

**EASTERN ILLINOIS UNIVERSITY**  
**2009 Maurice D. Shepherd Chemistry Contest**

**NOTE:** A correct answer is not listed among the choices for question 38. Hence, this question did not count.

**Useful Information:**  $N_A = 6.022 \times 10^{23}/\text{mol}$ ;  $R = 0.0821 \text{ L-atm/mol-K}$ ;  $1000 \text{ mL} = 1 \text{ L}$ ;  $K = ^\circ\text{C} + 273.15$ ;  $1 \text{ atm} = 760 \text{ mm Hg}$ ;  $c = 3.0 \times 10^8 \text{ m/s}$ ;  $1 \text{ Hertz, Hz} = 1/\text{s} = \text{s}^{-1}$ .

- The SI base unit for length is:  
a. mile (mi)    b. kilogram (kg)    c. foot (ft)    d. meter (m)    e. cubic centimeter ( $\text{cm}^3$ )
- Sugar dissolved in water is a(n):  
a. substance    b. homogenous mixture    c. heterogeneous mixture  
d. element    e. compound
- Both solids and liquids have (are):  
a. definite shape    b. compressible    c. indefinite shape  
d. definite volume    e. definite shape and volume
- In a perfect vacuum, light travels at 299,000,000 m/s. When the number part of this quantity is written in scientific notation and expressed to three significant figures it would be written as:  
a.  $2.990 \times 10^{-8}$     b.  $299 \times 10^{-8}$     c.  $2.99 \times 10^8$     d.  $299 \times 10^3$     e.  $299.000 \times 10^{-3}$
- The distance between atoms is sometimes given in picometers, where 1 pm is equivalent to  $1 \times 10^{-12}$  m. If the distance between the layers of atoms in a particular compound is given as 345 pm, what is the distance in cm?  
a.  $3.45 \times 10^{-6} \text{ cm}$     b.  $3.45 \times 10^{-8} \text{ cm}$     c.  $3.45 \times 10^{-10} \text{ cm}$   
d.  $3.45 \times 10^{-12} \text{ cm}$     e.  $3.45 \times 10^{-14} \text{ cm}$
- A sprinter runs a 100.0 m dash in 11.00 s. What is the sprinters speed in kilometers per hour?  
a. 9.091 km/h    b. 15.32 km/h    c. 18.33 km/h    d. 32.73 km/h    e. 545.4 km/h
- Four arrows are shot at a target. The arrows land near each other, but not close to the intended target. This is an example of:  
a. high accuracy and low precision    b. high accuracy and high precision  
c. low accuracy and low precision    d. low accuracy and high precision  
e. poor accuracy and poor precision
- The smallest scale division on a buret is 0.1 mL. When reading the buret scale, it should read to the nearest \_\_\_\_\_ place.  
a. units    b. tenths    c. hundredths    d. thousandths    e. ten thousandths
- The radius of a circle is measured to be 7.31 cm. How should the circle's area be reported? ( $A = \pi r^2$ )  
a.  $168 \text{ cm}^2$     b.  $167.9 \text{ cm}^2$     c.  $167.87 \text{ cm}^2$     d.  $167.874 \text{ cm}^2$     e.  $167.8745 \text{ cm}^2$
- How many 250-mg aspirin tablets can be made from 25.0 kg of aspirin?  
a. 1000    b. 10,000    c. 100,000    d.  $1 \times 10^6$     e.  $1 \times 10^7$
- Calculate the mass of aluminum that occupies the same volume as 66.7 g of cobalt. The density of cobalt is  $8.90 \text{ g/cm}^3$  and the density of aluminum is  $2.71 \text{ g/cm}^3$ .  
a. 2.77 g    b. 20.3 g    c. 0.362 g    d.  $1.61 \times 10^3 \text{ g}$     e. 0.00457 g
- What is the appropriate chemical symbol for the species that consists of 26 protons, 30 neutrons, and 24 electrons?  
a.  $\text{Ba}^{2+}$     b.  $\text{Cr}^{2-}$     c. Zn    d.  $\text{Ba}^{2-}$     e.  $\text{Fe}^{2+}$

