

AMERICAN CHEMICAL SOCIETY
2011 VIRGINIA SECTION
CHEMISTRY OLYMPIAD
FIRST YEAR EXAM

DIRECTIONS TO THE EXAMINER

This test is designed to be taken with an answer sheet on which the student records their responses. All answers are to be marked on the answer sheet. Each student should be provided the test booklet, Periodic Table with explanation of abbreviations, constants and equations, answer sheet, tie breaker question and scrap paper, all of which must be turned in upon completion of the exam.

Students are allowed to use calculators (the calculator may be either programmable or non programmable) and the student should be given at least 90 minutes to complete the exam.

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO

This is a 60 question multiple-choice exam with four or five choices for each question. There is only one correct or best answer to each question. When you select your answer, blacken completely the corresponding space on the answer sheet. If you wish to change an answer, be sure to erase your original answer completely. Any answer that has more than one blackened answer will be incorrect.

Turn in all exam materials when you have completed the exam.

The following information **MUST** be put on the answer sheet:

In Student name field

- a. **Test and School followed by a "space"** - Teacher code (Test code F = First, S = Second; i.e. FAB, where F is first year, AB is the school and teacher code for the student's teacher)
- b. **Student's Last Name followed by a "space" Student's First Name.** If your name is too long for the field, neatly continue writing your complete name in the margin.

Virginia Chemistry Olympiad First Year Exam

Directions for the First Year Virginia Olympiad Local Section Examination

When you have selected your answer to each question, blacken the corresponding space on the answer sheet using a #2 pencil. If you decide to change an answer, erase the unwanted mark very carefully, and remark the correct space. There is only one correct answer to each question. Any questions for which more than one response is given will not be counted.

Your score will be based on the number of correctly answered questions. It is to your advantage to answer every question.

1. The common name for the compound Na_2SO_4 is:

- (A) disodium sulfur tetraoxide
- (B) sodium sulfur oxide
- (C) sodium sulfite
- (D) sodium sulfate

2. Volume can be expressed in all of the following terms *except*:

- (A) liters
- (B) cubic centimeters
- (C) hectares
- (D) deci liters

The answers for questions 4 through 7 follow. Select the lettered choice that best fits the statement for each question and fill in the corresponding block on the answer sheet. You may use a choice more than once, once, or not at all.

- (A) density
- (B) molecular mass
- (C) freezing point
- (D) molarity
- (E) equilibrium constant

3. Can be expressed in grams per milliliter

4. Can be expressed in moles per liter

5. Can *not* be affected by changes in temperature and pressure.

6. At, STP, can be used to determine the molecular mass of a gas.

7. Which of the following terms does *not* involve a chemical change?

- I corrosion
- II sublimation
- III combustion
- IV condensation
- V distillation

- (A) I and II only
- (B) II and III only
- (C) II and IV only
- (D) I, III and V

8. The chemical formula of potassium carbonate is:

- (A) $\text{K}_3(\text{CO}_2)_2$
- (B) KCO_3
- (C) K_2CO_2
- (D) K_2CO_3

9. Which of the following has the proper number of significant figures in its answer? All are arithmetically correct.

- I $49.62 + 5.656 = 55.276$
- II $(3.693)(1.7326) = 6.3985$
- III $17.621/4.096 = 4.302$
- IV $5.2674 - 0.049 = 5.218$

- (A) I and II
- (B) I and III
- (C) II and IV
- (D) III and IV

10. The molar mass of iron(II) nitrate is:

- (A) 117.9 g/mol
- (B) 147.9 g/mol
- (C) 173.7 g/mol
- (D) 179.9 g/mol

11. The mass % of O in acetic acid, $\text{H}_3\text{C}_2\text{O}_2\text{H}$, is:

- (A) 36.3%
- (B) 53.3%
- (C) 40.0%
- (D) 55.1%

12. The number of sodium atoms in 8.20 grams of Na_3PO_4 , 163.9 g/mol, is

- (A) 3
- (B) 9.04×10^{22}
- (C) 3.01×10^{22}
- (D) 1.20×10^{23}

13. Which of the following substances exists as *gaseous diatomic* molecules at room temperature?

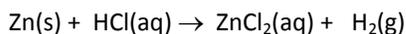
- I ozone
- II chlorine
- III argon
- IV carbon dioxide
- V oxygen

