國 立 清 華 大 學 命 題 紙

95 學年度 生醫工程與環境科學 系（所） 乙（環境分子科學） 組碩士班入學考試

科目 普 通 化 學 科目代碼 3101 共 6 頁第 1 頁 *請在【答案卷卡】內作答

I. Multiple Choices. Please choose the one alternative that best answers the question. (50%, 2% of each).

1. **The diameter of the Earth is approximately 12750 km.** If one could dig down straight towards the center of the Earth, one would find that the outermost 2890 km (the crust and the mantle) has an average density of about 4.5 g/cm^3. Farther down is the core. If the average density of the Earth is 5.5 g/cm^3, what is the average density of the Earth's core?
   [A] 11 g/cm^3 [B] 5.6 g/cm^3 [C] 6.2 g/cm^3 [D] 1.9 g/cm^3 [E] 8.7 g/cm^3

2. Which response gives the correct coordination number (C.N.) and oxidation number (O.N.) of the transition metal atom in $[Co(NH_3)_2(H_2O)_2Cl_2]^+$?
   [A] C.N. = 2; O.N. = +3 [B] C.N. = 4; O.N. = +1 [C] C.N. = 6; O.N. = +1
   [D] C.N. = 6; O.N. = +2 [E] C.N. = 6; O.N. = +3

3. Calculate the activity of Mg^{2+} in a solution containing 0.01 M $MgCl_2$ and 0.02 M Na_2SO_4.
   [A] 0.031 M [B] 0.015 M [C] 0.007 M [D] 0.0035 M [E] 0.0018 M

4. When 38.0 mL of 0.125 M H_2SO_4 is added to 100 mL of a solution of PbI_2, a precipitate of $PbSO_4$ forms. **The $PbSO_4$ is then filtered from the solution, dried, and weighed.** If the recovered $PbSO_4$ is found to have a mass of 0.0306 g with separation efficiency of 65%, what was the concentration of iodide ions in the original solution?
   [A] 3.10×10^{-4} M [B] 1.55×10^{-4} M [C] 6.20×10^{-3} M
   [D] 3.11×10^{-3} M [E] 1.55×10^{-3} M

5. 9.45 g of liquid hexane (C_6H_{14}) is introduced into a 10.0 L vessel containing 13.15 atm of oxygen gas at 21°C and ignited, yielding carbon dioxide and water. If the vessel is then cooled to –10 °C, what will be the gas pressure inside the vessel?
   [A] 3.09 atm [B] 13.15 atm [C] 1.42 atm [D] 10.9 atm [E] 12.6 atm

6. Calculate the standard enthalpy of formation (in kcal/mol) of liquid methanol, $CH_3OH(l)$, using the following information:

   $C(graph) + O_2 \rightarrow CO_2(g)$ $\Delta H° = -393.5$ kJ/mol
   $H_2(g) + (1/2)O_2 \rightarrow H_2O(l)$ $\Delta H° = -285.8$ kJ/mol
   $CH_3OH(l) + (3/2)O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H° = -726.4$ kJ/mol

   [A] –1,691.5 [B] –238.7 [C] –57.0 [D] 238.7 [E] 47.1

7. A ground-state atom of iron has ___ unpaired electrons and is _____.
[A] 0, diamagnetic [B] 6, diamagnetic [C] 4, diamagnetic
[D] 6, paramagnetic [E] 4, paramagnetic

8. A buffer solution has been prepared by adding 0.2 M of acetic acid and 0.1 M acetate. The pH of the solution has been adjusted to 5.0 by addition of NaOH. How many mol/L of NaOH is further required to increase the pH to 5.2?
[A] 0.016 M [B] 0.032 M **[C] 0.048 M** **[D] 0.064 M** [E] 0.096 M

9. The azide ion, N_3^-, is very reactive although it is isoelectronic with the very stable CO_2 molecule. This reactivity is reasonable inasmuch as
[A] a Lewis structure cannot be written for the azide ion that has nitrogen formal charges of zero.
[B] there is no valid Lewis structure possible for the azide ion.
[C] there are resonance structures for azide ion but not for carbon dioxide.
[D] nitrogen cannot form multiple bonds.
[E] charged species always decompose in solution.

