Name: _____ Date: _____

1. Which one of the following statements about atomic structure is false?
   A) The electrons occupy a very large volume compared to the nucleus.
   B) Almost all of the mass of the atom is concentrated in the nucleus.
   C) The protons and neutrons in the nucleus are very tightly packed.
   D) The number of protons and the number of neutrons are always the same in the neutral atom.

2. Which of the experiments listed below did *not* provide the information stated about the nature of the atom?
   A) The Rutherford experiment proved that the Thomson "plum pudding" model of the atom was essentially correct.
   B) The Rutherford experiment determined the charge on the nucleus.
   C) Millikan's oil-drop experiment showed that the charge on any particle was a simple multiple of the charge on the electron.
   D) The cathode-ray tube proved that electrons have a negative charge.

3. The ion $^{16}O^{2-}$ has
   A) 8 protons, 8 neutrons, 8 electrons
   B) 8 protons, 8 neutrons, 10 electrons
   C) 8 protons, 8 neutrons, 2 electrons
   D) 8 protons, 8 neutrons, 10 electrons
   E) 8 protons, 16 neutrons, 8 electrons

4. _____ form ions with a 2+ charge when they react with nonmetals.
   A) Alkali metals
   B) Alkaline earth metals
   C) Halogens
   D) Noble gases
   E) None of these choices

5. Which of the following formulas is *not* correct?
   A) $ZnSO_4$
   B) $Ca(OH)_2$
   C) NaS
   D) KF
   E) NH_4Br

6. Which is the correct formula for gold(I) oxide?
   A) AuO
   B) Au_2O
   C) AuO_2
   D) Au_2O_2
   E) Au_2O_3

7. Which of the following is *not* the correct chemical formula for the compound named?
   A) Li_2O lithium oxide
   B) Fe_2PO_4 iron(II) phosphate
   C) HCl hydrogen chloride
   D) $CaBr_2$ calcium bromide
   E) Zn_3P_2 zinc phosphide

8. The atomic mass of rhenium is 186.2. Given that 37.1% of natural rhenium is rhenium-185, what is the other stable isotope?
   A) $^{183}_{75}\text{Re}$
   B) $^{187}_{75}\text{Re}$
   C) $^{189}_{75}\text{Re}$
   D) $^{181}_{75}\text{Re}$
   E) $^{190}_{75}\text{Re}$

9. The average mass of a boron atom is 10.81. If you were able to isolate a single boron atom, what is the chance that you would randomly get an atom with mass 10.81?
   A) 0%
   B) 0.81%
   C) about 11%
   D) 10.81%
   E) greater than 50%

10. For which of the following compounds does 1.0 g represent 5.55×10^{-2} mol?
    A) NO_2
    B) H_2O
    C) NH_3
    D) C_2H_6
    E) NO

11. The mass of 0.82 mol of a diatomic molecule is 131.3 g. Identify the molecule.
    A) F_2
    B) Cl_2
    C) Br_2
    D) I_2
    E) Xe

12. $NaHCO_3$ is the active ingredient in baking soda. How many grams of oxygen are in 0.32 g of $NaHCO_3$?
    A) 0.011 g
    B) 1.0 g
    C) 0.061 g
    D) 0.0038 g
    E) 0.18 g

13. Compound X_2Y is 60% X by mass. Calculate the percent Y by mass of the compound X_2Y_2.
    A) 20%
    B) 30%
    C) 40%
    D) 60%
    E) 80%

14. An oxybromate compound, $NaBrO_x$, where x is a whole number, is analyzed and found to contain 52.95% Br by mass. What is x?
    A) 0
    B) 1
    C) 2
    D) 3
    E) 4

15. The empirical formula of a group of compounds is CHCl. Lindane, a powerful insecticide, is a member of this group. The molar mass of lindane is 290.8. How many atoms of carbon does a molecule of lindane contain?
    A) 2
    B) 3
    C) 4
    D) 6
    E) 8

16. When the equation $C_{10}H_{22} + O_2 \rightarrow CO_2 + H_2O$ is balanced with the smallest set of integers, the sum of the coefficients is
    A) 4
    B) 64
    C) 75
    D) 44
    E) 53

17. When the following equation is balanced, what is the sum of the coefficients?
    $Al_2(SO_4)_3 + Ca(OH)_2 \rightarrow Al(OH)_3 + CaSO_4$
    A) 4
    B) 9
    C) 8
    D) 3
    E) 10

18. A 6.32-g sample of potassium chlorate was decomposed according to the following equation:
    $2KClO_3 \rightarrow 2KCl + 3O_2$
    How many moles of oxygen are formed?
    A) 1.65 mol
    B) 0.051 mol
    C) 0.0344 mol
    D) 0.0774 mol
    E) none of these

19. 10.8 g of Al and 13.4 g of Br_2 react according to the following equation:

$$2Al + 3Br_2 \rightarrow 2AlBr_3$$

What mass of $AlBr_3$ is formed, assuming 100% yield?

