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(Question 1)

Consider a piston-cylinder system containing 1 mole of an ideal gas at the initial temperature T_1 and volume V_1 Suppose that there is a heating device that releases heat $Q = KT$ into the system, where K is a positive constant and T the temperature of the gas. After heating, the gas expands to volume V_2. The heat capacity at constant volume is C_V.

(1) Determine the final temperature T_2. **[8 %]**

(2) Is T_2 always higher than T_1? State your physical reasoning. **[8 %]**

(Question 2) Please answer the following questions.

(a) Can an ideal gas be condensed into liquid phase? Why? **[2 %]**

(b) Consider a certain gas whose PVT behavior obeys a virial equation of state:

$$Z = \frac{PV}{RT} = 1 + \frac{B}{V} + \frac{C}{V^2}$$

What are the physical meanings for the coefficients B and C? If this gas can undergo a vapor-liquid phase transition at the critical temperature T_c, derive B and C in terms of P_c, V_c, or T_c at the critical state and find the corresponding compressibility factor Z **[7 %]**

(c) Explain physically why B and C must have dimensions and the signs derived in (b) at the critical state for vapor-liquid phase transition **[4 %]**

(d) Sketch the profile of P as a function of V at $T = T_c$. **[4 %]**

(Question 3) Please answer "True" or "False" to the following questions. For those answered with "False", please justify your answer

(a) An idealized Otto cycle is called the air-standard Otto cycle. There are four strokes in the cycle. Assume that a reversible engine follows the air-standard cycle, other than the two adiabatic steps, the rest two steps in the cycle receive (or provide) no work. **[3 %]**

(b) A throttling process must be isothermal as well as isenthalpic. **[3 %]**

(c) For the reversible phase change at constant T and P, $\Delta S = \Delta H/T$ **[3 %]**

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(Question 4)

There is an adiabatic, steady-state, one-dimensional flow of a compressible fluid in the absence of shaft work and of changes in potential energy For the above-mentioned fluid flows in a horizontal pipe with constant cross-section area, therefore, we shall come to the equations as shown below

(a) Accordingly, please briefly explain the entire changing profile of a subsonic fluid velocity along the pipe (from entrance through the whole pipe line to exit) **[5 %]**

(b) When a supersonic fluid enters such a horizontal pipe of constant cross section, what would occur? ***[Note]*** Hence, the resulted outcome will show an abrupt but finite increase in pressure, and a decrease in velocity to a subsonic value **[3 %]**

$$\frac{dP}{dx} = -\frac{T}{V}\left(\frac{1+\dfrac{\beta u^2}{C_p}}{1-\mathrm{M}^2}\right)\frac{dS}{dx} \qquad u\frac{du}{dx} = T\left(\frac{\dfrac{\beta u^2}{C_p}+\mathrm{M}^2}{1-\mathrm{M}^2}\right)\frac{dS}{dx}$$

(Question 5)

Two heat blocks A and B have the respective masses of m_a (block A) and m_b (block B), and specific heat capacity of C_a (block A) and C_b (block B), respectively The two blocks are initially at different temperatures of T_a (block A) and T_b (block B) These two blocks are used as a heat source and a heat sink for a reversible heat engine. The heat engine operates until the temperature of the two blocks becomes identical. The final temperature is T_f. Assume the two blocks are insulated so that there is no heat lost to the environment.

(a) Calculate and express the final temperature of the two blocks T_f **[5 %]**

(b) Calculate and express the total work accomplished by this reversible heat engine (regards to problem (a)) **[5 %]**

(c) Prove that this reversible engine can achieve a thermal efficiency as $(1 - T_f / T_a)$, when $m_a \cdot C_a = m_b \cdot C_b$. **[6 %]**

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(Question 6)

In a binary system consisting of components *A* and *B*, the excess Gibbs energy of a binary liquid mixture at a temperature *T* and a pressure *P* can be expressed as

$$\frac{G^E}{RT} = x_A \ x_B \ (2x_A + x_B)$$

where x_A and x_B stand for mole fractions of component *A* and component *B*

(a) What are the activity coefficients of components *A* and *B*? **[7 %]**

(b) The vapor pressure of component *A* at 80°C is P_A = *560 mmHg* If the vapor phase behaves almost ideally, what is the range of the vapor pressure of component *B* at 80°C in order to form an azetrope with component *A* at 80°C. **[10 %]**

Please give all assumptions you have made leading to your answer

(Question 7)

For a closed and rigid system consisting of two phases in equilibrium, denoted as α and β phases, each individual phase is open to the other, and mass-transfer between phases may occur Please derive the criteria for the phase equilibria. **[17 %]**

<u>END OF PAPER.</u>