Part I

1. Which of the following *cannot* be classified as a substance?

(A) potassium bicarbonate   (C) air
(B) sodium dihydrogen phosphate   (D) nitrogen

2. The common name for the compound Na_2SO_4 is:

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

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

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

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

4. Can be expressed in grams per milliliter

5. Can be expressed in moles per liter

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

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

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

    I corrosion   II sublimation   III combustion
      IV condensation   V fermentation

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

9. The chemical formula of potassium carbonate is:

    (A) $K_3(CO_2)_2$ (C) K_2CO_2
    (B) KCO_3 (D) K_2CO_3

10. 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   (C) II and IV
    (B) I and III   (D) III and IV

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

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

12. The mass % of O in acetic acid, $H_3C_2O_2H$, is:

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

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

    (A) 3   (C) 3.01×10^{22}
    (B) 9.04×10^{22} (D) $1\ 20 \times 10^{23}$

14. Which of the following substances exists as *gaseous diatomic* molecules at room temperature?
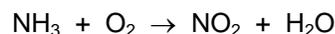
    I ozone   II chlorine   III argon
      IV carbon dioxide   V oxygen

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

15. 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
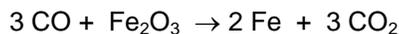
16. The sum of the coefficients for the reaction:

$$NH_3 + O_2 \rightarrow NO_2 + H_2O$$

when using whole numbers is:

    (A) 21   (B) 17   (C) 13   (D) 7

17. 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:

$$3\ CO + Fe_2O_3 \rightarrow 2\ Fe + 3\ CO_2$$

    (A) 21.4 gm   (C) 3.58 gm
    (B) 10.7 gm   (D) 1.19 gm

18. A compound contains 74.0% C, 4.14% H, and 21.9% O. What is the empirical formula for this compound?

    (A) $C_7H_4O_2$ (C) $C_9H_6O_2$

(B) C_5H_4O (D) $C_{10}H_5O_2$

19. 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}

20. 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

21. 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

22.   Two 5.0 L flasks are at the same temperature. One contains 0.20 moles of $H_2(g)$ and the other 0.10 moles of $He(g)$. 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

23. 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

24. 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

25. 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

26. 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

27. How many grams of $Ca(NO_3)_2$, 164.1 g/mol, are needed to make 200.0 mL of a 0.250 M solution of $Ca(NO_3)_2$?

(A) 0.0500 g   (C) 8.21 g
(B) 4.10 g   (D) 410 g

28. When a $(NH_4)_2SO_4$ solution is added to a $Ba(NO_3)_2$ solution:

(A) no chemical reaction occurs
(B) $BaSO_4$ precipitates
(C) NH_4NO_3 precipitates
(D) both NH_4NO_3 and $BaSO_4$ precipitate

29. A $_{24}^{52}Cr^{+2}$ ion has:

	protons	neutrons	electrons
(A)	24	28	22
(B)	22	30	24
(C)	24	54	22
(D)	24	28	26

30. 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

31. The type of bond that results when two elements have a difference in electronegativity of 2.7.

32. The bonds in a nitrogen molecule.

33. The bond in HCl

34. The type of bonds in CaF_2

35. The weakest bond listed above

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) $Pb^{+2}(aq)$, $NaNO_3(s)$ and $Cl_2(g)$

(B) $Pb^{+2}(aq)$, $Cl^-(aq)$ and $NaNO_3(s)$

(C) $PbCl_2(s)$, $N_2(g)$ and $O_2(g$
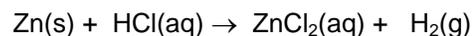
(D) $PbCl_2(s)$, $Na^+(aq)$ and $NO_3^-(aq)$

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 Which compound, when dissolved in water to make a 0.10 m solution, has the highest boiling point?

    (A) $H_3CCOONa$ (C) H_3COCH_3
    (B) $Ca(NO_3)_2$ (D) $CuSO_4$

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

$$Zn(s) + HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

How many liters of $H_2(g)$, at 25°C and 1.00 atm, can be prepared from 13.08 gm of Zn?

