本試題含單選題 25 題(75 分)，及三題敘述與計算題(25 分)，總分 100 分

(I). 單選題 (選出一個最適當的答案): 每題 3 分. (答案直接填入 "選擇題作答區" 內)

1. A pH meter displays pH=10.2456 for an aqueous solution, and the resolution of the pH meter is ±0.01. What would be the most appropriate number to record the pH of the solution?
   (A) 10.2456 (B) 10.246 (C) 10.25 (D) 10.2 (E) None of the above

2. Considering proper number of significant figures, $15.5 \times 20.6 \times 3.3 =$
   (A) 1053.69 (B) 1054 (C) 1050 (D) 1100 (E) None of the above

3. What is the chemical formula of chlorate ion?
   (A) $NaClO$ (B) $NaClO_3$ (C) ClO^- (D) ClO_3^- (E) None of the above

4. What is the chemical formula of methyl butyl ether?
   (A) $C_6H_{14}O$ (B) $C_5H_{12}O$ (C) $C_4H_{10}O$ (D) C_3H_8O (E) None of the above

5. Which of the following samples contains the fewest sodium atoms?
   (A) 1 mol sodium oxide (B) 45 g sodium fluoride (C) 50 g sodium chloride
   (D) 1 mol sodium nitrate (E) 100 g sodium iodide

6. A commonly used organic solvent, is 85.6% C and 14.4% H by mass with a molar mass of 84.2 g/mol. What is its molecular formula?
   (A) C_6H (B) CH_2 (C) C_5H_{24} (D) C_6H_{12} (E) C_4H_8

7. A diatomic molecule has the valance electron configuration of $(\sigma_{2s})^2(\sigma^*_{2s})^2(\sigma_{2p})^2(\pi_{2p})^4(\pi^*_{2p})^2$. What is the bond order of this molecule?
   (A) 0 (B) 1 (C) 2 (D) 3 (E) 4

8. How many different F-Cl-F angles exist in the ClF_4^+ molecular structure?
   (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

9. The crystal field stabilization energy (CFSE) for the V^{2+} ion in an octahedral complex is
   (A) $-\frac{6}{5}\Delta_o$ (B) $-\frac{4}{5}\Delta_o$ (C) $-\frac{2}{5}\Delta_o$ (D) 0 (E) None of the above

10. Which compound has the highest melting point?
    (A) $AgNO_3$ (B) H_2O (C) Potassium metal (D) NH_3 (E) $CH_3CH_2CH_2CH_2CH_2OH$

11. A method used by the U.S. Environmental Protection Agency (EPA) for determining the concentration of ozone in air is to pass the air sample through a "bubbler" containing sodium iodide, which removes the ozone according to the following equation:

    $$O_3(g) + 2NaI(aq) + H_2O(l) \longrightarrow$$
    $$O_2(g) + I_2(s) + 2NaOH(aq)$$
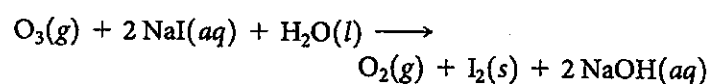
   How many grams of sodium iodide are needed to remove 1.3 mg of O_3?
    (A) 4.05×10^3 (B) 8.1×10^3 (C) 4.05×10^4 (D) 8.1×10^4 (E) None of the above

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12. Which of the following solution is the most acidic?
(A) 0.01 M H_2SO_4 (B) 1.0 M CH_3COOH (C) 1.0 M NH_4NO_3 (D) 1.0 M HF (E) 0.1 M HI

13. Acetonitrile (CH_3CN) is a polar organic solvent that dissolves many salts. The density of a 2.7 M LiBr solution in acetonitrile is 0.826 g/cm³. What is the mole fraction of LiBr in this solution?
(A) 0.6 (B) 0.45 (C) 0.30 (D) 0.15 (E) 0.08

14. A potassium 4f orbital has an angular momentum quantum number $l =$?
(A) 3 (B) 2 (C) 1 (D) 0 (E) None of the above

15. What is the number of angular nodes in a hydrogen $3d_{z^2}$ orbital?
(A) 0 (B) 1 (C) 2 (D) 3 (E) None of the above

16. The van der Waals equation of gas state is $\left(P + a\dfrac{n^2}{V^2} \right)(V - nb) = nRT$. What is the coefficient a related to?
(A) Strength of intermolecular interactions (B) Density of gas (C) Temperature (D) Excluded volume of the molecule (E) None of the above

17. At 800 K, the equilibrium constant for the dissociation of iodine molecule is $K_c = 3.1 \times 10^{-5}$. If an equilibrium mixture in a 10.0-L vessel contains 2.67×10^{-2} g of iodine atom, how many grams of iodine molecule are in the mixture?
(A) 0.68 (B) 0.0181 (C) 6.8 (D) 86 (E) 0.0362

18. What is the number of vibrational modes in the triiodide ion?
(A) 1 (B) 2 (C) 3 (D) 4 (E) 5

19. Which of the following statement is true?
(A) If you compare two reactions with similar collision factors, the one with the larger activation energy will be faster.
(B) A reaction that has a small rate constant must have a small frequency factor.
(C) Increasing the reaction temperature increases the fraction of successful collisions between reactants.
(D) Exothermic reactions are faster than endothermic reactions.
(E) If you double the temperature for a reaction, you cut the activation energy in half.

