AP Chemistry Final Exam
Version A   **Fall 2004**

80 Multiple Choice questions, 120 minutes

ONLY NON-GRAPHING, NON-PROGRAMMABLE CALCULATORS MAY BE USED.

Note: For all questions, assume that the temperature is 298 K, the pressure is 1.00 atmospheres, and solutions are aqueous unless otherwise specified.

Guessing: One-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly.

You may write on this exam; however, you will only be given credit for answers recorded on the Scantron sheet.

NAME:

PERIOD: 5   6   7

JANUARY 11-13, 2005

SCORE: _____   -   _____/4   =   _____
**   CORRECT   INCORRECT   OVERALL**

**   _____**
**   BLANK**

Directions: Each set of lettered choices below refers to the numbered statements immediately following it. Select the option that best fits each statement. A choice may be used once, more than once, or not at all in each set.

Questions 1-3

   A. $1s^2 2s^2 2p^6 3s^2 3p^5$
   B. $1s^2 2s^2 2p^6 3s^2 3p^6$
   C. $1s^2 2s^2 2p^6 2d^{10} 3s^2 3p^6$
   D. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$
   E. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$

   1. An impossible electronic configuration
   2. The ground-state configuration of a negative ion of a halogen
   3. The ground-state configuration of a common ion of a transition element

Questions 4-6

   A. A network solid with covalent bonding
   B. A molecular solid with zero dipole moment
   C. A molecular solid with hydrogen bonding
   D. An ionic solid
   E. A metallic solid

   4. Solid ethanol
   5. Si
   6. Sn

Questions 7-10

   A. Dipole-dipole bonding
   B. Hydrogen bonding
   C. Ionic bonding
   D. London dispersion forces
   E. Metallic bonding

   7. How iodine molecules are held together in the solid state
   8. Why the boiling point of HF is greater than the boiling point of HBr
   9. The strongest force that must be overcome to melt $NaNO_3$
   10. The strongest force that must be overcome to dissolve $(CH_3)_2CO$ in H_2O

Questions 11-13

   A. Allotropy
   B. Hybridization
   C. Isomerism
   D. Localized electrons
   E. Resonance

   11. Explains that the three bonds in sulfur trioxide are equivalent
   12. Explains that there are three naturally occurring forms of elemental carbon
   13. Explains that the bond angle in water is about 104.5°.

Directions: Choose the best option for each question or statement.
   14. The Lewis dot structure of which of the following molecules shows exactly two unshared pairs of valence electrons?
      A. Cl_2
      B. NH_3
      C. H_2O_2
      D. N_2
      E. CCl_4

15. The compound with the highest boiling point is most likely to be:
    A. MgO
    B. NaCl
    C. KBr
    D. CaO
    E. Not enough information given

16. The name of $Sn(SO_2)_2$ is:
    A. Tin (II) hyposulfite
    B. Tin (II) sulfite
    C. Tin (IV) hyposulfite
    D. Tin (IV) sulfite
    E. None of the above

17. Consider the following reaction: $2 NH_3 (g) + 3 O_2 (g) + 2 CH_4 (g) \rightarrow 2 HCN (g) + 6 H_2O (g)$
    If 5.00×10^3 kg each of NH_3, O_2, and CH_4 are reacted, what mass of HCN will be produced, assuming a 95% yield?
    A. 2.8×10^3 g
    B. 1.6×10^5 g
    C. 3.1×10^5 g
    D. 2.7×10^6 g
    E. 2.8×10^6 g

18. The hybridization present in the NH_4^+ compound is:
    A. sp^2
    B. sp^3
    C. sp^3d
    D. sp^3d^2
    E. Not enough information given

19. How many grams of calcium nitrate, $Ca(NO_3)_2$, contain 24 grams of oxygen atoms?
    A. 164 grams
    B. 96 grams
    C. 62 grams
    D. 50. grams
    E. 41 grams

20. The mass of H_2SO_4 in 50.0 milliliters of a 6.00-molar solution is
    A. 3.10 grams
    B. 12.0 grams
    C. 29.4 grams
    D. 294 grams
    E. 300. grams

21. A gaseous mixture containing 7.0 moles of nitrogen, 2.5 moles of oxygen, and 0.50 mole of helium exerts a total pressure of 0.90 atmospheres. What is the partial pressure of the nitrogen?
    A. 0.13 atm
    B. 0.27 atm
    C. 0.63 atm
    D. 0.90 atm
    E. 6.3 atm

22. The simplest formula for an oxide of nitrogen that is 36.8 percent nitrogen by weight is
    A. N_2O
    B. NO_2
    C. N_2O_5
    D. NO
    E. N_2O_3

23. What mass of H_2O will change from $-10.0°C$ to $35.0°C$ when absorbing 150.0 kJ of energy? (Specific heat of ice = 2.09 J/g°C, enthalpy of fusion = 6.01 kJ/mol, specific heat of water = 4.18 J/g°C)
    A. 24.3 g
    B. 299 g
    C. 501 g
    D. 895 g
    E. None of these

24. Which of the following atoms or ions is largest in size?
    A. O^{2-}
    B. F^{1-}
    C. Na^{1+}
    D. Mg^{2+}
    E. Cannot be determined from the information given.

