

國立清華大學命題紙

98 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 2401 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. Roughly speaking, the radius of an atom is about 10,000 times greater than that of its nucleus. If an atom were magnified so that the radius of its nucleus became 2.0 cm, about the size of a marble, what would be the radius of the atom in miles? (1 mi = 1609 m.)

- (a) 0.6 mi                      (b) 1.2 mi                      (c) 0.24 mi                      (d) 3.3 mi                      (e) 0.12 mi

2. Potassium dichromate,  $K_2Cr_2O_7$ , is used in tanning leather, decorating porcelain and water proofing fabrics. Calculate the number of chromium atoms in 78.82 g of  $K_2Cr_2O_7$ .

- (a)  $9.490 \times 10^{25}$  Cr atoms                      (b)  $2.248 \times 10^{24}$  Cr atoms                      (c)  $1.124 \times 10^{24}$  Cr atoms  
(d)  $3.227 \times 10^{23}$  Cr atoms                      (e)  $1.613 \times 10^{23}$  Cr atoms

3. The thickness of a piece of paper is 0.0036 in. Suppose a certain book has an Avogadro's number of pages. Calculate the thickness of the book in light-years.

- (a)  $2.2 \times 10^{21}$  light-yr                      (b)  $6.0 \times 10^{23}$  light-yr                      (c)  $5.8 \times 10^3$  light-yr  
(d)  $3.4 \times 10^{16}$  light-yr                      (e)  $6.0 \times 10^{16}$  light-yr

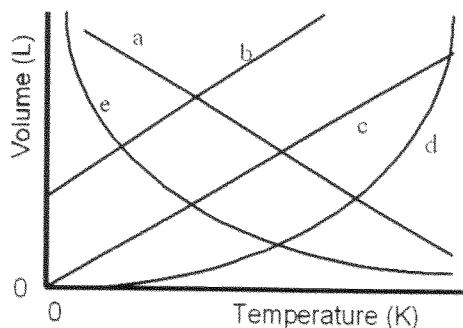
4. Hydrogen fluoride is used in the manufacture of Freons (which destroy ozone in the stratosphere) and in the production of aluminum metal. It is prepared by the reaction



In one process 6.00 kg of  $CaF_2$  are treated with an excess of  $H_2SO_4$  and yield 2.86 kg of HF. Calculate the percent yield of HF.

- (a) 93.0 %                      (b) 95.3 %                      (c) 47.6 %  
(d) 62.5 %                      (e) 42.5 %

5. Which of the lines on the figure below is the best representation of the relationship between the volume of a gas and its absolute temperature, other factors remaining constant?



- (a) line a                      (b) line b                      (c) line c                      (d) line d                      (e) line e

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6. Your favorite candy bar, Gummy Beakers, contains  $1.2 \times 10^6$  J of energy while your favorite soft drink, Coca Cola, contains  $6.7 \times 10^5$  J. If you eat two packs of Gummy Beakers a day and drink 3 cans of Coca Cola, what percent of your 2000 Calorie daily food intake is left for other foods?  
 (a) 53% (b) 47% (c) 27% (d) 11% (e) 3%
7. In which of the following processes is  $\Delta H = \Delta E$ ?  
 (a) Two moles of ammonia gas are cooled from  $325^\circ\text{C}$  to  $300^\circ\text{C}$  at 1.2 atm.  
 (b) One gram of water is vaporized at  $100^\circ\text{C}$  and 1 atm.  
 (c) Two moles of hydrogen iodide gas react to form hydrogen gas and iodine gas in a 40-L container.  
 (d) Calcium carbonate is heated to form CaO and  $\text{CO}_2$  in a container with variable volume.  
 (e) One mole of solid carbon dioxide sublimates to the gas phase.
8. Select the arrangement of electromagnetic radiation which starts with the lowest energy and increases to greatest energy.  
 (a) UHF, microwave, NIR, visible, UVA, UVC  
 (b) microwave, NIR, UHF, visible, UVA, UVC.  
 (c) UHF, NIR, microwave, visible, UVC, UVA.  
 (d) NIR, microwave, UHF, visible, UVC, UVA  
 (e) microwave, UHF, NIR, visible, UVA, UVC
9. Identify the element of Period 2 which has the following successive ionization energies, in kJ/mol.  
 $\text{IE}_1, 1314$        $\text{IE}_2, 3389$        $\text{IE}_3, 5298$        $\text{IE}_4, 8471$   
 $\text{IE}_5, 15992$        $\text{IE}_6, 28529$        $\text{IE}_7, 61345$        $\text{IE}_8, 84087$   
 (a) Li (b) B (c) N (d) O (e) Cl
10. Calculate the lattice energy of magnesium sulfide ( $\text{MgS}$ ).  
 $\text{Mg}(s) \rightarrow \text{Mg}(g) \quad \Delta H^\circ = 148 \text{ kJ/mol}$   
 $\text{Mg}(g) \rightarrow \text{Mg}^{2+}(g) + 2e^- \quad \Delta H^\circ = 2186 \text{ kJ/mol}$   
 $\text{S}_8(s) \rightarrow 8\text{S}(g) \quad \Delta H^\circ = 2232 \text{ kJ/mol}$   
 $\text{S}(g) + 2e^- \rightarrow \text{S}^{2-}(g) \quad \Delta H^\circ = 450 \text{ kJ/mol}$   
 $8\text{Mg}(s) + \text{S}_8(s) \rightarrow 8\text{MgS}(s) \quad \Delta H^\circ_f = -2744 \text{ kJ/mol}$   
 (a) -3406 kJ/mol (b) -3140 kJ/mol (c) -2720 kJ/mol  
 (d) -2104 kJ/mol (e) -1135 kJ/mol
11. In which one of the following is the best Lewis structure a resonance structure?  
 (a)  $\text{SO}_3$  (b)  $\text{BF}_3$  (c)  $\text{I}_3^-$  (d)  $\text{SCO}$  (e)  $\text{SO}_3^{2-}$

