EASTERN ILLINOIS UNIVERSITY
2017 Maurice Shepherd Chemistry Contest

Useful Information: $N_A = 6.022 \times 10^{23}$/mol; R = 0.0821 L-atm/mol-K; c = 3.00×10^8 m/s; 1000 mL = 1 L; K = °C + 273.15; 1 atm = 760 mm Hg; 1 Hertz, Hz = 1/s = s^{-1}.

Note: Some problems include the molar mass (molecular weight) of one or more substances. This information appears in parenthesis following a formula. Example, H_2O ($\mathcal{M}$ = 18.0 g/mol).

1. The speed of light is 186,282,397 miles/hour. This quantity rounded to four (4) significant is:
   a. 1863 b. 186,000,000 c. 1.863×10^6 d. 1.863×10^8 e. 186×10^{-6}

2. An automobile airbag inflates in 35 ms (read: milliseconds) upon activation. This is equivalent to:
   a. 0.0035 s b. 35000 μs (read: microseconds) c. 350 μs
   d. 3.5×10^3 s e. 3.5×10^{-3} μs

3. A typical first generation flash drive had a capacity of 250 MB (megabytes) whereas today, flash drives having capacities of 16 GB (gigabytes) are common. How many 250 MB flash drives equal the capacity of a 16 GB flash drive?
   a. 64 b. 0.064 c. 4 d. 4000 e. 156

4. The smallest area is:
   a. 100 cm^2 b. 100 m^2 c. 100 μm^2 d. 100 mm^2 e. 100 km^2

5. The density of air at 25 °C and atmospheric pressure is 1.2 kg/m^3. What is this density in g/cm^3?
   a. 0.12 g/cm^3 b. 0.0012 g/cm^3 c. 12 g/cm^3 d. 120 g/cm^3 e. 1.2×10^4 g/cm^3

6. Equal masses of the following metals are compared: aluminum (d = 2.70 g/cm^3); gold (d = 19.3 g/cm^3); iron (d = 7.9 g/cm^3); lead (d = 11.4 g/cm^3); magnesium (d = 1.74 g/cm^3). Which sample occupies the largest volume?
   a. aluminum b. gold c. iron d. lead e. magneisum

7. A human body contains approximately 0.15% by mass sodium. How many grams of sodium would be found in the body of a person weighing 85.0 kg?
   a. 0.13 g b. 1.3 g c. 13 g d. 1.3×10^2 g e. 1.3×10^3 g

8. Which of the following has the element symbol and name incorrectly matched?
   a. F, fluorine b. Sr, sulfur c. Mn, manganese
   d. Ar, argon e. Cr, chromium

9. A radioactive decay product of ^{238}U differs from ^{238}U by having 2 less protons, 2 less neutrons, and 2 less electrons. This atom is:
   a. ^{236}Th b. ^{234}Th c. ^{234}U d. ^{238}Pu e. ^{234}Ra

10. Boron nitride is a heat and chemically resistant refractory compound that is composed of boron (B) and nitrogen (N). The most likely formula for boron nitride is:
    a. BN b. BN_2 c. BN_3 d. B_2N_3 e. B_3N_2

11. The atom/ion below with the most electrons is:
    a. Rb^+ b. As^{2-} c. Ag^+ d. Ga^{3+} e. Br

12. Which of the listed formulas is (are) correct?

    i) $LiSO_4$ ii) $Mg(NO_3)_2$ iii) NH_4Cl

    a. i only b. i and iii c. iii only d. ii and iii e. i, ii, and iii

13. In the mineral $CaTa_2O_6$, tantalum (Ta) has an oxidation state (number) of:
    a. +1 b. +2 c. +3 d. +4 e. +5

14. A hydrate $MgCl_2(H_2O)_x$ (= $MgCl_2 \cdot xH_2O$) has a formula mass of 167.29 amu. In this hydrate, x = ___.
    a. 1 b. 2 c. 3 d. 4 e. 5

15. The compound with the highest percent, by mass, of fluorine is:
    a. LiF b. BeF_2 c. NaF d. MgF_2 e. UF_6

16. A compound with the empirical formula BNH_2 has a molar mass (molecular weight) of 80.5 g/mol. The actual formula of this compound is:
    a. BNH_2 b. $B_2N_2H_4$ c. $B_3N_3H_6$ d. $B_2N_4H_3$ e. $B_5N_5H_{15}$

17. A compound composed of phosphorous and oxygen is 43.6% P and 56.4% O by mass. What is the empirical formula of this compound
    a. PO b. P_3O_2 c. PO_4 d. P_2O_5 e. P_2O

18. The reaction: $2Mg\ (s) + O_2\ (g) \rightarrow 2MgO\ (s)$ is best classified as a _____ reaction
    a. decomposition b. combination c. neutralization
    d. single replacement e. double replacement

