Part I

1. Which of the following is *not* a chemical reaction?

   (A) combustion
   (B) distillation
   (C) fermentation
   (D) rusting

2. The correct name for the compound Na_3PO_3

   (A) trisodium phosphorus trioxide
   (B) trisodium phosphide trioxide
   (C) sodium phosphite
   (D) sodium phosphate

3. Pressure can be expressed in which of the following terms?:

   (A) liter-atmospheres (C) calories
   (B) pascals (D) hydrospheres

4. 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

5. Adipic acid, $HOOC(CH_2)_4COOH$, is a reactant in making nylon. How many moles are in 1.00 g of adipic acid?

   (A) 4.12×10^{21} (C) 146
   (B) 6.85×10^{-3} (D) 103

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

   I 64.073 + 7.219 = 71.292
   II (3.693)(0.0326) = 0.120
   III 12.48/3.735 = 3.34
   IV 18.408 – 7.349 = 11.06

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

7. The chemical formula of calcium phosphate is:

   (A) $Ca(PO_4)_2$ (C) Ca_3PO_3
   (B) $Ca_2(PO_4)_3$ (D) $Ca_3(PO_4)_2$

8. The molar mass, *M*, of vanadium (III) sulfide is:

   (A) 82.95 g/mol (C) 198.0 g/mol
   (B) 184.8 g/mol (D) 248.9 g/mol

9. The mass % of O in sodium salicylate, $NaC_7H_5O_3$, is:

   (A) 30.0% (B) 30.8% (C) 52.5% (D) 21.3%

10. An oxide of chromium has 2.17 g of Cr per gram of oxygen. What is the empirical formula?

    (A) CrO (B) Cr_2O_3 (C) Cr_3O_2 (D) CrO_2

11. Gypsun is a hydrate of calcium sulfate. When 4.78 g of gypsum are heated to dryness 3.08 g of $CaSO_4$ remain. The formula of gypsum is:

    (A) $CaSO_4 \bullet 4H_2O$ (C) $CaSO_4 \bullet 2H_2O$
    (B) $CaSO_4 \bullet 3H_2O$ (D) $CaSO_4 \bullet H_2O$

The answers for questions 12 through 16 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) Hydrogen (B) Helium (C) Carbon
(D) Nitrogen (E) Fluorine

12. Is *least* likely to bond with itself
13. In compounds it has the most oxidation numbers of the elements listed
14. Most of the binary compounds it forms are ionic
15. It forms more compounds than any of the elements.
16. Most abundant element in the troposphere, <12 km above sea level.

17. Given the balanced equation:

    $2X(s) + 3Fe(NO_3)_2(aq) \rightarrow 3Fe(s) + 2X(NO_3)_3(aq)$

    The element represented by X could be:

    (A) Al (B) Ca (C) Na (D) Cu

18. How many moles of silver are produced when 7.65 g of zinc are reacted with an excess of silver nitrate in the reaction:

    $Zn(s) + 2\ AgNO_3(aq) \rightarrow 2\ Ag(s) + Zn(NO_3)_2(aq)$

    (A) 0.0585 mol (C) 0.234 mol
    (B) 0.117 mol (D) 0.254 mol

19. A compound contains 85.63% boron and 14.37% hydrogen. What is the empirical formula of the compound?

    (A) $B_{10}H_7$ (B) B_5H_9 (C) BH_2 (D) $Be_{11}H_{13}$

20. How many grams of $N_2H_4(l)$ are required to react with 20.0 g of $N_2O_4(l)$ by the following reaction?

$2\ N_2H_4(l) + N_2O_4(l) \rightarrow 3\ N_2(g) + 4\ H_2O(l)$

(A) 6.97 g (C) 13.9 g

(B) 13.7 g (D) 27.9 g

21. Calculate the mass of 2.50 L of helium gas at STP.

(A) 0.112 g (C) 0.447 g
(B) 0.407 g (D) 0.894 g

22. When equal volumes, at the same temperature and pressure, of nitrogen and oxygen gas react to form NO_2. After the reaction the pressure and temperature are the same.

