

國 立 清 華 大 學 命 題 紙

97 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 2601 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. (60%, 2% of each)

(1) Based on the solubility rules, which of the following will occur if solutions of  $\text{CuSO}_4(\text{aq})$  and  $\text{BaCl}_2(\text{aq})$  are mixed?

- (a)  $\text{CuCl}_2$  will precipitate;  $\text{Ba}^{2+}$  and  $\text{SO}_4^{2-}$  are spectator ions.
- (b)  $\text{CuSO}_4$  will precipitate;  $\text{Ba}^{2+}$  and  $\text{Cl}^-$  are spectator ions.
- (c)  $\text{BaSO}_4$  will precipitate;  $\text{Cu}^{2+}$  and  $\text{Cl}^-$  are spectator ions.
- (d)  $\text{BaCl}_2$  will precipitate;  $\text{Cu}^{2+}$  and  $\text{SO}_4^{2-}$  are spectator ions.
- (e) No precipitate will form.

(2) Carbon forms so many more compounds than other elements because

- (a) carbon atoms can form more than four bonds.
- (b) carbon forms strong ionic bonds with many metals.
- (c) carbon atoms link up with each other to form chains and rings.
- (d) all carbon compounds are thermodynamically very stable.
- (e) carbon is an essential element for human body.

(3) Which of the following is a most strong Lewis base

- (a) diethyl ether
- (b) butane
- (c) cyclohexane
- (d) neopentane
- (e) amide.

(4) The diameter of a copper (Cu) atom is roughly  $1.3 \times 10^{-10}$  m. How many times can you divide evenly a piece of 10-cm copper wire until it is reduced to two separate copper atoms?

- (a) 28 times
- (b) 29 times
- (c) 30 times
- (d) 31 times
- (e) 32 times

(5) The gas pressure in an aerosol can is 1.8 atm at  $25^\circ\text{C}$ . If the gas is an ideal gas, what pressure would develop in the can if it were heated to  $475^\circ\text{C}$ ?

- (a) 0.095 atm
- (b) 0.717 atm
- (c) 3.26 atm
- (d) 4.52 atm
- (e) 34.2 atm

(6) How many molecules of  $\text{N}_2$  gas can be present in a 2.5 L flask at  $50^\circ\text{C}$  and 650 mmHg?

- (a)  $2.1 \times 10^{-23}$
- (b)  $4.9 \times 10^{22}$
- (c)  $3.1 \times 10^{23}$
- (d)  $3.6 \times 10^{25}$
- (e)  $8.1 \times 10^{22}$

(7) 5.00 g of hydrogen gas and 50.0 g of oxygen gas are introduced into an otherwise empty 9.00 L steel cylinder, and the hydrogen is ignited by an electric spark. If the reaction product is gaseous water and the temperature of the cylinder is maintained at  $35^\circ\text{C}$ , what is the final gas pressure inside the cylinder?

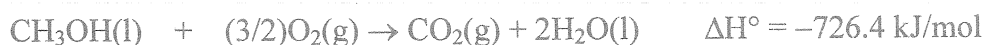
- (a) 7.86 atm
- (b) 18.3 atm
- (c) 2.58 atm
- (d) 6.96 atm
- (e) 0.92 atm

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科目 普通化學 科目代碼 2601 共 6 頁第 2 頁 \*請在【答案卷卡】內作答

(8) Calculate the standard enthalpy of formation of liquid methanol,  $\text{CH}_3\text{OH}(l)$ , using the following information:



- (a)  $-1691.5 \text{ kJ/mol}$    (b)  $-238.7 \text{ kJ/mol}$    (c)  $1691.5 \text{ kJ/mol}$    (d)  $47.1 \text{ kJ/mol}$    (e)  $-47.1 \text{ kJ/mol}$

(9) What is the energy in joules of one photon of microwave radiation with a wavelength  $0.122 \text{ m}$ ?

- (a)  $2.70 \times 10^{-43} \text{ J}$    (b)  $5.43 \times 10^{-33} \text{ J}$    (c)  $1.63 \times 10^{-24} \text{ J}$   
 (d)  $4.07 \times 10^{-10} \text{ J}$    (e)  $2.46 \times 10^9 \text{ J}$

(10) The second line of the Balmer series occurs at a wavelength of  $486.1 \text{ nm}$ . What is the energy difference between the initial and final levels of the hydrogen atom in this emission process?

