Practice Test 1

THE DIAGNOSTIC TEST

Note: For all questions involving solutions and/or chemical equations, assume that the system is in water unless otherwise stated.

Part A

Directions: Each set of lettered choices refers to the numbered statements or formulas that immediately follow it. Select the one lettered choice that best fits each statement or formula; then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1–4 refer to the periodic group shown as these elements are aligned in the periodic table. Letter choices are substituted for the respective elements.

	Halogen Group	
	(A)	
	(B)	
	(C)	
	(D)	
	(E)	

1. The element that is most active chemically
2. The element with the smallest ionic radius
3. The element with the lowest first ionization potential
4. The element that first shows some metallic properties at room temperature

Questions 5–7

(A) X^+
(B) X^{2+}
(C) X^{3+}
(D) XO_3^{2-}
(E) XO_4^{2-}

5. A type of ion found in sodium acetate
6. A type of ion found in aluminum oxide
7. A type of ion found in potassium phosphate

Questions 8–12

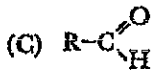
(A) Avogadro's number
(B) $P_1V_1 = P_2V_2$
(C) $V_1T_2 = V_2T_1$
(D) Dalton's Theory
(E) Gay-Lussac's Law

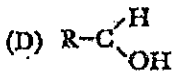
8. Proposes basic postulates concerning elements and atoms
9. Proposes a relationship between the combining volumes of gases with respect to the reactants and gaseous products
10. Proposes a temperature-volume relationship of gases
11. Proposes a concept regarding the number of particles in a mole
12. Proposes a volume-pressure relationship of gases

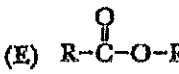
Questions 13–16

(A) R–OH

(B) R–O–R*

(C) 

(D) 

(E) 

(*Alkyl group that is not necessarily the same as R)

13. The organic structure designation that includes the functional group of an aldehyde
14. The organic structure designation that includes the functional group of an acid
15. The organic structure designation that includes the functional group of an ester
16. The organic structure designation that includes the functional group of an ether

Questions 17–21

(A) $H_2(g)$

(B) $CO_2(g)$

(C) $2N_2O(g)$

(D) 2NaCl (aq)

(E) $H_2SO_4(aq)$

17. The expression that can be used to designate a linear nonpolar molecule
18. The expression that can be used to designate 2 moles of atoms
19. The expression that can be used to designate 3 moles of atoms
20. The expression that can be used to designate 3 moles of ions
21. The expression that can be used to designate 6 moles of atoms

Questions 22–25

(A) Ionic substance

(B) Metallic substance

(C) Polar covalent molecule

(D) Nonpolar covalent molecule

(E) Aromatic organic structure

22. Carbon tetrachloride
23. Cesium chloride

24. Hydrogen chloride
25. Benzene

Part B

ON THE ACTUAL SAT II: CHEMISTRY TEST, THE FOLLOWING TYPE OF QUESTION MUST BE ANSWERED ON A SPECIAL SECTION (LABELED "CHEMISTRY") AT THE LOWER LEFT-HAND CORNER OF PAGE 2 OF YOUR ANSWER SHEET. THESE QUESTIONS ARE NUMBERED BEGINNING WITH 101 AND MUST BE ANSWERED ACCORDING TO THE FOLLOWING DIRECTIONS.

Directions: Each question below consists of two statements, I in the left-hand column and II in the right-hand column. For each question, determine whether statement I is true or false and whether statement II is true or false, and fill in the corresponding T or F ovals on your answer sheet. Fill in oval CE only if statement II is a correct explanation of statement I.

Sample Answer Grid:

CHEMISTRY *Fill in oval CE only if II is a correct explanation of I.

	I	II	CE*
101.	(T) (F)	(T) (F)	( )

101.	A catalyst can accelerate a chemical reaction	BECAUSE	a catalyst can decrease the activation energy required for the reaction to occur.
102.	Molten sodium chloride is a good electrical conductor	BECAUSE	sodium chloride in the molten state allows ions to move freely.
103.	Ice is less dense than liquid water	BECAUSE	water molecules are nonpolar.
104.	Two isotopes of the same element have the same mass number	BECAUSE	isotopes have the same number of protons.
105.	A saturated solution can be classified as dilute	BECAUSE	a solute can have a very low solubility in a solvent.
106.	Two liters of CO_2 can be produced by 1 gram of carbon burning completely	BECAUSE	the amount of gas evolved in a chemical reaction can be determined by using the mole relationship of the coefficients in the balanced equation.
107.	A reaction is at equilibrium when it reaches completion	BECAUSE	the concentrations of the reactants in a state of equilibrium equal the concentrations of the products.
108.	The anions in an electrochemical cell migrate to the cathode	BECAUSE	positively charged ions are attracted to the negatively charged cathode in an electrochemical cell.

109. A solution with pH = 5 has a higher concentration of hydronium ions than a solution with a pH = 3
BECAUSE pH is defined as $-\log [H^+]$.

110. An endothermic reaction can be spontaneous
BECAUSE both the enthalpy and the entropy changes affect the Gibbs free-energy change of the reaction.

111. Weak acids have small values for the equilibrium constant, K_a
BECAUSE the concentration of the hydronium ion is in the numerator of the K_a expression.

112. One mole of NaCl contains 2 moles of ions
BECAUSE NaCl is a stable salt at room temperature.

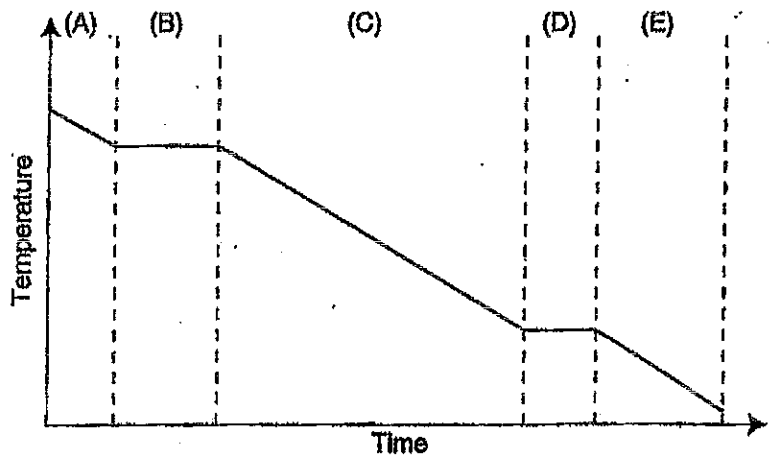
113. A pi bond is formed between the lobes of adjacent *p* orbitals in the same plane of two atoms that contain only one electron each
BECAUSE each of the two lobes of a single *p* orbital can hold two electrons of opposite spin.