19. Lithium hydroxide is used in space travel to remove exhaled carbon dioxide by astronauts. It reacts with the carbon dioxide to form lithium carbonate and water. The balanced equation that corresponds to this description is:
    a. $2LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$ b. $LiOH + CO_2 \rightarrow LiHCO_3 + H_2O$
    c. $Li(OH)_2 + CO_2 \rightarrow LiCO_3 + H_2O$ d. $2LiOH + CO_2 \rightarrow 2LiCO_3 + H_2O$
    e. $2Li_2OH + CO_2 \rightarrow Li_2CO_4 + H_2O$

20. Consider the incomplete equation: $6NO_2 + \_\_\_NH_3 \rightarrow 7N_2 + 12H_2O$. When this equation is balanced the coefficient before NH_3 would be:
    a. 1 b. 3 c. 6 d. 8 e. 9

21. Consider the following unbalanced equation: $BeO + C \rightarrow Be_2C + CO$. When this equation is balanced (simplest whole number coefficients), the coefficient for the C starting material is:
    a. 1 b. 2 c. 3 d. 4 e. 5

22. Which of the following chemical equations is not balanced? (Remember: if there is no coefficient preceding a formula, its coefficient is understood to be 1.)
    a. $C_6H_6 + 3H_2 \rightarrow C_6H_{12}$ b. $4Al + 3O_2 \rightarrow 2Al_2O_3$ c. $2NH_3 \rightarrow N_2 + 3H_2$
    d. $3Mg + N_2 \rightarrow Mg_3N_2$ e. $SOCl_2 + H_2O \rightarrow SO_2 + HCl$

23. Zinc is a more active metal than nickel and it will displace nickel ion from solution. Thus, when a piece of zinc metal is immersed in a solution of nickel(II) ion, the green solution slowly turns colorless indicating the formation of zinc ion and nickel metal precipitates from solution. Which ionic equation corresponds to this description?
    a. $2Zn^+ + Ni \rightarrow 2\ Zn + Ni^{2+}$ b. $Zn^{2-} + Ni^{2+} \rightarrow Zn + Ni$
    c. $Zn + Ni^{2+} \rightarrow Zn^{2+} + Ni$ d. $Zn + Ni^{2-} \rightarrow Zn^{2-} + Ni$
    e. $Zn + Ni \rightarrow Zn^+ + Ni^+$

24. Which of the following has Avogadro's number of particles?
    a. 35.5 g Cl_2 b. 16.0 g CH_4 c. 64.0 g N_2 d. 172 g $ZnCl_2$ e. 57.1 g $Ca(OH)_2$

25. 2-Butene-1-thiol ($\mathcal{M}$ = 88.18 g/mol) is one of the odorants in skunk spray. It can be detected by the human nose at a concentration in air of 12.3 ng/L (read: nanograms/liter). The number of molecules in 12.3 ng of 2-butene-1-thiol is:
    a. 8.40×10^{13} b. 2.37×10^{-34} c. 1.39×10^{-10} d. 8.37×10^{31} e. 4.32×10^{33}

26. A student measures out 16.8 mL of trifluoroacetic anhydride, $C_4F_6O_3$ ($\mathcal{M}$ = 210.0 g/mol; d = 1.49 g/mL) for use in a reaction. This corresponds to ____ moles of $C_4F_6O_3$.
    a. 0.0800 b. 0.119 c. 0.0537 d. 5.25 e. 0.0250

27. Given the reaction: $2C_6H_{12}$ (l) + $5O_2$ (g) → $2C_6H_{10}O_4$ (l) + $2H_2O$ (g). How many moles of O_2 are required to completely react with 75.0 mol C_6H_{12}?
    a. 375 b. 30.0 c. 188 d. 150 e. 750

28. Potassium superoxide, KO_2, is used in self-contained breathing equipment to absorb CO_2 and produce O_2: $4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$. If 5.0×10^2 g of KO_2 ($\mathcal{M}$ = 71.1 g/mol) reacts with excess CO_2, the theoretical yield of O_2, in moles, is:
    a. 7.0 b. 21 c. 1.8 d. 9.4 e. 5.3

29. Consider the following reaction: Al_2O_3 (s) + 6HCl (aq) → $2AlCl_3$ (aq) + $3H_2O$ (l). If 0.50 mol of Al_2O_3 and 2.0 mol of HCl are combined, the maximum number of moles of $AlCl_3$ that would be produced is:
    a. 1 b. 0.25 c. 4 d. 0.67 e. 2.5

30. Consider the following reaction: 3Sn + 2P → Sn_3P_2. When 0.018 mol of Sn reacts with excess P, the actual yield of Sn_3P_2 ($\mathcal{M}$ = 418.1 g/mol) is 2.0 g. The percent yield of this reaction is:
    a. 80% b. 28% c. 125% d. 54% e. 94%

31. Which substance has the smallest number of moles of bromide ions (Br^-) per mole of substance?
    a. copper(II) bromide b. magnesium bromide c. aluminum bromide
    d. iron(III) bromide e. silver bromide

