BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE (BITS) PILANI – Pilani Campus

FIRST SEMESTER, 2022 – 2023 | CHE G622 Advanced Chemical Engineering Thermodynamics | Comprehensive Examination

Time: 2.00 to 5.00 PM | Maximum Marks: 80 (40 %) | Date: 19. 12. 2022 (Monday) | **CLOSE + OPEN BOOK**

INSTRUCTIONS

1. **This question paper consists of two parts. Part A is close book and Part B is open (only text) book.**
2. **Part-B answer book will be supplied after you return Part-A answer book.**
3. **Make and state suitable, logical and scientifically justifiable assumptions if necessary.**

- **Give just 2 iterations for iterative procedure(s).**
- **Be to the point. Show all steps systematically.**

If words are required, answer in bulleted points. Do not use paragraphs.

PART A (CLOSE BOOK

Q1. [4 Marks] A renowned laboratory reports quadruple-point coordinates of 10.2 Mbar and 24.1°C for four-phase equilibrium of allotropic solid forms of the exotic chemical *β*-miasmone. Evaluate the claim.

Q2. [7 Marks] Derive an equation for the work of mechanically reversible, isothermal compression of 1 mol of a gas from an initial pressure P_1 to a final pressure P_2 when the equation of state is the virial expansion truncated to: $Z = 1 + B' P$. What is the physical significance of B'? How does the result compare with the corresponding equation for an ideal gas?

Q3. [12 Marks] A pure fluid is described by the canonical equation of state: $G = \Gamma(T) + RT \ln P$, where $\Gamma(T)$ is a substance-specific function of temperature. Determine for such a fluid, expressions for V, S, H, U, C_P, and C_V. Are these results consistent with those for an important model of gas-phase behavior? What is the model? If the fluid is not pure, how will you express *G*? Use standard nomenclature and define them.

Q4. [7 Marks] Show that: (**a**) The *partial molar mass* of a species in solution is equal to its molar mass. (**b**) A partial specific property of a species in solution is obtained by division of the partial molar property by the molar mass of the species. Any error in (**a**) and/or (**b**)?

PART B (ONLY OPEN TEXT BOOK)

Q5. [15 Marks] The higher heating value (HHV) of a fuel is its standard heat of combustion at 25°C with liquid water as a product; the lower heating value (LHV) is for water vapor as product. Are they right statements? (**a**) Explain the origins of these terms; (**b**) Determine the HHV and the LHV for natural gas, modeled as pure methane; (**c**) Determine the HHV and the LHV for a home-heating oil, modeled as pure liquid *n*-decane. For *n*-decane as a liquid $\Delta H^o_{f298} = -249{,}700\ \text{J·mol}^{-1}$.

Q6. [6 Marks] An egg, initially at rest, is dropped onto a concrete surface; it breaks. Prove that the process is irreversible. In modeling this process treat the egg as the system, and assume the passage of sufficient time for the egg to return to its initial temperature.

Q7. [6 Marks] A single gas stream enters a process at conditions T_1, P_1, and leaves at pressure P_2. The process is adiabatic. Prove that the outlet temperature T_2 for the actual (irreversible) adiabatic process is greater than that for a reversible adiabatic process. Assume the gas is ideal with constant heat capacities.

Q8. [12 Marks] The top tray of a distillation column and the condenser are at a pressure of 1.38 bar. The liquid on the top tray is an equimolar mixture of *n*-butane and *n*-pentane. The vapour from the top tray, assumed to be in equilibrium with the liquid, goes to the condenser where 50 mole % of the vapour is condensed. What is the temperature on the top tray? What are the temperature and composition of the vapour leaving the condenser?

Q9. [5 Marks] The following expressions have been proposed for the partial molar properties of a particular binary mixture: $\bar{M}_1 = M_1 + Ax_2$ and $\bar{M}_2 = M_2 + Ax_1$ Here, parameter *A* is a constant. Can these expressions possibly be correct? Explain.

Q10. [6 Marks] An engineer claims that the volume expansivity of an ideal solution is given by $\beta^{id} = \sum_i (x_i \beta_i)$ [submission over *i*]. Is this claim valid? If so, show why. If not, find a correct expression for β^{id}.

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