114. H_2S and H_2O have a significant difference in their boiling points
BECAUSE hydrogen sulfide has a higher degree of hydrogen bonding than water.

Part C

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. In each case, select the one that is best and then fill in the corresponding oval on the answer sheet.

40. Two immissible liquids, when shaken together vigorously, may form
(A) a solution
(B) a tincture
(C) a sediment
(D) a hydrated solution
(E) a colloidal dispersion



41. A thermometer is used to record the cooling of a confined pure substance over a period of time. During which interval on the cooling graph above is the system undergoing a change of state from a liquid to a solid?

42. If a principal energy level of an atom contains 18 electrons, they will be arranged in orbitals according to the pattern
    (A) $s^0p^6d^6$
    (B) $s^2p^6d^{10}$
    (C) $s^2d^6f^{10}$
    (D) $s^2p^6f^{10}$
    (E) $s^2p^2f^{14}$

43. For a particular organic compound, which of the following pairs can represent the empirical and the molecular formula, respectively?
    (A) CH and CH_4
    (B) CH and C_6H_6
    (C) CH_2 and C_2H_2
    (D) CH_2 and C_2H_5
    (E) CH_3 and C_2H_6

44. A liter of hydrogen is at 5°C temperature and under 640 torr pressure. If the temperature were raised to 60°C and the pressure decreased to 320 torr, how would the liter volume be modified?

    (A) $1\text{L} \times \frac{5}{60} \times \frac{640}{32}$

    (B) $1\text{L} \times \frac{60}{5} \times \frac{320}{640}$

    (C) $1\text{L} \times \frac{278}{333} \times \frac{640}{320}$

    (D) $1\text{L} \times \frac{333}{278} \times \frac{640}{320}$

    (E) $1\text{L} \times \frac{333}{278} \times \frac{320}{640}$

45. Of the following statements about the number of subatomic particles in an ion of $^{32}_{16}S^{2-}$, which is (are) true?
    I. 16 protons
    II. 14 neutrons
    III. 18 electrons
    (A) II only
    (B) III only
    (C) I and II only
    (D) I and III only
    (E) I, II, and III

46. The most active metallic elements are found in
    (A) the upper right corner of the periodic chart
    (B) the lower right corner of the periodic chart
    (C) the upper left corner of the periodic chart
    (D) the lower left corner of the periodic chart
    (E) the middle of the periodic chart, just beyond the transition elements

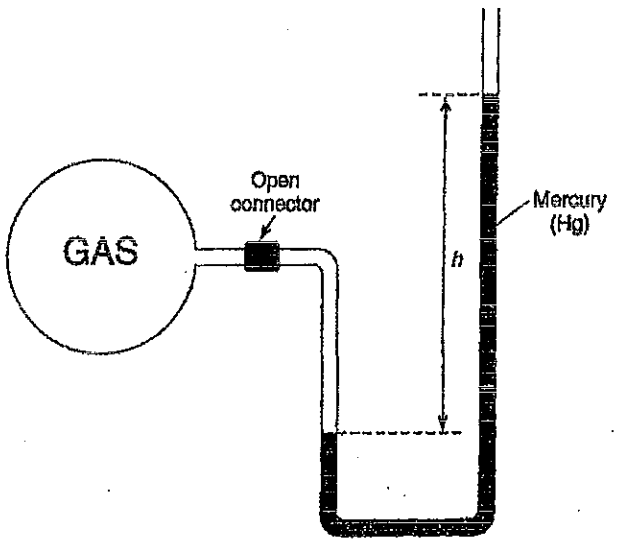
47. If 1 mole of each of the following substances was dissolved in 1,000 grams of water, which solution would have the highest boiling point?
    (A) NaCl
    (B) KCl
    (C) $CaCl_2$
    (D) $C_6H_{10}O_5$
    (E) $C_{12}H_{22}O_{11}$

48. A tetrahedral molecule, XY_4, would be formed if X were using the orbital configuration
    (A) p^2
    (B) s^2
    (C) sp
    (D) sp^2
    (E) sp^3

49. In the following reaction, how many liters of SO_2 at STP will result from the complete burning of pure sulfur in 8 liters of oxygen?

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

    (A) 1
    (B) 4
    (C) 8
    (D) 16
    (E) 32



50. In the above laboratory setup to measure the pressure of the confined gas, what will be true concerning the calculated pressure on the gas?
    (A) The gas pressure will be the same as the atmospheric pressure.
    (B) The gas pressure will be less than the atmospheric pressure.
    (C) The gas pressure will be greater than the atmospheric pressure.
    (D) The difference in the height (h) of mercury levels is equal to the pressure of the gas.
    (E) The height (h) of mercury has no effect on the pressure calculation since the column of mercury is only used to enclose the gas volume.

51. Which of the following changes in the experiment shown in question 50 would cause the pressure in the glass container to vary from that shown?
    (A) Use a U-tube of a greater diameter and maintain the height of mercury.
    (B) Increase the temperature of gas in the tube.
    (C) Increase the length of the upper portion of the right side of tubing.
    (D) Use a U-tube of a smaller diameter and maintain the height of mercury.
    (E) Replace the flask with one that has the same volume but has a flat bottom.

