Part I

1. The prefix meaning 1/10 of a unit is:

(A) kilo (C) centi
(B) deci (D) milli

2. The correct name for the compound $BaSO_3$ is:

(A) barium sulfate
(B) barium sulfur trioxide
(C) barium trisulfide
(D) barium sulfite

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

(A) atmospheres (C) torrs
(B) cubic centimeters (D) mm Hg

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) equilibrium constant
(C) freezing point (D) molarity
(E) molecular mass

4. Can be expressed in moles per liter of solution

5. Can be expressed in grams per liter

6. Will *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 represents a chemical change?

I rusting II subliming III condensation
IV burning V fermenting

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

9. The chemical formula of calcium chlorate is:

(A) $Ca(ClO_3)_2$ (C) $Ca_3(ClO_3)_2$
(B) $CaClO_3$ (D) $CaClO_2$

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

(A) 241.9 g/mol (C) 193.9 g/mol
(B) 229.6 g/mol (D) 117.9 g/mol

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

I 64.073 + 7.219 = 71.3
II (3.793)(0.0326) = 0.124
III 12.48/3.735 = 3.341
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

12. The mass % of C in sucrose, common table sugar, $C_{12}H_{22}O_{11}$ is:

(A) 26.7% (B) 37.6% (C) 42.1% (D) 51.4%

13. The number of oxygen atoms in 8.49 grams of K_3PO_4, 212.3 g/mol, is

(A) 4 (C) 9.63×10^{22}
(B) 2.41×10^{22} (D) 1.51×10^{25}

14. Which of the following elements exist as *gaseous diatomic* molecules at room temperature?

I nitrogen II hydrogen III chlorine
IV neon V iodine

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

15. Which of the following statements are correct for chemical reactions?

I The sum of the reactant atoms equals the sum of the product atoms
II For endothermic reactions the sum of the energy of the reactant moles equals the sum of the energy of the product moles
III The sum of the mass of the reactants equals the sum of the mass of the products
IV A chemical reaction may require or release heat, depending on the reactants and products

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

16. The sum of the coefficients for the reaction:

$$Al_4C_3 + HCl \rightarrow AlCl_3 + CH_4$$

when using whole numbers is:

(A) 7 (B) 13 (C) 20 (D) 23

17. When 8.34 g of Li_3N react with an excess of H_2O how many grams of LiOH are produced by the reaction:

$$Li_3N + 3H_2O \rightarrow 3LiOH + NH_3$$

(A) 25.0 gm (C) 9.77 gm
(B) 17.2 gm (D) 1.91 gm

18. A compound of oxygen and manganese contains 69.6% manganese by mass. What is the empirical formula for this compound?

(A) MnO (C) Mn_2O_3
(B) MnO_2 (D) Mn_3O_4

19. The number of molecules in 2.00 L of helium gas at STP are:

(A) 3.01×10^{23} (C) 2.69×10^{22}
(B) 5.38×10^{22} (D) 2.46×10^{22}

20. A gas occupies 40.0 mL at 10^{o} C and 745 mm Hg. and has a mass of 0.120 gm. The gas may be:

(A) chlorine (C) bromine
(B) argon (D) krypton

21. A gas in a cylinder with a moveable piston occupies 145 mL at 25^{o}C and exerts a pressure of 750 mm Hg. The gas is heated to 60^{o}C, when the gas volume is 160 mL, what is the pressure the gas exerts on the piston?

(A) 1631 mm Hg (C) 770 mm Hg
(B) 821 mm Hg (D) 760 mm Hg

22. Given the following compounds with their vapor pressures at 40^{o}C, arrange them in order of increasing normal boiling point.

I 2-bromopropane, 385 torr
II trans 1,2 dichloroethene, 653 torr
III ethanol, 105 torr

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

23. 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 liquid phase than in the gas phase
III The heat of melting is greater than the heat of vaporization
IV The liquid phase is more dense than the solid phase

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

24. Which of the following conditions will increase the solubility of a gas in water?

(A) all of the below
(B) decrease the water temperature
(C) decrease the volume of the gas
(D) increase the pressure of the gas

25. A solid is insoluble in water. It does not conduct electricity in the solid state but does conduct electricity when melted. What type of solid is it?