A) 107 g
B) 14.9 g
C) 22.4 g
D) 33.5 g
E) 24.2 g

20. A 15-g sample of lithium is reacted with 15 g of fluorine to form lithium fluoride: $2Li + F_2 \rightarrow 2LiF$. After the reaction is complete, what will be present?

A) 2.16 mol lithium fluoride only
B) 0.789 mol lithium fluoride only
C) 2.16 mol lithium fluoride and 0.395 mol fluorine
D) 0.789 mol lithium fluoride and 1.37 mol lithium
E) none of these

21. Which of the following solutions contains the greatest total ion concentration?

A) One mole of potassium chloride dissolved in 1.0 L of solution.
B) One mole of iron(II) nitrate dissolved in 1.0 L of solution.
C) One mole of potassium hydroxide dissolved in 1.0 L of solution.
D) One mole of sodium phosphate dissolved in 1.0 L of solution.
E) At least two of these solutions have an equal number of ions, and these contain the greatest total ion concentration.

22. How many grams of Na_2SO_4 are required to make 150.0 mL of a 0.180 *M* sodium sulfate solution?

A) 2.78 g
B) 3.21 g
C) 3.40 g
D) 3.84 g
E) none of these

23. A 51.24-g sample of $Ba(OH)_2$ is dissolved in enough water to make 1.20 L of solution. How many milliliters of this solution must be diluted with water in order to make 1.00 L of 0.100 molar $Ba(OH)_2$?

A) 400. mL
B) 333 mL
C) 278 mL
D) 1.20×10^3 mL
E) 249 mL

24. High concentrations of aqueous solutions of potassium sulfide and copper(II) nitrate are mixed together. Which statement is correct?
    A) Both KNO_3 and CuS precipitate from solution.
    B) No precipitate forms.
    C) CuS will precipitate from solution.
    D) KNO_3 will precipitate from solution.
    E) No reaction will occur.

25. Lead(II) nitrate reacts with sodium chloride in aqueous solution to form a precipitate. What is the net ionic equation for this reaction?
    A) $Pb^{2+}(aq) + 2NO_3^-(aq) \rightarrow Pb(NO_3)_2(s)$
    B) $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(s)$
    C) $Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)$
    D) $Na^+(aq) + NO_3^-(aq) \rightarrow NaNO_3(s)$
    E) $Na^+(aq) + Cl^{2-}(aq) \rightarrow Na_2Cl(s)$

26. Select the unbalanced net ionic equation for the reaction between aqueous lead nitrate and aqueous potassium iodide.
    A) $Pb(NO_3)_2(aq) + KI(aq) \rightarrow PbI_2(s) + KNO_3(aq)$
    B) $Pb^{2+}(aq) + NO_3^-(aq) + K^+(aq) + I^-(aq) \rightarrow Pb^{2+}(aq) + I^-(aq) + K^+(aq) + NO_3^-(aq)$
    C) $Pb^{2+}(aq) + NO_3^-(aq) + K^+(aq) + I^-(aq) \rightarrow PbI_2(s) + K^+(aq) + NO_3^-(aq)$
    D) $Pb^{2+}(aq) + I^-(aq) \rightarrow PbI_2(s)$
    E) none of these

27. You mix 50.0 mL of 2.00 *M* lead(II) nitrate with 50.0 mL of 2.00 *M* sodium chloride. What mass of lead(II) chloride should you form?
    A) 12.1 g
    B) 13.9 g
    C) 24.3 g
    D) 27.8 g
    E) none of these

28. A 0.350-g sample of an acid, HX, requires 25.4 mL of a 0.140 *M* NaOH solution for complete reaction. Calculate the molar mass of the acid.
    A) 42.3 g/mol
    B) 68.4 g/mol
    C) 98.4 g/mol
    D) 121.3 g/mol
    E) none of these

