmol)	$H_{298\,K}$ (kJ/kmol)	$H_{1500\,K}$ (kJ/kmol)
C_3H_8 (l)	-118910	-	-	-
O_2	0	8150	8682	49292
N_2	0	8141	8669	47073
CO_2	-393520	-	9364	71078
CO	-110530	-	8669	47517
H_2O (g)	-241820	-	9904	57999

4. Methane (CH_4) is burned with 25% excess air in a furnace operating at a pressure of 101 kPa. It is known that only 85% of the carbon burned to CO_2 with the remaining carbon forming CO. Determine the dew point temperature of the flue gas. [6]

5. Saturated steam at 1 atm and at a rate of 1150 kg/hr is mixed with superheated steam available at 400 °C and 1 atm to produce superheated steam at 300 °C. The mixing unit operates adiabatically. Calculate
   a. The amount of 300 °C superheated steam produced. [4]
   b. The volumetric flow rate of 400 °C superheated steam needed. [2]

6. Acetylene is produced from methane in the reaction

$$2CH_4\,(g) \rightarrow C_2H_2\,(g) + 3H_2\,(g)$$

An undesired side reaction is

$$C_2H_2\,(g) \rightarrow 2C\,(s) + H_2\,(g)$$

Methane is fed to the reactor at 1000 °C at the rate of 10 mol CH_4/s. Heat is transferred to the reactor at a rate of 975 kW. The product temperature is 1500 °C and the fractional conversion of methane is 0.6. Determine
   a. The product component flow rates [5]
   b. Yield of acetylene [2]
   c. The reactor efficiency which is define as the ratio of actual acetylene yield /acetylene yield with no side reaction. [3]

The following information is given.

Component	C_p (kJ/mol.°C)
CH_4 (g)	0.079
C_2H_2 (g)	0.052
H_2 (g)	0.031
C (s)	0.022

Tables and Charts:

Compound	Formula	Mol. wt.	State	$\Delta\hat{H}^\circ_f$ (kJ/g mol)	$\Delta\hat{H}^\circ_c$ (kJ/g mol)
Acetic acid	CH_3COOH	60.05	l	−486.2	−871.69
			g		−919.73
Acetaldehyde	CH_3CHO	40.052	g	−166.4	−1192.36
Acetone	C_3H_6O	58.08	aq, 200	−410.03	
			g	−216.69	−1821.38
Acetylene	C_2H_2	26.04	g	226.75	−1299.61
Ammonia	NH_3	17.032	l	−67.20	
			g	−46.191	−382.58
Methane	CH_4	16.041	g	−74.84	−890.4
Methyl alcohol	CH_3OH	32.042	l	−238.64	−726.55
			g	−201.25	−763.96
Methyl chloride	CH_3Cl	50.49	g	−81.923	−766.63†
Methyl cyclohexane	C_7H_{14}	98.182	l	−190.2	−4565.29
			g	−154.8	−4600.68

