DEPARTMENT OF CHEMISTRY AND BIOCHEMISTRY
EASTERN ILLINOIS UNIVERSITY
2019 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 = $^oC + 273.15$; 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 after the substance's formula. Example: water, H_2O ($\mathcal{M}$ = 18.0 g/mol).

1. One hundred million dozen popsicles are sold annually. This is equivalent to _____ popsicles.
   a. 1200 b. 1.2×10^9 c. 100×10^{-6} d. 1.2×10^{-10} e. 120 billion

2. A calculator result of 0.0038703365 is obtained from a multi-step calculation. This result when rounded to four (4) significant figures is:
   a. 0.0040 b. 0.0039 c. 3.8703×10^3 d. 0.0038703 e. 3.870×10^{-3}

3. Sand is primarily silica (SiO_2) in the form of quartz. Geologists define sand as particles ranging in size from 0.0063 cm to 0.20 cm, between silt and gravel on the size scale. 0.0063 cm is equivalent to:
   a. 0.063 mm (read: millimeters) b. 630 km (read: kilometers) c. 0.63 m
   d. 6.3 μm (read: micrometers) e. 6300 nm (read: nanometers)

4. The surface area (SA) to volume (V) ratio is a measurement used to characterize particles. Suppose you determine the $\frac{SA}{V}$ ratio of a cube having an edge length of 1 cm. What unit does this ratio have? (SA = number of sides x area of each side)
   a. cm^6 b. $cm^{-3}\left(=\frac{1}{cm^3}\right)$ c. cm^4 d. $cm^{-1}\left(=\frac{1}{cm}\right)$ e. no unit (dimensionless)

5. Sequestering CO_2 is a possible way to reduce CO_2 emissions. About 45 metric tons of CO_2/year can be sequestered currently, but about 4500 metric tons of CO_2/year need to be sequestered if this approach is to be effective. The needed sequestering capacity is what multiple of the current sequestering capacity?
   a. 10^3 b. 10^{-2} c. 100 d. 203,000 e. 4450

6. Dry sand has a bulk density of 80 lbs/ft^3 (read: pounds/cubic foot). Determine the volume occupied by 2.2×10^3 pounds of sand in cubic yards, yd^3 (1 yard = 3 feet)
   a. 28 yd^3 b. 0.036 yd^3 c. 1.1×10^{-3} yd^3
   d. 7.2×10^3 yd^3 e. 1.0 yd^3

7. The density of cobalt is 8.90 g/cm^3 and the density of aluminum is 2.71 g/cm^3. The mass of aluminum that occupies the same volume as 66.7 g of cobalt is:
   a. 2.77 g b. 20.3 g c. 0.362 g d. 1.61×10^3 g e. 0.00457 g

8. Water can be decomposed into hydrogen and oxygen by electrolysis. Knowing that water is 11.2% hydrogen by mass, what mass of hydrogen is produced by the electrolysis of 625 g of water?
   a. 7000 g b. 5.58 kg c. 0.558 g d. 70 g e. 0.179 kg

9. An intravenous glucose solution is 5.3% glucose by mass. Determine the mass of this solution that contains 74 g of glucose.
   a. 1.4 kg b. 3.9 g c. 1.4 mg d. 3.9×10^3 g e. 950 g

10. The ion $^{56}Fe^{3+}$ has __ protons, __ neutrons, and __ electrons.
    a. 30, 26, 27 b. 26, 30, 23 c. 20, 36, 23 d. 26, 30, 29 e. 30, 26, 33

11. Sodium borate, $Na_2B_xO_7$ has a formula mass of 201.22 amu. x = ___ in sodium borate.
    a. 1 b. 3 c. 4 d. 5 e. 7

12. The formula for tin(IV) bromide is:
    a. Ti_4B_3 b. Ti_4Br c. SnB_4 d. TiB_4 e. $SnBr_4$

13. Considering and applying the rules for ionic formulas, which formula is the likely formula for the Al containing mineral cryolite?
    a. $NaAl_2(OH)_4$ b. $Na_2Al_3(SO_4)_2$ c. $CaAlBr_2$ d. Na_3AlF_6 e. $K_2Al(NO_3)_3$