25. The compound with the least polar bond is:
    A. HF
    B. HCl
    C. HBr
    D. HI
    E. Cannot be determined from the information given.

26. How many milliliters of 11.6-molar HCl must be diluted to obtain 1.0 liter of 3.0-molar HCl?
    A. 3.9 mL
    B. 35 mL
    C. 260 mL
    D. 1,000 mL
    E. 3,900 mL

27. In addition to the information below, which of the following gives the minimum data required to determine the molecular mass of a substance by the freezing point depression technique?
    I. Difference in temperature between freezing point of solvent and freezing point of solution
    II. Molal freezing point depression constant, K_f, for solvent
    III. The degree to which the solute dissociates in solvent

    A. Freezing point of solvent
    B. Mass of solute
    C. Moles of solute and mass of solvent
    D. Moles of solute, mass of solvent, and vapor pressure of solvent
    E. No further information than that listed in I, II, and III is needed.

28. Hydrogen gas is collected over water at 24˚C. The total pressure of the sample is 755 mm of Hg. At 24˚C, the vapor pressure of water is 22 mm of Hg. What is the partial pressure of the hydrogen gas?
    A. 22 mm Hg
    B. 755 mm Hg
    C. 777 mm Hg
    D. 733 mm Hg
    E. 760 mm Hg

29. A 2.00-liter sample of nitrogen gas at 27˚C and 600. mm of Hg is heated until it occupies a volume of 5.00 liters. If the pressure remains unchanged, the final temperature of the gas is
    A. 68˚C
    B. 477˚C
    C. 950˚C
    D. 120˚C
    E. 677˚C

30. How many moles of O_2 are required in the combustion of 1 mole of propanoic acid?
    A. 2 moles
    B. 3 moles
    C. 9/2 moles
    D. 5/2 moles
    E. 7/2 moles

31. When a hydrate of Na_2CO_3 is heated until all the water is removed, it loses 54.3 percent of its mass. The formula of the hydrate is
    A. $Na_2CO_3 \cdot 10\ H_2O$
    B. $Na_2CO_3 \cdot 3\ H_2O$
    C. $Na_2CO_3 \cdot 7\ H_2O$
    D. $Na_2CO_3 \cdot H_2O$
    E. $Na_2CO_3 \cdot 5\ H_2O$

32. In the process of a covalent bond breaking,
    A. Energy is absorbed.
    B. Energy is released.
    C. No change in energy occurs.
    D. The change in energy depends on the particular bond.
    E. A new covalent bond forms.

33. Consider the following reaction: $2\ K + 2\ H_2O \rightarrow 2K^+ + 2\ OH^- + H_2$
    When 0.400 mole of potassium reacts with excess water at standard temperature and pressure as shown in the equation above, the volume of hydrogen gas produced is
    A. 1.12 liters
    B. 3.36 liters
    C. 6.72 liters
    D. 2.24 liters
    E. 4.48 liters

34. What is the hybridization of the central atom in the $SbCl_5$ molecule?
    A. sp_2
    B. sp^3
    C. sp^2d
    D. sp^3d
    E. sp^3d^2

35. Which does not describe any of the following molecules: CO_2, PCl_3, CCl_4, PCl_5, SF_6?
    A. Linear
    B. Tetrahedral
    C. Octahedral
    D. Trigonal pyramidal
    E. Square planar

36. A measured mass of a non-reactive metal was dropped into a small graduated cylinder half-filled with water. The following measurements were made.

    Mass of metal =   19.611 g
    Volume of water before addition of metal = 12.4 mL
    Volume of water after addition of metal =   14.92 mL

    The density of the metal should be reported as
    A. 7.7821 g/mL
    B. 7.782 g/mL
    C. 7.78 g/mL
    D. 7.8 g/mL
    E. 8 g/mL

37. Which of the following characteristics is common to elemental sulfur, chlorine, nitrogen, and carbon?
    A. They are gaseous elements at room temperature.
    B. They have oxides that are acid anhydrides.
    C. They have perceptible color at room temperature.
    D. They form ionic oxides.
    E. They react readily with hydrogen at room temperature.

38. Which of the following compounds is ionic and contains both sigma and pi covalent bonds?
    A. $Fe(OH)_3$
    B. H_2S
    C. NaCN
    D. HClO
    E. NO_2

39. A solution of toluene (also called 1-methylbenzene) in benzene is prepared. The mole fraction of toluene in the solution is 0.100. What is the molality of the solution?
    A. 0.100 m
    B. 0.921 m
    C. 1.42 m
    D. 0.703 m
    E. Cannot be determined from the information given.