52. Which of the following can be classified as amphoteric?
    (A) Na_3PO_4
    (B) HCl
    (C) NaOH
    (D) HSO_4^-
    (E) $C_2O_4^{2-}$

53. Standard conditions (STP) are
    (A) 0°C and 2 atm
    (B) 32°F and 76 torr
    (C) 273 K and 760 mm Hg
    (D) 4°C and 7.6 cm Hg
    (E) 0 K and 760 mm Hg

54. Laboratory results showed the composition of a compound to be 58.81% barium, 13.73% sulfur, and 27.46% oxygen. What is the empirical formula of the compound?
    (A) $BaSO_4$
    (B) BaS_2O
    (C) Ba_2SO_3
    (D) BaS_2O_4
    (E) Ba_2SO_4

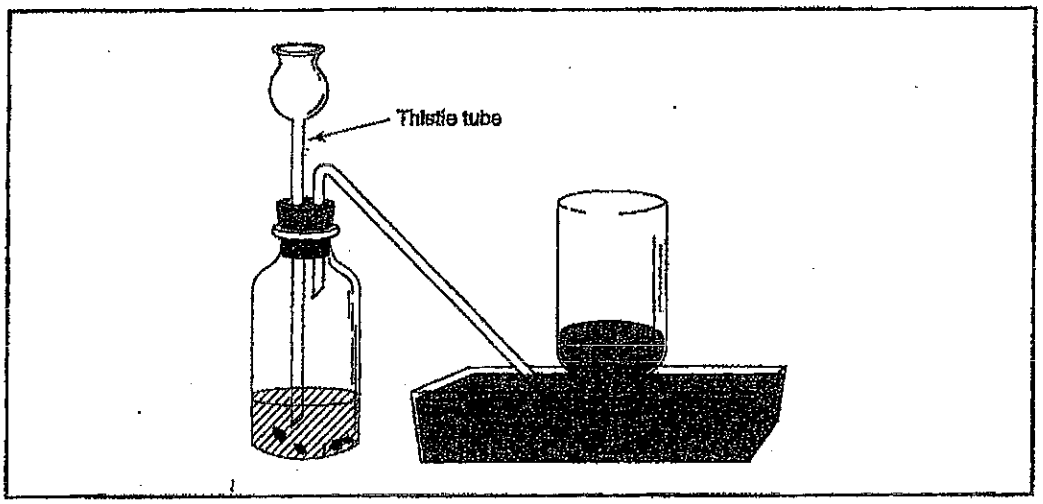
55. What is the percentage composition of calcium in calcium hydroxide, $Ca(\overline{OH})_2$? (1 mol = 74 g)
    (A) 40%
    (B) 43%
    (C) 54%
    (D) 69%
    (E) 74%

56. How many grams of hydrogen gas can be produced from the following reaction if 65 grams of zinc and 65 grams of HCl are present in the reaction?

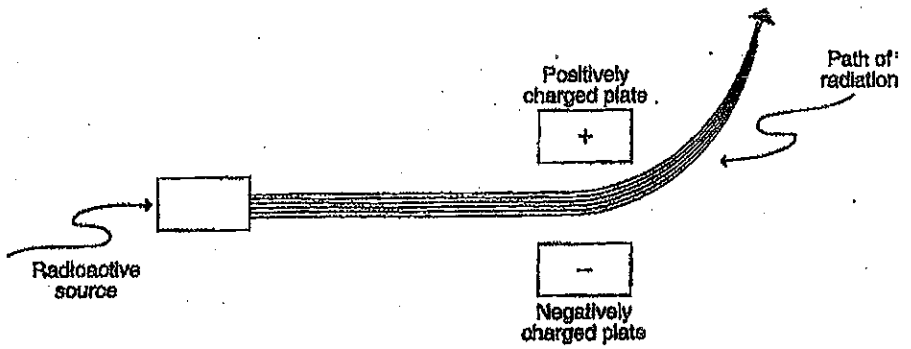
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

(A) 1
(B) 1.8
(C) 3.6
(D) 7
(E) 58

57. The following statements were recorded while preparing carbon dioxide gas in the laboratory. Which one involves an interpretation of the data rather than an observation?
(A) No liquid was transfered from the reaction bottle to the beaker.
(B) The quantity of solid minerals decreased.
(C) The cloudiness in the last bottle of limewater was caused by the product of the reaction of the colorless gas and the limewater.
(D) The bubbles of gas rising from the mineral remained colorless throughout the experiment.
(E) There was a 4°C rise in temperature in the reaction vessel during the experiment.



58. The above laboratory setup can be used to prepare which of the following?
I. $CO_2(g)$
II. $H_2(g)$
III. $NO(g)$
(A) I only
(B) III only
(C) I and III only
(D) II and III only
(E) I, II, and III



59. In the experiment diagrammed above, the radiation emitted by the source is probably
(A) ${}^{0}_{-1}e$
(B) ${}^{4}_{2}He$
(C) ${}^{1}_{2}H$
(D) a gamma ray
(E) ${}^{0}_{1}e$

60. Which of the following is (are) true regarding the aqueous dissociation of HCN, $K_a = 4.9 \times 10^{-10}$, at 25°C?
I. At equilibrium, $[H^+] = [CN^-]$.
II. At equilibrium, $[H^+] > [CN^-]$.
III. HCN(aq) is a strong acid.
(A) I only
(B) II only
(C) I and II only
(D) I and III only
(E) I, II, and III

61. This question pertains to the reaction represented by the following equation:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) + 150 \text{ kilojoules}$$

Suppose that 0.8 mole of NO is converted to NO_2 in the above reaction. What amount of heat will be evolved?
(A) 30 kJ
(B) 60 kJ
(C) 80 kJ
(D) 130 kJ
(E) 150 kJ

62. How does a Brønsted-Lowry acid differ from its conjugate base?
(A) The acid has one more proton.
(B) The acid has one less proton.
(C) The acid has one more electron.
(D) The acid has one less electron.
(E) The acid has more than one additional proton.

