

※ 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。

說明：答案一律寫在答案卷上；請依序作答，並標明題號。

($R = 8.314 \text{ J/mol K}$, $K_a(\text{NH}_4^+) : 5.6 \times 10^{-10}$, $K_a(\text{HNO}_2) : 4.0 \times 10^{-4}$, $K_a(\text{HCN}) : 6.2 \times 10^{-10}$,
 $K_a(\text{CH}_3\text{COOH}) : 1.8 \times 10^{-5}$, $K_a(\text{HF}) : 7.2 \times 10^{-4}$, $K_a(\text{HOCl}) : 3.5 \times 10^{-8}$)

一、選擇題：(單選 22 題，每題 3 分，不倒扣，共 66 分)

- Consider five identical flasks filled with 1.0 mole different gases at 0°C .
 Flask A: CO at 250 torr, Flask B: N₂ at 600 torr, Flask C: H₂ at 400 torr,
 Flask D: O₂ at 800 torr, Flask E: CH₄ at 600 torr,
 In which flask will the molecules have the greatest root mean square speed?
 (A)A (B)B (C)C (D)D (E)E
- How many of the following (CN⁺, NO⁻, O₂⁻, OF⁺, OF⁻) are diamagnetic?
 (A)1 (B)2 (C)3 (D)4 (E)5
- The wave function of 1s orbital for hydrogen atom may be represented as $(\pi a_0^3)^{-1/2} \exp(-r/a_0)$, where $a_0 = 5.29 \times 10^{-11} \text{ m}$. What's the location of the local maximum of the radial probability distribution?
 (A)0 (B) $a_0/2$ (C) a_0 (D) $3a_0/2$ (E) $2a_0$
- How many of the following molecules or ions (NO₃⁻, ClF₃, CO₃²⁻, PCl₃, BF₃) have triangle planar structures?
 (A)0 (B)1 (C)2 (D)3 (E)4
- What's the hybridization of Cl atom in ClF₃?
 (A) sp^3 (B) sp^2 (C) d^2sp^3 (D) d^2sp^2 (E) dsp^3
- Rank the following bonds in order from less polar to most polar:
 (1)N-O, (2)Ca-O, (3)C-F, (4)Br-Br, (5)K-F.
 (A)4, 1, 3, 5, 2 (B)4, 3, 1, 5, 2 (C)4, 3, 1, 2, 5 (D)4, 1, 3, 2, 5 (E)2, 5, 3, 1, 4
- How many reactions listed below at constant pressure are predicted to have greater ΔH than ΔE ?
 (a) $2 \text{ HF(g)} \rightarrow \text{H}_2\text{(g)} + \text{F}_2\text{(g)}$ (b) $\text{N}_2\text{(g)} + 3 \text{ H}_2\text{(g)} \rightarrow 2 \text{ NH}_3\text{(g)}$
 (c) $4 \text{ NH}_3\text{(g)} + 5 \text{ O}_2\text{(g)} \rightarrow 4 \text{ NO(g)} + 6 \text{ H}_2\text{O(g)}$ (d) $2 \text{ O}_3\text{(g)} \rightarrow 3 \text{ O}_2\text{(g)}$
 (A)0 (B)1 (C)2 (D)3 (E)4
- If both I₂(g) and I(g) have the same pressure, the process $\text{I}_2\text{(g)} \rightarrow 2\text{I(g)}$
 (A)is spontaneous at low temperature and high pressure. (B)is spontaneous at low temperature and low pressure. (C)is spontaneous at high temperature and high pressure. (D)is spontaneous at high temperature and low pressure. (E)is spontaneous at any temperature.