TABLE A-2 Properties of Saturated Water (Liquid–Vapor): Temperature Table

Temp. °C	Press. bar	Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		Temp. °C
		Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	
.01	0.00611	1.0002	206.136	0.00	2375.3	0.01	2501.3	2501.4	0.0000	9.1562	.01
4	0.00813	1.0001	157.232	16.77	2380.9	16.78	2491.9	2508.7	0.0610	9.0514	4
5	0.00872	1.0001	147.120	20.97	2382.3	20.98	2489.6	2510.6	0.0761	9.0257	5
6	0.00935	1.0001	137.734	25.19	2383.6	25.20	2487.2	2512.4	0.0912	9.0003	6
8	0.01072	1.0002	120.917	33.59	2386.4	33.60	2482.5	2516.1	0.1212	8.9501	8
10	0.01228	1.0004	106.379	42.00	2389.2	42.01	2477.7	2519.8	0.1510	8.9008	10
11	0.01312	1.0004	99.857	46.20	2390.5	46.20	2475.4	2521.6	0.1658	8.8765	11
12	0.01402	1.0005	93.784	50.41	2391.9	50.41	2473.0	2523.4	0.1806	8.8524	12
13	0.01497	1.0007	88.124	54.60	2393.3	54.60	2470.7	2525.3	0.1953	8.8285	13
14	0.01598	1.0008	82.848	58.79	2394.7	58.80	2468.3	2527.1	0.2099	8.8048	14
15	0.01705	1.0009	77.926	62.99	2396.1	62.99	2465.9	2528.9	0.2245	8.7814	15
16	0.01818	1.0011	73.333	67.18	2397.4	67.19	2463.6	2530.8	0.2390	8.7582	16
17	0.01938	1.0012	69.044	71.38	2398.8	71.38	2461.2	2532.6	0.2535	8.7351	17
18	0.02064	1.0014	65.038	75.57	2400.2	75.58	2458.8	2534.4	0.2679	8.7123	18
19	0.02198	1.0016	61.293	79.76	2401.6	79.77	2456.5	2536.2	0.2823	8.6897	19
20	0.02339	1.0018	57.791	83.95	2402.9	83.96	2454.1	2538.1	0.2966	8.6672	20
21	0.02487	1.0020	54.514	88.14	2404.3	88.14	2451.8	2539.9	0.3109	8.6450	21
22	0.02645	1.0022	51.447	92.32	2405.7	92.33	2449.4	2541.7	0.3251	8.6229	22
23	0.02810	1.0024	48.574	96.51	2407.0	96.52	2447.0	2543.5	0.3393	8.6011	23
24	0.02985	1.0027	45.883	100.70	2408.4	100.70	2444.7	2545.4	0.3534	8.5794	24
25	0.03169	1.0029	43.360	104.88	2409.8	104.89	2442.3	2547.2	0.3674	8.5580	25
26	0.03363	1.0032	40.994	109.06	2411.1	109.07	2439.9	2549.0	0.3814	8.5367	26
27	0.03567	1.0035	38.774	113.25	2412.5	113.25	2437.6	2550.8	0.3954	8.5156	27
28	0.03782	1.0037	36.690	117.42	2413.9	117.43	2435.2	2552.6	0.4093	8.4946	28
29	0.04008	1.0040	34.733	121.60	2415.2	121.61	2432.8	2554.5	0.4231	8.4739	29
30	0.04246	1.0043	32.894	125.78	2416.6	125.79	2430.5	2556.3	0.4369	8.4533	30
31	0.04496	1.0046	31.165	129.96	2418.0	129.97	2428.1	2558.1	0.4507	8.4329	31
32	0.04759	1.0050	29.540	134.14	2419.3	134.15	2425.7	2559.9	0.4644	8.4127	32
33	0.05034	1.0053	28.011	138.32	2420.7	138.33	2423.4	2561.7	0.4781	8.3927	33
34	0.05324	1.0056	26.571	142.50	2422.0	142.50	2421.0	2563.5	0.4917	8.3728	34
35	0.05628	1.0060	25.216	146.67	2423.4	146.68	2418.6	2565.3	0.5053	8.3531	35
36	0.05947	1.0063	23.940	150.85	2424.7	150.86	2416.2	2567.1	0.5188	8.3336	36
38	0.06632	1.0071	21.602	159.20	2427.4	159.21	2411.5	2570.7	0.5458	8.2950	38
40	0.07384	1.0078	19.523	167.56	2430.1	167.57	2406.7	2574.3	0.5725	8.2570	40
45	0.09593	1.0099	15.258	188.44	2436.8	188.45	2394.8	2583.2	0.6387	8.1648	45

TABLE A-2 (*Continued*)