(A) ionic (C) metallic
(B) molecular (D) network covalent

26. Which of the following depend on the number of particles in a solution?

I freezing point II Tyndal effect
III vapor pressure

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

27. How many grams of $CaCl_2$, 111 g/mol, are needed to make 200.0 mL of a 0.150 M solution of $CaCl_2$?

(A) 3.70 g (C) 0.0833 g
(B) 3.33 g (D) 0.0300 g

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

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

29. A $^{59}_{27}Co^{2+}$ ion has:

	protons	neutrons	electrons
(A)	27	32	25
(B)	27	30	25
(C)	25	34	27
(D)	27	32	27

30. Which of the following are generally characteristic properties of non-metals?

I high ionization energy III form negative ions
II low electronegativity IV reacts with other non-metals

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

31. Which statement concerning the structure of atoms is correct?

(A) Protons and neutrons have most of the mass and volume.
(B) Electrons have most of the mass and volume
(C) Electrons have most of the mass but little of the volume.
(D) Protons and neutrons have most of the mass but little of the volume.

32. The shape of a 2p orbital is:

(A) spherical (C) tetrahederal
(B) dumbbell (D) oval

The answers for questions 33 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

33. The bond responsible for water's high boiling point

34. The type of bonds in SO_3

35. The strongest bond listed above

36. Generally in going from left to right across the third row of the periodic table (Na to Ar) the:

(A) metallic character and electronegativity decreases
(B) ionization energy and electronegativity increases
(C) ionization energy and atomic radii decreases
(D) electronegativity and ionic radii increases

37. Which statements regarding first ionization energies are true?

I O is greater than C III Ca is greater than Mg
II F is greater than He IV N is greater than Si

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

38. When descending Group 15 (VA) the elements go from:

(A) non-metal to metalloid to metallic
(B) metalloid to non-metal to metallic
(C) metallic to non-metal to metalloid
(D) non-metal to metalic to metalloid

39. The *best* explanation why argon does not form a di-atomic molecule is:

(A) its atomic radius is too large
(B) its ionization energy is too high
(C) noble gases do not form chemical bonds
(D) it has a completed electron valence shell

40. The electron configuration of iron is:

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

41. Which of the following is the weakest bond?

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

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 of the following aqueous solutions has the *lowest* freezing point?

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

44. In the laboratory oxygen can be prepared by the following reaction.

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

How many liters of $O_2(g)$, at 25^oC and 1.00 atm, can be prepared from 0.500 moles of $KClO_3$?

(A) 12.2 L (B) 16.8 L (C) 18.3 L (D) 36.6 L

45. Calculate the heat released when 24.0 gm of NO is converted to NO_2 in the reaction:

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

(A) 113 kJ (C) 56.5 kJ
(B) 90.4 kJ (D) 45.2 kJ

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

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

47. Helium is preferred to hydrogen for filling balloons because it is:

(A) more available (C) lighter
(B) chemically inert (D) cheaper to produce

48. Which metal must be combined with chromium to produce a steel?

(A) magnesium (C) cooper
(B) zinc (D) iron

49. When substance X is dissolved in water, the only positive ions in the solution are hydrogen ions. Substance X could be:

(A) NaOH (C) H_2S
(B) NaH (D) NH_3

50. A student was told to obtain 10.00 mL of water, as precisely as possible. The student should use a:

(A) volumetric flask (C) graduated cylinder
(B) volumetric beaker (D) volumetric pipet

PART II

51. Calculate the density of SF_6 gas at $-50\ ^oC$ and 735 mm Hg.

(A) 7.72×10^{-3} g/cm^3 (C) 4.04×10^{-3} g/cm^3
(B) 6.52×10^{-3} g/cm^3 (D) 3.09×10^{-3} g/cm^3

52. Which set of reactants produces a gaseous product?

I 6M $HNO_3(aq)$ + Cu(s)
II 6M $HCl(aq)$ + $Na_2CO_3(s)$

(A) I only (C) I and II
(B) II only (D) neither I or II

53. When 1.363 g of the oxide X_2O_3 are treated with hydrogen gas, 0.967 g of an unknown metal are formed. What is the atomic mass of the metal X?

(A) 117 g/mol (C) 26.0 g/mol
(B) 58.6 g/mol (D) 19.5 g/mol

54. When one volume of nitrogen and two volumes of hydrogen, at the same temperature and pressure, react to make NH_3:

(A) both are consumed and the volume of ammonia formed is twice the initial volume of the nitrogen.
(B) both are consumed and the volume of ammonia formed is the same as the initial volume of the hydrogen.
(C) nitrogen is the limiting reagent and hydrogen is in excess
(D) hydrogen is the limiting reagent and nitrogen is in excess

55. 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^oC and the mass is 63.917 g, The atmospheric pressure is 748 mm Hg. Calculate the molar mass of the liquid.

