AMERICAN CHEMICAL SOCIETY

2003 VIRGINIA SECTION

CHEMISTRY OLYMPIAD

FIRST YEAR EXAM

Prepared by John Comerford

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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 that sheet. The tiebreaker is answered on the sheet and turned in with the answer sheet. Each student should be provided with an answer sheet and scratch paper, both of which must be turned in with the test booklet on completion of the exam.

Students are allowed to use programmable calculators and should be given 120 minutes to complete the exam. A Periodic Table, explanation of abbreviations, constants and equations are provided on page two of the exam. You may wish to explain the meaning of the notation L atm mol^{-1} K^{-1} to the students.

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO

This is a 70 question multiple-choice exam with four or five choices in Part I and four choices in Part II to each question and a tie-breaker that will be graded if your score is at least 40. 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. Answer the tiebreaker on the back of the answer sheet. You have 120 minutes to complete the exam.

The Part I, first 50 questions, will be scored on the number of correct answers. It is to your advantage to answer all of the Part I questions. The Part II, questions 51 through 70, will be scored on the number of correct answers. Credit is given for each part of the tiebreaker answered correctly.

Part I

1. Of the following, the simplest form of matter is:

   (A) a mixture   (C) an element
   (B) a liquid   (D) a solid

2. The correct name for the compound Na_2SO_3 is:

   (A) disodium sulfur trioxide
   (B) disodium sulfide trioxide
   (C) sodium sulfite
   (D) sodium sulfate

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

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

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

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

5. Which separation process depends on the differences in vapor pressures of the substances?

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

6. A student needs to measure 13.2 mL of water. Which piece of equipment will measure the volume most accurately?

   (A) 20 mL beaker
   (B) 25 mL volumetric flask
   (C) 25 mL graduated beaker
   (D) 25 mL graduated cylinder

7. The chemical formula of calcium phosphate is:

   (A) $Ca(PO_3)_2$ (C) Ca_2PO_3
   (B) $CaPO_4$ (D) $Ca_3(PO_4)_2$

8. The molar mass of chromium(III) sulfide is:

   (A) 200.2 g/mol   (C) 148.2 g/mol
   (B) 188.1 g/mol   (D) 84.1 g/mol

9. The % mass of O in $Sr(NO_3)_2$ is:

   (A) 32.1%   (C) 57.2%
   (B) 45.4%   (D) 66.7%

10. The number of potassium atoms in 87.2 grams of dipotassium trisulfide, K_2S_3 is:

    (A) 2   (C) 3.01×10^{23}
    (B) 1.50×10^{23} (D) 6.02×10^{23}

11. An 8.36 gm sample of nicotine contains 6.19 gm of C, 0.727 gm of H and 1.44 gm of N. The empirical formula of nicotine is:

    (A) C_8HN_2 (C) $C_7H_{10}N_2$
    (B) C_5H_7N (D) $C_{10}H_{13}N_2$

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

    I The sum of the reactant atoms equals the sum of the product atoms
    II The sum of the reactant moles equals the sum of the product moles
    III The sum of the mass of the reactants equals the sum of the mass of the products
    IV For ionic reactions the sum of the reactant charges equals the sum of the product charges

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

13. How many moles of copper are produced when 5.38 g of iron are reacted with an excess of copper nitrate solution in the reaction:

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

    (A) 0.0642 mol   (C) 0.0963 mol
    (B) 0.0772 mol   (D) 0.144 mol

14. For the reaction:

    $$NH_3 + F_2 \rightarrow N_2F_4 + HF$$

    The sum of the coefficients, for the balanced equation, using whole numbers is:

    (A) 12   (B) 14   (C) 16   (D) 17

15. Calculate the mass of 500 mL of oxygen gas at STP.

    (A) 0.178 g   (C) 0.714 g
    (B) 0.357 g   (D) 1.07 g

16. A gas occupies 60.0 mL at 20°C and 770 mm Hg. What volume will it occupy at 40°C and 735 mm Hg?

    (A) 58.8 mL   (C) 67.1 mL
    (B) 61.2 mL   (D) 115 mL

17. When equal volumes of hydrogen and chlorine gas, at the same temperature and pressure, react to form hydrogen chloride:

