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

FIRST SEMESTER, 2023 – 2024 | CHE G622 Advanced Chemical Engineering Thermodynamics | Mid-Semester Test

Time: 11.00 AM to 12.30 PM | Maximum Marks: 60 (30 %) | Date: 11. 10. 2023 (Wednesday) | **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.**

PART A (CLOSE BOOK)

Q1. [10 Marks] If the heat capacity of a substance is correctly represented by an equation of the form: $C_p = A + BT + DT^{-2}$. Develop the expression for the error resulting when $\langle C_P \rangle_H$ is assumed equal to C_P evaluated at the arithmetic mean of the initial and final temperatures.

Q2. [15 Marks] Consider the air conditioning of a class room through use of solar energy. At a particular location, experiment has shown that solar radiation allows a large tank of pressurized water to be maintained at 175°C. During a particular time interval, heat in the amount of 1500 kJ must be extracted from the class room to maintain its temperature at 24°C when the surroundings temperature is 33°C. Treating the tank of water, the class room, and the surroundings as heat reservoirs, determine the minimum amount of heat that must be extracted from the tank of water by any device built to accomplish the required cooling of the class room. No other sources of energy are available.

PART B (ONLY OPEN TEXT BOOK)

Q3. [10 Marks] Five mol of calcium carbide are combined with 10 mol of water in a closed, rigid, high-pressure vessel of 1800 cm^3 internal empty volume. Acetylene gas is produced by the reaction: $CaC_2(s) + 2H_2O(l) \rightarrow C_2H_2(g) + Ca(OH)_2(s)$. The vessel contains packing with a porosity of 40% to prevent explosive decomposition of the acetylene. Initial conditions are 25°C and 1 bar, and the reaction goes to completion. The reaction is exothermic, but owing to heat transfer, the final temperature is only 125°C. Determine the final pressure in the vessel. Note: At 125°C, the molar volume of $Ca(OH)_2$ is 33.0 $cm^3 \cdot mol^{-1}$. Ignore the effects of any gases (*e.g.,* air) initially present in the vessel.

Q4. [25 Marks] A natural-gas fuel contains 85 mol-% methane, 10 mol-% ethane, and 5 mol-% nitrogen.

(a) What is the standard (lower) heat of combustion ($kJ \cdot mol^{-1}$) of the fuel at 25°C with $H_2O(g)$ as a product?

(b) The fuel is supplied to a furnace with 50% excess air, both entering at 25°C. The products leave at 600°C. If combustion is complete and if no side reactions occur, how much heat (kJ per mol of fuel) is transferred in the furnace?

END