13. What is the correct formula of potassium sulfide?  
 a.  $\text{P}_2\text{SO}_4$       b.  $\text{KS}_2$       c.  $\text{K}_2\text{S}$       d.  $\text{S}_2\text{P}$       e.  $\text{K}_2\text{SO}_3$
14. The charge of hydrogen in  $\text{MgH}_2$  is:  
 a. -1      b. +1      c. 0      d. +2      e. -2
15. The formula weight (mass) of aluminum oxalate,  $\text{Al}_2(\text{C}_2\text{O}_4)_3$ , is  
 a. 157 amu      b. 181 amu      c. 232 amu      d. 266 amu      e. 318 amu
16. Consider the following unbalanced equation:  $\text{C}_3\text{H}_8 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ . When this equation is balanced such that the coefficient for  $\text{C}_3\text{H}_8$  is one (1), the coefficient for  $\text{O}_2$  is:  
 a. 2      b. 3      c. 4      d. 5      e. 6
17. One mole of which compound below would have the largest mass?  
 a. HI      b. HBr      c. HCl      d. HF      e.  $\text{H}_2\text{O}$
18. How many moles of  $\text{H}_2\text{O}$  are in 50.0 g of copper(II) sulfate pentahydrate ( $\text{CuSO}_4(\text{H}_2\text{O})_5$ ,  $M = 249.7$  g/mol)?  
 a. 1.00      b. 5.00      c. 0.20      d. 25      e. 2.5
19. Which one of the following chemical equations is not balanced. (Reminder: if there is no coefficient preceding a formula its coefficient is understood to be 1).  
 a.  $\text{Al}_4\text{C}_3 + 12 \text{H}_2\text{O} \rightarrow 4 \text{Al}(\text{OH})_3 + 3 \text{CH}_4$       b.  $\text{N}_2\text{H}_4 + 2 \text{O}_2 \rightarrow \text{N}_2 + 2 \text{H}_2\text{O}$   
 c.  $2 \text{NH}_4\text{NO}_3 \rightarrow 2 \text{N}_2 + \text{O}_2 + 4 \text{H}_2\text{O}$       d.  $2 \text{SF}_4 + \text{XeF}_4 \rightarrow 2 \text{SF}_6 + \text{Xe}$   
 e.  $\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{S}_2\text{O}_7$
20. Consider the three compounds: potassium oxide,  $\text{K}_2\text{O}$ , sodium oxide,  $\text{Na}_2\text{O}$ , and calcium oxide,  $\text{CaO}$ . With respect to the mass percent of oxygen in each compound:  
 a.  $\text{K}_2\text{O}$  has the largest mass percent of oxygen.  
 b.  $\text{Na}_2\text{O}$  has the largest mass percent of oxygen.  
 c.  $\text{CaO}$  has the largest mass percent of oxygen.  
 d.  $\text{K}_2\text{O}$  and  $\text{CaO}$  have the same mass percent of oxygen.  
 e. all have the same mass percent of oxygen.
21. A certain compound contains 40% carbon, 53.3 % oxygen and the rest is hydrogen. The empirical (simplest) formula of this compound is:  
 a. CO      b.  $\text{CH}_2\text{O}$       c.  $\text{CH}_3\text{O}$       d.  $\text{C}_2\text{H}_4\text{O}_2$       e.  $\text{C}_4\text{O}_5\text{H}$
22. Combustion of methane ( $\text{CH}_4$ ) in pure oxygen can be represented by the following balanced chemical reaction:  $\text{CH}_4(\text{g}) + 3 \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{g})$ . If this reaction is performed in air instead of pure oxygen, how many moles of air are needed for the combustion of one (1) mole of methane? The mol percent of oxygen in air is 20 %.  
 a. 3 mol      b. 0.2 mol      c. 1.67 mol      d. 1 mol      e. 15 mol
23. The decomposition of potassium chlorate ( $\text{KClO}_3$ ,  $M = 122.6$  g/mol) produces potassium chloride ( $\text{KCl}$ ,  $M = 74.5$  g/mol) and  $\text{O}_2$  gas ( $M = 32.0$  g/mol):  $2\text{KClO}_3(\text{s}) \rightarrow 2\text{KCl}(\text{s}) + 3\text{O}_2(\text{g})$ . What mass in grams of oxygen can be made from 2.46 g of potassium chlorate?  
 a. 0.642 g      b. 1.93 g      c. 0.963 g      d. 0.428 g      e. 3.69 g
24. Given the following balanced reaction:  $\text{CaO}(\text{s}) + 3\text{C}(\text{s}) \rightarrow \text{CaC}_2(\text{s}) + \text{CO}(\text{g})$ . How many moles of  $\text{CaC}_2$  will be formed when 1.0 mol of  $\text{CaO}$  and 18.0 g C react?  
 a. 0.5      b. 1      c. 1.5      d. 3      e. 4.5
25. How many grams of  $\text{NaCl}$  ( $M = 58.5$  g/mol) will be needed to make 1000.0 mL of 0.200 M  $\text{NaCl}$  solution?  
 a. 200 g      b. 20.0 g      c. 85.4 g      d. 11.7 g      e. 3.41 g