10. The enthalpy change due to the reaction of one mole of C_2H_4 with water to form C_2H_5OH can be estimated by
[A] BE(C=C) – 2BE(C–C) – BE(C–O)
[B] BE(C=C) + BE(O–H) – 2BE(C–C) – BE(C–O)
[C] BE(C–O) + BE(C–C) – BE(O–H) – BE(C=C)
[D] BE(O–H) + BE(C=C) – BE(C–H) – BE(C–O) – BE(C–C)
[E] BE(C–H) + BE(C–O) + BE(C–C) – BE(O–H) – BE(C=C)

11. According to VSEPR theory, which one of the following molecules should have a geometry that is trigonal bipyramidal?
[A] SF_4 [B] XeF_4 [C] NF_3 [D] SF_6 **[E] PF_5**

12. What is the central metal ion in vitamin B_{12}?
[A] Fe^{3+} [B] Fe^{2+} [C] Co^{2+} [D] Mg^{2+} [E] Ni^{2+}

13. The molar enthalpy of vaporization of hexane (C_6H_{14}) is 28.9 kJ/mol, and its normal boiling point is 68.73°C. What is the vapor pressure of hexane at 25°C?
[A] 171 torr [B] 4.44 torr [C]117 torr **[D] 3370 torr** [E] 759 torr.

14. What is the osmotic pressure of a solution prepared from 13.7 g of the electrolyte HCl and enough water to make 0.500 L of solution at 18°C?
[A] 0.55 atm [B] 1.10 atm [C] 8.95 atm [D] 17.9 atm [E] 35.9 atm

15. The isomerization of methyl isocyanide, $CH_3NC \rightarrow CH_3CN$, follows first-order kinetics. The half-lives were found to be 161 min at 199°C and 12.5 min at 230°C. Calculate the activation energy for this reaction (kJ/mol).
[A] 6.17×10^{-3} [B] 31.4 [C] 78.2 [D]124 [E] 163

16. When comparing acid strength of binary acids HX, as X varies within a particular group of the periodic table, which one of the following factors dominates in affecting the acid strength?
[A] bond strength
[B] withdrawing effects
[C] solubility
[D] percent ionic character of the H–X bond
[E] Le Châtelier's principle.

17. You have 500.0 mL of a buffer solution containing 0.20 M acetic acid (CH_3COOH) and 0.30 M sodium acetate (CH_3COONa). What will the pH of this solution be after the addition of 20.0 mL of 1.00 M NaOH solution? [$K_a = 1.8 \times 10^{-5}$]
[A] 4.41 [B] 4.74 [C] 4.56 [D] 4.92 [E] 5.07

18. Which response has both answers correct? Will a precipitate form when 250 mL of 0.33 M Na_2CrO_4 are added to 250 mL of 0.12 M $AgNO_3$? What is the concentration of the silver ion remaining in solution? ($K_{sp}(Ag_2CrO_4) = 1.1 \times 10^{-12}$)
[A] Yes, $[Ag^+] = 2.9 \times 10^{-6}$ M. **[B] Yes, $[Ag^+] = 0.060$ M.** **[C] Yes, $[Ag^+] = 1.3 \times 10^{-4}$ M.**
[D] No, $[Ag^+] = 0.060$ M [E] No, $[Ag^+] = 0.105$ M.

19. An unusual atmospheric reaction leading to ozone destruction is

$$CF_3O + O_3 \rightarrow CF_3O_2 + O_2$$

the analysis of which has yielded an Arrhenius frequency factor (A) and activation energy of 2.0×10^{-12} cm^3 $molecule^{-1}$ s^{-1} and 11.6 kJ/mol, respectively. Calculate the rate constant for this reaction at an altitude of 35 km, where the temperature is –34°C.
[A] 2.0×10^{-12} M^{-1} s^{-1} [B] 1.2×10^{9} M^{-1} s^{-1} [C] 3.5×10^{6} M^{-1} s^{-1}
[D] 7.9×10^{-15} M^{-1} s^{-1} [E] 6.8×10^{8} M^{-1} s^{-1}

20. The zinc-air battery shows much promise for electric cars because it is light-weight and rechargeable. The net transformation is $Zn(s) + 1/2\ O_2(g) \rightarrow ZnO(s)$. What is the energy under ambient operating conditions if the Gibb's free energy of ZnO(s) is -318.2 kJ/mol?

[A] 3.30 V [B] 3.26 V [C] 1.65 V [D] 1.63 V [E] 1.1 V

21. According to valence bond theory, what would be the set of hybrid orbitals used when a Period 4 transition metal forms a square planar complex?

[A] d^2sp [B] d^2p^2 [C] dsp^3 [D] sp^3 [E] dsp^2

22. Which of the following statements relating to molecular orbital (MO) theory is incorrect?

[A] Combination of two atomic orbitals produces one bonding and one antibonding MO.

[B] A bonding MO is lower in energy than the two atomic orbitals from which it is formed.

[C] Combination of two $2p$ orbitals may result in either σ or π MOs.

