KATHMANDU UNIVERSITY
End Semester Examination [C]
May/June, 2019

Marks Scored:

Level: B.Tech.
Year : II

Course : ENVE 204
Semester : I

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Exam Roll No. :

Time: 30 mins.

F. M. : 20

Registration No.:

Date 09 JUN 2019

SECTION "A"
[20 Q. × 1 = 20 marks]

Choose and Tick (√) the correct answer from the given choices.

1. A property of a chemical is predicted as $D \exp(E/T)$ where the unit of the property is in J/(s)(mm)(K) and D and E are constants. What is the unit of E?
   a. unit of the chemical
   b. unit of T
   c. J/(s)(mm)
   d. unitless

2. If a metal's specific property at 32 °F is 118 Btu/(hr)(ft^2)(°F/ft). What is the equivalent value at 273K in terms of Btu/(hr)(ft^2)(K/ft)?
   a. 0 b. 55 c. 212 d. 600

3. For 60 kPa vacuum, what is the equivalent absolute pressure in kPa?
   a. -60.0 b. 60.0 c. 41 d. 161

4. Which is the unit used for absolute temperature?
   a. °F b. °R c. °C d. °G

5. A sample in a lab is reported as 40% water and 60% ethanol. We can assume that the percentages are on the basis of
   a. mass b. mole c. molecules d. volume

6. When the process is carried out at steady state, which term of the general material balance can be deleted?
   a. flow in and out
   b. flow in and generation
   c. consumption and generation
   d. accumulation

7. A system in which material does not cross the system boundary is called:
   a. closed system
   b. isolated system
   c. open system
   d. adiabatic system

8. The ratio of the moles of a desired product to the moles of an undesired product is called:
   a. yield b. selectivity c. single-pass d. overall efficiency

Q9 to Q11: Calcium oxide (CaO) is formed by decomposing $CaCO_3$. In one reactor the reaction goes to 83% completion. MW of $CaCO_3$: 100, MW of CaO: 56.

9. What is the percentage of $CaCO_3$ in the solid product withdrawn from the kiln?
   a. 56 b. 27 c. 58 d. 44

10. What is the percentage of CaO in the solid product withdrawn from the kiln?
    a. 56 b. 27 c. 73 d. 100

11. What is the yield in terms of kg of CO_2 produced per kg of limestone fed into the process?
a. 0 b. 0.37 c. 0.4 d. 1.0

12. At the condition of vapor pressure, which of the following is true?
a. net evaporation is zero
b. evaporation is greater than condensation
c. evaporation is less than condensation
d. condensation is zero

13. A product contains 60% water and is produced at the rate of 200 kg/hr. You need to dry the product so that it contains only 20% water. How much water has to be evaporated per hour?
a. 100 kg/hr b. 178 kg/hr c. 200 kg/hr d. 275 kg/hr

14. Which type of conversion is based on what enters and leaves the reactor?
a. single-pass b. double-pass c. real d. ideal

15. Pure carbon is burned in oxygen. The flue-gas analysis is: CO_2: 77 mol%, CO: 12 mol% and O_2: 11 mol%. What was the percent excess oxygen used?
a. 11 b. 4.4 c. 22 d. 90

16. What is used to calculate moisture content in air?
a. Kay's method b. evaporation rate c. humidity d. saturation

17. Which of the following method will you use to find properties of a mixture of real gases?
a. Ideal gas law b. Van der Waal c. Kay's d. critical point

18. An ideal gas at 45°C and 1.1 atm is heated to 600°C at constant pressure, and then isothermally compressed to 10 atm. It is then isobarically cooled to 50°C, and finally is isothermally expanded to back to its initial state. For the overall process, determine ΔH and ΔU.
a. $\Delta H=0, \Delta U=0$ b. $\Delta H\neq 0, \Delta Q=0$ c. $\Delta H=0, Q\neq 0$ d. $\Delta H\neq 0, \Delta U\neq 0$

19. A liquid inside a well-insulated reactor is shaken very rapidly with another shaker. Which of the following is the most appropriate system for this process?
a. reactor only b. shaker only c. liquid and reactor d. liquid and shaker

20. The enthalpy of reaction when stoichiometric quantities of reactants at 25 °C and 1 atm react completely to produce products at the same state is also known as:
a. heat of reaction
b. standard heat of reaction
c. heat of formation
d. specific enthalpy

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Level : B.Tech.
Year : II
Time : 2 hrs. 30 mins.