40. How many moles of solid $Ba(NO_3)_2$ should be added to 300. mL of 0.20-molar $Fe(NO_3)_3$ to increase the concentration of the NO_3^- ion to 1.0-molar? (Assume that the volume of the solution remains constant.)
    A. 0.060 mole
    B. 0.24 mole
    C. 0.41 mole
    D. 0.12 mole
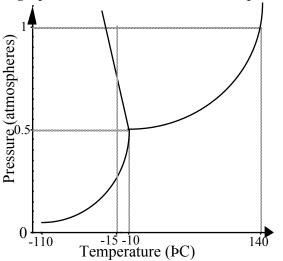   E. 0.30 mole

41. $1s^2\,2s^2\,2p^6\,3s^2\,3p^3$
    Atoms of an element, X, have the electronic configuration shown above. The compound most likely formed with magnesium is
    A. MgX
    B. MgX_2
    C. Mg_3X_2
    D. Mg_2X
    E. MgX_3

42. As the temperature of a sample of neon is raised from 20°C to 40°C, the average kinetic energy of the neon atoms changes by a factor of
    A. $\frac{1}{2}$
    B. $\frac{313}{293}$
    C. 4
    D. $\sqrt{\frac{313}{293}}$
    E. 2

43. Of the following, the least ideal gas is:
    A. CH_4
    B. F_2
    C. N_2
    D. NH_3
    E. Xe

Use the graph below to answer the next two questions.

44. The normal boiling point of the substance represented by the phase diagram above is approximately
    A. Lower than -15°C
    B. -15°C
    C. -10°C
    D. 140°C
    E. Cannot be determined from the information given

45. In the diagram above, the substance is most likely:
    A. H_2O_2
    B. H_2S
    C. I_2
    D. O_2
    E. Ne

46. Which of the following would be observed to be insoluble in water?
      I. NH_4F
      II. PbI_2
      III. $BaSO_4$

    A. I
    B. II
    C. III
    D. Both I and III
    E. Both II and III

47. Which of the following molecules has the shortest intramolecular bond length?
    A. Ne
    B. Cl_2
    C. I_2
    D. O_2
    E. Br_2

48. The elements in which of the following have most nearly the same atomic radius?
    A. B, C, N
    B. C, P, Se
    C. Ne, Ar, Kr
    D. Cr, Mn, Fe
    E. Mg, Ca, Sr

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49. Small samples of two unknown, pure, clear liquids are poured out on a lab bench. It is observed that Liquid B evaporates faster than Liquid A. Therefore, which of the following statements must be true?

        I.   Liquid A has stronger intermolecular forces than B.
        II. Liquid A has a greater molecular mass than B.
        III. Liquid A has a lower boiling point than B.

    A. I only
    B. II only
    C. I and II only
    D. I and III only
    E. I, II, and III

50. $CH_4 (g) + 2\ O_2 (g) \rightarrow CO_2 (g) + 2\ H_2O (l) + 889.1\ kJ$ $\Delta H_f^{\circ}\ H_2O\ (l) = -285.8\ kJ/mol$
                                                                              $\Delta H_f^{\circ}\ CO_2\ (g) = -393.3\ kJ/mol$

What is the standard heat of formation of methane, $\Delta H_f^{\circ}\ CH_4 (g)$, as calculated from the data above, in kJ/mole?
    A. -75.8
    B. -107.5
    C. -210.0
    D. 75.8
    E. 210.0

51. Which of the following is lower in energy than an emission line in the Paschen series?
    A. Microwaves
    B. Infrared
    C. Visible
    D. Ultraviolet
    E. Cannot be determined from the information given.

52. Which of the following elements would have the largest second ionization energy?
    A. Be
    B. B
    C. C
    D. N
    E. Cannot be determined from the information given.

53. Which of the following atoms would display the greatest degree of paramagnetism?
    A. K
    B. V
    C. Cr
    D. Mn
    E. Fe

54. The osmotic pressure at 25°C of a 0.500 M solution of K_2SO_4 in water is:
    A. 3.1 atm
    B. 4.5 atm
    C. 12.2 atm
    D. 36.7 atm
    E. 3720 atm

55. Which of the following compounds is definitely nonpolar?
    A. Cs_2S
    B. HC_2Cl
    C. CH_2Cl_2
    D. PH_3
    E. None of the above

56. What is the total number of resonance structures for the compound 2-butene?
    A. 1
    B. 2
    C. 3
    D. 4
    E. There are no resonance structures.

57. Which is a permissible set of the first two quantum numbers of the highest energy electron of Zr?
    A. 4, 1
    B. 4, 2
    C. 4, 3
    D. 5, 2
    E. 5, 3

58. Which series is ranked in order from largest to smallest (becoming more positive) electron affinity?
    A. Ar, Cl, S
    B. Cl, S, P
    C. S, P, Si
    D. P, Si, Al
    E. None of the above

59. Going down any group of the periodic table,
         I. Metallic character increases
         II. Atomic radius increases
         III. Electronegativity increases.

    A. I
    B. II
    C. III
    D. Both I and II
    E. I, II, and III

60. The energy associated with the transition from n = 2 to n = 4 is:
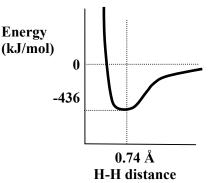   A. 4.08×10^{-19} J
    B. -4.08×10^{-19} J
    C. 5.44×10^{-19} J
    D. -5.44×10^{-19} J
    E. Not enough information given

61. Which compound contains carbon-carbon bonds of the highest bond order?
    A. C_2H_2
    B. C_2H_4
    C. C_2H_6
    D. C_3H_6
    E. Cannot be determined from the information given.