- (A) I and III
- (B) II and V
- (C) I, III and IV
- (D) II, III, and V

14. Symbols *used in chemical reactions* with their meaning are shown below. Which symbol, with its meaning is correct for *chemical reactions*?
- (A) (g) grams (C) (aq) dissolved in water
 (B) (l) liters (D) (;) precipitate is formed
15. The sum of the coefficients for the reaction:
- $$\text{NH}_3 + \text{O}_2 \rightarrow \text{NO}_2 + \text{H}_2\text{O}$$
- when using whole numbers is:
- (A) 21 (B) 17 (C) 13 (D) 7
16. When 13.0 gm of Fe_2O_3 , (159.7 g/mol), are reacted, how many grams of CO_2 are produced in the reaction:
- $$3 \text{CO} + \text{Fe}_2\text{O}_3 \rightarrow 2 \text{Fe} + 3 \text{CO}_2$$
- (A) 21.4 gm (C) 3.58 gm
 (B) 10.7 gm (D) 1.19 gm
17. A compound contains 74.0% C, 4.14% H, and 21.9% O. What is the empirical formula for this compound?
- (A) $\text{C}_7\text{H}_4\text{O}_2$ (C) $\text{C}_9\text{H}_6\text{O}_2$
 (B) $\text{C}_5\text{H}_4\text{O}$ (D) $\text{C}_{10}\text{H}_5\text{O}_2$
18. The number of molecules in 2.00 L of oxygen gas at STP are:
- (A) 6.02×10^{23} (C) 5.38×10^{22}
 (B) 1.72×10^{23} (D) 4.91×10^{22}
19. When equal volumes, at the same temperature and pressure, of hydrogen and nitrogen gas react to make ammonia gas:
- (A) nitrogen is the limiting reagent and hydrogen is in excess.
 (B) hydrogen is the limiting reagent and nitrogen is in excess
 (C) both are consumed and the volume of ammonia formed is twice the initial volume of nitrogen
 (D) both are consumed and the volume of ammonia formed is the same as the initial volume of nitrogen
20. A gas occupies 100.0 mL flask at 60°C , and 775 mm Hg. The gas has a mass of 0.596 gm. The gas may be:
- (A) bromine (C) chlorine
 (B) krypton (D) argon
21. Two 5.0 L flasks are at the same temperature. One contains 0.20 moles of $\text{H}_2(\text{g})$ and the other 0.10 moles of $\text{He}(\text{g})$. The two gases have equal:
- I masses II average molecular velocities
 III pressures IV average kinetic energies
- (A) I and III only (C) I, II and IV
 (B) I and IV only (D) II, III and IV
22. Which statement *best* explains why water has a higher boiling point than hydrogen chloride?
- (A) H_2O has a greater molar mass than HCl
 (B) H_2O has less molar mass than HCl
 (C) H_2O has greater intermolecular forces than HCl
 (D) H_2O has greater intramolecular forces than HCl
23. Which property is most useful in determining if a substance is a metal?
- (A) melting point (C) x-ray diffraction pattern
 (B) conductivity (D) brittleness
24. For water which of the following are correct?
- I. The molecular motion is greater in the gas phase than in the liquid phase
 II. The intermolecular forces are greater in the gas phase than in the liquid phase
 III. The heat of vaporization is greater than the heat of melting
 IV. The liquid phase is more dense than the solid phase
- (A) I and III only (C) I, III and IV only
 (B) I, II and III only (D) II, III and IV only
25. Which of the following conditions will increase the solubility of a gas in water?
- (A) all of the below
 (B) increase the water temperature
 (C) increase the volume of the gas
 (D) increase the pressure of the gas