29. Which of the following statements is(are) true?
Oxidation and reduction
I. cannot occur independently of each other.
II. accompany all chemical changes.
III. describe the loss and gain of electron(s), respectively.
IV. result in a change in the oxidation states of the species involved.
A) I only
B) II only
C) III only
D) IV only
E) I, III, and IV

30. What are the oxidation numbers of carbon in CO_2 and CO_3^{2-}, respectively?
A) +2, +6
B) +4, +6
C) -4, -4
D) -4, -6
E) +4, +4

31. In the following reaction, which species is the reducing agent?
$3Cu + 6H^+ + 2HNO_3 \rightarrow 3Cu^{2+} + 2NO + 4H_2O$
A) H^+
B) Cu
C) N in NO
D) Cu^{2+}
E) N in HNO_3

32. The following unbalanced reaction occurs in basic media:
$Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+} + Cr^{3+}$
The coefficient for water in the balanced equation is _____, and water appears on the _____ side of the equation.
A) 7, left
B) 7, right
C) 14, left
D) 14, right
E) none of these

Use the following to answer question 33:

Samples of the gases $H_2(g)$ and $SO_2(g)$ have equal masses and are at the same temperature and pressure. Calculate the following:

33. The ratio of volumes $\frac{^{V}H_2}{^{V}SO_2}$

A) 1.0
B) 0.18
C) 32
D) 5.6
E) 180

34. A balloon contains 10.0 g of neon gas. With the temperature kept constant, 10.0 g of argon gas is added. What happens?
A) The balloon doubles in volume.
B) The volume of the balloon expands by more than 2 times.
C) The volume of the balloon expands by less than 2 times.
D) The balloon stays the same size, but the pressure increases.
E) none of these

35. A sample of nitrogen gas has a volume of 160.0 mL at STP. What volume does the gas occupy if the absolute temperature and pressure are each quadrupled?
A) 640.0 mL
B) 40.00 mL
C) 160.0 mL
D) 400.0 mL
E) 89.60 L

36. It is found that 250. mL of gas at STP has a mass of 1.00 g. What is the molar mass?
A) 89.6 g/mol
B) 28.0 g/mol
C) 14.0 g/mol
D) 22.4 g/mol
E) none of these

37. Calculate the density of nitrogen at STP.
A) 0.312 g/L
B) 0.625 g/L
C) 0.800 g/L
D) 1.25 g/L
E) 1.60 g/L

38. A 250.0-L cylinder contains 65.0% He(*g*) and 35.0% Kr(*g*) by mass at 25.0° C and 1.35 atm total pressure. What is the partial pressure of He in this container?
    A) 0.473 atm
    B) 0.675 atm
    C) 0.878 atm
    D) 1.32 atm
    E) 1.35 atm

Use the following to answer question 39:

Consider three 1.0-L flasks at STP. Flask A contains Ar gas, flask B contains O_2 gas, and flask C contains H_2 gas.

39. In which flask do the gas particles have the lowest average kinetic energy?
    A) flask A
    B) flask B
    C) flask C
    D) The pas particles in all of the flasks have the same average kinetic energy.
    E) The gas particles in two of the flasks have the same average kinetic energy.

40. Under which of the following conditions does a gas behave most ideally?
    A) STP
    B) P = 1.0 atm, T = 100.0°C
    C) P = 0.50 atm, T = 100.0°C
    D) P = 0.50 atm, T = 0.0°C
    E) P = 2.0 atm, T = -100.0°C

Use the following to answer question 41:

Samples of the gases $H_2(g)$ and $SO_2(g)$ have equal masses and are at the same temperature and pressure. Calculate the following:

41. The ratio of the root-mean-square velocities $\dfrac{u_{\text{rms}}(\text{H}_2)}{u_{\text{rms}}(\text{SO}_2)}$
    A) 1.0
    B) 0.18
    C) 32
    D) 5.6
    E) 180

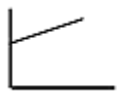
42. The root-mean-square velocity of CO gas at 35°C is
    A) 524 m/s.
    B) 177 m/s.
    C) 52.0 m/s.
    D) 16.6 m/s
    E) 5.58 m/s

43. Consider two samples of gas at the same volume and temperature that each contains 1.0 mol of gas. Sample A contains H_2 and sample B contains an unknown gas. The ratio of the impacts per second of gas A with the walls of the container to the impacts per second of gas B with the walls of the container is 4. Identify gas B.
    A) O_2
    B) Ar
    C) He
    D) CO_2
    E) Ne

