第一部分單選題(1-10)，每題 4 分。選擇最近正確之答案，答對得 4 分，答錯倒扣 1 分。
※ 注意：請於試卷內之「選擇題作答區」依序作答。

1. A photovoltaic cell is used to convert solar energy to electric energy. Estimate the maximum efficiency of a photovoltaic cell that is operated in steady state. Assume that the temperatures of the sun and of the photovoltaic cell are 6500 K and 300 K, respectively, and the cell is losing heat by conduction to the environment.
(a) 91.3%; (b) 93.3%; (c) 95.3%; (d) 97.3%

2. The mixing tank initially contains 50 kg of water at 25 °C. Suddenly the two inlet valves and the single outlet valve are opened, so that two water streams, each with a flow rate of 5 kg/min, flow into the tank, and a single exit stream with a flow rate of 10 kg/min leaves the tank. The temperature of one inlet stream is 80 °C, and that of the other is 50 °C. The tank is well mixed, so that the temperature of the outlet stream is always the same as the temperature of the water in the tank. Compute the steady-state temperature that will finally be obtained in the tank.
(a) 35 °C; (b) 45 °C; (c) 55 °C; (d) 65 °C

3. In the following properties, which one is Extensive property?
(a) density; (b) temperature; (c) gravitational field; (d) volume

4. One mole of an ideal gas at 25 °C is allowed to expand reversibly and isothermally from 1 dm^3 to 10 dm^3. What is the entropy change for the gas?
(a) 19 J/K; (b) 29 J/K; (c) 39 J/K; (d) 49 J/K

5. Determine the numbers of components (c), phases (p), and the degrees of freedom (f) of a system that is ice in a solution of water and ethanol.
(a) c = 2, p = 1, f = 3; (b) c = 2, p = 2, f = 2; (c) c = 3, p = 2, f = 3; (d) c = 3, p = 1, f = 4

6. Use the following data for the superheated vapor steam to calculate the fugacity of steam at 300 °C and 5 MPa.
For 300 °C and 0.01 MPa, H = 3076.5 kJ kg^{-1}, S = 9.28 kJ kg^{-1} K^{-1}, U = 2812.1 kJ kg^{-1}, V = 26.445 m^3 kg^{-1}.
For 300 °C and 5 MPa, H = 2924.5 kJ kg^{-1}, S = 6.21 kJ kg^{-1} K^{-1}, U = 2698.0 kJ kg^{-1}, V = 0.045 m^3 kg^{-1}.
(a) 4.4 MPa; (b) 5.4 MPa; (c) 6.4 MPa; (d) 7.4 MPa

7. The sublimation pressure of carbon dioxide as a function of temperature is as follows and the molar volume of CO_2 is 2.8 x 10^{-5} m^3 mol^{-1}.

T(K)	130	155	185	194	205
P(kPa)	0.032	1.674	44.02	101.3	227

Determine the heat of sublimation of CO_2 at 190 K.
(a) 6.2 kJ/mol; (b) 16.2 kJ/mol; (c) 26.2 kJ/mol; (d) 36.2 kJ/mol

8. An engineer claims to have invented a steady-flow device that will take air at 4 bar and 20 °C and separate it into two streams of equal mass, one at 1 bar and -20 °C and the second at 1 bar and 60 °C. Furthermore, the inventor states that his device operates adiabatically and does not require (or produce) work. Calculate the rate at which entropy is generated within the system [Assume the input rate of air is N_1. Air can be assumed to be an ideal gas with a constant heat capacity of C_P^* = 29.3 J/(mol K)].
(a) 8.25 N_1; (b) 9.25 N_1; (c) 10.25 N_1; (d) 11.25 N_1

9. A continuous-flow steam-heated mixing kettle will be used to produce a 20 wt% sulfuric acid solution at 65.6 °C from a solution of 90 wt% sulfuric acid at 0 °C and pure water at 21.1 °C. Estimate the amount of heat needed per kilogram of

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initial sulfuric acid solution to heat the mixture to the desired temperature. [Assume the enthalpy values for each solution is as follows: H_1 (90 wt% sulfuric acid at 0 °C) = -183 kJ/kg; H_2 (pure water at 21.1 °C) = 91 kJ/kg; H_3 (20 wt% sulfuric acid at 65.56 °C) = 87 kJ/kg]
(a) 56 kJ/kg; (b) 156 kJ/kg; (c) 256 kJ/kg; (d) 356 kJ/kg

10. Same as the question 9, estimate the temperature of the kettle effluent if the mixing process is carried out adiabatically
(a) 50 °C; (b) 60 °C; (c) 70 °C; (d) 80 °C

第二部分計算題(11-16)，題分註明於問題後方括弧內。

11. Obtain expressions for the two derivatives below and show that they are different. [Assume U is molar internal energy, T is temperature, P is pressure, C_v is the constant-volume heat capacity, and V is molar volume] [Hint: $dU = C_v dT + \left[T\left(\frac{\partial P}{\partial T}\right)_v - P\right]dV$] [5 points]

$$\left(\frac{\partial U}{\partial T}\right)_P \neq \left(\frac{\partial U}{\partial T}\right)_V$$

12. Stable equilibrium is very important in thermodynamics. Please describe the criteria for stable equilibrium in an isothermal and isobaric open system moving with the fluid velocity. [5 points]

13. A first-order reversible reaction (A ↔ B) was conducted in an isothermal, liquid-phase batch reactor. Only reactant A existed at the beginning of the reaction. The concentration of reactant A in the reactor as a function of reaction time is summarized in the following table. The concentration of A at equilibrium is 2 mol L^{-1}. What is the concentration of A (in mol L^{-1}) when the reaction time was at 1.5 hour? [14 points]

Reaction time (hour)	0	0.5	1.0	∞
Concentration of A (mol L^{-1})	10	6.9	5.0	2.0

14. A second-order irreversible reaction (A → B) is to be conducted in an isothermal, liquid-phase plug-flow reactor (PFR). The concentration of A in the feed is 3 mol L^{-1}. The rate constant is 0.0015 L mol^{-1} min^{-1}. What is the space time (in minute) when the conversion reaches 30%? [12 points]

15. A first-order irreversible reaction (A → B) is to be conducted isothermally with a constant volumetric flow rate in a set of equal-sized continuous stirred-tank reactor (CSTR) placed in series. The concentration of reactant A in the feed is 8 mol L^{-1}. The reaction rate constant is 0.025 min^{-1}. The volumetric flow rate is 0.05 L min^{-1}. The volume of each CSTR is 2 L. How many of CSTRs are required to achieve a conversion of greater than 90%? [12 points]

16. A gas-phase reaction (A + B → C) was catalyzed by a solid catalyst with dual surface sites (S_1 and S_2). A reaction mechanism is proposed as following:

Adsorption of A:	$A + S_1 \leftrightarrow A \cdot S_1$	k_A, K_A
Adsorption of B:	$B + S_2 \leftrightarrow B \cdot S_2$	k_B, K_B
Surface reaction:	$A \cdot S_1 + B \cdot S_2 \leftrightarrow C + S_1 + S_2$	k_{rxn}, K_{rxn}

where k and K represent forward rate constant and equilibrium constant, respectively. Derive the rate law for the generation rate of product C by assuming the surface reaction is the rate-limiting step. [12 points]

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