26. How many grams of $\text{Ca}(\text{NO}_3)_2$, 164.1 g/mol, are needed to make 200.0 mL of a 0.250 M solution of $\text{Ca}(\text{NO}_3)_2$?
- (A) 0.0500 g (C) 8.21 g
(B) 4.10 g (D) 410 g
27. When a $(\text{NH}_4)_2\text{SO}_4$ solution is added to a $\text{Ba}(\text{NO}_3)_2$ solution:
- (A) no chemical reaction occurs
(B) BaSO_4 precipitates
(C) NH_4NO_3 precipitates
(D) both NH_4NO_3 and BaSO_4 precipitate
28. A ${}^{52}_{24}\text{Cr}^{2+}$ ion has:
- | | protons | neutrons | electrons |
|-----|---------|----------|-----------|
| (A) | 24 | 28 | 22 |
| (B) | 22 | 30 | 24 |
| (C) | 24 | 54 | 22 |
| (D) | 24 | 28 | 26 |
29. Which of the following are generally characteristic properties of non-metals?
- | | |
|--------------------------|--------------------------|
| I high ionization energy | III form negative ions |
| II low electronegativity | IV react with non-metals |
- (A) I and III only (C) III, and IV only
(B) II and IV only (D) I, III and IV only
- The answers for questions 31 through 35 follow. Select the lettered choice that best fits the statement for each question and fill in the corresponding block on the answer sheet. You may use a choice more than once, once or not at all.
- (A) ionic (B) polar covalent (C) covalent
(D) metallic (E) hydrogen bonding
30. The type of bond that results when two elements that have a very large difference in electronegativity.
31. The bonds in a nitrogen molecule.
32. The bond in HCl
33. The type of bonds in CaF_2
34. The weakest bond listed above
35. Which compound, when dissolved in water to make a 0.10 m solution, has the highest boiling point?
- (A) CH_3COONa (C) H_3COCH_3
(B) $\text{Ca}(\text{NO}_3)_2$ (D) CuSO_4
36. Generally in going from left to right across the second row of the periodic table (Li to Ne) generally the:
- I metallic character decreases
II atomic radii increases
III ionization energy increases
IV electronegativity increases
- (A) I and III only (C) I, II and IV
(B) II and IV only (D) I, III and IV
37. The *best* explanation why krypton does not form a di-atomic molecule is:
- (A) its atomic radius is too small
(B) its ionization energy is too high
(C) noble gases do not form chemical bonds
(D) it has a completed electron valence shell
38. Which of the following combinations are most likely to form predominantly ionic type bonds?
- | | |
|---------------------|---------------------|
| I rubidium-chlorine | III silicon-oxygen |
| II hydrogen-oxygen | IV bromine-fluorine |
| V barium-chlorine | |
- (A) I and V only (C) II, III and IV only
(B) I, II and IV only (D) II, III and V only
39. The ground state electron configuration for Ni is?
- (A) $1s^2 2s^2 3s^2 3p^6 4s^2 4p^6 3d^{10}$
(B) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
(C) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
(D) $1s^2 2s^2 2p^6 3s^4 3p^6 4s^6 3d^2$
40. What is the geometry of the hybrid orbitals of an atom that has orbital hybridization sp^2 ?
- (A) pyramidal (C) bent
(B) linear (D) planar triangular
41. When solutions of lead nitrate and sodium chloride are mixed, the products of the reaction are:
- (A) $\text{Pb}^{+2}(\text{aq})$, $\text{NaNO}_3(\text{s})$ and $\text{Cl}_2(\text{g})$
(B) $\text{Pb}^{+2}(\text{aq})$, $\text{Cl}^-(\text{aq})$ and $\text{NaNO}_3(\text{s})$
(C) $\text{PbCl}_2(\text{s})$, $\text{N}_2(\text{g})$ and $\text{O}_2(\text{g})$
(D) $\text{PbCl}_2(\text{s})$, $\text{Na}^+(\text{aq})$ and $\text{NO}_3^-(\text{aq})$
42. Which of the following dissolves in water to form an acidic solution?
- (A) SO_3 (C) Na_2O
(B) Al_2O_3 (D) NH_3

43. In the laboratory, hydrogen can be prepared by the following *unbalanced* equation.



How many liters of $\text{H}_2\text{(g)}$, at 25°C and 1.00 atm , can be prepared from 13.08 gm of Zn ?

- (A) 4.48 L (C) 8.96 L
(B) 4.88 L (D) 9.76 L
44. Which of the following pollutants contributes the *most* to the formation of acid rain?
- (A) SO_2 (C) O_3
(B) CCl_2F_2 (D) CO_2
45. A student has to measure, precisely as possible, 16 mL of a liquid. Which of the following should be used?
- (A) 10 mL beaker (C) 25 mL volumetric flask
(B) 10 mL pipet (D) 10 mL graduated cylinder
46. Which type of chemical reaction in an automobile battery produces the electrical energy?
- (A) decomposition
(B) oxidation reduction
(C) neutralization
(D) double replacement
47. Which technique relies on the volatility of the substances to be separated?
- (A) filtration (C) solvent extraction
(B) distillation (D) precipitation
48. Calculate the volume of one mole of AgCl (143.3 g/mol), whose density is 5.56 g/cm^3 .
- (A) $1.26 \times 10^{-3}\text{ cm}^3$ (C) $3.93 \times 10^{-1}\text{ cm}^3$
(B) $2.58 \times 10^1\text{ cm}^3$ (D) $7.97 \times 10^2\text{ cm}^3$
49. A volatile liquid is placed in an empty 125 mL flask, mass 63.427 g , with a piece of Al foil with a pin hole in it. The liquid is vaporized at 100°C and the mass is 63.768 g . The atmospheric pressure is 748 mm Hg . Calculate the molar mass of the liquid.
- (A) 44.0 g/mol (C) 84.9 g/mol
(B) 67.0 g/mol (D) 166 g/mol

50. A mixture of the following gases, containing 0.050 mol of O_2 , 0.020 mol of N_2 , and 0.020 mol of CO_2 , exerts a pressure of 1.03 atm . The partial pressure exerted by the CO_2 is:

- (A) 1.0 atm (C) 0.29 atm
(B) 0.34 atm (D) 0.23 atm

51. In which of the following are there both sigma and pi bonds?

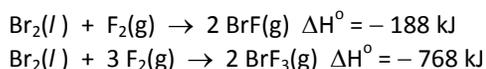
- I C_2H_6 II HCN III CO_2
IV O_2 V CBr_4

- (A) I, and II only (C) II, III and IV only
(B) I, II and III only (D) I, II and V only

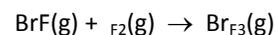
52. Which of the following arrangements of prefixes is in order of *decreasing* value?