62. The name for the compound $CH_3CH_2CH_2CH_2CHO$ is:
    A. Pentakenol
    B. Pentanal
    C. Pentanoic acid
    D. Pentanol
    E. Pentyl ether

63. Which of the following best represents the products of the net ionic equation for the reaction that occurs when solid barium phosphate and solid magnesium sulfide are added to water?
   A. $Mg^{2+} + PO_4^{3-} + BaS$
   B. $Mg_3(PO_4)_2 + Ba^{2+} + S^{2-}$
   C. $Mg_3(PO_4)_2 + BaS$
   D. $Mg^{2+} + PO_4^{3-} + Ba^{2+} + S^{2-}$
   E. $BaMg + SPO_4$

64. Which of the following conclusions can be drawn from J. J. Thomson's cathode ray experiments?
   A. Atoms contain electrons.
   B. Practically all the mass of an atom is contained in its nucleus.
   C. Atoms contain protons, neutrons, and electrons.
   D. Atoms have a positively charged nucleus surrounded by an electron cloud.
   E. No two electrons in one atom can have the same four quantum numbers.

65. The following properties are observed for an unknown element, Z: at room temperature, it is gray, lustrous solid. The compound ZCl_2 dissolves in water, forming a colorless solution. When a small sample of this solution is heated by a Bunsen burner, the flame is green. Element Z is most likely:
   A. Ba
   B. Ca
   C. Cu
   D. Fe
   E. Cannot be determined from the information given or the information is contradictory

66. One major contribution of Werner Heisenberg to science was that:
   A. Matter, like electromagnetic radiation, is a form of a wave.
   B. Energy is quantized into packets called quantum.
   C. Both the momentum and location of an electron cannot be exactly determined at the same time.
   D. Electrons only have certain, permissible energies that determine how they orbit the nucleus.
   E. None of the above

67. The graph at right represents the energy of two hydrogen atoms. Consider the following conclusions:
   I. The most stable form of H_2 exists at - 436 kJ/mol.
   II. The most likely radius of an H atom is 0.37 Å.
   III. The H_2 molecule forms as energy is absorbed by the atoms.

   Which of the above conclusion(s) is/are likely?
   A. I
   B. II
   C. III
   D. Both I and II
   E. I, II, and III

68. A 10.31 g sample of a compound contains 6.180 g carbon, 1.386 g hydrogen, and 2.744 g oxygen. What is the empirical formula of this compound?
   A. C_3H_8O
   B. C_3H_5O
   C. $C_3H_6O_2$
   D. $C_3H_9O_3$
   E. None of the above or more information is required

69. Given the following data, $\Delta H°_{rxn}$ for the following reaction is: $4\ NH_3\ (g) + 5\ O_2\ (g) \rightarrow 4\ NO\ (g) + 6\ H_2O\ (l)$
    A. −1170
    B. −150.
    C. −1540
    D. −1892
    E. None of the above

Substance	$\Delta H°_f$ (kJ/mol)
H_2O (l)	-286
NO (g)	90.0
NO_2 (g)	34.0
HNO_3 (aq)	-207
NH_3 (g)	-45.9

70. Which Group 2 element has chemical properties least like the other members of the group?
    A. Be
    B. Mg
    C. Ca
    D. Sr
    E. None of the above

71. Which of the following would have the greatest shielding effect?
    A. Ba
    B. Ca
    C. Xe
    D. Rb
    E. None of the above

72. Which element can exhibit more than one oxidation state in compounds?
    I. Cr
    II. Pb
    III. Sr

    A. I only
    B. I and II only
    C. II and III only
    D. I, II, and II
    E. None of these

73. Use the bond energies given below to estimate ΔH for this reaction: $H_2\ (g) + O_2\ (g) \rightarrow H_2O_2\ (g)$

    A. −127 kJ
    B. −209 kJ
    C. −484 kJ
    D. −841 kJ
    E. None of the above

Bond	Bond Energy (kJ/mol)
H-H	436
O-O	142
O=O	499
O-H	460

74. Which is the best description of a covalent bond?
    A. Electrons are simultaneously attracted by more than one nucleus.
    B. Filled orbitals of two or more atoms overlap one another.
    C. Unoccupied orbitals of two or more atoms overlap one another.
    D. Oppositely-charged ions attract one another.
    E. Electrons are promoted to unfilled or half-filled orbitals.

75. What is the formal charge on the chlorine atom in the chlorous acid?
  A. −1
  B. +1
  C. +3
  D. +5
  E. +7

76. How many carbon-carbon bonds are in a molecule of 2-methyl-2-butanol?
  A. 2
  B. 3
  C. 4
  D. 5
  E. None of the above

77. How many benzene-based molecules have the formula C_7H_7Cl?
  A. 1
  B. 2
  C. 3
  D. 4
  E. None of the above

78. The molar mass of a gas with a density of 5.8 g/L at 25°C and 740 mm Hg is closest to:
  A. 10 g/mol
  B. 20 g/mol
  C. 150 g/mol
  D. 190 g/mol
  E. None of the above

79. The vapor pressure of a pure liquid in a closed container depends on:
      I. Temperature of the liquid
      II. Quantity of liquid
      III. Surface area of the liquid

  A. I only
  B. I and II only
  C. II and III only
  D. I, II, and II
  E. None of these

80. What is the most likely boiling point of mixture of hexane (boiling point = 69°C) and heptane (boiling point = 98°C), in which heptane is the solvent?
  A. Below 69°C
  B. 69°C
  C. Between 69°C and 98°C
  D. 98°C
  E. Above 98°C

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Version C   **Fall 2004**

80 Multiple Choice questions, 120 minutes

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Note: For all questions, assume that the temperature is 298 K, the pressure is 1.00 atmospheres, and solutions are aqueous unless otherwise specified.