20. Based on the following reaction profile, which statement in the following is true regarding the reaction A→D?
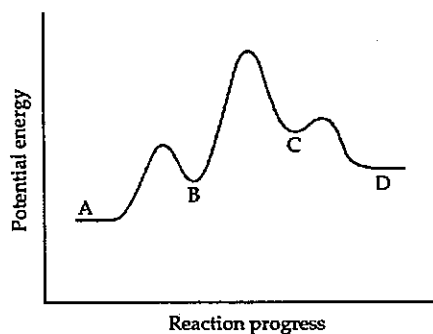
(A) A→B is the rate determining step.
(B) There are three intermediates.
(C) The overall reaction is exothermic.
(D) There are three transition states.
(E) Steady state of C can be assumed to solve the overall rate law.

21. The order of the elementary reaction $C_4H_9Br \rightarrow C_4H_9^+ + Br^-$ is?
(A) 0 (B) 1 (C) 2 (D) 3 (E) None of the above

22. How many geometric isomers are there for tetracarbonyldichloroiron(II)?
(A) 1 (B) 2 (C) 3 (D) 4 (E) 5

23. Two different proteins X and Y are dissolved in aqueous solution at 37 °C. The proteins bind in a 1:1 ratio to form XY. A solution that is initially 1.00 mM in each protein is allowed to reach equilibrium. At equilibrium, 0.20 mM of free X and 0.20 mM of free Y remain. What is the equilibrium constant for the reaction?

(A) 1.0×10^4 (B) 2.0×10^4 (C) 5.0×10^4 (D) 1.0×10^3 (E) 2.0×10^3

24. Which one of the following is paramagnetic?

(A) N_2 (B) $[ZnCl_4]^{2-}$ (C) $[Pd(NH_3)_2Cl_2]$ (D) $[V(H_2O)_6]^{3+}$ (E) $[Fe(CN)_6]^{4-}$

25. A 1 M solution of $Cu(NO_3)_2$ is placed in a beaker with a strip of Cu metal. A 1 M solution of $SnSO_4$ is placed in a second beaker with a strip of Sn metal. A salt bridge connects the two beakers, and wires to a voltmeter link the two metal electrodes. What is the emf generated by the cell under standard conditions? (Standard reduction potentials of Cu^+, Cu^{2+}, and Sn^{2+} are 0.52, 0.34, and -0.14, respectively.)

(A) 1.0. (B) 0.66 (C) 0.48 (D) 0.38 (E) 0.20

※ 注意：請於試卷上「非選擇題作答區」標明大題及小題題號，並依序作答。

(II). 敘述與計算題 (共 25 分)：

26. When one electron is added to an oxygen molecule, a superoxide ion (O_2^-) is formed. The addition of two electrons gives a peroxide ion (O_2^{2-}). Removal of an electron from O leads to O_2^+.

(26A) (5%) Construct the molecular orbital correlation diagram for O_2. You must fill in the electrons properly.

(26B) (2%) Give the bond order for each of the following species: O_2^+, O_2, O_2^-, O_2^{2-}.

(26C) (2%) Predict which species are paramagnetic.

27. Consider the gas-phase oxidation of HBr by O_2:

$$4 HBr(g) + O_2(g) \longrightarrow 2 H_2O(g) + 2 Br_2(g)$$

You find the reaction to be first order with respect to HBr and first order with respect to O_2. You propose the following mechanism:

$$HBr(g) + O_2(g) \longrightarrow HOOBr(g)$$
$$HOOBr(g) + HBr(g) \longrightarrow 2 HOBr(g)$$
$$HOBr(g) + HBr(g) \longrightarrow H_2O(g) + Br_2(g)$$

(27A) (5%) Based on the experimentally determined rate law, which step is rate determining? Show that the rate law derived from the mechanism is consistent with the experimental observation. You must clearly state the approximations you made in the derivation.

(27B) (5%) Additional experiments show that HOBr or HOOBr cannot be detected during the reactions, does this disprove your mechanism? Explain your answer.

28. For a particular reaction, ΔH is -32 kJ/mol and ΔS is -98 $JK^{-1}mol^{-1}$ at the standard condition. Assume ΔH and ΔS are temperature independent. Answer the following questions:

(28A) (3%) At what temperature will the reaction have ΔG = 0? You must show how you calculate it.

(28B) (3%) If the temperature is increased from that in part (28A), will the reaction be spontaneous or nonspontaneous? Explain your answer.

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