(A) 122 g/mol (C) 44.0 g/mol
(B) 84.9 g/mol (D) 18.0 g/mol

56. When 28.0 L of $H_2S(g)$ at STP are reacted with 62.8 g of O_2, how many grams of H_2O are formed from the reaction:

$$2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ SO_2(g) + 2\ H_2O(g)$$

(A) 14.8 g H_2O (C) 22.5 g H_2O
(B) 19.8 g H_2O (D) 23.6 g H_2O

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

$$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$$

I Potassium II Chlorine III Sulfur

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

58. Which of these electron diagrams could represent the ground state of the d electrons of nickel

(A) __ __ __ __ __ (C) __ __ __ __ __
(B) __ __ __ __ __ (D) __ __ __ __ __

59. Which of the following statements are correct?

I In a family of elements, the largest atom has the highest electronegativity
II In the third row of elements the halogen element has the highest 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) II and III only (D) II, III and IV only

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

I NH_3 II CO_2 III H_2O
IV OF_2 V CBr_4

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

61. Which of the following are exothermic reactions?

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. When 1.00 gm of $AlCl_3$, 133.3 g/mol, is dissolved in enough water to make 0.300 L of solution, what is the molarity of the Cl^- ions in the solution?

(A) 7.50×10^{-2} M (C) 1.25×10^{-2} M
(B) 2.50×10^{-2} M (D) 7.50×10^{-3} M

63. Which of the following HCl solutions has a pH of 1.0?

(A) 0.10 M HCl (C) 1.0 M HCl
(B) 0.50 M HCl (D) 2.0 M HCl

64. Which of the following reactions is fastest at room temperature?

(A) $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
(B) $2H_2O_2(g) \rightarrow 2H_2O(g) + O_2(g)$
(C) $2NO(g) + Br_2(g) \rightarrow 2NOBr(g)$
(D) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

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.

66. Boron trichloride, BCl_3, is a planar molecule while NCl_3 is pyramidal can *best* be explained by:

(A) nitrogen is more electronegative than boron
(B) the nitrogen atom in NCl_3 has a lone pair of electrons and the boron atom in BCl_3 does not.
(C) the nitrogen atom is smaller than the boron atom
(D) the boron atom in BCl_3 is hybridized sp^3 and the nitrogen atom in NCl_3 is hybridized sp^2

The heterogeneous equilibrium system below is used for questions 67 and 68

$$C(s) + CO_2(g) == 2CO(g) \quad \Delta H = 120kJ$$

67. Which of the following will shift the equilibrium to the product?

(A) add more C(s)
(B) decrease the temperature
(C) decrease the pressure on the system
(D) add more $CO_2(g)$

68. The equilibrium constant expression is:

(A) $K = \frac{[CO]^2}{[C][CO_2]}$ (C) $K = \frac{2[CO]}{[CO_2]+[C]}$

(B) $K = \frac{[CO_2] + [C]}{[CO]}$ (D) $K = \frac{[CO]^2}{[CO_2]}$

69. In the reaction:

$$NH_3(g) + H_2O(l) == NH_4^+(aq) + OH^-(aq)$$

Which pair are Bronsted-Lowry bases?

(A) NH_3 and NH_4^+ (C) H_2O and NH_4^+
(B) NH_3 and OH^- (D) H_2O and OH^-

70. When balanced

$$Sn^{2+}(aq) + MnO_4^-(aq) + H^+(aq) \rightarrow Sn^{4+}(aq) + Mn^{2+}(aq) + H_2O(l)$$

The equations Sn^{2+}/MnO_4^- ratio will be:

(A) 1/1 (B) 2/1 (C) 3/2 (D) 5/2

TIE BREAKER to be graded if your score is 40 or above. Do on the back of your answer sheet. Box in your answer to each part. 2 Pts each

Phosphorous pentachloride is added to a 1.00 L steel cylinder until the pressure is 13.2 atm at 180 ^{o}C. When the cylinder is heated to 427 ^{o}C, some of the PCl_5 decomposes and the pressure measures 24.2 atm. The following equilibrium is established:

$$PCl_5(g) == PCl_3(g) + Cl_2(g)$$

Assume that the gases behave ideally.

(a) Calculate the number of moles of PCl_5 that were placed in the steel bomb.
(b) Calculate the number of moles of PCl_5 that decomposed at 427 ^{o}C.
(c) How many moles of PCl_5, PCl_3 and Cl_2 are in the bomb at 427 ^{o}C?
(d) Calculate the partial pressure of each gas at 427 ^{o}C.
(e) Calculate the equilibrium constant K_c for the reaction at 427 ^{o}C.

2002 Virginia Section Chemistry Olympiad

Answer Sheet

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