Guessing: One-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly.

You may write on this exam; however, you will only be given credit for answers recorded on the Scantron sheet.

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PERIOD: 5   6   7

JANUARY 11-13, 2005

SCORE: _____   -   _____/4   =   _____
                         CORRECT   **INCORRECT**   **OVERALL**

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Directions: Each set of lettered choices below refers to the numbered statements immediately following it. Select the option that best fits each statement. A choice may be used once, more than once, or not at all in each set.

Questions 1-3

    A. $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^4$
    B. $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6$
    C. $1s^2\, 2s^2\, 2p^6\, 2d^{10}\, 3s^2\, 3p^6$
    D. $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^5$
    E. $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^{10}\, 4p^2$

1. The ground-state configuration for an atom of a metalloid
2. The ground-state configuration of a common ion of an alkaline earth element
3. The ground-state configuration of a common ion of a transition metal

Questions 4-6

    A. A network solid with covalent bonding
    B. An ionic solid
    C. A molecular solid with a dipole moment
    D. A molecular solid with hydrogen bonding
    E. A metallic solid

4. Pb
5. Solid fluoromethane
6. C

Questions 7-10

    A. Dipole-dipole bonding
    B. Hydrogen bonding
    C. Ionic bonding
    D. London dispersion forces
    E. Metallic bonding

7. The strongest force that must be overcome to melt $MgSO_4$
8. The strongest force that must be overcome to dissolve C_2H_6 in benzene.
9. How Kr atoms are held together in the solid state
10. Why the boiling point of PH_3 is lower than the boiling point of NH_3.

Questions 11-13

    A. Allotropy
    B. Delocalization
    C. Hybridization
    D. Isomerism
    E. Resonance

11. Explains that there are two forms of 2-butene
12. Explains that there are three naturally occurring forms of elemental carbon
13. Explains that the bond angle in methane is about 109º.

Directions: Choose the best option for each question or statement.

14. Which of the following molecules has the greatest bond order?
    A. Cl_2
    B. O_3
    C. H_2O_2
    D. N_2
    E. CCl_4

15. How many grams of barium nitrate, $Ba(NO_3)_2$, contain 48 grams of oxygen atoms?
   A. 62
   B. 94
   C. 130
   D. 780
   E. 4700

16. The mass of H_3PO_4 in 40.0 mL of a 3.00-molar solution is:
   A. 11.8 g
   B. 40.0 g
   C. 98.0 g
   D. 120. g
   E. 1.18×10^4 g

17. A gaseous mixture containing 3.0 moles of nitrogen, 0.5 moles of oxygen, and 2.50 moles of helium exerts a total pressure of 1.90 atmospheres. What is the partial pressure of the nitrogen?
   A. 0.37 atm
   B. 0.50 atm
   C. 0.95 atm
   D. 1.1 atm
   E. 1.9 atm

18. The simplest formula for an oxide of nitrogen that is 25.9 percent nitrogen by weight is
   A. N_2O
   B. NO_2
   C. N_2O_5
   D. NO
   E. N_2O_3

19. How many milliliters of 5.0-molar HCl must be diluted to obtain 1.0 liter of 1.6-molar HCl?
   A. 3.2
   B. 8.0
   C. 320
   D. 1,000
   E. 3,200

20. In addition to the information below, which of the following gives the minimum data required to determine the molecular mass of a substance by the boiling point elevation technique?
   I. Difference in temperature between boiling point of solvent and boiling point of solution
   II. Molal boiling point depression constant, K_b, for solvent

   A. No further information than that listed in I and II is needed.
   B. Mass of solute
   C. Mass of solute and mass of solvent
   D. Mass of solute, mass of solvent, and vapor pressure of solvent
   E. More than the information listed here is needed.

21. Oxygen gas is collected over water at 24°C. The total pressure of the sample is 795 mm of Hg. At 24°C, the vapor pressure of water is 22 mm of Hg. What is the partial pressure of the oxygen gas?
   A. 22 mm Hg
   B. 528 mm Hg
   C. 773 mm Hg
   D. 795 mm Hg
   E. 817 mm Hg

22. A 4.00-liter sample of nitrogen gas at 27°C and 500. mm of Hg is heated until it occupies a volume of 15.0 liters. If the pressure remains unchanged, the final temperature of the gas is
    A. −171 °C
    B. 80.0 °C
    C. 852°C
    D. 1130°C
    E. 1390°C

23. How many moles of O_2 are required in the combustion of 1 mole of butyl methyl ether?
    A. 4
    B. 7
    C. 11/2
    D. 15/2
    E. None of the above