(I) the volume of the NO_2 formed is twice the initial volume of the oxygen
(II) the volume of the NO_2 formed is the same as the initial volume of the oxygen
(III) nitrogen is the limiting reagent and oxygen is in excess
(IV) oxygen is the limiting reagent and nitrogen is in excess

(A) I only (C) I and III

(B) II only (D) II and IV

23. A gas occupies 40.0 mL at 10^oC and 745 mm Hg. What volume will it occupy at 40^oC and 775 mm Hg?

(A) 42.5 mL (C) 34.8 mL
(B) 46.0 mL (D) 154 mL

24. Which of the following elements is a solid at room temperature?

(A) chlorine (C) bromine
(B) fluorine (D) iodine

25. An increase in the temperature of a contained liquid:

(A) has no effect on the kinetic energy of the liquid
(B) decreases the vapor pressure of the liquid
(C) causes the vapor pressure above the liquid to increase
(D) causes fewer particles to escape the surface of the liquid

26. The structure of solid KCl can best be described as:

(A) network bonding of K to K atoms and Cl to Cl atoms
(B) molecular KCl units occupying lattice sites
(C) each K^+ ion surrounded by Cl^- ions and each Cl^- ion surrounded by K^+ ions.
(D) metallic bonding of K to K atoms and covalent bonding of Cl to Cl atoms

27. Which of the following is made up of particles with the highest average kinetic energy?

(A) $Fe_{(s)}$ at 50^oC (C) $H_2O_{(l)}$ at 40^oC
(B) $Br_{2(l)}$ at 50^oC (D) $CO_{2(g)}$ at 30^oC

28. A white solid at room temperature, has a high melting point and dissolves in water. The resulting solution conducts electricity. The substance may be:

(A) HCl (C) $CaCl_2$
(B) CCl_4 (D) SiO_2

29. How many grams of $Cu(NO_3)_2 \bullet 3H_2O$, 241.6 g/mol, are needed to make 400.0 mL of a 0.200 M solution of $Cu(NO_3)_2$?

(A) 15.0 g (C) 57.9 g
(B) 19.3 g (D) 121 g

30. When a NH_4NO_3 solution is added to a $BaCl_2$ solution:

(A) no precipitate occurs
(B) $Ba(NO_3)_2$ precipitates
(C) NH_4Cl precipitates
(D) both $Ba(NO_3)_2$ and NH_4Cl precipitate

31. The maximum number of electrons that can occupy the 5d orbitals are:

(A) 2 (B) 6 (C) 10 (D) 14

32. Which of the following are generally characteristic properties of metals?

I high ionization energy III form positive ions
II low electronegativity IV react with other metals

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

The answers for questions 33 through 37 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) K (B) Ti (C) Mn (D) Ga (E) Br

33 The element with the *lowest* electronegativity

34. The element with the *greatest* number of unpaired electrons in each of its atoms

35. The element that forms the compound X_2O_3

36. The element with the *largest* ionic radius

37. The element that has the *greatest* number of positive oxidation numbers

38. In the group 15 (5A) elements, as the atomic number increases, the:

(A) metallic character increases and electronegativity decreases

(B) ionization energy increases and electronegativity decreases

(C) ionization energy and atomic radii decreases

(D) electronegativity and ionic radii decreases

39. Which statements regarding first ionization energies are true?

I N is greater than F
II Li is greater than Na
III Br is greater than Te
IV Cr is greater than Fe

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

40. When two atoms of the same or different elements have equal electronegativities

(A) they can not unite

(B) they can unite and a polar bond is formed

(C) one or more pair of electrons is/are equally shared

(D) they bond and each atom has half-filled outer orbitals in each atom.

41. Which of the following combinations are most likely to form predominantly covalent bonds?

I hydrogen-sulfur III silicon-oxygen
II cesium-chlorine IV bromine-chlorine
V calcium-fluorine

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

42. Which of the following contains both ionic and covalent bonds?

(A) $H_4C_2Cl_2$ (C) NO_3^-
(B) Na_2SO_4 (D) PF_3

43. Which of the following is the strongest bond?

(A) ionic bond
(B) covalent bond
(C) polar covalent bond
(D) hydrogen bond

44. Which of the following aqueous solutions has the lowest boiling point?

(A) 0.05 m $SrBr_2$ (C) 0.10 m C_2H_5OH
(B) 0.05 m KBr (D) 0.05 m $HC_2H_3O_2$

45. Entropy is an expression of the :

(A) activation energy (C) reaction rate
(B) randomness (D) heat content

46. Calculate ΔH for the reaction:

$2\ NaClO_3(s) \rightarrow 2\ NaCl(s) + 3\ O_2(g)$

given ΔH_f $NaClO_3$,(s)– 365.6 kJ/mol and
ΔH_f NaCl(s) – 411.1 kJ/mol

(A) – 45.5 (C) – 776.7 kJ
(B) – 91.0 kJ (D) – 1553.4 kJ

47. In a gas phase system at constant temperature, a decrease in the volume will:

(A) increase the activation energy
(B) increase the reaction rate
(C) decrease the activation energy
(D) decrease the reaction rate