   (A) both are consumed and the volume of hydrogen chloride formed is the same as the volume of chlorine consumed
   (B) chlorine is the limiting reagent and the hydrogen is in excess
   (C) hydrogen is the limiting reagent and chlorine is in excess.
   (D) neither hydrogen nor chlorine is in excess

18. What volume of H_2 gas at STP is produced when 4.65 gm of Na are reacted with an excess of H_2O in the reaction:

   $$2\, Na\ +2\, H_2O\ \rightarrow\ H_2\ +2\, NaOH$$

   (A) 9.06 L   (C) 2.26 L

   (B) 4.53 L   (D) 1.14 L

19. A tank contains equal quantities of CO and N_2 gas at the same T and P.

   (A) They both have the same average speed
   (B) The CO molecules have a greater average speed than the N_2 molecules
   (C) The N_2 molecules have a greater average speed than the CO molecules
   (D) The relative speeds of N_2 molecules and CO molecules can't be determined without knowing the T in the tank.

20. 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

21. 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

22. Which of the following substances has particles with the highest average kinetic energy?

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

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

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

24. The melting point of a solid is *most* dependent on which of the following properties?

   (A) malleability   (C) molecular mass
   (B) bonding structure   (D) hardness

25. 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) NH_3 (C) $MgBr_2$
   (B) CCl_4 (D) SiO_2

26. How many grams of $Cu(NO_3)_2 \cdot 3H_2O$, needed to make 200.0 mL of a 0.150 M solution of $Cu(NO_3)_2$?

   (A) 0.030 g   (C) 7.25 g
   (B) 5.63 g   (D) 8.05 g

27. When a KNO_3 solution is added to an NH_4Cl solution:

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

28. Which element has the outer electron configuration s^2p^3?

   (A) Ca   (B) V   (C) Ga   (D) As

29. The reason why only two electrons can occupy an orbital is stated by the:

   (A) uncertainty principle
   (B) Hund's rule
   (C) wave-particle duality principle
   (D) Pauli exclusion principle

30. An antacid must have which of the following properties?

   (A) be a base   (C) neutralize bases
   (B) be an acid   (D) be a neutral compound

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) K   (B) Ti   (C) Mn   (D) Ga   (E) Br

31. The element with the *lowest* electronegativity

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

33. The element that can form the compound X_2O_3

34. The element with the *largest* ionic radius

35. The element with the *lowest* first ionization energy

36. 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 increases

37. When the following substances N_2O_3, NO, N_2, and NH_3 are arranged in order of *increasing* oxidation number of N the order is:

   (A) N_2. NO, $N_2O_3 = NH_3$
   (B) NH_3, N_2, NO, N_2O_3
   (C) N_2O_3, NO, N_2, NH_3
   (D) $NH_3 = N_2O_3$, NO, N_2

38. When two atoms 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) half-filled orbitals in each atom results.

39. The *best* explanation why helium 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

40. Which of the following combinations are most likely to form predominantly ionic bonds?

   I rubidium-chlorine   III silicon-oxygen
   II hydrogen-oxygen   IV bromine-fluorine
               V barium-chlorine

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

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

   (A) $H_4C_2Cl_2$ (C) NO_3^-
   (B) NH_4Cl (D) PF_3

42. Which of the following is the weakest bond?

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

43. Which of the following aqueous solutions has the highest boiling point?

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

44. When the potential energy of the products of a reaction is more than the potential energy of the reactants, the reaction always:

   (A) is endothermic
   (B) has a slow reaction rate
   (C) has a fast reaction rate
   (D) has a low activation energy

45. The following is a list of compounds and their ΔH_f values in kJ/mol. Which compound is thermodynamically the least stable?