24. When a hydrate of Na_2CO_3 is heated until all the water is removed, it loses 14.5 percent of its mass. The formula of the hydrate is
    A. $Na_2CO_3 \cdot 10\ H_2O$
    B. $Na_2CO_3 \cdot 3\ H_2O$
    C. $Na_2CO_3 \cdot 7\ H_2O$
    D. $Na_2CO_3 \cdot H_2O$
    E. $Na_2CO_3 \cdot 5\ H_2O$

25. $2\ K + 2\ H_2O \rightarrow 2K^+ + 2\ OH^- + H_2$
    When 0.650 mole of potassium reacts with excess water at standard temperature and pressure as shown in the equation above, the volume of hydrogen gas produced is
    A. 0.325 liters
    B. 7.28 liters
    C. 29.1 liters
    D. 0.650 liters
    E. 14.6 liters

26. What is the hybridization of the central atom in the BrF_3 molecule?
    A. sp^2
    B. sp^3
    C. sp^2d
    D. sp^3d
    E. sp^3d^2

27. A measured mass of a non-reactive metal was dropped into a small graduated cylinder half-filled with water. The following measurements were made.
    Mass of metal =   19.6 g
    Volume of water before addition of metal = 4.493 mL
    Volume of water after addition of metal =   14.95 mL

    The density of the metal should be reported as
    A. 1.8743 g/mL
    B. 1.874 g/mL
    C. 1.87 g/mL
    D. 1.8 g/mL
    E. 2 g/mL

28. Which does not describe any of the following molecules: NO_2^{1-}, PCl_3, SiH_4, SF_4, SF_6?
    A. Bent
    B. Tetrahedral
    C. Octahedral
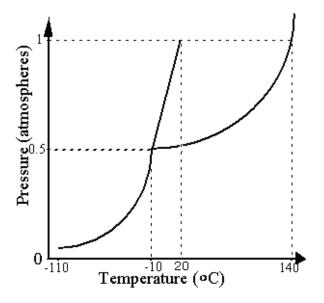   D. Trigonal pyramidal
    E. Square pyramidal

29. Which of the following characteristics is common to elemental oxygen, sulfur, selenium, tellurium, and polonium?
    A. They are gaseous elements at room temperature.
    B. They form ionic compounds with sodium.
    C. They have perceptible color at room temperature.
    D. They can have a (–2) oxidation state.
    E. None of the above.

30. Which of the following compounds is ionic and contains both sigma and pi covalent bonds?
    A. $Fe(OH)_3$
    B. H_2S
    C. $NaBrO_2$
    D. $HClO$
    E. None of the above

Use the graph below to answer the next two questions.

31. The normal freezing point of the substance represented by the phase diagram above is approximately:
    A. Below -10°C
    B. -10°C
    C. 20°C
    D. 140°C
    E. Cannot be determined from the information given

32. In the diagram above, the substance is most likely:
    A. H_2O
    B. Cl_2
    C. Br_2
    D. O_2
    E. Ne

33. As the temperature is raised from 100°C to 200°C, the rates of effusion of neon atoms changes by a factor of
    A. $\frac{1}{2}$
    B. $\sqrt{\frac{473}{373}}$
    C. 4
    D. $\frac{473}{373}$
    E. 2

34. Which of the following is would be observed to be insoluble in water?

I. NH₄OH
II. PbSO₄
III. AgBr
   A. I
   B. II
   C. III
   D. Both II and III
   E. I, II and III

35. A solution of toluene (also called 1-methylbenzene) in benzene is prepared. The mole fraction of benzene in the solution is 0.250. What is the molality of the solution?
   A. 0.0260
   B. 0.294
   C. 3.20
   D. 4.27
   E. Cannot be determined from the information given.

36. How many moles of solid $Al(NO_3)_3$ should be added to 400. mL of 0.50-molar $Fe(NO_3)_3$ to increase the concentration of the NO_3^- ion to 2.0-molar? (Assume that the volume of the solution remains constant.)
   A. 0.067
   B. 0.47
   C. 0.56
   D. 1.5
   E. 2.0

37. $1s^2\,2s^2\,2p^6\,3s^2\,3p^5$
   Atoms of an element, X, have the electronic configuration shown above. The compound most likely formed with calcium is
   A. CaX
   B. CaX_2
   C. Ca_3X_2
   D. Ca_2X
   E. CaX_3

38. The name of $Pb(ClO_2)_2$ is:
   A. Plumbic chlorite
   B. Plumbic hypochlorite
   C. Plumbous chlorite
   D. Plumbous hypochlorite
   E. None of the above

39. Consider the following reaction: $2\ NH_3\ (g) + 3\ O_2\ (g) + 2\ CH_4\ (g) \rightarrow 2\ HCN\ (g) + 6\ H_2O\ (g)$
   If 5.00×10^3 kg each of NH_3, O_2, and CH_4 are reacted, what mass of HCN will be produced, assuming a 85% yield?
   A. 2.8×10^3
   B. 1.6×10^5
   C. 3.1×10^5
   D. 2.4×10^6
   E. 2.8×10^6

40. Which of the following molecules has the longest intramolecular bond length?
   A. N_2
   B. KI
   C. I_2
   D. O_2
   E. Br_2