63. Two containers having 1 mole of hydrogen gas and 1 mole of oxygen gas, respectively, are opened. What will be the ratio of the rate of effusion of the hydrogen to that of the oxygen?
(A) $\sqrt{2}:1$
(B) 4 : 1
(C) 8 : 1
(D) 16 : 1
(E) $\sqrt{32}:1$

64. A molecule in which the electron configuration is a resonance hybrid is
(A) SO_2
(B) C_2H_6
(C) Cl_2
(D) HBr
(E) NaCl

65. What is the pH of a solution in which the $[OH^-]$ is 1.0×10^{-4}?
(A) −4
(B) +4
(C) +7
(D) −10
(E) +10

66. If 0.365 gram of hydrogen chloride is dissolved to make 1 liter of solution (Cl = 35.5 and H = 1), the pH concentration of the solution is
(A) 0.001
(B) 0.01
(C) 1
(D) 2
(E) 12

67. In the laboratory, a sample of hydrated salt was heated at 110°C for 30 minutes until all the water was driven off. The data were as follows:

Mass of the hydrate before heating = 250 grams
Mass of the hydrate after heating = 160 grams

From these data, what was the percent of water by mass in the original sample?
(A) 26.5
(B) 36
(C) 47
(D) 56
(E) 90

68. Which of the following oxides dissolves in water to form an acidic solution?
(A) Na_2O
(B) CaO
(C) Al_2O_3
(D) ZnO
(E) SO_3

69. In the laboratory, 20.0 milliliters of an aqueous solution of calcium hydroxide, $Ca(OH)_2$, was used in a titration. A drop of phenolphthalein was added to it to indicate the end point. The solution turned colorless after 20.0 milliliters of a standard solution of 0.050 M HCl solution was added. What was the molarity of the $Ca(OH)_2$?
(A) 0.01 M
(B) 0.025 M
(C) 0.50 M
(D) 0.75 M
(E) 1.00 M

70. Which of the following reactions will NOT spontaneously go to completion?
(A) $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
(B) $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2(g)$
(C) $Ag^+ + HCl \rightarrow AgCl(s) + H^+$
(D) $Cu + 2H^+ \rightarrow Cu^{2+} + H_2$; $E^0 = -0.34$ V
(E) $H_2SO_4 + 2NaOH \rightarrow 2Na_2SO_4 + 2H_2O$

71. For a laboratory experiment, a student placed sodium hydroxide crystals on a watch glass, assembled the titration equipment, and prepared a solution of 0.10 M sulfuric acid. Then he weighed 4 grams of sodium hydroxide and added it to enough water to make 1 liter of solution. What might be a source of error in the results of the titration?
(A) Some sulfuric acid evaporated.
(B) The sulfuric acid became more concentrated.
(C) The NaOH solution gained weight, thus increasing its molarity.
(D) The NaOH crystals gained H_2O weight, thus making the solution less than 0.1 M.
(E) The evaporation of sulfuric acid solution countered the absorption of H_2O by the NaOH solution.

72. If 60 grams of NO is reacted with sufficient O_2 to form NO_2 that is removed during the reaction, how many grams of NO_2 can be produced? (Molar masses: NO = 30 g/mol, NO_2 = 46 g/mol)
(A) 46
(B) 60
(C) 92
(D) 120
(E) 180

73. Based on the information shown, each of the following equations represents a reaction in which the entropy, ΔS, is positive EXCEPT
(A) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
(B) $Zn(s) + 2H^+(aq) \rightarrow H_2(g) + Zn^{2+}(aq)$
(C) $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$
(D) $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$
(E) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

74. $Cl_2(g) + 2Br^-$ (excess) $\rightarrow$?

When 1 mole of chlorine gas reacts completely with excess KBr solution, as shown above, the products obtained are

(A) 1 mol of Cl^- ions and 1 mol of Br^-
(B) 1 mol of Cl^- ions and 2 mol of Br^-
(C) 1 mol of Cl^- ions and 1 mol of Br_2
(D) 2 mol of Cl^- ions and 1 mol of Br_2
(E) 2 mol of Cl^- ions and 2 mol of Br_2

75. Two water solutions are made in the laboratory, one of glucose (molar mass = 180 g/mol), the other of sucrose (molar mass = 342 g/mol). If the glucose solution had 180 grams in 1,000 grams of water and the sucrose had 342 grams in 1,000 grams of water, which statement about the freezing points of the solutions is the most accurate?

(A) The glucose solution would have the lower freezing point.
(B) The sucrose solution would have the lower freezing point.
(C) The freezing point of the sucrose solution would be lowered twice as much as that of the glucose solution.
(D) Both solutions would have the same freezing point.
(E) The freezing points of the solutions would not be affected, because both solutes are nonpolar.

76. Which K_a value indicates the strongest acid?

(A) 1.3×10^{-2}
(B) 6.7×10^{-5}
(C) 5.7×10^{-10}
(D) 4.4×10^{-7}
(E) 1.8×10^{-16}

77. What mass of $CaCO_3$ is needed to produce 11.2 liters of CO_2 when the calcium carbonate is reacted with an excess amount of hydrochloric acid? (Molar masses: $CaCO_3$ = 100 g/mol, HCl = 36.5 g/mol, CO_2 = 44 g/mol)

(A) 25 g
(B) 44 g
(C) 50 g
(D) 100 g
(E) none of the above

78. By experimentation it is found that a saturated solution of $BaSO_4$ at 25°C contains 3.9×10^{-5} mole/liter of Ba^{2+} ions. What is the K_{sp} of the $BaSO_4$?

(A) 1.5×10^{-4}
(B) 1.5×10^{-9}
(C) 1.5×10^{-10}
(D) 3.9×10^{-10}
(E) 39×10^{-9}

79. What is the ΔH^0 value for the decomposition of sodium chlorate, given the following information?

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

(ΔH_f^0 values: $NaClO_3(s)$ = −85.7 kcal/mol, $NaCl(s)$ = −98.2 kcal/mol, $O_2(g)$ = 0 kcal/mol)

(A) 12.5 kcal
(B) −12.5 kcal
(C) 173.9 kcal
(D) −173.9 kcal
(E) $\frac{3}{2}$(173.9 kcal)

80. To the equilibrium reaction shown below:

$$AgCl(s) \rightleftharpoons Ag^+ + Cl^-$$

a beaker of concentrated HCl (12 M) is slowly added. Which is the best description of what will occur?

(A) More salt will go into solution, and the K_{sp} will remain the same.
(B) More salt will go into solution, and the K_{sp} will increase.
(C) Salt will come out of the solution, and the K_{sp} will remain the same.
(D) Salt will come out of the solution, and the K_{sp} will decrease.
(E) No change in concentration will occur, and the K_{sp} will increase.

