* 注意事項：請於答案卷內之「非選擇題作答區」標明題號依序作答

1 L · atm = 101.3 J; C = 3.00 x 10^8 m/s; h = 6.626 x 10^{-34} J · s; F = 96485 C/mol

Gas constant: R = 8.314 J/K · mol = 0.0821 L · atm/K · mol; Atomic mass: Ti = 47.88 g/mol

N_A = 6.022 x 10^{23} mol^{-1}

I. 選擇題（92%，每題答案可能 1 至多個，全部選對始得題分 4 分）

1. In which of the following diatomic molecules would the bond strength be expected to increase as an electron is removed?

    (A) H_2 (B) Be_2 (C) CN   (D) C_2 (E) OF

2. Consider the following cyclic process carried out in two steps on a gas:

    Step 1: 41 J of heat is added to the gas, and 12 J of expansion work is performed.

    Step 2: 55 J of heat is removed from the gas as the gas is compressed back to the initial state.

    The work for the gas compression in step 2 is:

    (A) 26 J   (B) 29 J   (C) -29 J   (D) 55 J   (E) none of the above

3. A sample of an ideal gas at 10.0 atm and 15.0 L is allowed to expand against a constant external pressure of 2.00 atm at a constant temperature. The work for the gas expansion is:

    (A) 12.2 kJ   (B) -12.2 kJ   (C) -120 kJ   (D) 120 kJ   (E) none of the above

4. Which of the following compounds has the lowest viscosity?

    (A) H_2O_2 (B) H_2O (C) CH_3OH (D) CH_3CH_2OH (E) CH_3OCH_3

5. Titanium metal has a body-centered cubic unit cell. The density of titanium is 4.50 g/cm^3. What is the atomic radius of titanium?

    (A) 328 pm   (B) 284 pm   (C) 142 pm   (D) 116 pm   (E) none of the above

6. Which of the following statements is true?

    (A) Accuracy refers to the degree of agreement among several measurements of the same quantity.

    (B) A random error means that a measurement has an equal probability of being high or low.

    (C) The SI unit for the amount of substance is kg.

    (D) The order the five metric prefixes is nano < centi < micro < mega < giga.

    (E) Using the rules of significant figures, the best answer to report for (481 × 0.0025) + 24.51 is 25.7.

7. The Schrödinger wave equation for a one-electron atom is

    $$\psi = \frac{1}{4\sqrt{2\pi}}\left(\frac{Z}{a_o}\right)^{3/2}(2-\sigma)e^{-\sigma/2}$$

    where $\sigma = Zr/a_0$, Z = 1 for hydrogen; a_0 = 5.29 x 10^{-11} m.

   Which of the following statements are true?

    (A) There are two nodes for this orbital.

    (B) It has nonzero amplitude at the nucleus (at r = 0).

    (C) It is the 2s orbital.

    (D) The square of the function evaluated at a particular point in space indicates the probability of finding an electron near that point.

    (E) We can know the exact path of the electron as it moves around the nucleus according to this equation.

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8. Which of the following compounds has the correct name?

   (A) $Cr(H_2PO_4)_3$, chromium (III) hydrogen phosphate

   (B) As_2O_3, diarsenic trioxide

   (C) $HBrO_2$, hypobromous acid

   (D) $Mg(NO_3)_2$, magnesium dinitrate

   (E) $[Ni(NH_2CH_2CH_2NH_2)_3]Br_2$, tris(ethylenediamine)nickel(II) bromide

9. Which of the following ions does have noble gas electron configurations?

   (A) Fe^{2+} (B) Ti^{4+} (C) Ba^{2+} (D) Te^{2-} (E) P^{3-}

10. How many of the following molecules possess dipole moments? SO_2, NF_3, PCl_5, H_2O, HF, CO_2

    (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

11. Of the following, which one has the largest bond angle?

    (A) O_3 (B) OF_2 (C) I_3^- (D) H_2S (E) SF_6

12. Which of the following aqueous solutions has the highest freezing point?

    (A) 0.01 m NaCl (B) 0.01 m acetic acid (C) 0.01 m $CaCl_2$ (D) 0.01 m HCl

    (E) 0.01 m sucrose ($C_{12}H_{22}O_{11}$)

13. The mechanism for the reaction of nitrogen dioxide with carbon monoxide to form nitric oxide and carbon dioxide is thought to be

    Step 1 $NO_2 + NO_2 \rightarrow NO_3 + NO$ Slow

    Step 2 $NO_3 + CO \rightarrow NO_2 + CO_2$ Fast

    Which of the following statements is true?

    (A) Step 1 is the rate determining step.

    (B) NO_3 is the catalyst.

    (C) The overall balanced equation for the reaction is: $NO_2 + CO \rightarrow NO + CO_2$.

    (D) The rate law is: Rate = $k[NO_2][CO]$.

    (E) The half-life is independent of $[CO]_o$.

14. A certain reaction has the following general form: $aA \rightarrow bB$

    At a particular temperature and $[A]_o = 2.00 \times 10^{-3}$ M, concentration versus time data were collected for this reaction, and a plot of 1/[A] versus time resulted in a straight line with a slope value of $+4.00 \times 10^{-2}$ L/mol · s.