41. The elements in which of the following have most nearly the same radius for their most common ion?
   A. Be, B, C
   B. C, P, Se
   C. N, S, Br
   D. Sn, As, S
   E. S, Cl, K

42. C_2H_6 (g) + 7/2 O_2 (g) → 2 CO_2 (g) + 3 H_2O (l) + 880.2 kJ $\Delta H_f°$ H_2O (l) = -285.8 kJ/mol
                                                                                         $\Delta H_f°$ CO_2 (g) = -393.3 kJ/mol

   What is the standard heat of formation of ethane, $\Delta H_f°$ C_2H_6 (g), as calculated from the data above, in kJ/mole?
   A. 2520
   B. −201.1
   C. −763.8
   D. - 2520
   E. 763.8

43. Which of the following is higher in energy than an emission line in the Lyman series?
   A. Infrared
   B. Visible
   C. Ultraviolet
   D. X-ray
   E. Cannot be determined from the information given.

44. Which of the following would have the largest ionization energy?
   A. Be
   B. B
   C. C
   D. N
   E. Cannot be determined from the information given.

45. Which of the following atoms would display the lowest detectable degree of paramagnetism?
   A. Co
   B. Ni
   C. Cu
   D. Zn
   E. Cannot be determined from the information given.

46. What mass of H_2O will change from –20.0°C to 55.0°C when absorbing 250.0 kJ of energy? (Specific heat of ice = 2.09 J/g°C, enthalpy of fusion = 6.01 kJ/mol, specific heat of water = 4.18 J/g°C)
   A. 0.398 g
   B. 0.413 g
   C. 39.8 g
   D. 413 g
   E. 459 g

47. Which of the following atoms or ions is smallest in size?
   A. P^{3-}
   B. S^{2-}
   C. Cl^{1-}
   D. K^{1+}
   E. Cannot be determined from the information given.

48. The compound with the most polar bond is:
   A. HF
   B. HCl
   C. HBr
   D. HI
   E. Cannot be determined from the information given.

49. Which of the following compounds is definitely nonpolar?

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A. Cs$_2$S
B. SF$_6$
C. CH$_2$Cl$_2$
D. PH$_3$
E. None of the above

50. In the process of covalent bond formation,
    A. Energy is absorbed.
    B. Energy is released.
    C. No change in energy occurs.
    D. The change in energy depends on the particular bond.
    E. None of the above.

51. What is the total number of resonance structures for the compound propanol?
    A. 1
    B. 2
    C. 3
    D. 4
    E. There are no resonance structures.

52. The compound with the lowest boiling point is most likely to be:
    A. CaS
    B. KBr
    C. RbI
    D. SrS
    E. Cannot be determined from the information given.

53. The hybridization present in the compound H$_2$F$^+$ is:
    A. sp^2
    B. sp^3
    C. sp^{3}d
    D. sp^{3}d^2
    E. Cannot be determined from the information given.

54. Which is a permissible set of the first two quantum numbers of the highest energy electron of W?
    A. 4, 1
    B. 5, 2
    C. 5, 3
    D. 6, 2
    E. 6, 3

55. Which series is ranked in order from largest to smallest (becoming more positive) electron affinity?
    A. Kr, Br, Se
    B. Ar, Cl, S
    C. Se, As, Ge
    D. As, Ge, Ga
    E. None of the above

56. Of the following, the least ideal gas is:
    A. CH$_4$
    B. F$_2$
    C. N$_2$
    D. NH$_3$
    E. Xe

57. Going left-to-right across any period of the periodic table,

        I. Atomic radius increases
        II. Electronegativity increases
        III. Effective nuclear charge increases

    A. I
    B. II
    C. III
    D. Both II and III
    E. I, II, and III

58. The energy associated with the transition from $n = 3$ to $n = 6$ is:
    A. 1.82×10^{-19} J
    B. -1.82×10^{-19} J
    C. 3.63×10^{-19} J
    D. -3.63×10^{-19} J
    E. Cannot be determined from the information given.

59. Which compound has the most unshared pairs of valence electrons?
    A. C_2H_2
    B. C_2H_4
    C. C_2H_6
    D. CH_4
    E. None of the above

60. The osmotic pressure at 65°C of a 0.800 M solution of Na_3PO_4 in water is:
    A. 17.1 atm
    B. 22.2 atm
    C. 88.8 atm
    D. 1730 atm
    E. 8990 atm

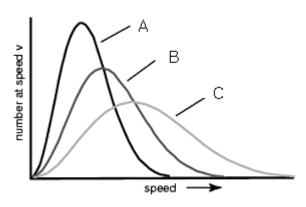61. The name for the compound $CH_3CH_2CH_2CH_2NH_2$ is:
    A. Butylamine
    B. Propylamine
    C. Aminobutoic acid
    D. Propylamide
    E. None of the above

62. Which of the following best represents the products of the net ionic equation for the reaction that occurs when solid barium oxalate and solid strontium sulfide are added to water?
    A. $Ba^{2+} + S^{2-} + SrC_2O_4$
    B. $BaS + Sr^{2+} + C_2O_4^{2-}$
    C. $BaS + SrC_2O_4$
    D. $Ba^{2+} + S^{2-} + Sr^{2+} + C_2O_4^{2-}$
    E. $SrBa + SC_2O_4$

63. Which of the following conclusions can be drawn from Robert Millikan's oil-drop experiments?
    A. Practically all the mass of an atom is contained in its nucleus.
    B. Atoms have a positively charged nucleus surrounded by an electron cloud.
    C. Electrical charges are always integral multiples of the charge of one electron.
    D. No two electrons in one atom can have the same four quantum numbers.
    E. None of the above.