81. When the following redox equation is balanced and all coefficients are reduced to lowest whole-number terms, what is the coefficient of H_2O?

$$HCl + KMnO_4 \rightarrow H_2O + KCl + MnCl_2 + Cl_2$$

(A) 1
(B) 2
(C) 5
(D) 8
(E) 16

82. Each of the following systems is at equilibrium in a closed container. A decrease in the total volume of each container will increase the number of moles of product(s) for which system?

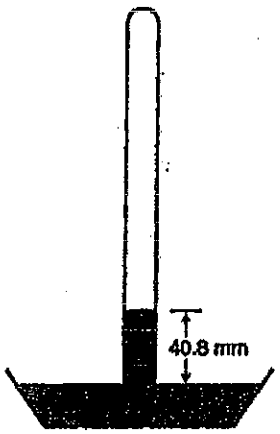
(A) $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$
(B) $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$
(C) $2NO(g) + O_2 \rightleftharpoons 2NO_2(g)$
(D) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$
(E) $Fe_3O_4(s) + 4H_2(g) \rightleftharpoons 3Fe(s) + 4H_2O(g)$

83. Which element(s), when forming an ionic bond, has (have) the following orbital notation?

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

I. Potassium
II. Sulfur
III. Chlorine

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



84. Hydrogen gas is collected in a eudiometer tube over water as shown above. The water level inside the tube is 40.8 millimeters higher than that outside. The barometric pressure is 730 millimeters Hg. The water vapor pressure at the room temperature of 29°C is found in a handbook to be 30.0 millimeters Hg. What is the pressure of the dry hydrogen?

(A) 659.2 mm Hg
(B) 689.2 mm Hg
(C) 697.0 mm Hg
(D) 740.8 mm Hg
(E) 800.8 mm Hg

85. How many moles of electrons are required to reduce 2.93 grams of nickel ions from melted $NiCl_2$? (Molar mass of Ni = 58.7 g/mol)

(A) 0.05
(B) 0.10
(C) 1.0
(D) 1.5
(E) 2.0

STOP

IF YOU FINISH BEFORE ONE HOUR IS UP, YOU MAY GO BACK TO CHECK YOUR WORK OR COMPLETE UNANSWERED QUESTIONS.

Practice T

ANSWERS AND EXPLANATIONS TO TEST

1. (A) In the halogen family, the most active nonmetal would be the top element, fluorine, because it has the highest electronegativity.
2. (A) As you proceed down a group, the ionic radius increases as additional energy levels are filled farther from the nucleus. Therefore fluorine, the top element, has the smallest ionic radius.
3. (E) Since astatine has the largest atomic radius and its outer electrons are shielded from the protons by a large number of interior electrons, it has the lowest first ionization potential.
4. (D) Some physical characteristics of metal are found in iodine, the fourth halogen down in the group.
5. (A) Sodium acetate has Na^+ and $C_2H_3O_2^-$ ions.
6. (C) Aluminum oxide has Al^{3+} and O^{2-} ions.
7. (A) Potassium phosphate has a K^+ and a PO_4^{3-} ion.
8. (D) John Dalton is credited with the basic postulates of atomic theory.
9. (E) Gay-Lussac is credited with the statement that, when gases combine, they do so in ratios of small whole numbers that are in relationship to the volumes of the reactants and the volumes of the products under the same conditions.
10. (C) Charles is credited with this temperature-volume relationship of gases:

    $\frac{V_1}{V_2} = \frac{T_1}{T_2}$ or $V_1T_2 = V_2T_1$ as shown in the question.

11. (A) Avogadro is credited with the concept regarding the number of particles in a mole, 6.02×10^{23}, and this number bears his name.
12. (B) Boyle is credited with the $P_1V_1 = P_2V_2$ relationship of gases.
13. (C) This includes the functional group of an aldehyde.
14. (D) This includes the functional group of an organic acid.
15. (E) An ester is the equivalent of an organic salt since it is usually formed from an organic alcohol, R–OH, plus an organic acid, $R^*–\overset{O}{\overset{\|}{C}}–OH$.

    The bonding is $R–O\overset{\cdots\cdots}{H}\overset{\cdots\cdots}{HO}–\overset{O}{\overset{\|}{C}}–R^*$;

    which gives $R–O–\overset{O}{\overset{\|}{C}}–R^* + H_2O$. ($R^*$ indicates that this hydrogen branch need not be the same as R.)
16. (B) This includes the functional group of an ether. It can be formed by the dehydration of two alcohol molecules. The reaction is

    $R–O\overset{\cdots\cdots}{H} + \overset{\cdots\cdots}{HO}–R^* \rightarrow R–O–R^* + H_2O$.
17. (B) The molecular structure of carbon dioxide is O=C=O, where the oxygens are 180° apart and, although the bonding is polar to the carbon, counteract each other to constitute a nonpolar molecule.
18. (A) A hydrogen gas molecule is diatomic; it has 2 mol of atoms in each mole of molecules, represented by H_2.
19. (B) Each CO_2 has three atoms per molecule; hence the expression can represent 3 mol of atoms in 1 mol of molecules.
20. (E) With complete ionization $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$, or 3 mol of ions per mole of H_2SO_4.
21. (C) The expression $2N_2O$ represents two triatomic molecules or 6 mol of atoms.
22. (D) Carbon tetrachloride has four hydrogens, each bonded to an sp^3 hybridized orbital. The four sp^3 orbitals of carbon are in a tetrahedral orientation so that the resulting configuration balances the polarity of each bond, forming a nonpolar covalent molecule.
23. (A) Because cesium is a very active metal, the chloride formed has an ionic bond and is an ionic substance.
24. (C) Chlorine's stronger electronegativity draws the hydrogen electron closer to itself more often, so that the charge distribution in the molecule is uneven, causing a negative and positive polarity. Therefore hydrogen chloride is a polar covalent molecule.

25 (F) Benzene is an aromatic (ring) structure classified as an organic substance.

101. (T, T, CE) A catalyst can accelerate a chemical reaction by lowering the activation energy required for the reaction to occur.