14. There are ___ electrons in 1.0×10^{-3} g of Li atoms:
    a. 8.7×10^{19} b. 8.7×10^{22} c. 2.6×10^{20} d. 2.6×10^{23} e. 1.8×10^{24}

15. Jade has the formula $NaAlSi_2O_6$. The mass percent of Si in jade is:
    a. 14.9% b. 27.8% c. 56.2% d. 29.8% e. 13.9%

16. One mole of which of the following compounds has the smallest mass?
    a. RbF b. Br_2 c. CH_2Cl_2 d. CaF_2 e. BF_3

17. An intermetallic compound used to make permanent magnets for high fidelity speakers is 33.78% Sm (samarium, Z = 62) and 66.22% Co by mass. Determine the empirical formula of this compound.
    a. $SmCo_5$ b. $SmCo_2$ c. Sm_2Co_3 d. Sm_3Co_7 e. $SmCo_4$

18. The reaction: HNO_3 (aq) + KOH (aq) → H_2O (l) + KNO_3 (aq) is a(n) _____ reaction.
    a. decomposition b. combination c. neutralization
    d. single replacement e. double replacement

19. Vanilmandelic acid, $C_9H_{10}O_5$, is a precursor of synthetic vanillin (vanilla). It is made by a combination reaction between guaiacol $C_7H_8O_2$ and another compound. The formula of this compound is:
    a. CO_2 b. $C_2H_5ClO_3$ c. $C_2H_4O_4$ d. $C_2H_2O_3$ e. H_2CO_3

20. When the unbalanced equation $Sb_2O_3 + HF \rightarrow SbF_3 + H_2O$ is balanced (simplest whole number coefficients), the coefficient in front of the HF would be:
    a. 2 b. 3 c. 4 d. 5 e. 6

21. Which of the following equations is not balanced? (Remember: if there is no coefficient preceding a formula, its coefficient is understood to be 1.)
    a. $3Mg + N_2 \rightarrow Mg_3N_2$ b. $H_2S + 2O_2 \rightarrow SO_2 + 2H_2O$ c. $2H_2O_2 \rightarrow 2H_2O + O_2$
    d. $2Fe_2O_3 + 3C \rightarrow 3CO_2 + 4Fe$ e. $C_6H_6 + 3H_2 \rightarrow C_6H_{12}$

22. Copper is a more active metal than silver and it will displace silver ion from solution. Thus, when a piece of copper wire is immersed in a solution containing silver(I) ion, the colorless solution slowly turns blue indicating the formation of copper ion and silver precipitates from solution. Which ionic equation corresponds to this description?
    a. $2Cu\ (s) + Ag^-\ (aq) \rightarrow 2Cu^{2+}\ (aq) + Ag\ (s)$ b. $Cu^{2-}\ (aq) + Ag\ (s) \rightarrow Cu\ (s) + Ag^{2-}\ (aq)$
    c. $2Cu^{2+}\ (aq) + Ag\ (s) \rightarrow 2Cu\ (s) + Ag^{2+}\ (aq)$ d. $Cu\ (s) + 2Ag^+\ (aq) \rightarrow Cu^{2+}\ (aq) + 2Ag\ (s)$
    e. $Cu\ (s) + 2Ag\ (s) \rightarrow Cu^{2-}\ (aq) + 2Ag^+\ (aq)$

23. The Hope Diamond is blue since it contains 8.0 µg/g (read: micrograms per gram (= 8.0 ppm)) of boron. Given that the diamond weighs 9.11 g, the number of boron atoms in the diamond is:
    a. 6.3×10^{12} b. 4.1×10^{12} c. 6.3×10^{16} d. 4.1×10^{18} e. 6.3×10^{20}