   (A) $H_2O(g)$ − 242   (C) $NO_2(g)$ + 34
   (B) $NH_3(g)$ − 46   (D) $NO(g)$ + 110

46. Using the information in 45 above, calculate the change in the enthalpy for the reaction:

   $4\,NH_3(g) + 7\,O_2(g) \rightarrow 4\,NO_2(g) + 6\,H_2O(g)$

   (A) −1500 kJ   (C) −162 kJ
   (B) −1132 kJ   (D) 1500 kJ

47. Entropy is an expression of the :

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

48. Which milligram quantity has three significant figures?

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

49. For the following equilibrium reaction

   $H_2(g) + I_2(g) == 2\,HI(g)\ \ \Delta H = 52$ kJ

Which of the following changes will shift the equilibrium towards the HI?

   I   increase the pressure
   II add $H_2(g)$ to the reaction
   III decrease the temperature
   IV remove $HI(g)$ from the reaction

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

50. A student determines the experimental value of the molecular weight of a compound to be 86.83 g/mol. The accepted value for the compound is 84.16 g/mol. The percent error is:

   (A) 3.17%   (C) 2.94%
   (B) 3.07%   (D) 2.67%

PART II

51. When 3.25 g of oxalic acid, $H_2C_2O_4 \cdot 2H_2O$, is heated to dryness how much dry oxalic acid would remain?

   (A) 2.71 g   (C) 2.32 g
   (B) 2.48 g   (D) 0.94 g

52. When 1.269 g of an unknown metal react with oxygen 1.363 g of the oxide X_2O are formed. The metal is:

   (A) cesium, Cs   (C) thallium, Tl
   (B) silver, Ag   (D) lead, Pb

53. 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 $KClO_3$, 122.6 g/mol, must react to produce 1.50 L of Cl_2 at STP?

   (A) 2.74 g   (C) 8.20 g
   (B) 5.47 g   (D) 18.4 g

54. Which gas *most* behaves like an ideal gas?

   (A) C_2H_6 (B) CF_4 (C) H_2 (D) NH_3

55. A 0.160 g sample of gas was collected in a 100 mL flask at 18 °C. The gas exerted a pressure of 725 mmHg. The gas is:

   (A) fluorine   (C) hydrogen sulfide
   (B) chlorine   (D) argon

56. Which terms are correctly matched for a liquid at 25 °C?

   (A) low boiling point   high ΔH_{vap} value
   (B) high boiling point   low vapor pressure
   (C) high boiling point   high vaporization rate
   (D) high ΔH_{vap} value   high vapor pressure

57. The central atom contains one or more pairs of unshared electrons in which of the following?

   I NH_4^+ II SF_4 III CO_2
      IV OF_2 V CBr_4

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

58. Which of the following statements are correct?

   I In a family of elements, the largest atom has the lowest ionization energy
   II In a row of elements the elements further to the right have the lower ionization energies
   III The half-filled 3p orbital has a higher ionization energy than the $3p^2$ or the $3p^4$ electron configuration
   IV It is easier to form a +2 ion than a +1 ion

   (A) I and II only   (C) I, III and IV only
   (B) I and III only   (D) II, III and IV only
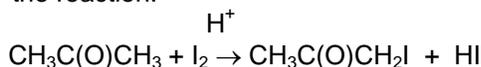
59. Which of the following are exothermic reactions?

    I $H_2O(s) \rightarrow H2O(l)$
    II $H_2O(g) \rightarrow H2O(l)$
    III $H(g) + H(g) \rightarrow H_2(g)$
    IV $NaCl(g) \rightarrow Na^+(g) + Cl^-(g)$

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

60. How many mL of 4.00 M HCl are needed to make 250.0 mL of a 0.200 M solution of HCl?

(A) 1.05 mL   (C) 12.5 mL
(B) 10.7 mL   (D) 32.1 mL

61. Propanone reacts with iodine in acid solution in the reaction:

$$\overset{H^+}{CH_3C(O)CH_3 + I_2 \rightarrow CH_3C(O)CH_2I + HI}$$

The following data were collected in the rate study

$[CH_3C(O)CH_3]$	$[I_2]$	$[H^+]$	Initial Rate
0.010	0.010	0.010	1
0.020	0.010	0.010	2
0.020	0.020	0.010	2
0.020	0.010	0.020	4