Course : ENVE 204
Semester : I
F. M. : 55

SECTION "B"

Answer *ALL* questions. The data or information not given in the questions should be assumed properly.

1. The following table shows the annual inputs of phosphurus to a lake:

	Short tons/yr
Source	
Lake "B"	3000
Land drainage	7000
Municipal waste	20000
Industrial waste	5000
Outflow	-4000
Retained	25000

a. Convert the retained phosphorus to concentration in micrograms per liter assuming that the lake contains 2.2×10^{14} gal of water and that the average phosphorus retention time is 2.20 yr. Note that 1 short ton = 2000 lb. [3]
b. What percentage of the input comes from municipal water? [1]
c. If 25 ppb of phosphorus triggers nuisance algal blooms, would removing 20% of the phosphorus in the municipal waste and all the phosphorus in the industrial waste be effective in reducing the eutrophication (i.e., the unwanted algal blooms) in lake? [3]

2. The following two gas phase reactions is taking place in a process:
$C_2H_6 \rightarrow C_2H_4 + H_2$ and $C_2H_6 + H_2 \rightarrow 2CH_4$. The product distribution measured in the gas phase reaction of C_2H_6 was found as C_2H_6: 30%, C_2H_4: 30%, H_2: 10% and CH_4: 30%.
a. What species was the limiting reactant? [2]
b. What species was the excess reactant? [1]
c. What was the conversion of C_2H_6 to CH_4? [2]
d. What was the selectivity of C_2H_4 relative to CH_4? [2]

3. It is observed that 12 lb of nitrogen gas at 125 °F are stored in a cylinder having a volume of 0.8 ft^3. Calculate the pressure in atmospheres in the cylinder
a. assuming N_2 to be an ideal gas, [2]
b. and using the compressibility factor method. [4]

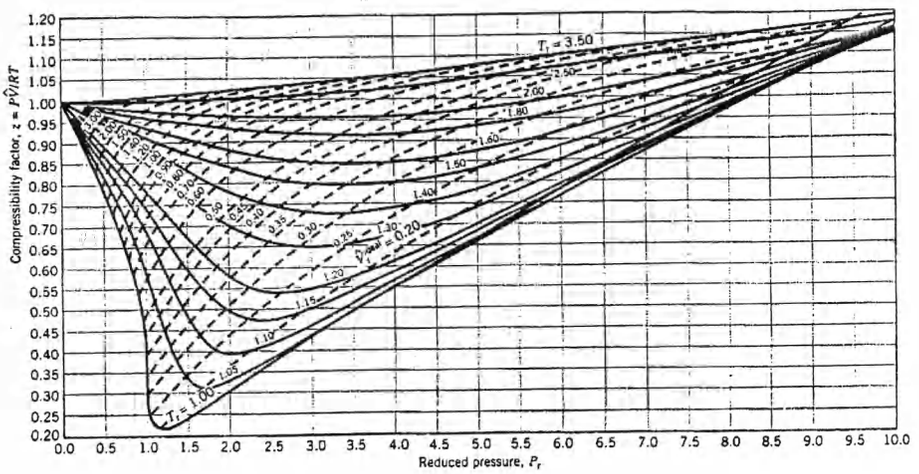

Figure: Generalized compressibility chart.

Use R = 10.73 (psia)(ft^3)/(lb mol)(°R) = 0.7302 (atm)(ft^3)/(lb mol)(°R). For van der Waal's equation, take a = 1.347×10^6 atm (cm^3/g mol)^2 and b = 38.6 cm^3/g mol. Take p_c = 33.5 atm and T_c = 126.2 K.

4. Describe the mass balance method by deriving the general mass balance equation and then applying that to various conditions that you encounter in Environmental Engineering. [6]

5. A synthesis gas has the composition of CO_2 : 3.7 percent; CO : 20.4 percent; H_2 : 14 percent; CH_4 : 0.9 percent; and N_2 : 61 percent. It is burned in a furnace with 33% excess air. Calculate the Orsat analysis of the flue gas. [6]

6. A simplified process for the production of SO_3 to be used in the manufacture of sulfuric acid is shown below. Sulfur is burned with 100% excess air in the burner, but for the reaction $S + O_2 \rightarrow SO_2$, only 85% conversion of the S to SO_2 is achieved. In the converter, the conversion of SO_2 to SO_3 is 90% complete. Calculate the lb of air required per 100 lb of sulfur burned, and the concentrations in mole fraction of the components in the exit gas from the burner and from the converter. [4+3]