26. Which of the following solutions of ionic compounds has the lowest concentration of  $\text{Cl}^-$  ions in solution?  
a. 0.14 M KCl    b. 0.04 M  $\text{FeCl}_3$     c. 0.54 M NaCl    d. 0.28 M  $\text{FeCl}_2$     e. 0.22 M  $\text{CuCl}_2$
27. What is the mass percent of KBr in a solution that is prepared by dissolving 29.3 g KBr ( $\mathcal{M} = 119.0$  g/mol) in  $5.00 \times 10^2$  g  $\text{H}_2\text{O}$ .  
a. 0.0492%    b. 24.6%    c. 5.86%    d. 17.1%    e. 5.54%
28. What volume of concentrated HCl solution (12.5 M) is required to prepare 500.0 mL of 1.50 M HCl solution?  
a. 0.75 L    b. 1.25 L    c. 12.5 mL    d. 60.0 mL    e. 6.25 mL
29. Calculate the molarity of a solution made by dissolving 3.50 g of KCl ( $\mathcal{M} = 74.55$  g/mol) in enough water to produce 5.00 L of solution?  
a.  $9.39 \times 10^{-3}$  M    b. 0.700 M    c. 1.43 M    d. 52.2 M    e. 14.9 M
30. What is the density of He ( $\mathcal{M} = 4.0$  g/mol) at STP (standard temperature and pressure:  $0^\circ\text{C}$  and 1 atm pressure)?  
a. 4.00 g/L    b. 0.0446 g/L    c. 0.178 g/L    d. 22.4 g/L    e. 0.250 g/L
31. A sample of oxygen gas occupies a volume of 2.10 L at  $25^\circ\text{C}$ . What volume will this sample occupy at  $150^\circ\text{C}$ ? (Assume no change in pressure.)  
a. 12.6 L    b. 22.4 L    c. 1.48 L    d. 0.35 L    e. 2.98 L
32. A cylinder in an automobile engine has a volume of 0.600 L. The engine takes in air at a pressure of 1 atm and a temperature of 300 K and compresses it to a volume of 75.0 mL at 360 K. Determine the air pressure in the cylinder after compression.  
a. 9.6 atm    b. 6.7 atm    c. 8.0 atm    d. 0.0067 atm    e. 150 atm
33. When sodium is reacted with water, hydrogen gas is formed according to the reaction:  
 $2 \text{Na (s)} + 2 \text{H}_2\text{O (l)} \rightarrow 2 \text{NaOH (aq)} + \text{H}_2 \text{(g)}$ . If 1.00 g of sodium ( $\mathcal{M} = 22.99$  g/mol) is reacted with excess water, what volume of hydrogen would be produced at 298 K and 0.988 atm?  
a. 0.0217 L    b. 0.539 L    c. 1.08 L    d. 2.15 L    e. 24.8 L
34. For which of the following gases would the particles have the highest speed at  $25.0^\circ\text{C}$ ?  
a.  $\text{F}_2$     b. Ar    c.  $\text{CH}_4$     d.  $\text{N}_2$     e. All have the same speed
35. "First-run" helium/neon is a mixture used for many spectroscopic applications. If the mole fraction of neon in the mixture is 0.875, determine the partial pressure of neon if the total pressure in the helium/neon container is 1.13 atm.  
a. 0.774 atm    b. 0.875 atm    c. 0.989 atm    d. 1.13 atm    e. 1.29 atm
36. Which of the following species would have the highest first ionization energy?  
a. Na    b. P    c. Li    d. Ca    e. F
37. Which of the following elements has five valence electrons in a ground state atom?  
a. B    b. Cu    c. Hg    d. F    e. N
38. Which of the following orbitals is occupied by at least one electron in a chlorine atom?  
a. 3d    b. 3f    c. 4d    d. 4f    e. 5s