    (A) 4.48 L   (B) 4.88 L   (C) 8.96 L   (D) 9.76 L

45. Calculate the heat released when 10.0 L at STP of NO is converted to NO_2 in the reaction:

$$2 NO(g) + O_2(g) \rightarrow 2 NO_2(g) \quad \Delta H = -113 \text{ kJ}$$

    (A) 23.2 kJ   (C) 46.4 kJ
    (B) 25.2 kJ   (D) 50.4 kJ

46. In a gas phase system at constant temperature, an increase in pressure usually will:

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

47. 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

48. 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

49. Which type of chemical reaction in an automobile battery produces the electrical energy?

    (A) decomposition
    (B) oxidation reduction

(C) neutralization
(D) double replacement

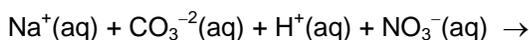50. Which technique relies on the volatility of the substances to be separated?

(A) filtration   (C) solvent extraction
(B) distillation   (D) precipitation

PART_II

51. Calculate the volume of one mole of AgCl, whose density is 5.56 g/cm^3.

(A) 1.26×10^{-3} cm^3 (C) 3.93×10^{-1} cm^3
(B) 2.58×10^{1} cm^3 (D) 7.97×10^{2} cm^3

52. What are the products of the reaction:

$Na^+(aq) + CO_3^{-2}(aq) + H^+(aq) + NO_3^-(aq) \rightarrow$

(reactants and products are not balanced)

(A) $Na_2CO_3(s) + H_2O(l) + NO_2(g)$

(B) $NaNO_3(s) + H_2CO_3(aq)$

(C) $Na^+(aq) + NO_3^-(aq) + H_2CO_3(aq)$

(D) $Na^+(aq) + NO_3^-(aq) + CO_2(g) + H_2O(l)$

53. When 1.962 g of the metallic oxide X_2O_3 are treated with hydrogen gas, 1.676 g of X metal are formed. What is the atomic mass of the metal X?

(A) 141 g/mol   (C) 88.9 g/mol
(B) 103 g/mol   (D) 27.0 g/mol

54. 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

55. A mixture of the following gases, containing 0.050 mol of O_2, 0.020 mol of N_2, and 0.020 mol of

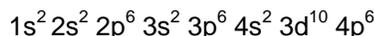CO_2, exerts a pressure of 1.03 atm. The partial pressure exerted by the CO_2 is:

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

56 In the following species which element has the highest oxidation number?

$$AlF_6^{-3} \quad\quad Ca(ClO_3)_2 \quad\quad KNO_3 \quad Na_2Cr_2O_7$$

(A) Al   (B) Cl   (C) N   (D) Cr

57. In forming an *ionic* bond which of the following elements will have the electron configuration:

$$1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^{10}\, 4p^6$$

I Strontium   II Iodine   III Selenium

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

58. In an evacuated glass tube HCl gas is inserted in one end and NH_3 gas is inserted in the other end. A white solid forms in a ring inside the tube.

(A) the ring forms closer to the HCl end of the tube
(B) the ring forms in the middle of the tube
(C) the solid is NH_4
(D) the solid is NCl_3

59. Which of the following statements are correct?

I In a family of elements, the largest atom has the lowest electronegativity
II In the third row of elements the halogen element has the lowest electronegativity
III For all elements its second ionization energy is greater than its first ionization energy
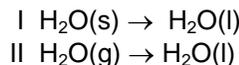IV It is easier to form a -2 ion than a -1 ion

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

60. 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
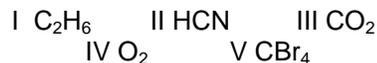
(A) I, and II only   (C) II, III and IV only
(B) I, II and III only   (D) I, II and V only