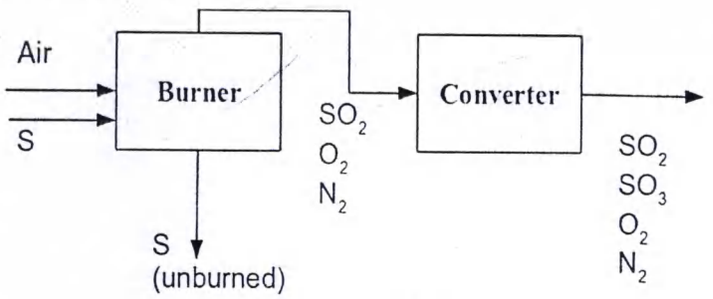

Figure for Q. 6.

7. The percent absolute humidity of air at 33 °C and a total pressure of 110 kPa is 25%. Calculate:
   a. the percent relative humidity, [1]
   b. the humidity, [2]
   c. the partial pressure of the water vapor in the air. [2]
   d. What is the dew point of the air? [1]

8. a. What is the application of a steam table in process calculations? Explain with a specific example in environmental engineering. [3]
   b. A 5-MW steam-driven turbine operates in the steady state using 33 kg/s of steam. The inlet conditions for the steam are $p = 2500$ kPa and $T = 500$ °C with enthalpy of 3500 kJ/kg. The outlet conditions are 450 kPa, saturated vapor. The entering velocity of the steam is 300 m/s and the exit velocity is 30 m/s. What is the heat transfer in kilowatts for the turbine as the system? [7]

CONVERSION FACTORS

HEAT, ENERGY, OR WORK EQUIVALENTS

	$(ft)(lb_f)$	kWh	(hp)(hr)	Btu	calorie*	joule
$(ft)(lb_f)$	1	3.766×10^{-7}	5.0505×10^{-7}	1.285×10^{-3}	0.3241	1.356
kWh	2.655×10^{6}	1	1.341	3.4128×10^{3}	8.6057×10^{5}	3.6×10^{6}
(hp)(hr)	1.98×10^{6}	0.7455	1	2.545×10^{3}	6.4162×10^{5}	2.6845×10^{6}
Btu	7.7816×10^{2}	2.930×10^{-4}	3.930×10^{-4}	1	2.52×10^{2}	1.055×10^{3}
calorie*	3.086	1.162×10^{-6}	1.558×10^{-6}	3.97×10^{-3}	1	4.184
joule	0.7376	2.773×10^{-7}	3.725×10^{-7}	9.484×10^{-4}	0.2390	1

*The thermochemical calorie = 4.184 J.

PRESSURE EQUIVALENTS

	mm Hg	in. Hg	bar	atm	kPa	psia
mm Hg	1	3.937×10^{-2}	1.333×10^{-3}	1.316×10^{-3}	0.1333	1.934×10^{-2}
in. Hg	25.40	1	3.386×10^{1}	3.342×10^{-2}	3.386	0.4912
bar	750.06	29.53	1	0.9869	100.0	14.51
atm	760.0	29.92	1.013	1	101.3	14.696
kPa	7.502	0.2954	1.000×10^{-2}	9.872×10^{-3}	1	0.1451
psia	51.71	2.036	6.893×10^{-2}	6.805×10^{-2}	6.893	1

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psia	51.71	2.036	6.893×10^{-2}	6.805×10^{-2}	6.893	1

Table 4. Properties of Saturated Water and Steam (Temperature)

