單選題

1. Hydrogen and lithium react very differently, although they are both members of Group 1. What is the primary reason for this difference?

   [A] Electron affinity increases going down a group.

   [B] The metallic character increases going down a group.

   [C] Electronegativity increases going down a group.

   [D] The ionization energy increases going down a group.

   [E] There is a very large difference in the atomic radii of H and Li.

2. Brass is an example of

   [A] an interstitial alloy.　　　[B] a superconductor.　　　[C] a substitutional alloy.

   [D] a network solid.　　　[E] none of these

3. Pentane ($C_5H_{12}$) and hexane ($C_6H_{14}$) form an ideal solution.　The vapor pressures of pentane and hexane at 25 °C are 511 torr and 150 torr, respectively.　The mole fraction of hexane in a pentane-hexane solution is 0.50.　Calculate the mole fraction of pentane in the vapor in equilibrium at 25 °C with this solution.

   [A] 0.89　　　　[B] 0.23　　　[C] 0.77　　　[D] 0.50　　　[E] none of these

4. The spectrochemical series is

   $$I^- < Br^- < Cl^- < F^- < OH^- < H_2O < NH_3 < en < NO_2^- < CN^-$$

   (en = ethylenediamine, $NH_2CH_2CH_2NH_2$)

   Which of the following complexes will absorb visible radiation of the highest energy?

   [A] $[Co(en)_3]^{3+}$　[B] $[Co(I)_6]^{3-}$　[C] $[Co(OH)_6]^{3-}$　[D] $[Co(H_2O)_6]^{3+}$　[E] $[Co(NH_3)_6]^{3+}$

5. Which of the following will increase the rigidity of a polymer?

   [A] shorter polymer chains　　　[B] make chains more branched

   [C] introduce the possibility of hydrogen bonding between chains

   [D] use atactic instead of isotactic chains　　　[E] decrease cross-linking

6. Nitrogen fixation

   [A] is used to produce nitric acid.　　　[B] is used to manufacture ammonia.

   [C] transforms nitrogen to other nitrogen-containing compounds.

   [D] is used to recover sulfur from underground deposits.　　　[E] none of these

7. Which of the following statements concerning the complex ion $Co(en)_2Cl_2^+$ is true?

   (en = ethylenediamine, $NH_2CH_2CH_2NH_2$)

[A] The geometric isomers of the complex ion have identical chemical properties.

[B] Since en is a strong field ligand (large $\Delta$), the complex ion is paramagnetic.

[C] The complex ion exhibits two geometric isomers (*cis* and *trans*) and two optical isomers.

[D] The complex ion exhibits *cis* and *trans* geometric isomers, but no optical isomers.

[E] The complex ion contains Co(I).

8. Which of the following sets has elements with the most nearly identical atomic radii?

   [A] Ne, Ar, Kr, Xe      [B] Mg, Ca, Sr, Ba      [C] Cr, Mn, Fe, Co

   [D] C, P, Se, I      [E] Be, B, C, N

9. For the process $X^-(g) \rightarrow X^-(aq)$, select the ion with the most negative value of $\Delta S$.

   [A] $F^-$      [B] $I^-$      [C] $Cl^-$      [D] $Br^-$

10. Which of the following names is a correct one?

    [A] 1,1-dimethyl-2,2-diethylbutane      [B] 2-bromo-1-chloro-4,4-diethyloctane

    [C] *cis*-1,3-dimethylpropane      [D] 3,4-dichloropentane

    [E] 1-chloro-2,4-methyl-3-ethylcyclohexane

11. Which has the greatest number of unpaired electrons?

    [A] The square planar complex $Ni(CN)_4^{2-}$.      [B] The tetrahedral complex $FeCl_4^-$.

    [C] Neither of the above have any unpaired electrons.

    [D] Both (A and B) have the same number (non-zero) of unpaired electrons.

    [E] More information is needed.

12. A mixture of NaCl and $NaNO_3$ is 31.7% sodium by mass. What is the approximate percent of NaCl in this mixture?

    [A] 30%      [B] 32%      [C] 34%      [D] 38%      [E] 36%

13. How many of the following did Dalton not discuss in his atomic theory?

    I. isotopes    II. Ions    III. Protons    IV. Neutrons    V. electrons

    [A] 4      [B] 5      [C] 1      [D] 2      [E] 3

14. Which of the following statements is true?

    [A] The concentration of the products equals that of reactants and is constant at equilibrium.

    [B] An endothermic reaction shifts toward reactants when heat is added to the reaction.