    (A) It is a first-order reaction.

    (B) The rate law is: Rate = $k[A]$.

    (C) The rate constant is 4.00×10^{-2} L/mol · s.

    (D) The half-life for this reaction is 1.25×10^4 s.

    (E) It takes 1.88×10^4 seconds for the concentration of A to decrease to 8.00×10^{-4} M.

15. At 25°C, a saturated solution of benzoic acid ($K_a = 6.4 \times 10^{-5}$) has a pH of 2.80. The water solubility of benzoic acid is:

    (A) $1.6 \times 10^{-3} M$ (B) 4.2×10^{-2} M (C) $6.4 \times 10^{-5} M$ (D) 2.80 (E) none of the above

16. In the titration of 0.100 M ammonia ($K_b = 1.8 \times 10^{-5}$) with 0.100 M HCl, which of the following indicator would be best to use to mark the endpoint?

    (A) alizarin yellow (10.1 - 12.0) (B) phenolphthalein (8.2 - 10.0) (C) methyl red (4.8 - 6.0)

    (D) methyl orange (3.2 - 4.4) (E) crystal violet (0.2 - 1.8)

17. Consider the titration of 25.0 mL of 0.100 M pyridine (K_b =1.7 x 10^{-9}) with 0.100 M HCl. Calculate the pH of the resulting solution after the addition of the HCl.

   (A) 0.0 mL HCl , pH = 9.11

   (B) 12.5 mL HCl (total), pH = 5.32

   (C) 25.0 mL HCl (total), pH = 3.27

   (D) 26 mL HCl (total), pH = 2.04

   (E) none of the above

18. A solution saturated with a salt of the type MX_2 (composed of M^{2+} and X^-) has an osmotic pressure of 4.00×10^{-2} atm at 25°C. Assume ideal behavior for the solution. The K_{sp} value for the salt is:

   (A) 1.64×10^{-4} (B) 4.00×10^{-2} (C) 5.45×10^{-2} (D) 6.47×10^{-4} (E) none of the above

19. Liquid water at 25°C is introduced into an evacuated, insulated vessel. For the process

   (A) $\Delta H > 0$ (B) $\Delta S > 0$ (C) $\Delta T_{water} > 0$ (D) $\Delta S_{surr} = 0$ (E) $\Delta S_{univ} = 0$

20. The equilibrium constant K for the dissociation reaction of a molecule X_2

   $X_2(g) \rightleftharpoons 2X(g)$

   was measured as a function of temperature (Kelvin). A graph of ln (K) versus $1/T$ for this reaction gives a straight line with a slope of -1.467×10^4 K and a y-intercept of 13.49.

   (A) $\Delta H^o = 122.0$ kJ   (B) $\Delta S^o = 112.1$ kJ/K   (C) $\Delta G^o_{298\ K} = 88.59$ kJ

   (D) $K = 1.288 \times 10^{-7}$ at 500°C   (E) None of the above

21. The following unbalanced equation represents an oxidation–reduction reaction that occurs in basic solution: $MnO_4^-(aq) + S^{2-}(aq) \rightarrow MnS(s) + S(s)$

   How many moles of S^{2-} are required to produce 1 mole of MnS?

   (A) 1   (B) 2   (C) 3.5   (D) 4.5   (E) None of the above

22. Which of the following statements concerning nuclear reaction is *true*?

   (A) The mass of a nucleus is always more than the sum of the masses of the component nucleons.

   (B) Nuclear fusion occurs among the heavy nuclei, whereas fission occurs more readily for light nuclei.

   (C) Both fission and fusion produce more stable nuclides and are thus exothermic.

   (D) The rates of radioactive decay processes, like the rates of chemical reactions, are sensitive to temperature and pressure changes.

   (E) Electron capture transforms $^{7}_{4}$Be into $^{6}_{3}$Li.

23. Which of the following statements is true about the octahedral complexes of Ni^{2+}?

   (A) The strong-field complex is diamagnetic.

   (B) The weak-field complex is paramagnetic.

   (C) There are 2 unpaired electrons in weak-field complexes.

   (D) Ni^{2+} has $3d^8$ electron configuration.

   (E) In the octahedral complex, the $3d$ orbitals are degenerate.

II. 計算問答題 (8%)

24. Consider the galvanic cell based on the following half-reactions:

$Zn^{2+} + 2e^- \rightarrow Zn \qquad E° = -0.76$ V

$Fe^{2+} + 2e^- \rightarrow Fe \qquad E° = -0.44$ V
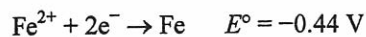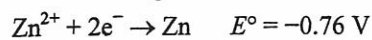
(a) Sketch the galvanic cells. Show the direction of electron flow and identify the cathode and anode. (3%)

(b) Calculate $E°_{cell}$. (1%)

(c) Calculate $\Delta G°$ and K for the cell reaction at 25°C. (2%)

(d) Calculate E_{cell} at 25°C when $[Zn^{2+}] = 0.50$ M and $[Fe^{2+}] = 5.0 \times 10^{-5}$ M. (2%)

試題隨卷繳回