102. (T, T, CE) Sodium chloride is an ionic substance and when molten is a good electrical conductor, and the reason is that in the molten state the ions are free to migrate to the anode and cathode.

103. (T, F) Ice is less dense than liquid water. Water molecules, however, are polar, not nonpolar, and water expands as these molecules arrange themselves into a crystal lattice.

104. (F, T) The statement that isotopes of the same element have the same mass number is false. Isotopes of the same element have the same number of protons but vary in the number of neutrons in the nucleus. Therefore, these isotopes have the same atomic number but different mass numbers.

105. (T, T, CE) A solute that has a very low solubility in a particular solvent can reach the saturated point in a solution with that solvent, but the solution can still be classified as dilute. The term *dilute* merely refers to a small amount of solute in a solvent.

106. (T, T, CE) The reaction is:

$$C + O_2 \rightarrow CO_2$$

and shows 1 mol or 12 g of carbon produces 1 mol or 22.4 L of CO_2. Then

$$2\text{L } CO_2 \times \frac{12\text{ g C}}{22.4\text{ L } CO_2} = 1.07\text{ g C}.$$

So the statement is correct, and the assertion explains it correctly.

107. (F, F) A reaction at equilibrium has reached a point where the forward and reverse reactions are occurring at equal rates. The concentrations of the reactants and products, however, are not necessarily equal and are described by the K_{eq} value at the temperature of the reaction.

108. (F, T) In an electrochemical reaction, anions migrate to the anode. It is true that positively charged ions (cations) are attracted to the negatively charged cathode.

109. (F, T) The value pH = 5 can be expressed as

$$[H_3O^+] = 1 \times 10^{-5}\,\frac{\text{mol}}{\text{L}}$$

and pH = 3 as

$$[H_3O^+] = 1 \times 10^{-3}\,\frac{\text{mol}}{\text{L}}.$$

Thus pH = 3 represents a larger concentration of hydronium ions, H_3O^+.

110. (T, T, CE). The first statement is true. The change in Gibbs free energy, ΔG, depends on the enthalpy change, ΔH, and the entropy change, ΔS, from the equation $\Delta G = \Delta H - T\Delta S$. Thus, statement II is also true and explains the first statement.

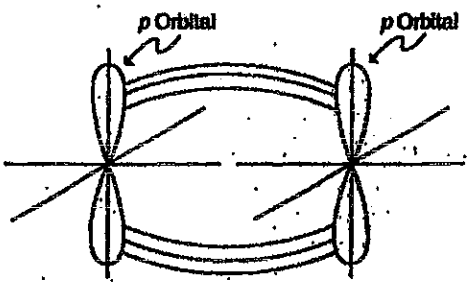
111. (T, T, CE) In the expression for the equilibrium constant of an acid, $[H_3O^+]$ is in the numerator:

$$K_a = \frac{[H_3O^+][Y^-]}{[HY]}$$

As $[H_3O^+]$ decreases in the weak acids, the numerator becomes smaller as the denominator gets larger, therefore giving smaller K_a values.

112. (T, T) Both statements are true, but they are not related.

113. (T, F) A pi bond is formed between *p* lobes of adjacent atoms and in the same plane:



However, each *p* orbital consisting of two lobes can hold a total of two electrons, so the reason is false.

114. (T, F) The assertion that the boiling points of H_2S and H_2O are significantly different is true, but the reason is false. Water has the higher degree of hydrogen bonding.

40. (E) Two immiscible liquids, when shaken together vigorously, may each form small, colloidal-size particles, dispersed in the other liquid.

41. (D) In the graph, the first plateau must represent the condensation from gas to liquid because there is a second, lower plateau, which would represent the second change of state, from liquid to solid.

42. (B) If the electrons have the same principal energy level, they will fill the s^2, p^6, then the d^{10} level. This progression is from the lowest energy sublevel to the highest, to accommodate 18 electrons.

43. (B) The empirical formula identifies the atoms present and the lowest-whole-number ratio of their occurrence as CH. The molecular formula, which gives the actual composition of the compound, must then be a multiple of the empirical formula: C_6H_6.

44. (D) Considering the concepts behind Charles's Law and Boyle's Law, you can arrive at the fraction to be used in kelvins and torrs. The volume must increase with an increase in temperature and also increase with a decrease in pressure. Therefore the fractions would be $\frac{333\text{ K}}{278\text{ K}}$ and $\frac{640\text{ torr}}{320\text{ torr}}$. Using the combined gas law equation,

$$\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$$

and solving for V_2, you get

$$V_2 = \frac{T_2}{T_1} \times \frac{P_1}{P_2}$$

which is the same answer.

45. (D) The atomic mass, 32, is the total number of neutrons and protons. Since the atomic number, 16, gives the number of protons, $32 - 16 = 16$, or the number of neutrons, statement II is false. Since this ion has a charge of −2, it has two more electrons than protons, or 18 electrons. Statements I and III are true.

46. (D) The most active metallic elements are found in the lower left corner of the periodic table.

47. (C) The rise in the boiling point depends on the number of particles in solution. One mole of $CaCl_2$ gives 3 mol of ions, more than any other substance listed:

$$CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$$

The number of moles of ions given by the other substances are as follows:

(A) = 2, (B) = 2, (D) = 1, (E) = 1.

48. (E) The sp^3 hybrid has the tetrahedron configuration. The sp^2 (D) is trigonal planar. The sp (C) is lineal. The s (B) and p (A) are the usual orbital structures.

49. (C) The reaction is

$$\underset{8\text{L}}{S(s)} + \underset{x\text{L}}{O_2(g)} \rightarrow SO_2(g)$$

The given (8 L) and the unknown (x L) are shown above. Since the equation, according to Gay-Lussac's Law, shows that 1 volume of oxygen yields 1 volume of sulfur dioxide, then

$$8\text{ L } O_2 \times \frac{1\text{ L } SO_2}{1\text{ L } O_2} = 8\text{ L } SO_2$$

50. (C) The fact that the mercury level in the U-tube is higher in the right side of the tube indicates that the pressure in the flask is higher than the atmospheric pressure exerted on the open end of the tube on the right side. If the pressure inside the flask were the same as the atmospheric pressure, the height of the mercury would be the same in both sides of the U-tube.