Temp. t (°C)	Pressure MPa	Volume, m^3/kg v_L	v_V	Enthalpy, kJ/kg h_L	h_V	Entropy, kJ/(kg·K) s_L	s_V	Temp. t (°C)
0.01	0.0006117	0.0010002	206.00	0.001	2500.9	0.0000	9.1555	**0.01**
5	0.0008726	0.0010001	147.02	21.019	2510.1	0.0763	9.0249	**5**
10	0.001228	0.0010003	106.31	42.021	2519.2	0.1511	8.8998	**10**
15	0.001706	0.0010009	77.881	62.984	2528.4	0.2245	8.7804	**15**
20	0.002339	0.0010018	57.761	83.920	2537.5	0.2965	8.6661	**20**
25	0.003170	0.0010030	43.341	104.84	2546.5	0.3673	8.5568	**25**
30	0.004247	0.0010044	32.882	125.75	2555.6	0.4368	8.4521	**30**
35	0.005629	0.0010060	25.208	146.64	2564.6	0.5052	8.3518	**35**
40	0.007384	0.0010079	19.517	167.54	2573.5	0.5724	8.2557	**40**
45	0.009594	0.0010099	15.253	188.44	2582.5	0.6386	8.1634	**45**
50	0.012351	0.0010121	12.028	209.34	2591.3	0.7038	8.0749	**50**
55	0.015761	0.0010145	9.5649	230.24	2600.1	0.7680	7.9899	**55**
60	0.019946	0.0010171	7.6677	251.15	2608.8	0.8312	7.9082	**60**
65	0.025041	0.0010199	6.1938	272.08	2617.5	0.8935	7.8296	**65**
70	0.031201	0.0010228	5.0397	293.02	2626.1	0.9550	7.7540	**70**
75	0.038595	0.0010258	4.1291	313.97	2634.6	1.0156	7.6812	**75**
80	0.047415	0.0010290	3.4053	334.95	2643.0	1.0754	7.6110	**80**
85	0.057867	0.0010324	2.8259	355.95	2651.3	1.1344	7.5434	**85**
90	0.070182	0.0010359	2.3591	376.97	2659.5	1.1927	7.4781	**90**
95	0.084609	0.0010396	1.9806	398.02	2667.6	1.2502	7.4150	**95**
100	0.10142	0.0010435	1.6719	419.10	2675.6	1.3070	7.3541	**100**
105	0.12090	0.0010474	1.4185	440.21	2683.4	1.3632	7.2951	**105**
110	0.14338	0.0010516	1.2094	461.36	2691.1	1.4187	7.2380	**110**
115	0.16918	0.0010559	1.0359	482.55	2698.6	1.4735	7.1827	**115**
120	0.19867	0.0010603	0.89130	503.78	2705.9	1.5278	7.1291	**120**
125	0.23222	0.0010649	0.77011	525.06	2713.1	1.5815	7.0770	**125**
130	0.27026	0.0010697	0.66808	546.39	2720.1	1.6346	7.0264	**130**
135	0.31320	0.0010747	0.58180	567.77	2726.9	1.6872	6.9772	**135**
140	0.36150	0.0010798	0.50852	589.20	2733.4	1.7393	6.9293	**140**
145	0.41563	0.0010850	0.44602	610.69	2739.8	1.7909	6.8826	**145**
150	0.47610	0.0010905	0.39250	632.25	2745.9	1.8420	6.8370	**150**
155	0.54342	0.0010962	0.34650	653.88	2751.8	1.8926	6.7926	**155**
160	0.61814	0.0011020	0.30682	675.57	2757.4	1.9428	6.7491	**160**
165	0.70082	0.0011080	0.27246	697.35	2762.8	1.9926	6.7066	**165**
170	0.79205	0.0011143	0.24262	719.21	2767.9	2.0419	6.6649	**170**
175	0.89245	0.0011207	0.21660	741.15	2772.7	2.0909	6.6241	**175**
180	1.0026	0.0011274	0.19386	763.19	2777.2	2.1395	6.5841	**180**
185	1.1233	0.0011343	0.17392	785.32	2781.4	2.1878	6.5447	**185**
190	1.2550	0.0011414	0.15638	807.57	2785.3	2.2358	6.5060	**190**
195	1.3986	0.0011488	0.14091	829.92	2788.9	2.2834	6.4679	**195**
200	1.5547	0.0011565	0.12722	852.39	2792.1	2.3308	6.4303	**200**
205	1.7240	0.0011645	0.11509	874.99	2794.9	2.3779	6.3932	**205**
210	1.9074	0.0011727	0.10430	897.73	2797.4	2.4248	6.3565	**210**
215	2.1055	0.0011813	0.094689	920.61	2799.4	2.4714	6.3202	**215**
220	2.3193	0.0011902	0.086101	943.64	2801.1	2.5178	6.2842	**220**

Table 5. Properties of Saturated Water and Steam (Pressure)

