1. (10%)

A steam turbine in a small electric power plant is designed to accept 4000 kg/h of steam at 30 bar and 500 °C and exhaust the steam at 10 bar. Assuming that the turbine is adiabatic and has been well designed ($\dot{S}_{gen} = 0$), compute the exit temperature of the steam and the power generated by the turbine.

Superheated Vapor (*Continued*)

T (°C)	P = 1.00 MPa (179.91)			
	$\hat{V}$	$\hat{U}$	$\hat{H}$	$\hat{S}$
Sat.	0.194 44	2583.6	2778.1	6.5865
200	0.2060	2621.9	2827.9	6.6940
250	0.2327	2709.9	2942.6	6.9247
300	0.2579	2793.2	3051.2	7.1229
350	0.2825	2875.2	3157.7	7.3011
400	0.3066	2957.3	3263.9	7.4651
500	0.3541	3124.4	3478.5	7.7622
600	0.4011	3296.8	3697.9	8.0290

	P = 2.50 MPa (223.99)				P = 3.00 MPa (233.90)			
Sat.	0.079 98	2603.1	2803.1	6.2575	0.066 68	2604.1	2804.2	6.1869
225	0.080 27	2605.6	2806.3	6.2639	—	—	—	—
250	0.087 00	2662.6	2880.1	6.4085	0.070 58	2644.0	2855.8	6.2872
300	0.098 90	2761.6	3008.8	6.6438	0.081 14	2750.1	2993.5	6.5390
350	0.109 76	2851.9	3126.3	6.8403	0.090 53	2843.7	3115.3	6.7428
400	0.120 10	2939.1	3239.3	7.0148	0.099 36	2932.8	3230.9	6.9212
450	0.130 14	3025.5	3350.8	7.1746	0.107 87	3020.4	3344.0	7.0834
500	0.139 98	3112.1	3462.1	7.3234	0.116 19	3108.0	3456.5	7.2338
600	0.159 30	3288.0	3686.3	7.5960	0.132 43	3285.0	3682.3	7.5085

$\hat{V}$ [=] m³/kg;　$\hat{U}$, $\hat{H}$ [=] J/g = kJ/kg;　$\hat{S}$ [=] kJ/kg K

2. (15%)

From experimental data it is known that at moderate pressures the volumetric equation of state may be written as $Pv = RT + BP$. Show that the van der Waals equation ($P = \dfrac{RT}{v-b} - \dfrac{a}{v^2}$) leads to the following expression for the virial coefficient $B = b - a/RT$. The temperature at which $B = 0$ is called the Boyle temperature. Show that for the van der Waals fluid, $T_{Boyle} = 3.375 T_C$. State the physical significance of Boyle temperature.

3. (12%)

Vapor-liquid equilibrium data for the A-B system at a constant temperature of 350 K shows that component B follows Henry's law in the range $0 < X_B \leqq 0.05$. At this temperature the following data point has been reported $X_A = 0.975$, $y_A = 0.942$, P = 1035 mmHg, and the vapor pressures are $P^o_A = 1000$ mmHg, $P^o_B = 800$ mmHg. Calculate y_B and P when $X_B = 0.04$.

4. (13%)

In the system A-B, activity coefficients can be expressed by

$$\ln \gamma_A = 0.5\, X_B^2 \text{ and } \ln \gamma_B = 0.5\, X_A^2$$

The vapor pressure of A and B at 80°C are $P^o_A = 900$ mmHg, $P^o_B = 600$ mmHg.
Is there an azeotrope in this system at 80°C, and if so, what is the azeotrope pressure and composition?

注意：背面有試題

5. (10%)

The trimerization: $3A(g) \rightarrow A_3(g,l)$

is carried out isothermally and without pressure drop in a PFR at 298 K and 2 atm. As the concentration of A_3 increases down the reactor and A_3 begins to condense. The vapor pressure of A_3 at 298K is 0.5 atm. If an equal molar mixture of A and inert, I, is fed to the reactor at what conversion of A will A_3 begin to condense?

$$A(g) \rightarrow \frac{1}{3} A_3(g,l)$$

$$\text{Condensation begins at } y = \frac{P_V}{P_T} = \frac{0.5\text{ atm}}{2\text{ atm}} = 0.25$$

6. (15%)

The following reactions were found to occur while trying to make a desired product B

$$A \rightarrow B \quad -r_{A1}=k_{1A}C_A^2$$
$$A \rightarrow X \quad -r_{A2}=k_{2A}C_A$$
$$A+X \rightarrow Y \quad -r_{A3}=k_{3A}C_AC_X$$

Species X and Y are both foul pollutants

(a) What is the instantaneous selectivity of B with respect to the foul pollutant X and Y?

(b) How would you carry out this reaction to maximize the formation of B?

Additional Information

$k_{1A}=0.5e^{-10,000/T}$ min^{-1}, T in degree Kelvin

$k_{2A}=50e^{-20,000/T}$ min^{-1}, T in degree Kelvin

$k_{3A}=100e^{-5,000/T}$ min^{-1}, T in degree Kelvin

7. (10%)

The gas-phase decomposition: $3A \rightarrow 2B+C$ was carried out in a constant volume batch reactor. $t_{1/10}$ was the time necessary for the concentration of A to fall to 1/10 of its initial concentration. Run1 through 4 were carried out at 80°C, while run 5 was carried out at 28°C. Please determine the reaction order, specific reaction rate, and the activation energy.

Run	1	2	3	4	5
Initial concentrations C_{A0} (g-mol/L)	0.090	0.150	0.245	0.41	0.245
$t_{1/10}$ (min)	109.2	40.2	14.8	5.4	90.2

8. (15%)

A second-order gas reaction $3A \rightarrow 2B+C$ is taking place in 40 meters of a pipe packed with catalyst. The diameter of the pipe is 2 cm. The pellet size is 3 mm in diameter and the porosity is 50%. The density of catalyst is 4 g/cm^3. The specific reaction rate is 1 (m^6/kmol-kg cat-h). There is 1 kg/h of gas passing through the bed and the entering concentration of A is 0.1 kmol/m^3. The entering pressure is 2 atm. The properties of the gas are similar to air that the density is 1 kg/m^3 and the viscosity is 1.82×10^{-5} kg/m-s.

(a) What is the conversion if there is no pressure drop?

(b) What is the conversion if there pressure drop is considered?

Hint.　The Ergun equation: $$\frac{dP}{dz} = -\frac{G}{\rho g_c D_p}\left(\frac{1-\phi}{\phi^3}\right)\left[\overbrace{\frac{150(1-\phi)\mu}{D_p}}^{\text{Term 1}} + \overbrace{1.75G}^{\text{Term 2}}\right]$$

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