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科目 普通化學 科目代碼 2401 共 6 頁第 3 頁 \*請在【答案卷卡】內作答

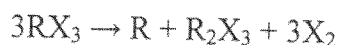
12. According to molecular orbital (MO) theory, the twelve outermost electrons in the  $O_2$  molecule are distributed as follows:
- (a) 12 in bonding MOs, 0 in antibonding MOs      (b) 10 in bonding MOs, 2 in antibonding MOs.  
(c) 9 in bonding MOs, 3 in antibonding MOs.      (d) 8 in bonding MOs, 4 in antibonding MOs.  
(e) 7 in bonding MOs, 5 in antibonding MOs.
13. 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  $\sigma$  or  $\pi$  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.
14. The strongest intermolecular interactions between pentane ( $C_5H_{12}$ ) molecules arise from
- (a) dipole-dipole forces.      (b) London dispersion forces.      (c) hydrogen bonding.  
(d) ion-dipole interactions.      (e) carbon-carbon bonds.
15. Benzaldehyde (M.W. = 106.1 g/mol), also known as oil of almonds, is used in the manufacture of dyes and perfumes and in flavorings. What would be the freezing point of a solution prepared by dissolving 75.00 g of benzaldehyde in 850.0 g of ethanol?  $K_f = 1.99^\circ C/m$ , freezing point of pure ethanol =  $-117.3^\circ C$
- (a)  $-117.5^\circ C$       (b)  $-118.7^\circ C$       (c)  $-119.0^\circ C$       (d)  $-120.6^\circ C$       (e)  $-122.1^\circ C$
16. Hydrogen forms metallic (interstitial) hydrides with the  $d$  and  $f$  transition elements. Which of the following statements is correct?
- (a) These substances have distinct stoichiometric formulas like ionic hydrides.  
(b) Hydrogen forms bonds with the metals by donating its electron to the valence band of the metal.  
(c) Hydrogen molecules and atoms occupy holes within the crystal structure of the metal.  
(d) These substances are useful catalysts.  
(e) These hydrides are stabilized by hydrogen bonding forces.
17. Predict the products for the following set of reactants.
- $$Ca_3As_2(s) + H_2O(l) \rightarrow$$
- (a)  $As^{3+}(aq) + Ca(OH)_2(aq)$       (b)  $As^{3+}(aq) + Ca(OH)_2(aq)$       (c)  $As(OH)_3(s) + Ca(OH)_2(aq)$   
(d)  $AsH_3(g) + Ca(OH)_2(aq)$       (e)  $CaH_2(aq) + As_2O_3(aq)$

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科目 普通化學 科目代碼 2401 共 6 頁第 4 頁 \*請在【答案卷卡】內作答

18. The compound  $RX_3$  decomposes according to the equation:



In an experiment the following data were collected for the decomposition at  $100^\circ\text{C}$ . What is the average rate of reaction over the entire experiment?