Press. MPa	Temp. t (°C)	Volume, m^3/kg v_L	v_V	Enthalpy, kJ/kg h_L	h_V	Entropy, kJ/(kg·K) s_L	s_V	Press. MPa
0.001	6.97	0.0010001	129.18	29.298	2513.7	0.1059	8.9749	**0.001**
0.002	17.50	0.0010014	66.990	73.435	2532.9	0.2606	8.7227	**0.002**
0.003	24.08	0.0010028	45.655	100.99	2544.9	0.3543	8.5766	**0.003**
0.004	28.96	0.0010041	34.792	121.40	2553.7	0.4224	8.4735	**0.004**
0.005	32.88	0.0010053	28.186	137.77	2560.8	0.4763	8.3939	**0.005**
0.006	36.16	0.0010064	23.734	151.49	2566.7	0.5209	8.3291	**0.006**
0.007	39.00	0.0010075	20.525	163.37	2571.8	0.5591	8.2746	**0.007**
0.008	41.51	0.0010085	18.099	173.85	2576.2	0.5925	8.2274	**0.008**
0.009	43.76	0.0010094	16.200	183.26	2580.3	0.6223	8.1859	**0.009**
0.010	45.81	0.0010103	14.671	191.81	2583.9	0.6492	8.1489	**0.010**
0.012	49.42	0.0010119	12.359	206.91	2590.3	0.6963	8.0850	**0.012**
0.014	52.55	0.0010133	10.691	219.99	2595.8	0.7366	8.0312	**0.014**
0.016	55.31	0.0010147	9.4309	231.55	2600.7	0.7720	7.9847	**0.016**
0.018	57.80	0.0010160	8.4433	241.95	2605.0	0.8035	7.9437	**0.018**
0.020	60.06	0.0010171	7.6482	251.40	2608.9	0.8320	7.9072	**0.020**
0.025	64.96	0.0010198	6.2034	271.93	2617.4	0.8931	7.8302	**0.025**
0.030	69.10	0.0010222	5.2286	289.23	2624.6	0.9439	7.7675	**0.030**
0.035	72.68	0.0010244	4.5252	304.25	2630.7	0.9876	7.7146	**0.035**
0.040	75.86	0.0010264	3.9931	317.57	2636.1	1.0259	7.6690	**0.040**
0.045	78.71	0.0010282	3.5761	329.55	2640.9	1.0601	7.6288	**0.045**
0.05	81.32	0.0010299	3.2401	340.48	2645.2	1.0910	7.5930	**0.05**
0.06	85.93	0.0010331	2.7318	359.84	2652.9	1.1452	7.5311	**0.06**
0.07	89.93	0.0010359	2.3649	376.68	2659.4	1.1919	7.4790	**0.07**
0.08	93.49	0.0010385	2.0872	391.64	2665.2	1.2328	7.4339	**0.08**
0.09	96.69	0.0010409	1.8695	405.13	2670.3	1.2694	7.3942	**0.09**
0.10	99.61	0.0010431	1.6940	417.44	2674.9	1.3026	7.3588	**0.10**
0.12	104.78	0.0010473	1.4284	439.30	2683.1	1.3608	7.2976	**0.12**
0.14	109.29	0.0010510	1.2366	458.37	2690.0	1.4109	7.2460	**0.14**
0.16	113.30	0.0010544	1.0914	475.34	2696.0	1.4549	7.2014	**0.16**
0.18	116.91	0.0010576	0.97753	490.67	2701.4	1.4944	7.1620	**0.18**
0.20	120.21	0.0010605	0.88574	504.68	2706.2	1.5301	7.1269	**0.20**
0.25	127.41	0.0010672	0.71870	535.35	2716.5	1.6072	7.0524	**0.25**
0.30	133.53	0.0010732	0.60579	561.46	2724.9	1.6718	6.9916	**0.30**
0.35	138.86	0.0010786	0.52420	584.31	2732.0	1.7275	6.9401	**0.35**
0.40	143.61	0.0010836	0.46239	604.72	2738.1	1.7766	6.8954	**0.40**
0.45	147.91	0.0010882	0.41390	623.22	2743.4	1.8206	6.8560	**0.45**
0.50	151.84	0.0010926	0.37480	640.19	2748.1	1.8606	6.8206	**0.50**
0.55	155.46	0.0010967	0.34259	655.88	2752.3	1.8972	6.7885	**0.55**
0.60	158.83	0.0011006	0.31558	670.50	2756.1	1.9311	6.7592	**0.60**
0.65	*161.99*	*0.0011044*	*0.29258*	*684.22*	*2759.6*	*1.9626*	*6.7321*	***0.65***
0.70	164.95	0.0011080	0.27276	697.14	2762.7	1.9921	6.7070	**0.70**
0.80	170.41	0.0011148	0.24033	721.02	2768.3	2.0460	6.6615	**0.80**
0.90	175.36	0.0011212	0.21487	742.72	2773.0	2.0944	6.6212	**0.90**
1.00	179.89	0.0011272	0.19435	762.68	2777.1	2.1384	6.5850	**1.00**
1.10	184.07	0.0011330	0.17744	781.20	2780.7	2.1789	6.5520	**1.10**