[D] A species with a bond order of zero will not be stable

[E] In a stable molecule having an even number of electrons, all electrons must be paired.

23. Raoult's Law relates the vapor pressure of the solvent above the solution to its mole fraction in the solution. Which of the following is an accurate statement?

[A] Raoult's Law applies exactly to all solutions.

[B] Raoult's Law works best when applied to concentrated solutions.

[C] Raoult's Law works best when applied to dilute solutions.

[D] Raoult's Law applies only to non-ideal solutions.

[E] None of these statements is accurate.

24. Although the periodic table is organized according to the atomic numbers of the elements, chemists are more interested in the arrangement of the electrons for their studies. Which of the following statements about the electron configurations and their quantum numbers is correct?

[A] The size of an atom is associated with the angular momentum quantum number.

[B] The valence electrons of atoms in a particular group have the same principal and angular momentum quantum numbers.

[C] The valence electrons of atoms in a particular group have the same angular momentum quantum number but have different principal quantum numbers.

[D] Quantum numbers for the electrons tell us little about the relative energies of the electrons.

[E] None of these statements is correct.

25. It is found that 1 g of bacteria can decompose protein at a maximum rate of 20 g/day. At the same time, the bacteria would decompose protein at a rate of 10 g/day when the protein concentration is 15 mg/L. What would be the rate of protein decomposition by 2 g bacteria if the protein concentration is 5 mg/L.

[A] 6.7 g/day [B] 10 g/day [C] 13.4 g/day [D] 15 g/day [E] 18 g/day

II. A sample of solid naphthalene is introduced into an evacuated flask. Use the data below to calculate the equilibrium vapor pressure of naphthalene ($C_{10}H_8$) in the flask at 35°C. (7 %)

Compounds	$\Delta H°_f$ (25°C)	$\Delta G°_f$ (25°C)
$C_{10}H_8(s)$	78.5 kJ/mol	201.6 kJ/mol
$C_{10}H_8(g)$	150.6 kJ/mol	224.1 kJ/mol

III. Gold (Au) crystallizes in a cubic close-packed structure (the face-centered cubic unit cell) and has a density of 19.3 g/cm^3. Please calculate the atomic radius of gold in picometers. (7 %)

IV. A solution contains Ag^+, Cu^{2+}, Zn^{2+} and Ca^{2+}. Please develop a qualitative analysis scheme to separate these ions from solution. (8 %)

V. A coordination compound contains the following physicochemical properties:

(1) The particle empirical formula is $KM(CrO_4)Cl_2(NH_3)_4$, where M is an unknown element.

(2) It has A (red) and B (blue) crystal forms.

(3)When 1.0 mole of A or B reacts with 1.0 mole $AgNO_3$, 0.5 mole of a red precipitate forms immediately.

(4) After the reaction in (3), 1.0 mole of A reacts very slowly with 1.0 mole of silver oxalate ($Ag_2C_2O_4$) to form 2.0 mole of white precipitate.

(5) After the reaction in (3), 1.0 mole of B does not react further with 1.0 mole of $AgNO_3$.

From the information shown above, please determine the following:

(a) The coordination number of M. (3%)

(b) The type of chemical bonding of group(s) bonded to M. (4%)

(c) The stereochemistry of the red and blue forms. (3%)

VI. The quantum-mechanical treatment of the hydrogen atom gives the energy, E, of the electron as a function of the principal quantum number, n:

$$E = \frac{h^2}{8\pi^2 m_e a_0^2 n^2} \quad (n=1, 2, 3,\ldots.) \qquad (1)$$

Where h is Planck's constant, m_0 is the electron mass, and a_0 is 52.92×10^{-12} m. Please write the expression of equation (1) in the form E = - (constant)$\frac{1}{n^2}$. Evaluate the constant (in J), and compare the expression with the corresponding expression from Bohr's theory. (6%)

VII. The atmospheric concentration of carbon dioxide is 345 ppm under STP condition. Please convert this value to mg/m^3 at 0°C and 0.85 atm. (6 %)

VIII. Draw the partial (valence-level) orbital diagram and write the electron configuration of the atom and monoatomic ion of the element with the following ionization energies (in KJ/mol). (6 %)

IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7	IE_8
999	2251	3361	4564	7013	8495	27106	31669

Note: The atomic masses of elements are as follows:

H = 1.0	C = 12.0	O = 16.0	F = 19.0	Na = 23.0	Mg = 24.3
S = 32.1	Cl = 35.5	Cr = 52.0	Ag = 107.9	Zn = 65.4	I = 126.9
Au = 197.0	Pb = 207.2				