Time (s)	0	2	6	8	10	12
$[RX_3]$ (mol $L^{-1}$ )	0.85	0.67	0.41	0.33	0.20	0.16

- (a)  $0.011 \text{ mol L}^{-1}\text{s}^{-1}$       (b)  $0.019 \text{ mol L}^{-1}\text{s}^{-1}$       (c)  $0.044 \text{ mol L}^{-1}\text{s}^{-1}$   
 (d)  $0.049 \text{ mol L}^{-1}\text{s}^{-1}$       (e)  $0.069 \text{ mol L}^{-1}\text{s}^{-1}$

19. The gas-phase reaction  $\text{CH}_3\text{NC} \rightarrow \text{CH}_3\text{CN}$  has been studied in a closed vessel, and the rate equation was found to be:  $\text{rate} = -\Delta[\text{CH}_3\text{NC}]/\Delta t = k[\text{CH}_3\text{NC}]$ . Which one of the following actions is least likely to cause a change in the rate of the reaction?

- (a) lowering the temperature.  
 (b) adding a catalyst.  
 (c) using a larger initial amount of  $\text{CH}_3\text{NC}$  in the same vessel.  
 (d) using a bigger vessel, but the same initial amount of  $\text{CH}_3\text{NC}$ .  
 (e) continuously removing  $\text{CH}_3\text{CN}$  as it is formed.

20. Stearic acid, a nature's most common fatty acid, dimerizes when dissolved in hexane:



The equilibrium constant for this reaction at  $28^\circ\text{C}$  is 2900. Estimate the equilibrium constant at  $38^\circ\text{C}$ .

- (a)  $4.7 \times 10^5$       (b)  $2.6 \times 10^4$       (c)  $1.9 \times 10^3$       (d) 320      (e) 18

21. What is the  $[\text{H}_3\text{O}^+]$  in a solution that consists of  $0.15 \text{ M}$   $\text{C}_2\text{N}_2\text{H}_8$  (ethylene diamine) and  $0.35 \text{ M}$   $\text{C}_2\text{N}_2\text{H}_9\text{Cl}$ ? ( $K_b = 4.7 \times 10^{-4}$ )

- (a)  $2.0 \times 10^{-3} \text{ M}$       (b)  $1.1 \times 10^{-3} \text{ M}$       (c)  $6.3 \times 10^{-9} \text{ M}$   
 (d)  $2.1 \times 10^{-10} \text{ M}$       (e)  $5.0 \times 10^{-11} \text{ M}$

22.  $10.0 \text{ mL}$  of a  $0.100 \text{ mol/L}$  solution of a metal ion  $\text{M}^{2+}$  is mixed with  $10.0 \text{ mL}$  of a  $0.100 \text{ mol/L}$  solution of a ligand  $\text{L}$ . A reaction occurs in which the product is  $\text{ML}_3^{2+}$ . Approximately, what is the maximum concentration of  $\text{ML}_3^{2+}$ , in  $\text{mol/L}$ , which could result from this reaction?

- (a) 0.10      (b) 0.05      (c) 0.033      (d) 0.025      (e) 0.017

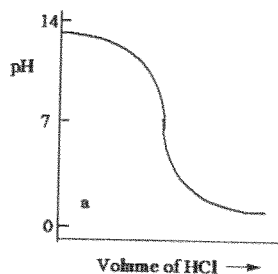
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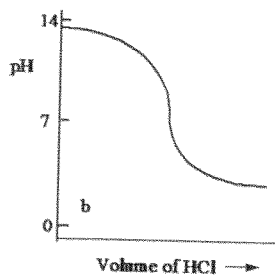
科目 普通化學 科目代碼 2401 共 6 頁第 5 頁 \*請在【答案卷卡】內作答

23. Which one of the following is the best representation of the titration curve which will be obtained in the titration of a weak base ( $0.10 \text{ mol L}^{-1}$ ) with HCl of the same concentration?

