●可以使用不具儲存程式功能之電子計算機

1.

(a) Please derive $C_p - C_V = T\left(\frac{\partial V}{\partial T}\right)_p\left(\frac{\partial P}{\partial T}\right)_V$ **(5%) and show the relation between heat capacity at constant volume (*Cv*) and constant pressure (*Cp*) for the ideal gas. (5%)**

(b) 5 mole of ideal gas is at 5 bar pressure and 100℃. The value C_p / C_V **of this gas is 1.3. The gas is allowed to expand reversibly and adiabatically to a pressure of 0.5 bar (The gas constant** $R = 83.14\ bar\ cm^3/K\ mol = 8.314\ J/K\ mol$**). What are the initial and final volumes of the gas ? (5%)**

(c) from (b), what is the final temperature ? (5%)

(d) from (b), please calculate ΔU **and** ΔH **for the expansion process. (5%)**

2. Please explain the first, second and third laws of thermodynamics. (15%)

3. Consider the Brayton cycle that consists of the following steps: (1) isobaric compression; (2) reversible adiabatic compression; (3)isobaric expansion; and (4) reversible adiabatic expansion.

(a) Please draw the P-V plot to describe the Brayton cycle. (5%)

(b) Please express its maximum thermodynamic efficiency by the pressure (*P*) and heat capacity (*Cv, Cp*). (10%)

4. Consider the following reaction: $4\ NH_{3(g)} + 5\ O_{2(g)} \rightarrow 4\ NO(g) + 6\ H_2O_{(g)}$
Ammonia gas enters the reactor of a nitric acid plant mixed with 30% more dry air than is required for the complete conversion of the ammonia to nitric oxide and water vapor. If the gas enter the reactor at 75℃, if conversion is 80%, if no side reaction occur. And if the reactor operates adiabatically, what is the temperature of the gases leaving the reactor? Assume ideal gases. (25%)

Heat Capacities of Gases in the Ideal-Gas State

Constants in equation $C_P^{ig}/R = A + BT + CT^2 + DT^{-2}$ T (kelvins) from 298 to T_{max}

Chemical species		T_{max}	$C_{P_{298}}^{ig}/R$	A	$10^3\ B$	$10^6\ C$	$10^{-5}\ D$
Air		2000	3.509	3.355	0.575	......	−0.016
Ammonia	NH_3	1800	4.269	3.578	3.020	......	−0.186
Bromine	Br_2	3000	4.337	4.493	0.056	......	−0.154
Carbon monoxide	CO	2500	3.507	3.376	0.557	......	−0.031
Carbon dioxide	CO_2	2000	4.467	5.457	1.045	......	−1.157
Carbon disulfide	CS_2	1800	5.532	6.311	0.805	......	−0.906
Chlorine	Cl_2	3000	4.082	4.442	0.089	......	−0.344
Hydrogen	H_2	3000	3.468	3.249	0.422	......	0.083
Hydrogen sulfide	H_2S	2300	4.114	3.931	1.490	......	−0.232
Hydrogen chloride	HCl	2000	3.512	3.156	0.623	......	0.151
Hydrogen cyanide	HCN	2500	4.326	4.736	1.359	......	−0.725
Nitrogen	N_2	2000	3.502	3.280	0.593	......	0.040
Nitrous oxide	N_2O	2000	4.646	5.328	1.214	......	−0.928
Nitric oxide	NO	2000	3.590	3.387	0.629	......	0.014
Nitrogen dioxide	NO_2	2000	4.447	4.982	1.195	......	−0.792
Dinitrogen tetroxide	N_2O_4	2000	9.198	11.660	2.257	......	−2.787
Oxygen	O_2	2000	3.535	3.639	0.506	......	−0.227
Sulfur dioxide	SO_2	2000	4.796	5.699	0.801	......	−1.015
Sulfur trioxide	SO_3	2000	6.094	8.060	1.056	......	−2.028
Water	H_2O	2000	4.038	3.470	1.450	......	0.121

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5. Consider the equation of state: $Z = 1 + \frac{P_r}{T_r}\left(0.1620 - \frac{0.4253}{T_r} - \frac{0.0677}{T_r^3}\right)$

Please fine the fugacity coefficient (ϕ_i) at 50℃ and 68.95 bar (P_c = 77.1 bar, T_c = 144℃). (20%)