- (A) milli, centi, kilo, deci
(B) micro, milli, centi, kilo
(C) kilo, centi, deci, milli
(D) kilo, deci, milli, micro

53. For the reactions:

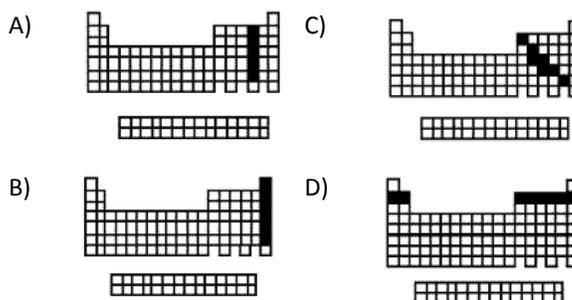


Determine ΔH° for the reaction:



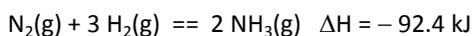
- (A) -290 kJ (C) -580 kJ
(B) -478 kJ (D) -956 kJ

54. Which represents the elements in the $n = 2$ energy level?



55. Which of the following statements about the rates of chemical reactions is *false*?
- Increasing the temperature of a system does not always increase the rate.
 - Increasing the concentration of a reactant does not always increase the rate.
 - Increasing the pressure on a gaseous system always increases the rate.
 - In general, the more chemical bonds that have to be broken, the slower the rate.

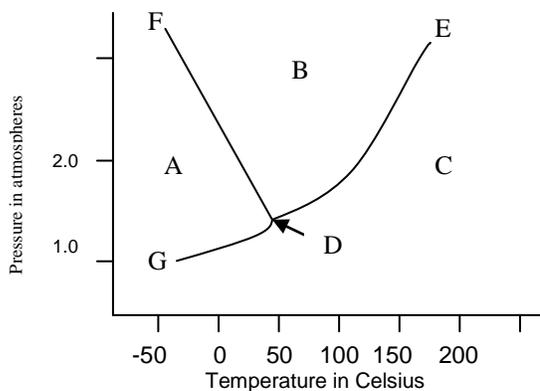
Use the reaction to answer the following questions.



56. In a closed 1.00 L container, the equilibrium concentrations are 0.033 moles of $\text{N}_2(\text{g})$, 0.047 moles of $\text{H}_2(\text{g})$ and 0.035 moles of NH_3 . Calculate K_c for the reaction in the 1.00 L container.
- (A) 0.025 (B) 23 (C) 350 (D) 470
57. Which of the following changes would increase the yield of the NH_3 ?
- increase volume
 - decrease volume
 - increase pressure
 - decrease pressure
 - increase temperature
 - decrease temperature
- (A) I, III and V (C) II, III and V
 (B) II, IV and VI (D) II, III, and VI

58. Which of the following reactions is a reduction-oxidation (REDOX) reaction?

- $2 \text{KClO}_3 \rightarrow 2 \text{KCl} + 3 \text{O}_2$
- $2 \text{HCl} + \text{Na}_2\text{CO}_3 \rightarrow 2 \text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$
- $3 \text{CaCl}_2 + 2 \text{Na}_3\text{PO}_4 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 6 \text{NaCl}$
- $2 \text{Fe}_2\text{S}_3 + 3 \text{CO}_2 \rightarrow 2 \text{Fe}_2\text{O}_3 + 3 \text{CS}_2$



59. What phase changes occur when the temperature is held constant at 25°C and the pressure is increased from 0.5 atm to 3 atm?
- gas to liquid to solid
 - gas to solid to liquid
 - liquid to solid to gas
 - solid to liquid to vapor
60. Which of the following pairs, when mixed, will produce a visible change?
- $\text{KOH}(\text{aq})$ and $\text{HCl}(\text{aq})$
 - $\text{Pb}(\text{NO}_3)_2(\text{aq})$ and $\text{HCl}(\text{aq})$
 - $\text{HNO}_3(\text{aq})$ and $\text{Cu}(\text{s})$
 - $\text{Cu}(\text{NO}_3)_2(\text{aq})$ and $\text{NH}_3(\text{aq})$
- (A) II, and IV only (C) I, III and IV
 (B) I, II and III (D) II, III, and IV

END OF TEST