Temp. °C	Press. bar	Specific Volume m³/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Sat. Vapor s_g	Temp. °C
50	.1235	1.0121	12.032	209.32	2443.5	209.33	2382.7	2592.1	.7038	8.0763	50
55	.1576	1.0146	9.568	230.21	2450.1	230.23	2370.7	2600.9	.7679	7.9913	55
60	.1994	1.0172	7.671	251.11	2456.6	251.13	2358.5	2609.6	.8312	7.9096	60
65	.2503	1.0199	6.197	272.02	2463.1	272.06	2346.2	2618.3	.8935	7.8310	65
70	.3119	1.0228	5.042	292.95	2469.6	292.98	2333.8	2626.8	.9549	7.7553	70
75	.3858	1.0259	4.131	313.90	2475.9	313.93	2321.4	2635.3	1.0155	7.6824	75
80	.4739	1.0291	3.407	334.86	2482.2	334.91	2308.8	2643.7	1.0753	7.6122	80
85	.5783	1.0325	2.828	355.84	2488.4	355.90	2296.0	2651.9	1.1343	7.5445	85
90	.7014	1.0360	2.361	376.85	2494.5	376.92	2283.2	2660.1	1.1925	7.4791	90
95	.8455	1.0397	1.982	397.88	2500.6	397.96	2270.2	2668.1	1.2500	7.4159	95
100	1.014	1.0435	1.673	418.94	2506.5	419.04	2257.0	2676.1	1.3069	7.3549	100
110	1.433	1.0516	1.210	461.14	2518.1	461.30	2230.2	2691.5	1.4185	7.2387	110
120	1.985	1.0603	0.8919	503.50	2529.3	503.71	2202.6	2706.3	1.5276	7.1296	120
130	2.701	1.0697	0.6685	546.02	2539.9	546.31	2174.2	2720.5	1.6344	7.0269	130
140	3.613	1.0797	0.5089	588.74	2550.0	589.13	2144.7	2733.9	1.7391	6.9299	140
150	4.758	1.0905	0.3928	631.68	2559.5	632.20	2114.3	2746.5	1.8418	6.8379	150
160	6.178	1.1020	0.3071	674.86	2568.4	675.55	2082.6	2758.1	1.9427	6.7502	160
170	7.917	1.1143	0.2428	718.33	2576.5	719.21	2049.5	2768.7	2.0419	6.6663	170
180	10.02	1.1274	0.1941	762.09	2583.7	763.22	2015.0	2778.2	2.1396	6.5857	180
190	12.54	1.1414	0.1565	806.19	2590.0	807.62	1978.8	2786.4	2.2359	6.5079	190
200	15.54	1.1565	0.1274	850.65	2595.3	852.45	1940.7	2793.2	2.3309	6.4323	200
210	19.06	1.1726	0.1044	895.53	2599.5	897.76	1900.7	2798.5	2.4248	6.3585	210
220	23.18	1.1900	0.08619	940.87	2602.4	943.62	1858.5	2802.1	2.5178	6.2861	220
230	27.95	1.2088	0.07158	986.74	2603.9	990.12	1813.8	2804.0	2.6099	6.2146	230
240	33.44	1.2291	0.05976	1033.2	2604.0	1037.3	1766.5	2803.8	2.7015	6.1437	240
250	39.73	1.2512	0.05013	1080.4	2602.4	1085.4	1716.2	2801.5	2.7927	6.0730	250

TABLE A-4 Properties of Superheated Water Vapor

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 0.06 bar = 0.006 MPa (T_{sat} = 36.16°C)				p = 0.35 bar = 0.035 MPa (T_{sat} = 72.69°C)			
Sat.	23.739	2425.0	2567.4	8.3304	4.526	2473.0	2631.4	7.7158
80	27.132	2487.3	2650.1	8.5804	4.625	2483.7	2645.6	7.7564
120	30.219	2544.7	2726.0	8.7840	5.163	2542.4	2723.1	7.9644
160	33.302	2602.7	2802.5	8.9693	5.696	2601.2	2800.6	8.1519
200	36.383	2661.4	2879.7	9.1398	6.228	2660.4	2878.4	8.3237
240	39.462	2721.0	2957.8	9.2982	6.758	2720.3	2956.8	8.4828
280	42.540	2781.5	3036.8	9.4464	7.287	2780.9	3036.0	8.6314
320	45.618	2843.0	3116.7	9.5859	7.815	2842.5	3116.1	8.7712
360	48.696	2905.5	3197.7	9.7180	8.344	2905.1	3197.1	8.9034
400	51.774	2969.0	3279.6	9.8435	8.872	2968.6	3279.2	9.0291
440	54.851	3033.5	3362.6	9.9633	9.400	3033.2	3362.2	9.1490
500	59.467	3132.3	3489.1	10.1336	10.192	3132.1	3488.8	9.3194
	p = 0.70 bar = 0.07 MPa (T_{sat} = 89.95°C)				p = 1.0 bar = 0.10 MPa (T_{sat} = 99.63°C)			
Sat.	2.365	2494.5	2660.0	7.4797	1.694	2506.1	2675.5	7.3594
100	2.434	2509.7	2680.0	7.5341	1.696	2506.7	2676.2	7.3614
120	2.571	2539.7	2719.6	7.6375	1.793	2537.3	2716.6	7.4668
160	2.841	2599.4	2798.2	7.8279	1.984	2597.8	2796.2	7.6597
200	3.108	2659.1	2876.7	8.0012	2.172	2658.1	2875.3	7.8343
240	3.374	2719.3	2955.5	8.1611	2.359	2718.5	2954.5	7.9949
280	3.640	2780.2	3035.0	8.3162	2.546	2779.6	3034.2	8.1445
320	3.905	2842.0	3115.3	8.4504	2.732	2841.5	3114.6	8.2849
360	4.170	2904.6	3196.5	8.5828	2.917	2904.2	3195.9	8.4175
400	4.434	2968.2	3278.6	8.7086	3.103	2967.9	3278.2	8.5435
440	4.698	3032.9	3361.8	8.8286	3.288	3032.6	3361.4	8.6636
500	5.095	3131.8	3488.5	8.9991	3.565	3131.6	3488.1	8.8342