48. Which milligram quantity has three significant figures?

(A) 0.670 mg (C) 600 mg
(B) 670 mg (D) 6701 mg

49. A student calculates, from experimental values, the molecular weight of a compound to be 68.68 g/mol. The accepted value for the compound is 66.94 g/mol. The percent error is :

(A) 1.09% (C) 2.53%
(B) 1.11% (D) 2.60%

50. A student spills some 6.0 M nitric acid on their hand. Which is the best treatment for the spill?

(A) pour 6.0 M Na OH on the hand
(B) sprinkle solid sodium carbonate on the hand
(C) rinse the hand in cold water
(D) apply burn ointment and gauze on the hand

Part II

51. It takes 8.00×10^4 gallons of water to fill a swimming pool. What is the volume of the swimming pool? one gallon = 3.79×10^3 mL.

(A) 3.03×10^4 m^3 (C) 3.03×10^2 m^3
(B) 3.03×10^3 m^3 (D) 30.3 m^3

52. Assuming that gasoline is octane, C_8H_{18}, and that it is completely combusted to yield carbon dioxide and water, how many moles of oxygen are required to burn 1.0 gallons (about 50 moles) of gasoline?

(A) 1250 (B) 425 (C) 313 (D) 25

53. When 1.398 g of an unknown metal react with oxygen 1.684 g of the oxide X_2O are formed. What is the atomic mass of the metal X?

(A) 108 g/mol (C) 39.1 g/mol
(B) 78.2 g/mol (D) 23.0 g/mol

54. Chlorine gas may be produced in the laboratory by the following reaction:

$$KClO_3 + 6\ HCl \rightarrow KCl + 3\ Cl_2 + 3\ H_2O$$

What mass of $KClO_3$ must react to produce 5.00 L of Cl_2 at STP?

(A) 36.8 g (C) 13.5 g
(B) 27.4 g (D) 9.12 g

55. A V^{3+} ion has the electron configuration:

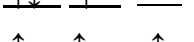
(A) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^3$
(B) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
(C) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2$
(D) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

55. According to kinetic molecular theory, which of the following statements are correct for 4.0 g of hydrogen gas and 4.0 g of helium gas in the same container at the same temperature?

I. The average kinetic energy of each gas is the same
II. The partial pressure exerted by each gas is the same
III. The average velocity of the molecules of each gas is the same
IV. Collisions between the gas molecules and with the walls of the container are elastic

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

57. Which of these electron diagrams could represent the ground state of the 3pvalence electrons of a phosphorus atom.

(A)  (C)

(B) (D)

58. Oxalic acid, $H_2C_2O_4$, reacts with permanganate ions by the following reaction:

$$5H_2C_2O_4(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

How many mL of 0.165 M $KMnO_4$ solution are required to react with 25.0 mL of 0.249 M $H_2C_2O_4$ solution?

(A) 10.0mL (C) 15.1mL
(B) 13.5mL (D) 37.7mL

59. How many mL of 3.50 M HCl are needed to make 500.0 mL of a 0.150 M solution of HCl?

(A) 1.05 mL (C) 21.4 mL
(B) 10.7 mL (D) 32.1 mL

60. Which of the following are exothermic reactions?

I $H_2O(g) \rightarrow H_2O(l)$
II $H_2O(s) \rightarrow H_2O(l)$

III $H(g) + H(g) \rightarrow H_2(g)$
IV $NaCl(g) \rightarrow Na^+(g) + Cl^-(g)$

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

61. In which of the following does the central atom contain one or more pairs of unshared electrons?

I NH_3 II H_2O III CO_2
IV BF_3 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

62. Each element A, B, C and D belongs in a different chemical family. The families are Group I, VA(14), VA(15) and VIA(16) and are in the first, second or third row of the periodic table. Based on the following, arrange the elements in increasing group order (Group I first, VIA last).

Element A is the second most abundant element, by weight, in the earth's crust and is used extensively in the electronic industry.

Element B is used extensively in fertilizers but is environmentally unsafe in natural waters.