The rate equation for the reaction is:

(A) rate = $k[CH_3C(O)CH_3]^2[I_2]$
(B) rate = $k[CH_3C(O)CH_3]$
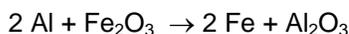(C) rate = $k[CH_3C(O)CH_3][I_2]^2$
(D) rate = $k[CH_3C(O)CH_3][I_2]$

62. Which of the following substances has the greatest solubility in water at $25^\circ C$?

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

63. Given the following reactions:

$2 Al + 3/2 O_2 \rightarrow Al_2O_3$ $\Delta H = -1674$ kJ
$2 Fe + 3/2 O_2 \rightarrow Fe_2O_3$ $\Delta H = -825$ kJ
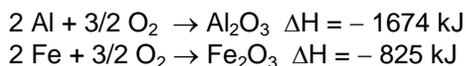
Calculate the heat of the thermite reaction:

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

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

64. The procedure used in determining the concentration of an acid by using a base of known concentration is called:

(A) titration   (C) neutralization
(B) salinization   (D) oxidation-reduction

65. The concentration of one of the listed molecules that helps prevent the loss of heat radiated from the earth's surface is greatly affected by human activity. Which molecule is it?

(A) NO_2 (B) O_3 (C) CO   (D) CO_2

66. Which of the following molecules has a trigonal pyramidal structure?

(A) BF_3 (B) NH_3 (C) CH_4 (D) BrF_3

67. For the equilibrium reaction:

$CO(g) + 2 H_2(g) \leftrightarrow CH_3OH(g)$ $K_c = 2.2 \times 10^2$
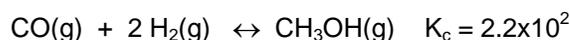
At equilibrium the CO concentration was 0.20 M and the H_2 concentration was 0.30 M Calculate the CH_3OH equilibrium concentration.

(A) 0.20 M   (C) 13 M
(B) 4.0M   (D) 26 M

68. Which of the following properties do acetic acid and its acetate ion have? Acetic acid $K_a = 1.8 \times 10^{-5}$

	Acetic acid	acetate ion
(A)	strong acid	strong base
(B)	strong acid	weak base
(C)	weak acid	strong base
(D)	weak acid	weak base

69. The sum of coefficients for the balanced equation:

$NO_3^- + I^- + H^+ \rightarrow NO + I_2 + H_2O$
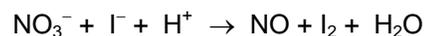
are:

(A) 31   (B) 25   (C) 17   (D) 13

70. A solution, which has a pH of 5.0:

(A) is basic
(B) has a hydrogen ion concentration 10^5 M
(C) has a hydroxide ion concentration 10^{-9} M
(D) is neutral

Name _____

Signature _____

TIE BREAKER.
Do the following problems, turn in with your answer sheet. <u>Box in your answer to each part.</u> 2 Pts each

    (A) A 4.081 gm sample of a compound containing carbon, hydrogen and chlorine was found to have 2,985 gm of Cl and 1.001 gm of carbon. What is the empirical formula of the compound?

    (B) A 3.728 gm sample of the compound was heated in a 1.00 L closed container. At 70 $^{\circ}$C the gas exerted a pressure of 1.083 atm. What is the molecular formula of the compound?

    (C) Draw an electron-dot diagram of the compound. You may use –– for bonds. Be sure and show all electrons.

    (D) In addition to the diagram you drew in (C) there is/are other structural isomers (same molecular formula but with different arrangements of the atoms) for the compound. Draw it or them.

    (E) Of the isomers you have drawn, in (C) and (D) above identify any that is/are non-polar.

2003 Virginia Section Chemistry Olympiad
Answer Sheet

First Year Exam

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