32. Muriatic acid is used for cleaning brick and tile. It is a 5.0 M HCl solution. The mass of HCl ($\mathcal{M}$ = 36.5 g/mol) in 3.79 L (1 gallon) of muriatic acid is:
    a. 19 g b. 6.9×10^2 g c. 1.8×10^2 g d. 1.9×10^4 g e. 0.021 g

33. 15.0 mL of 0.022 M acetic acid solution is diluted to a total volume of 0.250 L. The molarity of acetic acid ($\mathcal{M}$ = 60.0 g/mol) in the dilute solution is:
    a. 5.5 M b. 3.3×10^{-4} M c. 0.020 M d. 0.00132 M e. 0.55 M

34. A sample of air occupies a volume a 1.0 L. Determine the volume this sample of air occupies if the pressure and Kelvin temperature each double.
    a. 0.25 L b. 0.50 L c. 1.0 L d. 2.0 L e. 4.0 L

35. An ordinary (and now, almost obsolete) incandescent light bulb contains a small quantity of argon to minimize the rate of evaporation of the tungsten filament. A 6.0×10^2 mL light bulb contains 1.5×10^{-5} mol of argon. Determine the pressure exerted by the argon when the bulb is at temperature of 65 °C.
    a. 6.9×10^{-4} atm b. 0.069 atm c. 1.3×10^{-7} atm
    d. 0.25 atm e. 4.2×10^{-4} atm

36. Which of the following gases is more dense than air at 1 atm and 25 °C? (Hint: for the purpose of this question assume air entirely nitrogen.)
    a. CO_2 b. Cl_2 c. SF_6 d. Ar e. all of the preceding

37. Calcium hydride, CaH_2, is used as a portable hydrogen source since it reacts rapidly with water to produce hydrogen: CaH_2 (s) + $2H_2O$ (l) → $Ca(OH)_2$ (aq) + $2H_2$ (g). The mass of CaH_2 ($\mathcal{M}$ = 42.1 g/mol) needed to produce 125 L of H_2 gas at STP (0 °C and 1.00 atm) is:
a. 0.132 g b. 469 g c. 2.96 g d. 11.2 g e. 117 g

38. The quantum number m_l designates:
a. orbital orientation in space b. orbital size c. orbital shape
d. direction of electron spin e. the number of spherical nodes in an orbital

39. Which of the following combinations of quantum numbers is possible for an electron in a 3p orbital?
a. n = 3, l = 1, m_l = 1 b. n = 3, l = 2, m_l = 0 c. n = 2, l = 1, m_l = 1
d. n = 2, l = 2, m_l = 1 e. n = 3, l = 0, m_l = 1

40. The electron capacity (maximum number of electrons) in the n = 3 shell is:
a. 2 b. 6 c. 9 d. 12 e. 18

41. Which of the following is the correct electron configuration of germanium (Ge, Z = 32)?
a. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4d^{10}\ 4p^2$ b. [Ar] $4s^2\ 4d^{10}\ 4p^2$ c. [Kr] $4s^2\ 3d^{10}\ 4p^2$
d. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^2$ e. [Kr] $4s^2\ 4d^{10}\ 4p^2$

42. Which of the following elements and/or ions would be expected to have the same electron configuration as chloride ion, Cl^-?
a. Br^- b. S c. Sc^{3+} d. Cl e. Na^+

43. The first ionization energy is the energy required to remove the least tightly held electron from a gaseous atom: X (g) → X^+ (g) + e^-. Which of the following elements would be expected to have the highest first ionization energy?
a. Li b. F c. Ca d. Se e. Ba

44. Consider the elements Ca, Mg, and K. The correct order for the first ionization energy of these elements from smallest to largest is:
a. K < Ca < Mg b. K < Mg < Ca c. Ca < K < Mg d. Ca < Mg < K e. Mg < K < Ca

45. Which listed element has the Lewis atom dot structure $\cdot\dot{\underset{\cdot}{\mathrm{X}}}\cdot$
a. beryllium b. potassium c. aluminum d. bromine e. helium

46. Which of the following compounds would contain 26 valence electrons in its Lewis dot structure?
a. CF_4 b. ClF c. NCl_3 d. H_2O e. OCS

47. Which of the following compounds would have a tetrahedral molecular geometry?
a. CBr_4 b. H_2S c. SO_3 d. PH_3 e. CS_2

48. Which of the following bonds would you expect to be the most polar?
a. F—F b. F—O c. Br—Br d. C—F e. C—Cl

49. Which of the following is an endothermic process?
a. NH_3 (g) → NH_3 (l) b. ice melting c. burning natural gas
d. condensation of water vapor e. all are endothermic processes

50. The specific heat capacity of water is 4.184 J/g · °C. Which of the following processes would require the most energy to accomplish?
a. heat 1 g of water from 25.0 °C to 26.0 °C b. heat 5 g of water from 25.0 °C to 25.5 °C
c. heat 0.25 mol of water from 25.0 °C to 27.0 °C d. heat 1 g of water from 298 K to 300 K
e. heat 1 mol of water from 25.0 °C to 26.0 °C