61. In which of the following reactions does the entropy increase?

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

III $H(g) + H(g) \rightarrow H_2(g)$
IV $NaCl(g) \rightarrow Na^+(g) + Cl^-(g)$
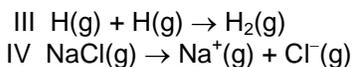
(A) I and III only   (C) II and III only
(B) I and IV only   (D) II and IV only

62. For the reaction:

$$2 A + B \rightarrow C + 2 D$$

the following kinetic data was obtained

$[A]_o$	$[B]_o$	Initial Rate M/s
1.00	1.00	1.2×10^{-2}
2.00	1.00	2.3×10^{-2}
2.00	2.00	9.4×10^{-2}
3.00	3.00	3.2×10^{-1}

the rate equation is:

(A) rate = $k[A][B]$ (C) rate = $k[A][B]^2$

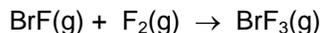(B) rate = $k[A]^2[B]$ (D) rate = $k[A]^2[B]^2$

63. In a potential energy diagram, the difference between the potential energy of the products and the potential energy of the reactants is equal to the:

(A) heat of the reaction
(B) entropy of the reaction
(C) activation energy of the forward reaction
(D) activation energy of the reverse reaction

64. For the reactions:

$Br_2(l) + F_2(g) \rightarrow 2 BrF(g) \quad \Delta H^\circ = -188 \text{ kJ}$
$Br_2(l) + 3 F_2(g) \rightarrow 2 BrF_3(g) \quad \Delta H^\circ = -768 \text{ kJ}$

Determine ΔH° for the reaction:

$$BrF(g) + F_2(g) \rightarrow BrF_3(g)$$

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

65. 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.

Use the following reaction to answer questions 66 thru 68.

$N_2(g) + 3 H_2(g) == 2 NH_3(g) \quad \Delta H = -92.4 \text{ kJ}$

66. In a closed 1.00 L container, 0.050 moles of $N_2(g)$ is reacted with 0.10 moles of $H_2(g)$ and 0.035 moles of NH_3 were produced at equilibrium. What was the percent yield?

(A) 35%   (B) 44%   (C) 53%   (D) 70%

67. Calculate K_c for the reaction in the 1.00 L container.

(A) 0.025   (B) 23   (C) 350   (D) 470

68. Which of the following changes would increase the yield of the NH_3?

I increase volume   II decrease volume
III increase pressure   IV decrease pressure
V increase temperature   VI decrease temperature

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

69. Which of the following pairs, when mixed, will produce a visible change?

I KOH (aq) and HCl (aq)
II $Pb(NO_3)_2$ (aq) and HCl (aq)
III HNO_3 (aq) and Cu(s)
IV $Cu(NO_3)_2$ (aq) and NH_3 (aq)

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

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

TIE BREAKER to be graded if your score is 40 or above.   Box in your answer to each part. 2 Pts each

Nitrogen dioxide gas is placed in a 5.00 L steel bomb until the pressure is 2.89 atm at 400 K. The bomb is heated to 800 $^{\circ}$C, some of the NO_2 decomposes and the pressure measures 8.01 atm. The following equilibrium is established:

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

Assume that the gases behave ideally.

(a) Calculate the number of moles of NO_2 that were placed in the steel bomb.
(b) How many moles of NO_2, NO and O_2 are in the bomb at 800 K?
(c) Calculate the number of moles of NO_2 that decomposed at 800 K.
(d) Calculate the partial pressure of each gas at 800 K.
(e) Calculate the equilibrium constant K_c for the reaction at 800 K.

2004 Virginia Section Chemistry Olympiad
Answer Sheet

First Year Exam

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

Tiebreaker answers:

(a) 0.440 moles

(b) 0.610 moles

(c) NO_2 0.100 moles, NO 0.340 moles O_2 0.170 moles

(d) NO_2 1.31 atm., NO 4.46 atm. O_2 2.23 atm.

(e) $K_c = 0.393$