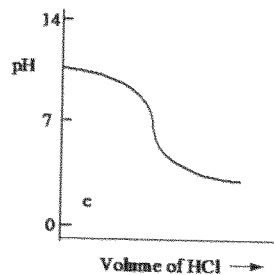
(a)



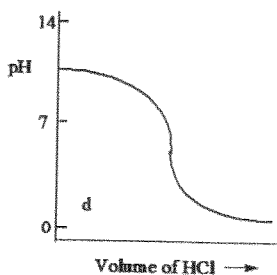
(b)



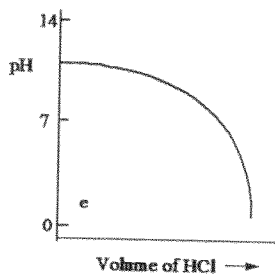
(c)



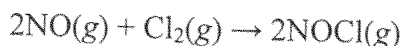
(d)



(e)



24. Nitric oxide reacts with chlorine to form NOCl. The data refer to 298 K.



Substance:	NO(g)	Cl <sub>2</sub> (g)	NOCl(g)
$\Delta H^\circ_f$ (kJ/mol):	90.29	0	51.71
$\Delta G^\circ_f$ (kJ/mol):	86.60	0	66.07
$S^\circ$ (J/K·mol):	210.65	223.0	261.6

What is the value of  $\Delta G^\circ$  for this reaction at 550 K?

(a) -143.76 kJ

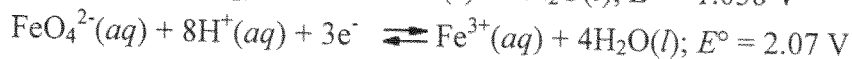
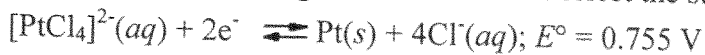
(b) -78.78 kJ

(c) -22.24 kJ

(d) -10.56 kJ

(e) -8.47 kJ

25. Examine the following half-reactions and select the strongest oxidizing agent among the substances.



(a)  $[\text{PtCl}_4]^{2-}(aq)$

(b) RuO<sub>4</sub>(s)

(c) HFeO<sub>4</sub><sup>-</sup>(aq)

(d) H<sub>4</sub>XeO<sub>6</sub>(aq)

(e) Cl<sup>-</sup>(aq)

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- (II). Both the ideal gas law and Van der Waal equation can be used to describe the state of a fluid. Please describe and show these two equations and plot  $PV/nRT$  versus  $P$  to explain the behaviors of ideal and of typical real gases. Discuss the difference in application of these two gaseous equations. (8%)
- (III). Explain what is Bohr radius and the relationship between Bohr radius and quantum confinement effect. In addition, identify the change in bandgap as well as optical properties when the particle sizes are narrowed down to near Bohr radius. (10%)
- (IV). (a) Please explain Hund's rule, and show how it applies to the ground state of titanium atoms. (3%)  
(b) Take titanium dioxide as an example, describe, with appropriate explanations, the key factors which affect the magnitude of the lattice energy of a semiconductor catalyst. (4%)
- (V). The  $d_{xy}$  and the orbitals  $d_x^2 - y^2$  both lie in the  $xy$  plane, yet for a metal ion in an octahedral complex the energy of the  $d_{xy}$  orbital is lower than that of the  $d_x^2 - y^2$  orbital. Explain this using the arguments of crystal field theory. (7%)
- (VI). (a) Explain what is meant by the terms "unit cell" and "cell parameter". (4%)  
(b) Copper metal has a face-centered cubic unit cell. The edge length of the unit cell is 361 pm, and the atomic weight of copper is 63.55 amu. Calculate the density of the copper in  $\text{g/cm}^3$  and radius of a copper atom in pm ( $1 \text{ amu} = 1.661 \times 10^{-24} \text{ g}$ ). (6%)
- (VII). A water solution contains mainly  $(\text{NH}_4)_2\text{HPO}_4$  at a concentration of  $10^{-2} \text{ M}$ . Please calculate the pH value of the water solution at  $25^\circ\text{C}$ . (8%)  
(Given: acidity constants for phosphate:  $\text{pK}_{a1} = 2.3$ ;  $\text{pK}_{a2} = 7.2$ ;  $\text{pK}_{a3} = 12.3$ ; for ammonia  $\text{pK}_{a1} = 9.3$ )

Note: The atomic masses of elements are as follows:

H = 1.0	C = 12.0	N = 14.0	O = 16.0	F = 19.0	Na = 23.0
Mg = 24.3	Al = 27.0	S = 32.1	Cl = 35.5	K = 39.1	Cr = 52.0
Mn = 54.9	Ni = 58.7	Cu = 63.5	Br = 79.9	I = 126.9	