Element C is a yellow solid at 25 °C. It is in an acid that is used extensively in industry.

Element D is the only member of its family that is a gas at 25° C. It is used as a reducing agent.

(A) D, A, C, B (C) C, A, B, D
(B) C, B, A, D (D) D, A, B, C

63. Given the following reactions:

$2\ Al + 3/2\ O_2 \rightarrow Al_2O_3 \quad \Delta H_f = -1674$ kJ
$2\ Fe + 3/2\ O_2 \rightarrow Fe_2O_3 \quad \Delta H_f = -825$ kJ

Calculate the heat of the thermite reaction:

$2\ Al + Fe_2O_3 \rightarrow 2\ Fe + Al_2O_3$

(A) – 2499 kJ (C) 849 kJ
(B) – 849 kJ (D) 2499 kJ

64. Which of the following substances has the greatest solubility in water at 25°C?

(A) gasoline (C) silicon dioxide
(B) table salt (D) carbon tetrachloride

65. Calculate the H^+ concentration in a 0.10 M HCN solution. K_a HCN 4.9×10^{-10}.

$HCN \rightleftarrows H^+ + CN^-$

(A) 0.1 M (C) 4.9×10^{-11} M
(B) 4.9×10^{-10} M (D) 7.0×10^{-6} M

66. In the laboratory helium gas can be separated from oxygen gas by diffusion of the gases because when the gases are at the same temperature and pressure the:

(A) helium diffuses 2.8 times faster
(B) helium diffuses 8.0 times faster
(C) oxygen diffuses 2.8 times faster
(D) oxygen diffuses 8.0 times faster

67. Which of the following statements about the rates of chemical reactions is *false*?

(A) Increasing the temperature of a system does not always increase the rate.
(B) Increasing the concentration of a reactant does not always increase the rate.
(C) Increasing the pressure on a gaseous system always increases the rate.
(D) In general, the more chemical bonds that have to be broken, the slower the rate.

68. The equilibrium expression for the reaction is:

$2\ NO(g) + O_2(g) \rightleftarrows 2NO_2(g)$

(A) $K = \dfrac{[NO]^2[O_2]}{[NO_2]^2}$ (C) $K = \dfrac{[NO_2]^2}{[NO]^2+[O_2]}$

(B) $K = \dfrac{[NO]^2 + [O_2]}{[NO_2]^2}$ (D) $K = \dfrac{[NO_2]^2}{[NO]^2[O_2]}$

69. Which of the following pairs, when mixed, will *not produce a visible change*?

(A) $Cu(NO_3)_2$ (aq) and NH_3 (aq)
(B) $AgNO_3$ (aq) and HCl (aq)
(C) $Na(NO_3)$ (aq) and NH_4Cl (aq)
(D) HNO_3 (aq) and Fe(s)

70. Which of the following molecules have a net molecular dipole?

I CO_2 II H_2O III BeH_2 IV NH_3

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

Virginia Section First Year Exam: Student Name _____

School _____ Teacher _____

TIE BREAKER to be graded if your score is 45 or above. . Box in your answer to each part. 2 Pts each

When solutions of sodium sulfate and silver(I) nitrate are mixed a precipitate is formed.

(a) Write the formula for the precipitate

(b) Write the overall and the net ionic equations for the reaction

(c) How many moles of each ion are present in 100mL of the 1.5 M sodium sulfate solution?

(d) How many moles of each ion are present in 150 mL of the 1.0 M silver(I) nitrate solution?

(e) After mixing the two solutions in (c) and (d) above, calculate the molarity of the ions remaining in solution. Assume that the solution volumes are additive and that none of the precipitate is soluble.

2005 Virginia Section Chemistry Olympiad
Answer Sheet

First Year Exam

1 B	19 D	37 B	55 A
2 A	20 A	38 A	56 C
3 B	21 C	39 B	57 C
4 B	22 C	40 C	58 A
5 B	23 D	41 C	59 B
6 C	24 A	42 D	60 A
7 D	25 C	43 A	61 D
8 C	26 A	44 B	62 D
9 A	27 C	45 C	63 C
10 B	28 B	46 C	64 A
11 D	29 A	47 B	65 C
12 B	30 C	48 A	66 D
13 B	31 B	49 D	67 B
14 C	32 D	50 A	68 B
15 D	33 B	51 B	69 B
16 C	34 D	52 A	70 C
17 C	35 B	53 C	
18 A	36 A	54 D	