24. Elemental arsenic can be obtained by the reaction: $2As_2O_3 + 3C \rightarrow 4As + 3CO_2$. The mass of As_2O_3 ($\mathcal{M}$ = 197.84 g/mol) needed to produce 64.0 g of As by this reaction is:
    a. 32.1 g b. 84.5 g c. 98.9 g d. 169 g e. 338 g

25. The reaction: $CHCl_3 + 2HF \rightarrow CHClF_2 + 2HCl$ is the first reaction in series of reactions used to make Teflon. The number of moles $CHCl_3$ that must react to produce 41.1 g HCl ($\mathcal{M}$ = 36.46 g/mol) is:
    a. 0.56 b. 1.13 c. 1.28 d. 2.26 e. 20.6

26. Beryllium carbide can be made by the reaction: $2BeO + 3C \rightarrow Be_2C + 2CO_2$. If 37.7 g of Be_2C ($\mathcal{M}$ = 30.04 g/mol) is obtained by the reaction of 251 g of BeO ($\mathcal{M}$ = 25.01 g/mol) and excess carbon, the percent yield is:
    a. 12.5 b. 15.0 c. 17.7 d. 25.0 e. 29.9

27. The compound SeF_4 can be made by the reaction: $3Se + 4ClF_3 \rightarrow 3SeF_4 + 2Cl_2$. If 5.0 mol of Se and 6.0 mol of ClF_3 are reacted, the maximum number of moles of SeF_4 that can produced is:
    a. 5.0 b. 4.5 c. 8.0 d. 15 e. 2.5

28. Which of the following is a weak acid in water?
    a. HNO_3 b. acetic acid c. sulfuric acid d. HCl e. all are weak acids

29. 1.0 L of 1.0 M KBr (aq) solution contains _____ solute particles as 1.0 L of 1.0 M sucrose solution ($C_{11}H_{22}O_{11}$ (aq)) and _____ solute particles as 1.0 L of 1.0 M $FeCl_3$ (aq) solution.
    a. twice as many, half as many
    b. the same number of, half as many
    c. twice as many, twice as many
    d. half as many, the same number of
    e. the same number of, the same number of

30. A solution of $NiCl_2$ ($\mathcal{M}$ = 129.6 g/mol) is prepared by dissolving 4.86 g of $NiCl_2$ in enough water to make 125.0 mL of solution. The molarity of $NiCl_2$ in this solution is:
    a. 3.33 M b. 0.0188 M c. 0.0750 M d. 5.04 M e. 0.300 M

31. The concentration of sugar in a particular juice drink is 0.41 M. If the sugar is glucose ($C_6H_{12}O_6$, $\mathcal{M}$ = 180.15 g/mol), how many moles of carbon atoms from glucose are in 177 mL of this drink?
    a. 0.073 mol b. 0.44 mol c. 0.86 mol d. 2.3 mol e. 28 mol

32. Muriatic acid is a solution of hydrochloric acid sold in hardware stores for cleaning brick and tile. It is a 5.0 M HCl solution. The directions for cleaning tile with muriatic acid say to dissolve 60 mL (¼ cup) of muriatic acid in enough water to make 3.8 L (1 gallon) solution. Determine the molarity of hydrochloric acid in a solution prepared in this manner.
    a. 0.079 M b. 0.32 M c. 3.2 M d. 1.3 M e. 79 M

33. One mole of an ideal gas is placed in a cylinder with a moveable piston. Which of the following properties of the confined gas does not change as the piston is compressed:
    a. volume
    b. mass and volume
    c. mass
    d. density
    e. volume and density

34. Under which conditions will 1.0 mole of an ideal gas be at the lowest pressure?
    a. V = 100 mL, T = 300 K
    b. V = 10.0 L, T = 125 ^oC
    c. V = 1.0 L, T = 25 ^oC
    d. V = 10.0 L, T = 300 K
    e. V = 100 mL, T = 500 K

