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_2	O_2	H_2O
Molar fraction	0.05	0.04	0.91

At 700°C, for the reaction to form the product H_2O :

$$2H_2 + O_2 \rightarrow 2H_2O, \qquad \Delta G^0 = -393 \text{ KJ} \qquad \text{(I)}$$

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

μ_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 $\mu_k = G_k^0 + RT \ln a_k$, where a_k indicates the activity of species k . Derive the expression of ΔG for reaction (I) in terms of ΔG^0 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 $0 = \Delta G^0 + RT \ln(K)$. 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

國立臺灣大學 113 學年度碩士班招生考試試題

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:

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$$

(a) Use the data in **Table 1** to determine the values of ΔH and ΔG 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

$$\text{at (-) electrode: } CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e^-$$

$$\text{at (+) electrode: } 2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$$

Wat is the voltage of the fuel cell?

(d) Assuming the Carnot engine is powered by burning methane at 600° 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.

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Constant:

Avogardo's number $N_A = 6.02\times10^{23}\ \text{mol}^{-1}$

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 more of the material starting with elements in their most stable pure states (e.g., C (graphite), O_2 (g), etc.).

Substance (form)	$\Delta_f H$ (kJ)	$\Delta_f G$ (kJ)	S (J/K)	C_P (J/K)	V (cm^3)
H_2 (g)	0	0	130.68	28.82	
H (g)	217.97	203.25	114.71	20.78	
H^+ (aq)	0	0	0	0	
H_2O (l)	−285.83	−237.13	69.91	75.29	18.068
H_2O (g)	−241.82	−228.57	188.83	33.58	
O_2 (g)	0	0	205.14	29.38	
O_2 (aq)	−11.7	16.4	110.9		
OH^- (aq)	−229.99	−157.24	−10.75	−148.5	
CH_4 (g)	−74.81	−50.72	186.26	35.31	
C_2H_6 (g)	−84.68	−32.82	229.60	52.63	
C_3H_8 (g)	−103.85	−23.49	269.91	73.5	
C_2H_5OH (l)	−277.69	−174.78	160.7	111.46	58.4
$C_6H_{12}O_6$ (glucose)	−1268	−910	212	115	
CO (g)	−110.53	−137.17	197.67	29.14	
CO_2 (g)	−393.51	−394.36	213.74	37.11	

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