TEST BANK

to accompany

Chemistry

FOR SCIENTISTS AND ENGINEERS

PRELIMINARY EDITION

Fine • Beall • Stuehr

Leonard W. Fine
Columbia University

Herbert Beall
Worcester Polytechnic Institute

Julie B. Ealy
Columbia University

Mark H. Kleinman
Columbia University

Harcourt College Publishers
Fort Worth Philadelphia San Diego New York Orlando Austin
San Antonio Toronto Montreal London Sydney Tokyo

Printed in the United States of America

ISBN 0-03-026021-3

012 814 7654321

CONTENTS

Matter and Measurement

1. All of the following are macroscopic properties of a sample EXCEPT
   a) Its color
   b) Its electrical conductivity
   c) The percentages of the elements that compose it
   d) The arrangements of the atoms in its structure

2. Which of the following is a microscopic property of matter?
   a) Density
   b) The distances between atoms
   c) Color
   d) Hardness

3. Which of the following would NOT be a reasonable model to explain the stated macroscopic property?
   a) Solids are rigid, therefore the molecules in a solid must be constrained to fixed positions.
   b) Liquids flow. Therefore the molecules in a liquid must be free to move around.
   c) Nylon thread is strong. Therefore the molecules of nylon must be long and intertwined.
   d) Gold can be pounded into thin sheets. Therefore individual gold atoms can be pounded flat.

4. Which of the following is a general procedure in chemistry?
   a) Develop microscopic models involving such things as atoms, molecules and bonds to explain observed macroscopic properties
   b) Infer the nature of macroscopic properties such as color and density from what we already know about microscopic properties
   c) Develop models that are correct in all circumstances
   d) Avoid using models because they may not be completely accurate

5. All of the following are chemical processes EXCEPT
   a) A liquid vaporizing to form a gas
   b) An acid dissolving a metal
   c) The rusting of iron
   d) The conversion of starch to carbon dioxide and water in an animal

6. Which of the following operations will yield an intensive property?
   a) Determining the energy of a sample in joules
   b) Multiplying one extensive property by another extensive property
   c) Dividing one extensive property by another extensive property
   d) Measuring the length of an object in meters

7. What are the units of v in the equation $v = \sqrt{\frac{3RT}{M}}$ where R is in erg/mol·K, T is in K, M is in g/mol and erg = $g{\cdot}cm^2/s^2$?
   a) cm/s
   b) cm^2/s^2
   c) g·cm/s
   d) s/mol

8. What is the best answer for the following calculation, $\frac{12.3 + 0.316}{72.}$?
   a) 0.175222
   b) 0.1752
   c) 0.18
   d) 0.2

9. Which of the following is not a physical property?
   a) Density
   b) Color
   c) Ability to be drawn into a wire
   d) Ability to burn

10. Which of the following statements is true?
   a) Measurements with errors have no value.
   b) Errors can be ignored in calculations involving measurements.
   c) Measurements without stated errors are difficult to interpret.
   d) Measurements should be done sufficiently carefully so that there are no errors.

11. Which of the following operations will yield an intensive property?
   a) Determining the energy of a sample in joules
   b) Multiplying one extensive property by another extensive property
   c) Dividing one extensive property by another extensive property
   d) Measuring the length of an object in meters

12. Which of the following is an intensive property?
    a) Density
    b) Temperature
    c) Color
    d) Volume

13. What are the units of R in the equation PV = nRT if P is in torr, V is in mL, n is in mol, and T is in K?
    a) mol·K/torr·mL
    b) torr·K/mL·mol
    c) torr·mL/mol·K
    d) torr·mol/mL·K

14. What are the units of v in the equation $v = (RT/M)^{1/2}$ where R is in J/mol·K, T is in K, M is in kg/mol and J = kg·m^2/s^2?
    a) m/s
    b) m^2/s^2
    c) kg·m/s
    d) s/mol

15. Units have all of the following properties EXCEPT
    a) They give physical reality to pure numbers
    b) They allow for the creation of conversion factors
    c) They give an indication of the magnitude of the error involved in a measurement
    d) They are necessary for solving real problems

16. What is the best answer for (12.3 + 0.316)/72?
    a) 0.175222
    b) 0.1752
    c) 0.18
    d) 0.2

17. What is the best answer for the following calculation, (12.3 + 0.316)/72.0?
    a) 0.17522
    b) 0.175
    c) 0.18
    d) 0.2

18. What is the best answer for the following calculation, (12 + 0.316)/72?
    a) 0.17106
    b) 0.171
    c) 0.17
    d) 0.2

19. When a 4.9827g object with a density of 8.8937 g/cm^3 is dropped into a liquid with a density of 0.7289 g/cm^3, what mass of liquid will it displace?

a) 0.4084 g
b) 4.9827 g
c) 0.5602 g
d) 0.08196 g

20. All of the following are true EXCEPT

a) Atoms are made up of electrons, protons, and neutrons.
b) All atoms of a given element contain the same number of neutrons.
c) Chemical combinations of atoms are called compounds.
d) The atomic number of an element indicates the number of protons in each atom of the element.