44. How is the volume of the container related to the volume of an ideal gas?
    A) The volume of the container is less than the volume of an ideal gas.
    B) The volume of the container is more than the volume of an ideal gas.
    C) They are equal.
    D) The relationship depends on the gas.
    E) none of these

Use the following to answer question 45:

Which graph represents the plot?

a)  b)  c)  d)  e) none of these

45. The ratio *V*/*n* versus the Kelvin temperature of an ideal gas (constant pressure)

46. Which one of the following statements is *false*?
    A) The change in internal energy, ΔE, for a process is equal to the amount of heat absorbed at constant volume, q_v.
    B) The change in enthalpy, ΔH, for a process is equal to the amount of heat absorbed at constant pressure, q_p.
    C) A bomb calorimeter measures ΔH directly.
    D) If q_p for a process is negative, the process is exothermic.
    E) The freezing of water is an example of an exothermic reaction.

47. For a particular process q = -10 kJ and w = 25 kJ. Which of the following statements is true?
    A) Heat flows from the surroundings to the system.
    B) The system does work on the surroundings.
    C) ΔE = -35 kJ
    D) All of these are true.
    E) None of these is true.

48. Consider the following reaction:
    $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $\Delta H = -198$ kJ
    Calculate the energy change associated with 23.8 g of SO_2 reacting with excess O_2.
    A) -73.5 kJ
    B) -36.8 kJ
    C) -147 kJ
    D) -4.71×10^3 kJ
    E) -198 kJ

49. Calculate the work for the expansion of an ideal gas from 3.0 to 5.6 L against a pressure of 1.8 atm at constant temperature.
    A) 4.7 L•atm
    B) –4.7 L•atm
    C) 0
    D) 4.8 L•atm
    E) –1.4 L•atm

Use the following to answer question 50:

Consider a gas in a 1.0-L bulb at STP that is connected via a valve to another bulb that is initally evacuated. Answer the following questions about what occurs when the valve between the two bulbs is opened.

50. What is true about the value of ΔE?
    A) It is greater than zero.
    B) It is equal to zero.
    C) It is less than zero.

51. Two metals of equal mass with different heat capacities are subjected to the same amount of heat. Which undergoes the smaller change in temperature?
    A) The metal with the higher heat capacity.
    B) The metal with the lower heat capacity.
    C) Both undergo the same change in temperature.
    D) To determine this, you need to know the initial temperatures of the metals.
    E) To determine this, you need to know which metals you are talking about.

Use the following to answer question 52:

One mole of a liquid is vaporized at its boiling point, 65°C and 1.00 atm. ΔH_{vap} for the liquid is 43.8 kJ/mol at 65° C.

52. Calculate *w*.
    A) 27.7 J
    B) –27.7 J
    C) -2.81×10^3 J
    D) 2.81×10^3 J
    E) none of these

53. When a student performs an endothermic reaction in a calorimeter, how (if any) does the calculated value of ΔH differ from the actual value if the heat exchanged with the calorimeter is not taken into account?
    A) ΔH_{calc} is more negative because the calorimeter always absorbs heat from the reaction.
    B) ΔH_{calc} is less negative because the calorimeter absorbs heat from the reaction.
    C) ΔH_{calc} is more positive because the reaction absorbs heat from the calorimeter.
    D) ΔH_{calc} is less positive because the reaction absorbs heat from the calorimeter.
    E) ΔH_{calc} equals the actual value because the calorimeter does not absorb heat.

54. 75.0 mL of a pure liquid at 245 K is mixed with 100.0 mL of the same pure liquid at 365. K. What is the final temperature of the mixture?
A) 295 K
B) 305 K
C) 314 K
D) 325 K
E) none of these

55. Using Hess's law and equations 1-3 below, find $\Delta H°$ at 25°C for the oxidation of $C_2H_5OH(l)$.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 3H_2O(l) + 2CO_2(g)$$

1. $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ $\Delta H° = -1411$ kJ
2. $C(\text{graphite}) + 3H_2(g) + (1/2)O_2(g) \rightarrow C_2H_5OH(l)$ $\Delta H° = -278$ kJ
3. $C_2H_4(g) + H_2O(l) \rightarrow C_2H_5OH(l)$ $\Delta H° = -44$ kJ

A) 44 kJ
B) 632 kJ
C) -1367 kJ
D) -1742 kJ
E) none of these

56. The combustion of methanol takes place according to the reaction

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$$

Calculate ΔH for the combustion of 1 mol of methanol under standard conditions. Use the following standard enthalpies of formation:

$\Delta H°_f$ for $CH_3OH(l) = -238.5$ kJ/mol
$\Delta H°_f$ for $CO_2(g) = -393.5$ kJ/mol
$\Delta H°_f$ for $H_2O(l) = -285.6$ kJ/mol

A) +726.2 kJ/mol
B) -726.2 kJ/mol
C) +1452.4 kJ/mol
D) -1452.4 kJ/mol
E) none of these

57. From the following list of observations, choose the one that most clearly supports the conclusion that electromagnetic radiation has wave characteristics.
    A) the emission spectrum of hydrogen
    B) the photoelectric effect
    C) the scattering of alpha particles by metal foil
    D) diffraction
    E) cathode "rays"

58. Light has a wavelength of 5.8×10^2 nm. What is the energy of a photon of this light?
    A) 1.14×10^{-19} J
    B) 3.42×10^{-19} J
    C) 2.62×10^{18} J
    D) 3.81×10^{-20} J
    E) 1.28×10^{-18} J

59. Which of the following statements is(are) true?
    I. An excited atom can return to its ground state by absorbing electromagnetic radiation.
    II. The energy of an atom is increased when electromagnetic radiation is emitted from it.
    III. The energy of electromagnetic radiation increases as its frequency increases.
    IV. An electron in the $n = 4$ state in the hydrogen atom can go to the $n = 2$ state by emitting electromagnetic radiation at the appropriate frequency.
    V. The frequency and wavelength of electromagnetic radiation are inversely proportional to each other.
    A) II, III, IV
    B) III, V
    C) I, II, III
    D) III, IV, V
    E) I, II, IV

60. Which of the following is *not* determined by the principal quantum number, *n*, of the electron in a hydrogen atom?
    A) the energy of the electron
    B) the minimum wavelength of the light needed to remove the electron from the atom.
    C) the size of the corresponding atomic orbital(s)
    D) the shape of the corresponding atomic orbital(s)
    E) All of the above are determined by *n*.

61. How many electrons in an atom can have the quantum numbers $n = 3$, $l = 1$?
    A) 10
    B) 2
    C) 6
    D) 18
    E) 32

62. How many f orbitals have the value $n = 3$?
    A) 0
    B) 3
    C) 5
    D) 7
    E) 1

63. Which of the following atoms or ions has 3 unpaired electrons?
    A) Co
    B) O
    C) Ca
    D) Br^-
    E) Zn^{2+}

64. What is the electron configuration for the barium atom?
    A) $1s^22s^22p^63s^23p^63d^{10}4s^2$
    B) [Xe] $6s^2$
    C) $1s^22s^22p^63s^23p^64s^1$
    D) $1s^22s^22p^63s^23p^64s^2$
    E) none of these

65. For which element are the d orbitals completely filled in the neutral atom?
    A) potassium
    B) vanadium
    C) phosphorus
    D) iron
    E) bromine

66. An element has the electron configuration [Kr] $4d^{10}5s^25p^2$. The element is a(n)
    A) nonmetal.
    B) transition element.
    C) metal.
    D) lanthanide.
    E) actinide.

67. Place the elements C, N, and O in order of increasing ionization energy.
    A) C, N, O
    B) O, N, C
    C) C, O, N
    D) N, O, C
    E) none of these

68. The statement that the first ionization energy for an oxygen atom is lower than the first ionization energy for a nitrogen atom is
    A) consistent with the general trend relating changes in ionization energy across a period from left to right, because it is easier to take an electron from an oxygen atom than from a nitrogen atom.
    B) consistent with the general trend relating changes in ionization energy across a period from left to right, because it is harder to take an electron from an oxygen atom than from a nitrogen atom.
    C) inconsistent with the general trend relating changes in ionization energy across a period from left to right and due to the fact that the oxygen atom has two doubly occupied 2p orbitals and nitrogen has only one.
    D) inconsistent with the general trend relating changes in ionization energy across a period from left to right and due to the fact that oxygen has one doubly occupied 2p orbital and nitrogen does not.
    E) incorrect.

69. Which of the following statements is true about the ionization energy of Mg^{+}?
    A) It will be equal to the ionization energy of Li.
    B) It will be equal to and opposite in sign to the electron affinity of Mg.
    C) It will be equal to and opposite in sign to the electron affinity of Mg^{+}.
    D) It will be equal to and opposite in sign to the electron affinity of Mg^{2+}.
    E) none of the above