

※ 注意：請於試卷上「選擇題作答區」依序作答。

第一部份 選擇題 (每題 3 分，共 54 分) (請考生將答案填寫於答案卷上之選擇題作答區)

1. A 0.4230-g sample of impure sodium nitrate was heated, converting all the sodium nitrate to 0.2864 g of sodium nitrite and oxygen gas. Which is the percent of sodium nitrate in the original sample?

- (A) 65% (B) 74% (C) 83% (D) 92%

2. Which of the following combination of solutions will NOT produce any precipitate?

- (A) $K_2CrO_4(aq) + Ba(NO_3)_2(aq)$ (B) $NaBr(aq) + RbCl(aq)$ (C) $K_2CO_3(aq) + MgI_2(aq)$ (D) $Na_2CrO_4(aq) + AlBr_3(aq)$

3. For the van der Waals gas, it shows the equation:

$$\left[P_{obs} + a \left(\frac{n}{V} \right)^2 \right] (V - nb) = nRT$$

Which of the following gas has the largest value of b in standard state?

- (A) Cl_2 (B) Ne (C) O_2 (D) He

4. A 10.0 mL sample of an HCl solution has a pH of 2.000. What volume of water must be added to change the pH to 4.000?

- (A) 10 mL (B) 90 mL (C) 490 mL (D) 990 mL

5. Which of the following statements is true?

- (A) When a base is dissolved in water, the lowest possible pH of the solution is 7.0.
 (B) When an acid is dissolved in water, the lowest possible pH is 0.
 (C) A strong acid solution will have a lower pH than a weak acid solution.
 (D) A 0.0010 M $Ba(OH)_2$ solution has a pOH that is twice the pOH value of a 0.0010 M KOH solution.

6. A chemist needs to prepare a solution buffered at pH 4.30 using the following acids and its sodium salt. Consider the ratio of $[HA]/[A^-]$ and pK_a of each acid, which of the following acid can make the buffer system work best?

- (A) Chloroacetic acid ($K_a = 1.35 \times 10^{-3}$) (B) Propanoic acid ($K_a = 1.3 \times 10^{-5}$)
 (C) Benzoic acid ($K_a = 6.4 \times 10^{-5}$) (D) Hypochlorous acid ($K_a = 3.5 \times 10^{-8}$)

7. Use the K_{sp} to derive which of the following salts has the lowest solubility in pure water?

- (A) Copper(II) sulfide ($K_{sp} = 8.5 \times 10^{-45}$) (B) Silver(I) sulfide ($K_{sp} = 1.6 \times 10^{-49}$)
 (C) Mercury(II) sulfide ($K_{sp} = 1.6 \times 10^{-54}$) (D) Bismuth(III) sulfide ($K_{sp} = 1.1 \times 10^{-73}$)

8. At constant pressure and temperature, in which of the following systems is work done on the system by the surroundings?

- (A) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ (B) $CO(g) + H_2O(g) \rightarrow H_2(g) + CO_2(g)$
 (C) $Ca_3P_2(s) + 6H_2O(l) \rightarrow 3Ca(OH)_2(s) + 2PH_3(g)$ (D) $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$

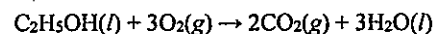
9. What's the change in entropy that occur when a sample containing 2.00 moles of water is heated from 50°C to 150°C at 1 atm pressure? The molar heat capacities for $H_2O(l)$ and $H_2O(g)$ are 75.3 J/K·mol and 36.4 J/K·mol respectively, and the enthalpy of vaporization for water is 40.7 kJ/mol at 100°C.

- (A) 220 J/K (B) 250 J/K (C) 280 J/K (D) 310 J/K

10. Which of the following reaction is expected to have a positive value for ΔS° ?

- (A) $C_2H_4(g) + H_2O(l) \rightarrow C_2H_5OH(l)$ (B) $SiF_6(aq) + H_2(g) \rightarrow 2HF(g) + SiF_4(g)$
 (C) $CO(g) + Cl_2(g) \rightarrow COCl_2(g)$ (D) $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

11. A fuel cell designed to react grain alcohol with oxygen has the following net reaction:



The maximum work 1 mole of alcohol can yield by this process is 1320 kJ. What is the theoretical maximum voltage this cell can achieve?

- (A) 1.14 V (B) 1.20 V (C) 1.26 V (D) 1.32 V

12. Which of the following sets of quantum numbers are allowed?

- (A) $n = 2, \ell = 1, m_\ell = -1, m_s = -1$ (B) $n = 3, \ell = 3, m_\ell = 0, m_s = -\frac{1}{2}$
 (C) $n = 4, \ell = 1, m_\ell = 1, m_s = +\frac{1}{2}$ (D) $n = 5, \ell = -4, m_\ell = 2, m_s = +\frac{1}{2}$

13. Assume that a hydrogen atom's electron has been excited to the $n = 5$ level. How many different wavelengths of light can be emitted as this excited atom loses energy?