51. (B) The only change listed that would change the pressure of the gas inside the flask is to increase the temperature of the gas. This would cause the pressure to rise.

52. (C) An amphoteric substance must be able to be a proton, (H^+), donor and a proton receiver. The bisulfate ion, HSO_4^-, is the only choice that can either accept a proton and become H_2SO_4, or lose a proton and become the sulfate ion, SO_4^{2-}.

53. (C) Standard conditions are 273 K and 760 mm Hg.

54. (A) Dividing the percentage of each element by the atomic mass of that element gives the basic ratio of atoms, but not necessarily in whole numbers. Thus, (Ba) 58.8 ÷ 137 = 0.43, (S) 13.7 ÷ 32 = 0.43, (O) 27.5 ÷ 16 = 1.72.

Because atoms occur in whole numbers, you now must manipulate these numbers mathematically to get whole numbers. Usually dividing each number by the smallest one helps to accomplish this: (Ba) 0.43 ÷ 0.43 = 1, (S) 0.43 ÷ 0.43 = 1, (O) 1.72 ÷ 0.43 = 4. The empirical formula is $BaSO_4$.

55. (C) The percentage composition can be found by dividing each total atomic mass in the formula by the molar mass of the compound.

$$CA = 40 \quad 40 \div 74 \times 100\% = 54\% \text{ Ca}$$
$$O = 32 \quad 32 \div 74 \times 100\% = 43\% \text{ O}$$
$$2H = \frac{2}{74} \quad 2 \div 74 \times 100\% = 2.7\% \text{ H}$$

56. (B) The solution setup is:

$$\underset{65\text{ g}}{Zn} + \underset{73\text{ g}}{2HCl} \rightarrow ZnCl_2 + \underset{2\text{ g}}{H_2}(g)$$

Note that the equation mass is calculated under the substances that have mass units above them. According to the calculated equation masses, 73 g of HCl would be needed to react with 65 g of zinc. Since there is only 65 g of HCl, we use this and disregard the 65 g of Zn.

$$65\text{ g HCl} \times \frac{2\text{ g } H_2}{73\text{ g HCl}}$$
$$= 1.78 \text{ or } 1.8\text{ g of } H_2$$

57. (C) All the other statements represent observations because they merely record what was seen.

58. (E) The setup is appropriate for the collection of a basically nonsoluble gas by the displacement of water. All three gases fit this description.

59. (A) Because the paths of the particles from the radioactive source bend toward the positive plate, the source must be negatively charged. The only radioactive particle that fits this criterion is the beta particle, $_{-1}^{0}e$.

60. (A) The small K_a indicates that this is a weak acid, so statement III is false. When HCN ionizes, it can be shown that $HCN \rightleftharpoons H^+ + CN^-$. This is a molar ratio of 1 : 1, so statement I must be true.

61. (B) Since the equation shows that 2 mol of NO react to release 150 kJ, the solution is

$$0.8\text{ mol NO} \times \frac{150\text{ kJ}}{2\text{ mol NO}} = 60\text{ kJ}$$

This problem would be solved in the same manner if the heat had been expressed in kilocalories. To convert one unit to the other, use 4.18×10^3 J = 1 kcal.

62. (A) In the Brønsted-Lowry acid-base theory:

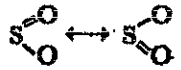
$$HCl + NH_3 \rightarrow NH_4^+ + Cl^-$$
acid base conjugate acid conjugate base

63. (B) According to Graham's Law, the rates of effusion of two gases are inversely proportional to the square roots of their molar masses. Since 1 mol O_2 = 32 g and 1 mol H_2 = 2 g,

$$\frac{H_2\text{ rate}}{O_2\text{ rate}} = \frac{\sqrt{32}}{\sqrt{2}} = \sqrt{\frac{16}{1}} = \frac{4}{1}$$

Therefore, the effusion rate of hydrogen is four times faster than that of oxygen.

64. (A) The structure of SO_2 is a resonance hybrid, shown as follows:



65. (E) The K_w of water is

$$K_w = [H^+][OH^-] = 10^{-14}$$

If $[OH^-] = 1.0 \times 10^{-4}$, then

$$[H^+] = \frac{10^{-14}}{10^{-4}} = 10^{-10}$$

and

$$pH = -\log[H^+] = 10$$

66. (D) $0.365\text{ g HCl} \times \frac{1\text{ mol HCl}}{36.5\text{ g HCl}}$

$= 0.01$ mol HCl

0.01 mol HCl $\rightarrow 0.01$ mol H^+ + 0.01 mol Cl^-

If $[H^+] = 0.01 = 1 \times 10^{-2}$ mol/L, then pH = 2.

67. (B) Hydrate mass before heating = 250 g
− Hydrate mass after heating = 160 g
Water loss = 90 g

$$\frac{90\text{ g mass loss}}{250\text{ g original mass}} \times 100\% = 36\% \text{ by mass}$$

68. (E) Since metallic oxides are basic anhydrides, the only nonmetallic oxide is SO_3. The reaction is as follows

$$SO_3 + H_2O \rightarrow H_2SO_4 \text{(sulfuric acid)}$$

69. (B) In the titration, the reaction is:

$$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$$

The acid to base ratio is 2 : 1, or (moles acid used) = 2(moles base used), so

$M_aV_a = 2M_bV_b$ where M is the molarity and V is the volume expressed in liters, then

$$M_b = \frac{M_aV_a}{2V_b}$$

$$M_b = \frac{0.05\text{ M} \times 0.02\text{ L}}{2(0.02\text{ L})} = 0.025\text{ M}$$

70. (D) All the reactions will go to completion except (D), which will not occur spontaneously at all. If E^0 had been positive, however, this redox reaction would occur.

71. (D) Sodium hydroxide is hygroscopic and will attract water to its surface area. This water will influence its mass; consequently there will be less sodium hydroxide in the mass used.

72. (C) $\underset{60\text{g}}{2NO} + O_2 \rightarrow \underset{92\text{g}}{2NO_2}$

This is a mass stoichiometry problem. The equation masses are placed beneath the substances that have quantities above them.