9. How many nodes are there for the 3s orbital of the hydrogen atom?
 (A)0 (B)1 (C)2 (D)3 (E)4
10. Calculate ΔE (in kJ) when 2 mole of a liquid is vaporized at its boiling point (77°C) and 1.0 atm, given that $\Delta H_{\text{vap}} = 30.0 \text{ kJ/mol}$ at 77°C .
 (A)63.5 (B)27.8 (C)33.6 (D)22.4 (E)54.2
11. How much water should be added to 10.0 mL of 12.0 M HCl so that it has the same pH as 0.90 M acetic acid, CH_3COOH ?
 (A)30 mL (B)300 mL (C)3 L (D)30 L (E)300 L
12. How many of the following 0.10 M solutions (CaBr_2 , KNO_2 , NH_4ClO_4 , NH_4NO_2 , HNO_2) are acidic?
 (A)3 (B)2 (C)1 (D)4 (E)5
13. Name the following:
- $$\begin{array}{c}
 \text{Cl} \quad \text{O} \\
 | \quad || \\
 \text{CH}_3-\text{CH}-\text{CH}-\text{C}-\text{CH}(\text{CH}_3)_2 \\
 | \\
 \text{CH}_2 \\
 | \\
 \text{CH}_3
 \end{array}$$
- (A)3-methyl-4-chloro-1-isopropylpentanone (B)4-chloro-2,5-dimethyl-3-heptanone
 (C)2-chloro-3-ethyl-1-isopropylbutanone (D)2-butyl, chloro, isobutanoyl methane
 (E)isopropyl-chloro, methylbutyl ketone
14. How many isomers of an alcohol (formula $\text{C}_4\text{H}_{10}\text{O}$) can be oxidized to acid?
 (A)1 (B)2 (C)3 (D)4 (E)5
15. What's the total number of structural and geometric (cis-trans) isomers of $\text{C}_3\text{H}_5\text{Cl}$?
 (A)4 (B)5 (C)6 (D)7 (E)8
16. What's the total number of pentapeptides composed of two phenylalanines, two glycines, and one alanine?
 (A)20 (B)24 (C)30 (D)60 (E)120
17. The reaction $2 \text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{NO}_2(\text{g})$ is believed to take place by the following mechanism:
- $$\begin{array}{ll}
 (1) \text{NO} + \text{NO} \rightleftharpoons \text{N}_2\text{O}_2 & \text{(rate constant: } k_1 \text{ and } k_{-1}, \text{ fast)} \\
 (2) \text{O}_2 + \text{N}_2\text{O}_2 \rightarrow 2 \text{NO}_2 & \text{(rate constant } k_2, \text{ slow)}
 \end{array}$$
- Derive the expression of $[\text{N}_2\text{O}_2]$ by using steady-state approximation.
- (A) $k_1[\text{NO}]^2/(k_{-1} + k_2[\text{O}_2])$ (B) $k_{-1}[\text{NO}]^2/(k_1 + k_2[\text{O}_2])$ (C) $k_{-1}[\text{NO}]/(k_2 + k_1[\text{O}_2])$
 (D) $k_{-1}[\text{NO}]/(k_1 + k_2[\text{O}_2])$ (E) $k_1[\text{NO}]/(k_2 + k_1[\text{O}_2])$
18. What's $d[\text{NO}_2]/dt$ under the condition $k_{-1} \gg k_2[\text{O}_2]$ in Problem 17?
 (A) $k_{-1}k_2[\text{NO}]^2[\text{O}_2]/k_1$ (B) $k_{-1}k_2[\text{NO}][\text{O}_2]/k_1$ (C) $2k_1k_2[\text{NO}]^2[\text{O}_2]/k_{-1}$
 (D) $k_{-1}k_2[\text{NO}]^2/k_1$ (E) $k_1k_2[\text{NO}]^2[\text{O}_2]/k_{-1}$

19. The concentration of Mg^{2+} in seawater is 0.05 M. At what pH will 99 % of the Mg^{2+} be precipitated as the hydroxide? (K_{sp} for $Mg(OH)_2 = 9.0 \times 10^{-12}$)
 (A)9.1 (B)11.1 (C)8.1 (D)12.1 (E)10.1
20. Order the following in order of increasing base strength:
 (1) H_2O , (2) F^- , (3) OCl^- , (4) NH_3 , (5) CN^-
 (A)2, 1, 3, 5, 4 (B)1, 2, 3, 5, 4 (C)2, 1, 3, 4, 5 (D)4, 5, 3, 2, 1 (E)1, 2, 3, 4, 5
21. Which of the following is paramagnetic?
 (A) $[Zn(H_2O)_6]^{2+}$ (B) $[Co(NH_3)_6]^{3+}$ (strong field) (C) $[Cu(en)_3]^+$
 (D) $[Fe(en)_3]^{2+}$ (strong field) (E) $[Mn(en)_3]^{2+}$ (strong field)
22. The complex ion $[TiBr_4]^{2-}$ is tetrahedral. How many unpaired electrons are there in the complex?
 (A)0 (B)1 (C)2 (D)3 (E)4

二、非選擇題：(共 34 分，計算題務必列出計算過程，只寫答案不計分)

1. Benzene (C_6H_6) have a melting point of 5.0 °C, with an enthalpy of fusion of 10.0 kJ/mol. The molar heat capacities at constant pressure for solid and liquid benzene are 100.0 J/K,mol and 130.0 J/K,mol, respectively.
 (a) Calculate ΔH_{sys} (in kJ) for the freezing of benzene at 10.0 °C.
 (b) Calculate of ΔS_{sys} and ΔS_{surr} in (a). (此小題不需算出最後的數值)
 (14 %)
2. Consider the reaction $3A + B + C \rightarrow D + E$, where the rate law is defined as
 $-d[A]dt = (1.5 \times 10^2 \text{ L}^3/\text{mol}^3 \text{ s})[A]^2[B][C]$
 An experiment is carried out where $[B]_0 = 2.0 \text{ M}$, $[C]_0 = 1.0 \text{ M}$ and $[A]_0 = 2.0 \times 10^{-4} \text{ M}$.
 (a) What's the half-life of A ?
 (b) What's the concentration of D after 1.0 min? (12 %)
3. Describe how to make 2-methyl-2-propanol from an alkene. (8 %)