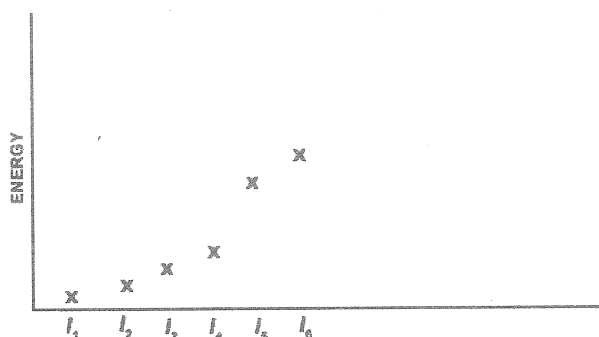
- (a)  $2.44 \times 10^{18} \text{ J}$    (b)  $4.09 \times 10^{-19} \text{ J}$    (c)  $4.09 \times 10^{-22} \text{ J}$   
 (d)  $4.09 \times 10^{-28} \text{ J}$    (e)  $1.07 \times 10^{-48} \text{ J}$

(11) Which one of the following statements about orbital energies is incorrect?

- (a) Which one of the following statements about orbital energies is incorrect?  
 (b) In many-electron atoms the energy of an orbital depends on both  $n$  and  $l$ .  
 (c) Inner electrons shield outer electrons more effectively than do electrons in the same orbital.  
 (d) The splitting of sublevels in many-electron atoms is explained in terms of the penetration effect.  
 (e) The energy of a given orbital increases as the nuclear charge  $Z$  increases.

(12) Which of the elements listed below has the following pattern for its first six ionization energies? ( $I_1$  = first ionization energy,  $I_2$  = second ionization energy, etc.)

- (a) Ca   (b) Si   (c) Al   (d) Se   (e) P



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科目 普通化學 科目代碼 2601 共 6 頁第 3 頁 \*請在【答案卷卡】內作答

(13) Calculate the energy change for the reaction



given the following ionization energy (IE) and electron affinity (EA) values.

Parameter	IE	EA
K	419 kJ/mol	48 kJ/mol
I	1,010 kJ/mol	295 kJ/mol

- (a) -124 kJ/mol    (b) -715 kJ/mol    (c) 715 kJ/mol    (d) 1429 kJ/mol    (e) None of these
- (14) The Lewis structure for a chlorate ion,  $\text{ClO}_3^-$ , should show \_\_\_\_ single bond(s), \_\_\_\_, double bond(s), and \_\_\_\_ lone pair(s).  
 (a) 2, 1, 10    (b) 3, 0, 9    (c) 2, 1, 8    (d) 3, 0, 10    (e) 2, 1, 9
- (15) Which one of the following molecules has tetrahedral geometry?  
 (a)  $\text{XeF}_4$     (b)  $\text{BF}_3$     (c)  $\text{AsF}_5$     (d)  $\text{CF}_4$     (e)  $\text{NH}_3$
- (16) Each of the following substances is a liquid at  $-50^\circ\text{C}$ . Place these liquids in order of *increasing* vapor pressure.  
 (a) ethanol < propane < dimethyl ether    (b) ethanol < dimethyl ether < propane  
 (c) propane < dimethyl ether < ethanol    (d) dimethyl ether < ethanol < propane  
 (e) propane < ethanol < dimethyl ether
- (17) The solubility of oxygen in lakes high in the Rocky Mountains is affected by the altitude. If the solubility of  $\text{O}_2$  from the air is  $2.67 \times 10^{-4}$  M at sea level and  $25^\circ\text{C}$ , what is the solubility of  $\text{O}_2$  at an elevation of 12,000 ft where the atmospheric pressure is 0.657 atm? Assume the temperature is  $25^\circ\text{C}$ , and that the mole fraction of  $\text{O}_2$  in air is 0.209 at both 12,000 ft and at sea level.  
 (a)  $1.75 \times 10^{-4}$  M    (b)  $2.67 \times 10^{-4}$  M    (c)  $3.66 \times 10^{-5}$  M  
 (d)  $4.06 \times 10^{-4}$  M    (e) None of the above.
- (18) The vapor pressure of water at  $20^\circ\text{C}$  is 17.5 mmHg. What is the vapor pressure of water over a solution prepared from  $2.00 \times 10^2$  g of sucrose ( $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ) and  $3.50 \times 10^2$  g water?  
 (a) 0.51 mmHg    (b) 16.0 mmHg    (c) 17.0 mmHg    (d) 18.0 mmHg    (e) 19.4 mmHg

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科目 普通化學 科目代碼 2601 共 6 頁第 4 頁 \*請在【答案卷卡】內作答

(19) Nitric oxide reacts with chlorine to form nitrosyl chloride, NOCl. Use the following data to determine the rate equation for the reaction.



