本試題是否可以使用計算機：☑可使用 ，☐不可使用　（請命題老師勾選）

**This examination paper contains FIVE (5) questions and comprises Three (3) printed pages. All questions carry EQUAL (20) marks.**

**(Question 1)**

(1) Show that the second virial coefficient $B$ is zero at the Boyle temperature. [5%]

(2) Use the generalized correlation for $B$ as shown below to estimate the reduced Boyle temperature for simple fluids based on the simplest form of the virial equation. [5%]

$$\frac{BP_c}{RT_c} = B^{(0)} + \omega B^{(1)}$$

where $B^{(0)} = 0.083 - \frac{0.422}{T_r^{1.6}}$, $B^{(1)} = 0.139 - \frac{0.172}{T_r^{4.2}}$, and $P_c$, $T_c$, $\omega$, $T_r$ indicate the critical pressure, critical temperature, acentric factor, reduced temperature, respectively.

(3) The $P_c$, $T_c$, and $\omega$ of *n*-butane are 37.96 bar, 425.1 K, and 0.2, respectively. Calculate the molar volume of *n*-butane at 510 K and 25 bar by the generalized compressibility-factor correlation. [5%]

(4) Calculate the molar volume of *n*-butane at 510 K and 25 bar by the generalized virial-coefficient correlation. [5%]

**(Question 2)**

What is the maximum temperature that can be reached by the combustion of methane with 20% excess air? Both the methane and the air enter the burner at 25°C. You need to write down the reaction. The assumed path diagram is also needed with all mole numbers of the reactants and products clearly indicated. The first guess to initiate the trial of maximum temperature is set to be 1,000 K. [20%]

**[Note]**

(1) $\Delta H^{\circ}_{298} (= \sum_i \nu_i \cdot H^{o}_{i,298})$ based on 1 mole of methane for the reaction is –802,625 J.

(2) $C_p$ for each chemical species ($i$) is a function of temperature and can be expressed as

$$C_{p,i}/R = A_i + B_i T + C_i T^2 + D_i T^{-2}$$

where $T$ is the absolute temperature in the Kelvin scale. The change of A for the reaction (i.e. $\Sigma \nu_i A_i$) is 43.471, the change of B is $9.502\times10^{-3}$, the change of C is 0, and the change of D is $-0.645\times10^{5}$.

(3) You should conduct a trial-and-error iteration, in order to answer this question. Please do the trial-and-error twice (no more than twice and no less than twice) to give the answer.

**(Question 3)**

A turbine is supplied with 5000 $lb_m/h$ steam of 900 psia and 820°F ($H$ = 1405 $Btu/lb_m$). The exhaust pressure is 80 psia. The exhaust steam is then passed through an adiabatic throttling meter, where it expands to 1 atm and a temperature of 240°F ($H$ = 1164 $Btu/lb_m$). Heat loss from the turbine is estimated to be 140,000 Btu/h.

(1) What is the quality of the steam exhausting from the turbine (i.e. the vapor content)? [10%]

(2) What is the power output delivered by the turbine? [10%]

**Steam Table (Superheated)**

$V$ = specific volume [$ft^3/lb_m$]　　$U$ = specific internal energy [$Btu/lb_m$]

$H$ = specific enthalpy [$Btu/lb_m$]　　$S$ = specific entropy [$Btu/(lb_mR)$]