    [C] Catalysts are an effective means of changing the position of an equilibrium.

    [D] When two opposing processes are proceeding at identical rates, the system is at equilibrium.

    [E] None of the above statements is true.

15. Which of the following is optically active (i.e., chiral)?
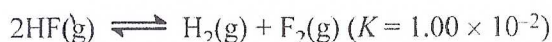
    [A] 2-chloropropane    [B] $CH_2Cl_2$    [C] $HN(CH_3)_2$    [D] 3-chloropentane

    [E] 2-chlorobutane

16. A solution contains 0.018 moles each of $I^-$, $Br^-$, and $Cl^-$. When the solution is mixed with 200 mL of 0.24 M $AgNO_3$, how much $AgCl(s)$ precipitates out?

    $K_{sp}$    AgI    $= 1.5 \times 10^{-16}$
    $K_{sp}$    AgBr   $= 5.0 \times 10^{-13}$
    $K_{sp}$    AgCl   $= 1.6 \times 10^{-10}$

    [A] 0.0 g    [B] 5.0 g    [C] 3.3 g    [D] 1.7 g    [E] 2.6 g

17. Consider the following reaction:

    $2HF(g) \rightleftharpoons H_2(g) + F_2(g)$ ($K = 1.00 \times 10^{-2}$)

    Given 1.00 mole of HF(g), 0.500 mole of $H_2(g)$, and 0.750 mole of $F_2$ (g) are mixed in a 5.00-L flask, determine the reaction quotient, $Q$, and the net direction to achieve equilibrium.

    [A] $Q = 0.150$; the equilibrium shifts to the left.

    [B] $Q = 0.375$; the equilibrium shifts to the right.

    [C] $Q = 0.375$; the equilibrium shifts to the left.

    [D] $Q = 0.150$; the equilibrium shifts to the right.

    [E] $Q = 0.150$; the system is at equilibrium.

18. Calculate the pH of 0.10 M $NH_4CN$. ($K_b$ for $NH_3 = 1.8 \times 10^{-5}$; $K_a$ for HCN $= 6.2 \times 10^{-10}$)

    [A] 8.87    [B] 9.23    [C] 5.13    [D] 5.79    [E] 8.21

19. Which is the correct mathematical expression for the molar solubility (s) in mol/L (S) of $Fe_3(PO_4)_2$?

    [A] $108S^5$    [B] $12S^3$    [C] $6S^2$    [D] $5S^6$    [E] $6S^5$

20. What is the expected osmotic pressure (in torr) of a 0.0100 M solution of NaCl in water at 25 °C?

    [A] 0.245    [B] 186    [C] 15.6    [D] 372    [E] none of these

21. Which one of the following statements is *false*?

    [A] A bomb calorimeter measures $\Delta H$ directly.

    [B] If $q_p$ for a process is negative, the process is exothermic.

    [C] The freezing of water is an example of an exothermic reaction.

    [D] The change in internal energy, $\Delta E$, for a process is equal to the amount of heat absorbed at constant volume, $q_v$.

    [E] The change in enthalpy, $\Delta H$, for a process is equal to the amount of heat absorbed at constant pressure, $q_p$.

22. In a certain reversible expansion, a system at 300 K absorbs exactly $6.00 \times 10^2$ J of heat. In the irreversible recompression to the original state of the system, twice as much work was done on the system as was performed on the surroundings in the expansion. What is the entropy change of the system in the recompression step?

    [A] -2.00 J/K      [B] 0.00 J/K      [C] 2.00 J/K      [D] 4.00 J/K      [E] -4.00 J/K

23. A first-order reaction is 42% complete at the end of 17 minutes. What is the value of the rate constant?

    [A] $3.2 \times 10^{-2}$ min$^{-1}$      [B] 20 min$^{-1}$      [C] 31 min$^{-1}$      [D] $5.1 \times 10^{-2}$ min$^{-1}$      [E] none of these

24. Mixing 40.0 mL of a 4.00 M sodium chloride solution with 20.0 mL of a 5.00 M calcium chloride solution results in a solution with a chloride ion concentration of

    [A] 7.00 M.      [B] 6.00 M.      [C] 4.50 M.      [D] 4.33 M.      [E] none of these

25. Which statement is *true* of a process in which one mole of a gas is expanded from state A to state B?

    [A] It is not possible to have more than one path for a change of state.

    [B] The final volume of the gas will depend on the path taken.

    [C] The amount of work done in the process must be the same, regardless of the path.

    [D] When the gas expands from state A to state B, the surroundings are doing work on the system.