- (A) 8 (B) 9 (C) 10 (D) 11

14. Which of the following compounds or ion exhibit NO resonance?

- (A) AsI_3 (B) CNO^- (C) O_3 (D) CO_3^{2-}

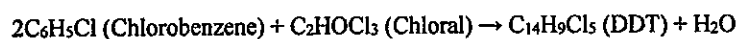
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15. Which of the following statements concerning SO₂ is NOT correct?
 (A) The central sulfur atom is sp² hybridized. (B) The bond angles about the central sulfur atom are about 120 degrees.
 (C) The resonance structures of SO₂ exist. (D) One of the sulfur-oxygen bond is longer than the other one.
16. Concerning the energy split of orbital in octahedral (Δ_{oct}) and tetrahedral (Δ_{tet}) crystal field, which of the following relationship between Δ_{oct} and Δ_{tet} is true?
 (A) $\Delta_{\text{tet}} = \frac{2}{3}\Delta_{\text{oct}}$ (B) $\Delta_{\text{tet}} = \frac{4}{9}\Delta_{\text{oct}}$ (C) $\Delta_{\text{tet}} = \frac{3}{2}\Delta_{\text{oct}}$ (D) $\Delta_{\text{tet}} = \frac{9}{4}\Delta_{\text{oct}}$
17. Which of the following statement is true?
 (A) The coordination number of a metal ion in an octahedral complex is 8.
 (B) All tetrahedral complex ions are low-spin.
 (C) The formula for triaquatrimminechromium(III) sulfate is [Cr(H₂O)₃(NH₃)₃](SO₄)₃.
 (D) Hemoglobin contains Fe³⁺.
18. The mass percent of carbon in a typical human is 18%, and the mass percent of ¹⁴C in natural carbon is 1.6 × 10⁻¹ %. For an 80-kg person, how many decay events per second occur in this person due to the β-particle decay of ¹⁴C? (For ¹⁴C, half-life for β-decay is 5730 years.)
 (A) 2800 (B) 3800 (C) 4800 (D) 5800

※ 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。

第二部份 計算題 (共有 3 大題，總分 46 分) (請考生將答案填寫於答案卷上之作答區，並標明題號。)

1. DDT, an insecticide harmful to fish, birds, and humans, is produced by the following reaction:



In a government lab, 1273.32 g of chlorobenzene is reacted with 596.75 g of chloral.

- Which reactant is limited? (3 分)
- What mass of DDT is formed, assuming 100% yield? (4 分)
- What mass of the excess reactant is left over? (3 分)
- If the actual yield of DDT is 284.36 g, what is the percent yield? (3 分)

2. The following data were collected in two studies of reaction: 2A + B → C + D

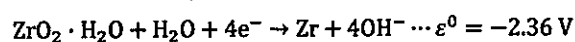
Where Rate = $-\frac{d[A]}{dt}$. In exp 1, [B]₀ = 5.0 M. In exp 2, [B]₀ = 10.0 M.

Times (s)	Exp 1 [A] (M) × 10 ⁻²	Exp 2 [A] (M) × 10 ⁻²
0	10.0	10.0
20	6.67	5.00
40	5.00	3.33
60	4.00	2.50
80	3.33	2.00
100	2.86	1.67
120	2.50	1.43

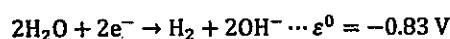
- Explain why [B] is much greater than [A]. (3 分)
- Derive the rate law and calculate value of rate constant for this reaction. (6 分)
- Which of the following mechanisms could be correct for this reaction? Justify your reason. (5 分)

I. A + B ⇌ E (fast equilibrium) E + B → C + D (slow)	II. A + B ⇌ E (fast equilibrium) E + A → C + D (slow)	III. A + A → E (slow) E + B → C + D (fast)
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3. Zirconium is one of the few metals that retains its structure integrity upon exposure to radiation. The fuel rods in most nuclear reactors therefore are often made of zirconium. Answer the following questions about the redox properties of zirconium based on the half-reaction:



- Use the appended standard reduction half potential, is zirconium metal capable of reducing water to form hydrogen gas at standard conditions? (4 points)



- Write down a balanced equation for the reduction of water by zirconium. (5 points)
- Calculate ΔG^0 , and equilibrium constant for the reduction of water by zirconium metal. (6 points)
- If 1.00 × 10³ kg of Zr (91.22 a.u.) reacts, what mass of H₂ is produced? What volume of H₂ at 1.0 atm and 1000°C is produced? (4 points)

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