**Note:** A correct answer is not listed among the choices for the preceding question. Hence, this question did not count.

39. Which of the following is the correct electron configuration for arsenic (As)?
- $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$
  - $1s^2 2s^2 2p^6 2d^{10} 3s^2 3p^6 4s^2 4p^3$
  - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 3f^5$
  - $1s^2 1p^6 2s^2 2p^6 3s^2 3p^6 4s^2 4p^5$
  - $1s^2 1p^6 2s^2 2p^6 2d^{10} 3s^2 3p^5$
40. The bonding in HCl is best described as \_\_\_\_\_ and the bonding in LiF is best described as \_\_\_\_\_.
- ionic, ionic
  - ionic, covalent
  - ionic, polar covalent
  - polar covalent, ionic
  - polar covalent, metallic
41. Which of the following statements is true?
- Electromagnetic radiation with longer wavelengths has higher energy than shorter wavelength radiation.
  - Electromagnetic radiation with longer wavelengths travels through space faster than shorter wavelength radiation.
  - Electromagnetic radiation with high frequency has higher energy than low frequency radiation.
  - Electromagnetic radiation with high frequency travels through space faster than lower frequency radiation.
  - As the wavelength of radiation decreases, its frequency also decreases.
42. How many valence electrons does  $\text{CO}_3^{2-}$  possess?
- 18
  - 20
  - 22
  - 24
  - 30
43. Odd-electron molecules and ions (aka radicals) are unstable relative to even electron molecules and ions. Which of the following is a radical:
- $\text{NH}_4^+$
  - NO
  - $\text{SO}_3$
  - $\text{POCl}_3$
  - $\text{BH}_4^-$
44. In which set do all the elements have the same number of valence electrons?
- P, S, Cl
  - Ag, Cd, Ar
  - Na, Ca, Ba
  - P, Se, I
  - Mg, Sr, Ca
45. Silane ( $\text{SiH}_4$ ) has the following molecular structure:
- tetrahedral
  - square planar
  - octahedral
  - trigonal planar
  - trigonal pyramidal
46. The bond angle in  $\text{H}_2\text{Se}$  is about:
- $120^\circ$
  - $60^\circ$
  - $180^\circ$
  - $90^\circ$
  - $109^\circ$
47. The chemistry of the group \_\_\_\_\_ elements is characterized by gaining two electrons.
- 1A(1)
  - 2A(2)
  - 1B(11)
  - 6A(16)
  - 7A(17)
48. Which of the following is an endothermic process?
- freezing water
  - burning wood
  - boiling water
  - condensation of water vapor
  - all are endothermic process
49. The heat released when 5 g of propane burns is \_\_\_\_\_ than (as) the amount of heat released when 1 mg of propane burns?
- 5 times smaller
  - 200 times smaller
  - 5000 times smaller
  - 200 times larger
  - 5000 times larger
50. What is the quantity of heat evolved at constant pressure when 3.5 mol  $\text{H}_2\text{O}$  (l) is formed from the combustion of  $\text{H}_2$  (g) and  $\text{O}_2$  (g)?  $\text{H}_2$  (g) +  $\frac{1}{2}\text{O}_2$  (g)  $\rightarrow$   $\text{H}_2\text{O}$  (l);  $\Delta H^\circ = -285.8$  kJ
- $2.9 \times 10^2$  kJ
  - $1.0 \times 10^3$  kJ
  - 82 kJ
  - $5.7 \times 10^2$  kJ
  - $1.8 \times 10^4$  kJ