

※ 考生請注意：本試題不可使用計算機。請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. For a gas obeying the van der Waals equation of state ($p = \frac{\bar{R}T}{\bar{v}-b} - \frac{a}{\bar{v}^2}$),

(a) show that $(\frac{\partial c_v}{\partial v})_T = 0$. (5%)

(b) show that $(s_2 - s_1)_T = R \cdot \ln \frac{V_2 - b}{V_1 - b}$. (5%)

(c) develop expression for $c_p - c_v$. (5%)

2. Determine the Gibbs function of formation of methane at the standard state, 25°C and 1 atm, in kJ/kmol, and compare with the value given in Table A. (15%)

Table A
Thermochemical Properties of Selected Substances at 298K and 1 atm

Substance	Formula	Molar Mass, M (kg/kmol)	Enthalpy of Formation, \bar{h}_f° (kJ/kmol)	Gibbs Function of Formation, \bar{g}_f° (kJ/kmol)	Absolute Entropy, \bar{s}° (kJ/kmol · K)	Heating Values	
						Higher, HHV (kJ/kg)	Lower, LHV (kJ/kg)
Carbon	C(s)	12.01	0	0	5.74	32,770	32,770
Hydrogen	H ₂ (g)	2.016	0	0	130.57	141,780	119,950
Nitrogen	N ₂ (g)	28.01	0	0	191.50	—	—
Oxygen	O ₂ (g)	32.00	0	0	205.03	—	—
Carbon monoxide	CO(g)	28.01	-110,530	-137,150	197.54	—	—
Carbon dioxide	CO ₂ (g)	44.01	-393,520	-394,380	213.69	—	—
Water	H ₂ O(g)	18.02	-241,820	-228,590	188.72	—	—
Water	H ₂ O(l)	18.02	-285,830	-237,180	69.95	—	—
Hydrogen peroxide	H ₂ O ₂ (g)	34.02	-136,310	-105,600	232.63	—	—
Ammonia	NH ₃ (g)	17.03	-46,190	-16,590	192.33	—	—
Oxygen	O(g)	16.00	249,170	231,770	160.95	—	—
Hydrogen	H(g)	1.008	218,000	203,290	114.61	—	—
Nitrogen	N(g)	14.01	472,680	455,510	153.19	—	—
Hydroxyl	OH(g)	17.01	39,460	34,280	183.75	—	—
Methane	CH ₄ (g)	16.04	-74,850	-50,790	186.16	55,510	50,020
Acetylene	C ₂ H ₂ (g)	26.04	226,730	209,170	200.85	49,910	48,220
Ethylene	C ₂ H ₄ (g)	28.05	52,280	68,120	219.83	50,300	47,160
Ethane	C ₂ H ₆ (g)	30.07	-84,680	-32,890	229.49	51,870	47,480
Propylene	C ₃ H ₆ (g)	42.08	20,410	62,720	266.94	48,920	45,780
Propane	C ₃ H ₈ (g)	44.09	-103,850	-23,490	269.91	50,350	46,360
Butane	C ₄ H ₁₀ (g)	58.12	-126,150	-15,710	310.03	49,500	45,720
Pentane	C ₅ H ₁₂ (g)	72.15	-146,440	-8,200	348.40	49,010	45,350
Octane	C ₈ H ₁₈ (g)	114.22	-208,450	17,320	463.67	48,260	44,790
Octane	C ₈ H ₁₈ (l)	114.22	-249,910	6,610	360.79	47,900	44,430
Benzene	C ₆ H ₆ (g)	78.11	82,930	129,660	269.20	42,270	40,580
Methanol	CH ₃ OH(g)	32.04	-200,890	-162,140	239.70	23,850	21,110
Methanol	CH ₃ OH(l)	32.04	-238,810	-166,290	126.80	22,670	19,920
Ethanol	C ₂ H ₅ OH(g)	46.07	-235,310	-168,570	282.59	30,590	27,720
Ethanol	C ₂ H ₅ OH(l)	46.07	-277,690	-174,890	160.70	29,670	26,800

3. Please show in both a schematic diagram of the system and a T-s diagram of the cycle for a regenerative gas turbine engine with an intercooling and a reheat. Please explain how the efficiency of the gas turbine engine can be improved by the regenerator, the intercooler and the reheater. (20%)

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4. An insulated rigid tank is divided into two equal parts by a partition. Initially, one part contains n kmol of an ideal gas of nitrogen at a pressure p_1 and a temperature T_1 , and the other side is evacuated. The partition is now removed, and the gas fills the entire tank.
- Determine the final temperature T_2 and the final pressure p_2 . (6 %)
 - Determine the total entropy change (kJ/K) during this process. (10 %)

5. Show that for an ideal gas undergoing a reversible, adiabatic process in a closed system obeys

$$pv^k = \text{constant},$$

with constant specific heat ratio k . (14 %)

6. Air enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 300 K, and a velocity of 6 m/s through an inlet with an area of 0.1 m^2 . At the exit, the pressure is 7 bar, the temperature is 450 K, and the velocity is 2 m/s. Heat transfer from the compressor to its surroundings occurs at a rate of 120 kJ/min. Employing the ideal gas model, with the universal gas constant $\bar{R} = 8.314 \text{ kJ/kmol}\cdot\text{K}$ and $c_p = 1 \text{ kJ/kg}\cdot\text{K}$,
- determine the mass flow rate \dot{m} at the inlet, and (10 %)
 - calculate the power input to the compressor, in kW. (10 %)