64. The following properties are observed for an unknown element, A: at room temperature, it is gray, lustrous solid. The compound ACl_3 dissolves in water, forming an orange solution. When a small sample of this solution is heated by a Bunsen burner, the flame is also orange. Element A is most likely:
   A. Ca
   B. Cu
   C. Fe
   D. Sr
   E. Cannot be determined from the information given or the information is contradictory

65. Hund's rule is best shown by the electronic configuration of an atom of the element:
   A. B
   B. N
   C. Cr
   D. Mn
   E. Kr

66. For the graph at the right, it is known that, of the three curves, two are for the same substance and one is of a different substance. Consider the following conclusions:

   I. $T_A > T_B$ if they are of the same substance.
   II. (Molar mass)$_A$ > (molar mass)$_C$ if they are different substances at the same T.
   III. (Average kinetic energy)$_C$ > (average kinetic energy)$_B$ if they are different substances at the same T.

   Which of the above conclusion(s) is/are likely?
   A. I
   B. II
   C. III
   D. Both I and II
   E. I, II, and III

67. A 5.281 g sample of a compound contains 3.334 g carbon, 0.446 g hydrogen, and 1.481 g oxygen. What is the most likely empirical formula of this compound?
   A. C_3H_8O
   B. C_3H_5O
   C. $C_6H_{16}O_2$
   D. $C_3H_9O_3$
   E. $C_4H_9O_2$

68. Which property of an element is most dependent on the shielding effect?
   A. Atomic number
   B. Atomic mass
   C. Atomic radius
   D. Number of stable isotopes
   E. None of the above

69. What is the density of propane at 25°C and 740 mm Hg?
   A. 0.509 g/L
   B. 0.570 g/L
   C. 1.75 g/L
   D. 1.96 g/L
   E. None of the above

70. Given the following data, $\Delta H°_{rxn}$ for the following reaction is: $4\,NH_3\,(g) + 5\,O_2\,(g) \rightarrow 4\,NO\,(g) + 6\,H_2O\,(l)$

A. −1170
B. −150.
C. −1540
D. −1892
E. None of the above or more information is
required

Substance	$\Delta H°_f$ (kJ/mol)
H_2O (l)	-286
NO (g)	90.0
NO_2 (g)	34.0
HNO_3 (aq)	-207
NH_3 (g)	-45.9

71. Which element can exhibit more than one oxidation state in compounds?
   I. Ag
   II. Pb
   III. Sr

   A. I only
   B. II only
   C. I and II only
   D. II and III only
   E. I, II, and III

72. Use the bond energies given below to estimate ΔH for this reaction: $2 H_2$ (g) + O_2 (g) → $2 H_2O$ (g)
   A. −905 kJ
   B. −469 kJ
   C. 451 kJ
   D. 475 kJ
   E. 841 kJ

Bond	Bond Energy (kJ/mol)
H-H	436
O-O	142
O=O	499
O-H	460.

73. Which is the best description of a covalent bond?
   A. Electrons are simultaneously attracted by more than one nucleus.
   B. Filled orbitals of two or more atoms overlap one another.
   C. Unoccupied orbitals of two or more atoms overlap one another.
   D. Oppositely-charged ions attract one another.
   E. All valence electrons are shared between atoms

74. What is the formal charge on the sulfur atom in the sulfurous acid?
   A. −2
   B. +2
   C. +4
   D. +6
   E. None of the above

75. How many carbon-carbon bonds are in a molecule of 3-methyl-1-butanol?
   A. 2
   B. 3
   C. 4
   D. 5
   E. None of the above

76. How many benzene-based molecules have the formula C_8H_{10}?
   A. 1
   B. 2
   C. 3
   D. 4
   E. None of the above

77. The vapor pressure of a pure liquid in a closed container depends on:
   I. Temperature of the liquid

II. Volume of liquid
III. Surface area of the liquid

    A. I only
    B. I and II only
    C. II and III only
    D. I, II, and III
    E. None of these

78. What is the most likely boiling point of mixture of hexane (boiling point = 69°C) and heptane (boiling point = 98°C), in which heptane is the solvent?
    A. Below 69°C
    B. 69°C
    C. Between 69°C and 98°C
    D. 98°C
    E. Above 98°C

79. Small samples of two unknown, pure, white solids are placed in crucibles, and heated with a Bunsen burner. It is observed that Solid X melts faster than Solid Z. Therefore, which of the following statements must be true?
    I. Solid X has weaker intermolecular forces than Z.
    II. Solid X is more combustible than Z.
    III. Solid X has a lower molecular mass than Z.

    A. I only
    B. II only
    C. III only
    D. I and III only
    E. I, II, and III

80. Which Group 7 element has chemical properties least like the other members of the group?
    A. Cl
    B. Br
    C. I
    D. At
    E. None of the above