| $P$/(psia) ($t^{sat}$/°F) | | sat. liq. | sat. vap. | TEMPERATURE: $t$(°F) 340 | 360 | 380 | 400 | 420 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| | $V$ | 0.0176 | 5.471 | 5.715 | 5.885 | 6.053 | 6.218 | 6.381 | 6.622 | 7.018 |
| 80 | $U$ | 281.89 | 1102.1 | 1114.0 | 1122.3 | 1130.4 | 1138.4 | 1146.3 | 1158.1 | 1177.4 |
| (312.04) | $H$ | 282.15 | 1183.1 | 1198.6 | 1209.4 | 1220.0 | 1230.5 | 1240.8 | 1256.1 | 1281.3 |
| | $S$ | 0.4534 | 1.6208 | 1.6405 | 1.6539 | 1.6667 | 1.6790 | 1.6909 | 1.7080 | 1.7349 |
| | $V$ | 0.0176 | 5.167 | 5.364 | 5.525 | 5.684 | 5.840 | 5.995 | 6.223 | 6.597 |
| 85 | $U$ | 286.24 | 1102.9 | 1113.1 | 1121.5 | 1129.7 | 1137.8 | 1145.8 | 1157.6 | 1177.0 |
| (316.26) | $H$ | 286.52 | 1184.2 | 1197.5 | 1208.4 | 1219.1 | 1229.7 | 1240.1 | 1255.5 | 1280.8 |
| | $S$ | 0.4590 | 1.6159 | 1.6328 | 1.6463 | 1.6592 | 1.6716 | 1.6836 | 1.7008 | 1.7279 |
| | $V$ | 0.0177 | 4.895 | 5.051 | 5.205 | 5.356 | 5.505 | 5.652 | 5.869 | 6.223 |
| 90 | $U$ | 290.40 | 1103.7 | 1112.3 | 1120.8 | 1129.1 | 1137.2 | 1145.3 | 1157.2 | 1176.7 |
| (320.28) | $H$ | 290.69 | 1185.3 | 1196.4 | 1207.5 | 1218.3 | 1228.9 | 1239.4 | 1254.9 | 1280.3 |
| | $S$ | 0.4643 | 1.6113 | 1.6254 | 1.6391 | 1.6521 | 1.6646 | 1.6767 | 1.6940 | 1.7212 |
| | $V$ | 0.0177 | 4.651 | 4.771 | 4.919 | 5.063 | 5.205 | 5.345 | 5.551 | 5.889 |
| 95 | $U$ | 294.38 | 1104.5 | 1111.4 | 1120.0 | 1128.4 | 1136.6 | 1144.7 | 1156.7 | 1176.3 |
| (324.13) | $H$ | 294.70 | 1186.2 | 1195.3 | 1206.5 | 1217.4 | 1228.1 | 1238.7 | 1254.3 | 1279.8 |
| | $S$ | 0.4694 | 1.6069 | 1.6184 | 1.6322 | 1.6453 | 1.6580 | 1.6701 | 1.6876 | 1.7149 |
| | $V$ | 0.0177 | 4.431 | 4.519 | 4.660 | 4.799 | 4.935 | 5.068 | 5.266 | 5.588 |
| 100 | $U$ | 298.21 | 1105.2 | 1110.6 | 1119.2 | 1127.7 | 1136.0 | 1144.2 | 1156.3 | 1175.9 |
| (327.82) | $H$ | 298.54 | 1187.2 | 1194.2 | 1205.5 | 1216.5 | 1227.4 | 1238.0 | 1253.7 | 1279.3 |
| | $S$ | 0.4743 | 1.6027 | 1.6116 | 1.6255 | 1.6389 | 1.6516 | 1.6638 | 1.6814 | 1.7088 |

**(Question 4)**

Consider a binary aqueous mixture. The enthalpy $\Delta H$ and entropy $\Delta S$ of mixing are given respectively by

$$\Delta H = 2.1 \cdot RT \cdot x_1^2 x_2 \text{ and } \Delta S = -R \cdot \left(1.9 \cdot x_1 x_2^2 + x_1 \cdot \ln x_1 + x_2 \cdot \ln x_2\right),$$

where $x_i$ is the mole fraction for the component $i$ ($i$=1,2), $R$ the gas constant and $T$ temperature.

(1) Determine the Gibbs free energy of mixing $\Delta G$. [5%]

(2) Determine the excess Gibbs free energy $G^E$. Also, $G^E$ ($x_1 \to 0$) = ? Explain why physically. [5%]

(3) Evaluate the activity coefficient $\gamma_i^{\infty}$ for each species in the dilute limit. [5%]

(4) Determine the Henry constant $H_i$ for each species. The fugacity of a pure liquid $i$ is $f_i$. [5%]

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**(Question 5)**

It is well known that adding salt, NaCl, to a pot of water will result in an increase in the boiling temperature. The enthalpies of saturated liquid water and saturated water vapor at 100 °C are 419.1 kJ/kg and 2676.0 kJ/kg, respectively. The molecular weight of NaCl is 58.44 g/mol. Please clearly state all assumptions and simplifications leading to your answers.

(1) Please establish a relationship between the boiling temperature and the amount of salt, NaCl, added in weight percentage (wt%), if the temperature effect on the changes in enthalpies of saturated liquid water and water vapor is insignificant. [17%]

(2) How much NaCl is needed to render a 1°C-increase in boiling temperature? [3%]

**END OF PAPER.**

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