    [E] The amount of heat released in the process will depend on the path taken.

26. A cylinder of oxygen gas contains 26.4 g of $O_2$. Another cylinder, twice the volume of the cylinder containing oxygen (and at the same conditions of pressure and temperature), contains $CO_2$ gas. Assuming ideal behavior, what is the mass of the carbon dioxide?

    [A] 72.6 g      [B] 52.8 g      [C] 36.3 g      [D] 13.2 g      [E] none of these

27. The element with the lowest melting point is:

    [A] Tl      [B] B      [C] Ga      [D] Al      [E] All have the same melting point.

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

    $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

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

    [A] 13.7 V      [B] 1.14 V      [C] 2.01 V      [D] 2.28 V      [E] 0.760 V

29. Which of the following species has the largest dissociation energy?

    [A] $O_2$      [B] $O_2^-$      [C] $O_2^{2+}$      [D] $O_2^+$      [E] $O_2^{2-}$

30. A sample of wood from an Egyptian mummy case gives a $^{14}C$ count of 9.4 cpm/gC (counts per minute per gram of carbon). How old is the wood? (The initial decay rate of $^{14}C$ is 15.3 cpm/gC, and its half-life is 5730 years.)

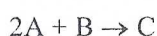    [A] 4030 yr　　[B] 4570 yr　　[C] 6400 yr　　[D] 3420 yr　　[E] none of these

31. For a particle in a cubic box, how many degenerate energy levels have energy equal to $14 h^2/8 mL^2$?
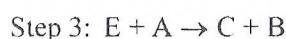
    [A] 3　　[B] 12　　[C] 1　　[D] 8　　[E] 6

32. The electron configuration of $Cr^{3+}$ is

    [A] $[Ar]3d^3$　　[B] $[Ar]4s^23d^4$　　[C] $[Ar]4s^23d^1$　　[D] $[Ar]4s^13d^2$　　[E] none of these

33. The reaction

    $2A + B \rightarrow C$

    has the following proposed mechanism:

    Step 1: $A + B \rightleftharpoons D$ (fast equilibrium)

    Step 2: $D + B \rightarrow E$

    Step 3: $E + A \rightarrow C + B$

    If step 2 is the rate-determining step, then the rate of formation of C should equal:

    [A] $k[A]^2[B]^2$　　[B] $k[A][B]^2$　　[C] $k[A]$　　[D] $k[A][B]$　　[E] $k[A]^2[B]$

34. Which of the following statements is (are) true?

    I. An excited atom can return to its ground state by absorbing electromagnetic radiation.

    II. The energy of an atom is increased when electromagnetic radiation is emitted from it.

    III. The energy of electromagnetic radiation increases as its frequency increases.

    IV. An electron in the $n = 4$ state in the hydrogen atom can go to the $n = 2$ state by emitting electromagnetic radiation at the appropriate frequency.

    V. The frequency and wavelength of electromagnetic radiation are inversely proportional to each other.

    [A] III, IV, V　　[B] I, II, IV　　[C] I, II, III　　[D] II, III, IV　　[E] III, V

35. Of the following, which molecule has the smallest bond angle?

    [A] $CH_2$　　[B] $H_2O$　　[C] $NH_3$　　[D] More than one of the above has equally small bond angles.
    [E] $CCl_4$

36. Initial rate data have been determined at a certain temperature for the gaseous reaction $2NO + 2H_2 \rightarrow N_2 + 2H_2O$.
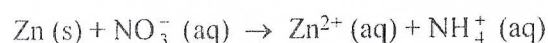
| $[NO]_0$ | $[H_2]_0$ | Initial Rate (M/s) |
|---|---|---|
| 0.10 | 0.20 | 0.0150 |
| 0.10 | 0.30 | 0.0225 |
| 0.20 | 0.20 | 0.0600 |

The numerical value of the rate constant is:

[A] $3.0 \times 10^{-3}$ [B] 7.5 [C] 380 [D] 0.75 [E] $3.0 \times 10^{-4}$

37. When the following reaction is balanced in acidic solution, what is the coefficient of water?

$Zn\,(s) + NO_3^-\,(aq) \rightarrow Zn^{2+}\,(aq) + NH_4^+\,(aq)$

[A] 4 [B] 3 [C] 2 [D] 1 [E] none of these

38. Which of the following species is not amphoteric?

[A] $H_2PO_4^-$ [B] $HSO_4^-$ [C] $H_2O$ [D] $HPO_4^{2-}$ [E] all of the above are amphoteric

39. In the molecular orbital description of CO,

[A] the bond order is 3. [B] the highest energy electrons occupy antibonding orbitals.

