

一、選擇題（單選，請選出最適合的答案，每題 5 分，共 40 分）

※ 注意：請於試卷內之「選擇題作答區」依序作答。

1. Which of the following is not within the scope of thermodynamics?
  - (A) The rate of a falling stone from Eiffel tower
  - (B) The Curie temperature of iron
  - (C) The melting temperature of ice
  - (D) The efficiency of a refrigerator
  
2. Which of the following is a state function?
  - (A) Heat
  - (B) Work
  - (C) Entropy
  - (D) Velocity
  
3. Which system do you think has the lowest entropy (assuming of the same mass)?
  - (A) A glass of water
  - (B) Shaved ice
  - (C) A pot of hot water
  - (D) A pool of melting snow
  
4. Which of the following statement regarding Carnot cycle is NOT true?
  - (A) Operate at the maximum efficiency of a heat engine
  - (B) The entropy flows in is more than entropy flows out
  - (C) Not practical
  - (D) The expansion of working fluid is isothermal
  
5. Which of the following is least likely to be included in a refrigerator?
  - (A) Turbine
  - (B) Boiler
  - (C) Pump
  - (D) Condenser
  
6. Which of the following phase transformation can potentially involve a critical point?
  - (A) Dry ice and carbon dioxide gas
  - (B) Water and ice
  - (C) Diamond and graphite
  - (D) Helium liquid and helium gas
  
7. Why is the oxygen in the air not liquefied when the temperature is slightly below oxygen's boiling point?
  - (A) Oxygen won't mix with nitrogen
  - (B) Oxygen is heavier than nitrogen

見背面

- (C) There is a solubility gap for nitrogen/oxygen system  
(D) Mixing of gases increases entropy

8. Which of the following is NOT a colligative property of dilute solutions?

- (A) Osmotic pressure  
(B) Solubility  
(C) Vapor pressure  
(D) Freezing temperature

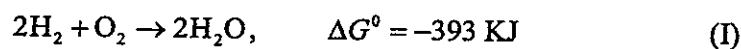
二、計算與問答題（每小題 6 分，共 60 分）

※ 注意：請於試卷內之「非選擇題作答區」標明題號依序作答。

1. A gas mixture at one atmosphere total pressure has the following composition:

Component	H <sub>2</sub>	O <sub>2</sub>	H <sub>2</sub> O
Molar fraction	0.05	0.04	0.91

At 700°C, for the reaction to form the product H<sub>2</sub>O:



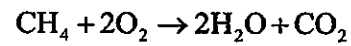
Given the internal energy change  $dU = TdS - PdV + \sum_{i=1}^n \mu_i dn_i$ , where

$\mu_i$  and  $n_i$  are the chemical potential and the molar number of species  $i$ , respectively.

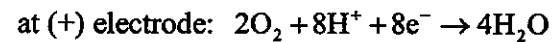
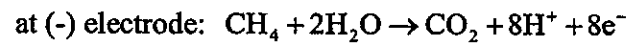
- (a) Use Legendre transformation to derive the Gibbs free energy change  $dG$  from  $dU$ . (Hint: use product rule,  $d(XY) = YdX + XdY$ , to change variables.)
- (b) Providing the definition  $\mu_k = G_k^\circ + RT \ln a_k$ , where  $a_k$  indicates the activity of species  $k$ . Derive the expression of  $\Delta G$  for reaction (I) in terms of  $\Delta G^\circ$  and the activities of gas species.
- (c) At equilibrium the system free energy change  $\Delta G = 0$ , the equilibrium constant  $K$  can be derived from  $0 = \Delta G^\circ + RT \ln(K)$ . What is the equilibrium constant of reaction (I) for the given conditions? Briefly explain the meaning of the results you acquired for reaction (I)
- (d) The activity of a gas species  $k$ ,  $a_k$ , is defined as its partial pressure normalized by 1 atm. Following the second law of thermodynamics, determine whether reaction (I) will spontaneous occur for the given composition and conditions.
- (e) Explain why the chemical reaction (I) and most of the chemical reactions do not go to completion?

接次頁

2. Consider a fuel cell and a Carnot engine that both use methane as their fuel. The chemical and combustion reactions are the same as the following:



- (a) Use the data in Table 1 to determine the values of  $\Delta H$  and  $\Delta G$  for this reaction occurred in the fuel cell (for one mole of methane). Assume that the reaction occurs at ambient temperature and pressure.
- (b) Assuming ideal performance, how much electrical work can you get out of the cell, for each mole of methane fuel?
- (c) The half reactions for the fuel cell are



What is the voltage of the fuel cell?

- (d) Assuming the Carnot engine is powered by burning methane at  $600^\circ\text{C}$ , how much heat is expelled for each mole of combusted methane?
- (e) Basing on results in (b) and (c), compare the efficiency of a fuel cell and a Carnot engine. Explain why one technology is more efficient than the other.

見背面

Constant:

Avogadro's number  $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$

Faraday constant  $F = 96485 \text{ C/mol}$

Gas constant  $R = 8.314 \text{ J/mol} \cdot \text{K}$

Table 1. Thermodynamics Properties of Selected Substances

All of the values in this table are for one mole of material at 298 K and 1 bar. The form of the substance, either solid (s), liquid (l), gas (g) or aqueous solution (aq), is denoted after the chemical formula. Data for aqueous solutions are at a standard concentration of 1 mole per kilogram water. The enthalpy and Gibbs free energy of formation,  $\Delta_f H$  and  $\Delta_f G$ , represent the changes in  $H$  and  $G$  upon forming one mole of the material starting with elements in their most stable pure states (e.g., C (graphite),  $\text{O}_2$  (g), etc.).

Substance (form)	$\Delta_f H$ (kJ)	$\Delta_f G$ (kJ)	$S$ (J/K)	$C_P$ (J/K)	$V$ (cm <sup>3</sup> )
H <sub>2</sub> (g)	0	0	130.68	28.82	
H (g)	217.97	203.25	114.71	20.78	
H <sup>+</sup> (aq)	0	0	0	0	
H <sub>2</sub> O (l)	-285.83	-237.13	69.91	75.29	18.068
H <sub>2</sub> O (g)	-241.82	-228.57	188.83	33.58	
O <sub>2</sub> (g)	0	0	205.14	29.38	
O <sub>2</sub> (aq)	-11.7	16.4	110.9		
OH <sup>-</sup> (aq)	-229.99	-157.24	-10.75	-148.5	
CH <sub>4</sub> (g)	-74.81	-50.72	186.26	35.31	
C <sub>2</sub> H <sub>6</sub> (g)	-84.68	-32.82	229.60	52.63	
C <sub>3</sub> H <sub>8</sub> (g)	-103.85	-23.49	269.91	73.5	
C <sub>2</sub> H <sub>5</sub> OH (l)	-277.69	-174.78	160.7	111.46	58.4
C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> (glucose)	-1268	-910	212	115	
CO (g)	-110.53	-137.17	197.67	29.14	
CO <sub>2</sub> (g)	-393.51	-394.36	213.74	37.11	

試題隨卷繳回