Experiments	[NO]	[Cl <sub>2</sub> ]	Initial rate
#1	0.22	0.065	0.96 M/min
#2	0.66	0.065	8.6 M/min
#3	0.44	0.032	1.9 M/min

- (a) rate =  $k[\text{NO}]$                                       (b) rate =  $k[\text{NO}][\text{Cl}_2]^{1/2}$                                       (c) rate =  $k[\text{NO}][\text{Cl}_2]$   
(d) rate =  $k[\text{NO}]^2[\text{Cl}_2]$                                       (e) rate =  $k[\text{NO}]^2[\text{Cl}_2]^2$
- (20) 50.0 g of N<sub>2</sub>O<sub>4</sub> is introduced into an evacuated 2.00 L vessel and allowed to come to equilibrium with its decomposition product, N<sub>2</sub>O<sub>4</sub>(g)  $\rightleftharpoons$  2NO<sub>2</sub>(g). For this reaction, K<sub>c</sub> = 0.133. Once the system has reached equilibrium, 5.00 g of NO<sub>2</sub> is injected into the vessel, and the system is allowed to equilibrate once again. Calculate the mass of N<sub>2</sub>O<sub>4</sub> in the final equilibrium mixture.  
(a) 39.5 g                      (b) 35.3 g                      (c) 30.3 g                      (d) 25.2 g                      (e) 43.7 g
- (21) Which one of the following statements about strong acids is true?  
(a) All strong acids have H atoms bonded to electronegative oxygen atoms.  
(b) Strong acids are 100% ionized in water.  
(c) The conjugate base of a strong acid is itself a strong base.  
(d) Strong acids are very concentrated acids.  
(e) Strong acids produce solutions with a higher pH than weak acids.
- (22) What is the pH of a solution prepared by mixing 50.0 mL of 0.300 M HCl with 450.0 mL of 0.400 M HIO<sub>3</sub>? [K<sub>a</sub>(HIO<sub>3</sub>) =  $1.6 \times 10^{-1}$ ]  
(a) 1.52                      (b) 0.80                      (c) 0.72                      (d) 0.89                      (e) 0.66
- (23) You are asked to go into the lab and prepare an acetic acid -sodium acetate buffer solution with a pH of  $4.00 \pm 0.02$ . What molar ratio of CH<sub>3</sub>COOH to CH<sub>3</sub>COONa should be used? [K<sub>a</sub> =  $1.8 \times 10^{-5}$ ]  
(a) 0.18                      (b) 0.84                      (c) 1.19                      (d) 5.50                      (e) 0.10
- (24) For the electrochemical cell Ni(s) | Ni<sup>2+</sup>(1 M) || H<sup>+</sup>(1 M) | H<sub>2</sub>(1 atm) | Pt(s), which one of the following changes will cause a decrease in the cell voltage?  
(a) Increase the pressure of H<sub>2</sub> to 2.0 atm.                                      (b) Decrease the mass of the nickel electrode.  
(c) Lower the pH of the cell electrolyte.                                      (d) Decrease the concentration of Ni<sup>2+</sup> ion.  
(e) None of the above.