[C] six molecular orbitals contain electrons. [D] there are two unpaired electrons.

[E] All of the above are false.

40. The limiting reactant in a reaction

[A] has the lowest ratio of coefficient in the balanced equation/moles available.

[B] has the lowest ratio of moles available/coefficient in the balanced equation.

[C] is the reactant for which you have the fewest number of moles.

[D] has the lowest coefficient in a balanced equation.

[E] none of these

41. The molar mass of a solid as determined by freezing point depression is 10% higher than the true molar mass. Which of the following experimental errors could not account for this discrepancy?

[A] The solid dissociated slightly into two particles when it dissolved.

[B] More than the recorded amount of solvent was pipetted into the solution.

[C] Before the solution was prepared, the container was rinsed with solvent and not dried.

[D] Not all the solid was dissolved.

[E] Some solid was left on the weighing paper.

42. Which of the following is the smallest hole in a closest-packed lattice of spheres?

[A] octahedral [B] tetrahedral [C] trigonal [D] cubic [E] none of these

43. What type of structure does the $XeOF_2$ molecule have?

    [A] pyramidal    [B] tetrahedral    [C] T-shaped    [D] trigonal planar    [E] octahedral

44. A mixture of hydrogen and chlorine remains unreacted until it is exposed to ultraviolet light from a burning magnesium strip. Then the following reaction occurs very rapidly:

    $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$      $\Delta G = -45.54$ kJ
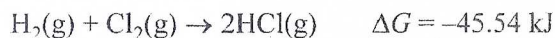
    $\Delta H = -44.12$ kJ

    $\Delta S = -4.76$ J/K

    Select the statement below that best explains this behavior.

    [A] The negative value for $\Delta S$ slows down the reaction.

    [B] The reaction is spontaneous, but the reactants are kinetically stable.

    [C] The reaction has a small equilibrium constant.

    [D] The ultraviolet light raises the temperature of the system and makes the reaction more favorable.

    [E] The reactants are thermodynamically more stable than the products.

45. The triple point of iodine is at 90 torr and 115 °C. This means that liquid $I_2$

    [A] cannot exist at 1 atmosphere pressure.    [B] is more dense than $I_2$ (s).

    [C] cannot exist above 115 °C.                [D] can exist at pressure of 10 torr.

    [E] cannot have a vapor pressure less than 90 torr.

46. The combustion of methanol takes place according to the reaction:

    $2CH_3OH (l) + 3O_2 (g) \rightarrow 2CO_2 (g) + 4H_2O (l)$
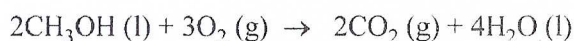
    Compute $\Delta H$ for the combustion of one mole of methanol under standard conditions.    Use the following standard enthalpies of formation:

    $\Delta H_f^\circ$ for $CH_3OH$ (l) = -238.5 kJ/mol

    $\Delta H_f^\circ$ for $CO_2$ (g) = -393.5 kJ/mol

    $\Delta H_f^\circ$ for $H_2O$ (l) = -285.6 kJ/mol

    [A] +1452.4 kJ/mol    [B] -1452.4 kJ/mol    [C] -726.2 kJ/mol    [D] +726.2 kJ/mol

    [E] none of these

47. When the equation for the following reaction in basic solution is balanced, what is the sum of the coefficients?

    $MnO_2 + HO_2^- \rightarrow MnO_4^-$

    [A] 14    [B] 9    [C] 11    [D] 31    [E] 18

48. What is the hybridization of Cl in the molecule $ClF_3$?

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

49. Which of the following statements is true concerning ideal gases?

    [A] At STP, 1.0 L of Ar(g) contains about twice the number of atoms as 1.0 L of Ne(g) since the molar mass of Ar is about twice that of Ne.

    [B] The temperature of the gas sample is directly related to the average velocity of the gas particles.

    [C] The gas particles in a sample exert attraction for one another.

    [D] A gas exerts pressure as a result of the collisions of the gas molecules with the walls of the container.

    [E] All of the above are false.

50. Gold (atomic mass = 197) is plated from a solution of chlorauric acid, $HAuCl_4$; it deposits on the cathode. Calculate the time it takes to deposit 0.50 gram of gold, passing a current of 0.10 amperes. (1 faraday = 96,485 coulombs)

    [A] 6.0 hours　　[B] 2.0 hours　　[C] 41 minutes　　[D] 1.0 hour　　　[E] none of these