35. A 2.48 g sample of an unknown gas occupies 1.07 L at 2.0 atm and 373 K. This gas is:
    a. H_2 b. N_2 c. O_2 d. F_2 e. Cl_2

36. Lithium metal reacts with water to form hydrogen gas: $2Li (s) + 2H_2O (l) \rightarrow H_2 (g) + 2LiOH (aq)$. How many grams of Li are needed to generate 48.0 L of H_2 gas at a pressure of 0.995 atm and a temperature of 32.0 ^oC.
    a. 26.5 g b. 13.2 g c. 6.63 g d. 126 g e. 0.275 g

37. One mole of which gas molecules or atoms would have the greatest average kinetic energy (KE) at 25.0°C and 1 atm.
    a. F_2 (g) b. Ar (g) c. CH_4 (g) d. N_2 (g) e. all have the same KE

38. The _____ subshell contains only one orbital.
    a. 5d b. 6f c. 4s d. 3d e. 1p

39. If an electron has a principal quantum number (n) of 7 and an angular momentum quantum number (l) of 3, the subshell designation is _____.
a. 7f b. 7s c. 7p d. 3f e. 3d

40. The electron configuration of the valence electrons of an atom in its ground state is ns^2np^1. This atom is a group _____ element.
a. 1A (1) b. 3A (13) c. 5A (15) d. 3B (3) e. 1B (11)

41. The ground state electron configuration of scandium is _____.
a. $[Kr]5s^24d^1$ b. $[Ne]3s^22d^1$ c. $[Ar]4s^23p^1$ d. $[Ar]4s^24p^1$ e. $[Ar]4s^23d^1$

42. Which of the following ions have a noble gas electron configuration: Cl^+, H^-, Al^{3+}, Cs^{2+}, and P^{3-}?
a. Cl^+, H^-, Al^{3+} b. H^-, Al^{3+}, Cs^{2+} c. Cl^+, Cs^{2+} d. H^-, Al^{3+}, P^{3-} e. Cs^{2+}, P^{3-}

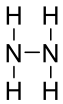
43. A selenium atom has ___ core electrons and ___ valence electrons.
a. 24, 4 b. 26, 1 c. 28, 6 d. 4, 14 e. 24, 6

44. The first ionization energy is the energy required to remove the least tightly held electron from a gaseous atom: $X(g) \rightarrow X^+(g) + e^-$. Which of the following elements would be expected to have the greatest first ionization energy?
a. aluminum b. silicon c. sulfur d. chlorine e. argon

45. Which of the following atoms has the smallest atomic radius?
a. F b. Ba c. I d. Li e. Ni

46. The valence electron count including adjustment for charge in the ICl_4^- ion is:
a. 35 b. 9 c. 40 d. <u>36</u> e. 32

47. The skeletal Lewis structure of N_2H_2 is shown at right. When this structure is completed:



a. there will be a nitrogen-nitrogen triple bond
b. there will be a nitrogen-nitrogen double bond
c. each nitrogen will have one nonbonding electron pair
d. each nitrogen will have two nonbonding electron pairs
e. each hydrogen will have one nonbonding electron pair

48. Using the VSEPR model, the electron-domain geometry of the central atom in O_3 is _____
a. linear b. trigonal planar c. tetrahedral
d. trigonal bipyramidal e. octahedral

49. Which of the following is an endothermic process?
a. freezing water b. burning gasoline c. boiling water
d. condensation of water vapor e. all are endothermic process

50. How much heat is released when 100.0 kg of H_2O cools from 75.0 °C to 25.0 °C. The specific heat of water is 4.184 J/g-°C.
a. 418 kJ b. 0.478 kJ c. 1.20×10^3 kJ d. 8.37 kJ e. 2.09×10^4 kJ