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- (25) Aluminum does not corrode as does iron, because
- (a) Al does not react with  $O_2$ .
  - (b) A protective layer of  $Al_2O_3$  forms on the metal surface.
  - (c) Al is harder to oxidize than is Fe.
  - (d) Fe gives cathodic protection to Al.
  - (e) The electrical circuit cannot be completed on an Al surface.
- (26) Two well-known complex ions containing Ni are  $[Ni(H_2O)_6]^{2+}$ , which is green, and  $[Ni(en)_3]^{2+}$ , which is purple. Which one of the following statements is true?
- (a) The crystal field splitting energy ( $\Delta$ ) is greater for  $[Ni(en)_3]^{2+}$  than for  $[Ni(H_2O)_6]^{2+}$ .
  - (b)  $[Ni(en)_3]^{2+}$  absorbs energy in the red region of the spectrum.
  - (c) Both complex ions are diamagnetic.
  - (d)  $[Ni(H_2O)_6]^{2+}$  transmits light with wavelengths of approximately 650–700 nm.
  - (e) The green complex absorbs green light.
- (27) One can safely assume that the  $3s$ - and  $3p$ -orbitals will form molecular orbitals similar to those formed when  $2s$ - and  $2p$ -orbitals interact. According to molecular orbital theory, what will be the bond order for the  $Cl_2^+$  ion?
- (a) 0.5                      (b) 1.0                      (c) 1.5                      (d) 2.0                      (e) 3.0
- (28) In the following reaction, identify X.
- $${}^{10}_5B(X,\alpha) {}^7_3Li$$
- (a)  $\alpha$                       (b) n                      (c) p                      (d)  ${}^0_{+1}e$                       (e)  $\beta$
- (29) Which is the product of the reaction of one mole of HCl with one mole of 1-butyne?
- (a) 1-chloro-1-butene                      (b) 1-chloro-2-butene                      (c) 2-chloro-1-butene  
(d) ethyl chloride + acetylene                      (e) none of these
- (30) The *secondary structure* of a protein is the
- (a) configuration of those parts of the chain stabilized by a regular pattern of covalent bonds between C and O groups of the backbone of the chain.
  - (b) configuration of those parts of the chain stabilized by a regular pattern of hydrogen bonds between CO and NH groups of the backbone of the chain.
  - (c) specific order of amino acids in the chain.
  - (d) overall three-dimensional structure of the molecule.
  - (e) overall arrangement of several polypeptide chains into one functional unit.

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科目 普通化學 科目代碼 2601 共 6 頁第 6 頁 \*請在【答案卷卡】內作答

(II) For the reaction  $\text{CuS(s)} + \text{H}_2\text{(g)} \rightleftharpoons \text{H}_2\text{S(g)} + \text{Cu(s)}$

$$\Delta G^\circ_f(\text{CuS}) = -53.6 \text{ kJ/mol} \quad \Delta G^\circ_f(\text{H}_2\text{S}) = -33.6 \text{ kJ/mol}$$

$$\Delta H^\circ_f(\text{CuS}) = -53.1 \text{ kJ/mol} \quad \Delta H^\circ_f(\text{H}_2\text{S}) = -20.6 \text{ kJ/mol}$$

- (a) Calculate  $\Delta G^\circ$  and  $\Delta H^\circ$  at 298 K and 1 atm pressure. (2%)
- (b) Calculate the equilibrium constant for this reaction at 298 K. (2%)
- (c) Calculate  $\Delta S^\circ$  at 298 K and 1 atm pressure. (2%)
- (d) Calculate  $\Delta G$  at 798 K and 1 atm pressure (assume  $\Delta S^\circ$  and  $\Delta H^\circ$  do not change with temperature). (2%)

(III) A radioisotope has a nuclear half-life of 24 h and a biological half-life of 16 h. A person accidentally swallowed sufficient quantities of this isotope to give an initial “whole body” count rate of 1000 counts per minute. What was the count rate after 30 hour? (7%)

(IV) A microwave oven operated at  $1.22 \times 10^8 \text{ nm}$  is used to heat 150 mL of water from 20 °C to 100 °C. Calculate the number of photons needed if 92.0 percent of microwave energy is converted to the thermal energy of water. (8%)

(V) Supercritical fluid technology has a great deal of potential for the extraction and/or treatment of chemicals from environmental samples.

- (a) Please use triple point diagram to indicate the region of supercritical fluid and its principles for extraction. (5%)
- (b) Carbon dioxide is one of the materials most often used for supercritical extraction (SFE). Please indicate why  $\text{CO}_2$  is suitable for SFE? What's the difference of the extraction procedures between organic and inorganic analytes when  $\text{CO}_2$  is used for extraction fluid? (5%)

(VI) A student prepared three coordination compounds containing chromium, with the following properties:

Formula	Color	Cl <sup>-</sup> ion in solution per formula unit
CrCl <sub>3</sub> ·6H <sub>2</sub> O	Violet	3
CrCl <sub>3</sub> ·6H <sub>2</sub> O	Light green	2
CrCl <sub>3</sub> ·6H <sub>2</sub> O	Dark green	1

Write modern formula of these compounds and suggest a method for confirming the number of Cl<sup>-</sup> ion present in solution in each case. (7%)

Note: The atomic masses of elements are as follows:

H = 1.0	He = 4.0	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
Mn = 54.9	Cu = 63.5	Br = 79.9	I = 126.9		