Using the equation relationship gives

$$60\text{ g NO} \times \frac{92\text{ g NO}_2}{60\text{ g NO}} = 92\text{ g NO}_2$$

Using the mole method gives

$$60\text{ g NO} \times \frac{1\text{ mol NO}}{30\text{ g NO}} = 2\text{ mol NO}$$

Using the equation coefficients gives

$$2\text{ mol NO} \times \frac{2\text{ mol NO}_2}{2\text{ mol NO}} = 2\text{ mol NO}_2$$

then

$$2\text{ mol NO}_2 \times \frac{46\text{ g NO}_2}{1\text{ mol NO}_2} = 92\text{ g NO}_2$$

73. (E) Since in this reaction 4 volumes of gases are forming 2 volumes of product, the randomness of the system is decreasing. Therefore, entropy is decreasing and ΔS is negative. In all the other reactions randomness is increasing.

74. (D) The reaction is

$$Cl_2(g) + 2Br^-(\text{excess}) \rightarrow 2Cl^- + Br^2(g)$$

Here 2 mol of chloride ions and 1 mol of Br_2 molecules are produced.

75. (D) Since both solutions were 1 molal and neither compound ionized into more particles, the freezing points would be the same.

76. (A) $HY \rightleftharpoons H^+ + Y^-$

Since $[H^+]$ is in the numerator of K_a:

$$K_a = \frac{[H^+][Y^-]}{[HY]}$$

The stronger the acid, the greater are $[H^+]$ and the K_a value. Of the choices given, 1.8×10^{-5} is the largest.

77. (C) $\underset{100\text{g}}{CaCO_3} + 2HCl \rightarrow CaCl_2 + H_2O + \underset{22.4\text{L}}{CO_2}$ (11.2 L)

This is a mass-volume problem with the mass and volume indicated below the equation.

Using the factor-label method gives

$$11.2\text{ L CO}_2 \times \frac{100\text{ g CaCO}_3}{22.4\text{ L CO}_2} = 50\text{ g CaCO}_3$$

Using the mole method gives

$$11.2\text{ L CO}_2 \times \frac{1\text{ mol CO}_2}{22.4\text{ L CO}_2} = 0.5\text{ mol CO}_2$$

$$0.5\text{ mol CO}_2 \times \frac{1\text{ mol CaCO}_3}{1\text{ mol CO}_2} = 0.5\text{ mol CaCO}_3$$

$$0.5\text{ mol CaCO}_3 \times \frac{100\text{ g CaCO}_3}{1\text{ mol CaCO}_3} = 50\text{ mol CaCO}_3$$

78. (B) $K_{sp} = [Ba^{2+}][SO_4^{2-}]$

If $[Ba^{2+}] = 3.9 \times 10^{-5}$, then $[SO_4^{2-}]$ must also equal the same amount, so

$$K_{sp} = [3.9 \times 10^{-5}][3.9 \times 10^{-5}]$$
$$= 15.2 \times 10^{-10} \text{ or } 1.5 \times 10^{-9}.$$

79. (B) $\Delta H^0_{reaction} = \Delta H^0_f$ (products) $- \Delta H^0_f$ (reactants)

$\Delta H^0_{reaction} = -98.2 \text{ kcal} - (-85.7 \text{ kcal})$

$\Delta H^0_{reaction} = -12.5 \text{ kcal}$

80. (C) Since the HCl solution will add to the chloride ion concentration, according to Le Châtelier's Principle the equilibrium will shift in the direction to reduce this disturbance, so the K_{sp} will remain the same but salt will come out of solution. This process:

$$AgCl \rightleftharpoons Ag^+ + Cl^-$$

will continue until the K_{sp} is reestablished. This phenomenon is called the "common ion effect."

81. (D) $HCl + KMnO_4 \rightarrow H_2O + KCl + MnCl_2 + Cl_2$

oxidation: $2Cl^- \rightarrow Cl_2 + 2e^-$

reduction: $8H^+ + MnO_4^- + 5e^- \rightarrow Mn^{2+} + 4H_2O$

5 (oxidation reaction) and 2 (reduction reaction) will balance the e^- gain and loss, giving

$10Cl^- \rightarrow 5Cl_2 + 10e^-$

$16H^+ + 2MnO_4^- + 10e^- \rightarrow 2Mn^{2+} + 8H_2O$

Therefore

$16HCl + 2KMnO_4 \rightarrow 8H_2O + 2KCl + 2MnCl_2 + 5Cl_2$

82. (C) A decrease in volume will cause the equilibrium to shift in the direction that has less volume(s) of gas(es). In every case except (C) this is the reverse reaction, which decreases the product. The coefficients give the volume relationships.

83. (E) Each of the elements when becoming ions has this configuration of 18 electrons.

K with 19 electrons $- e^- \rightarrow K^+$ with 18 electrons

S with 16 electrons $+ 2e^- \rightarrow S^{2-}$ with 18 electrons

Cl with 17 electrons $+ e^- \rightarrow Cl^-$ with 18 electrons

84. (C) Change the water height to the equivalent Hg height:

$$40.8 \text{ mm } H_2O \times \frac{1 \text{ mm Hg}}{13.6 \text{ mm } H_2O}$$

$= 3$ mm Hg

Adjust for the difference in height to get the gas pressure. Pressure on the gas is

730 mm Hg − 3 mm Hg
= 727 mm Hg.

Vapor pressure of H_2O at 29°C accounts for 30 mm Hg pressure. Therefore

727 mm Hg − 30 mm Hg
= 697 mm Hg

85. (B) The reaction is

$$Ni^{2+} + 2e^- \rightarrow Ni\ (s)$$

Since 2 mol of electrons are required to form 1 mol of nickel, and

$$2.9 \text{ g Ni} \times \frac{1 \text{ mol Ni}}{58.7 \text{ g Ni}} = 0.05 \text{ mol Ni}$$

then

$$0.05 \text{ mol Ni} \times \frac{2 \text{ mol electrons}}{1 \text{ mol Ni}}$$

= 0.1 mol of electrons