Answer Key

1. d	11. c
2. b	12. d
3. d	13. c
4. a	14. a
5. a	15. c
6. c	16. c
7. a	17. b
8. c	18. c
9. d	19. a
10. c	20. b

Elements and Compounds

1. The name of the compound with the formula, Li_2CO_3

a) Lithium (II) carbide b) Lithium carbonite
c) Lithium carbonate d) Lithium carbonium

2. The formula for the compound, sodium sulfate, is

a) Na_2SO_4 b) Na_2S
c) Na_2SO_3 d) Na_2SO

3. What are the percentages by mass of each element in $CaCl_2$?

a) 33.3% Ca and 66.7% Cl
b) 36.1% Ca and 63.9% Cl
c) 53.1% Ca and 46.9% Cl
d) 69.3% Ca and 30.7% Cl

4. What is the percentage by mass of barium in the compound $Ba(OH)_2$?

a) 33.3% b) 50.0%
c) 80.1% d) 88.9%

5. Which of the following is NOT a logical consequence of the law of definite proportions?

a) Matter consists of atoms that have finite sizes.
b) Fixed whole numbers of atoms combine to form compounds.
c) Atoms are hard spheres.
d) Atoms of the same element are the same.

6. All of the following are statements of the law of definite proportions EXCEPT

a) All samples of sodium chloride have the same composition, no matter what the source.
b) No matter where a sodium chloride sample comes from, it will always have the same percentages of each element.
c) The amount of sodium that will combine with one gram of chlorine to form sodium chloride is a fixed number.
d) There can only be one compound formed by any pair of elements.

7. How is it that two atoms of different masses can be atoms of the same element?
   a) The number of neutrons in each atom are the same and neutrons control chemical reactions.
   b) The numbers of protons in each atom are the same and protons control chemical reactions.
   c) The numbers of electrons in each atom are the same and electrons control chemical reactions.
   d) The numbers of electrons and protons are the same for both atoms. Only the numbers of neutrons in each atom are different.

8. Which of the following is NOT part of Dalton's atomic theory?
   a) Matter is composed of atoms.
   b) Atoms are infinitely small.
   c) Atoms combine in small whole numbers to form compounds.
   d) Atoms of different elements are different.

9. Calculate the average atomic mass of Ga. Naturally occurring Ga is composed of 60.0% ^{69}Ga, that has an atomic mass of 68.911, and 40.0% ^{71}Ga, that has an atomic mass of 70.931.
   a) 69.72 amu b) 69.92 amu
   c) 70.00 amu d) 70.12 amu

10. What is the mass in grams of one atom of sodium?
   a) 3.82×10^{-23}g b) 6.95×10^{24} g
   c) 23.0 g d) 4.35×10^{-2} g

11. The average atomic mass of Ga is 69.72. Naturally occurring Ga is composed of 60.0% ^{69}Ga, which has an atomic mass of 68.91, and 40.0% of ^{71}Ga. What is the atomic mass of ^{71}Ga?
   a) 69.72 amu b) 69.92 amu
   c) 70.94 amu d) 71.00 amu

12. The average atomic mass of Ga is 69.72. Naturally occurring Ga is composed of ^{69}Ga, which has an atomic mass of 68.91, and of ^{71}Ga, which has an atomic mass of 70.93. What percentage of naturally occurring Ga is ^{71}Ga?
   a) 30.% b) 40.%
   c) 50.% d) 60.%

13. All of the following are true about isotopes EXCEPT
  a) Different isotopes of the same element have almost identical chemical behavior.
  b) The number given as a left superscript of an atomic symbol (for example ^{14}C) is the integer closest to the atomic mass.
  c) Naturally occurring elements are always a mixture of isotopes.
  d) Copper which is listed as having an atomic mass of 63.546, is a mixture of isotopes.

14. How many fluorine atoms would it take to make up a mass of 2.83×10^{-22} g?
  a) 25 atoms
  b) 6.022×10^{23} atoms
  c) 1 atom
  d) 9 atoms

15. How many sodium atoms would it take to make up a mass of 3.82×10^{-21} g?
  a) 1 atom
  b) 6.022×0^{23} atom
  c)100 atoms
  d) 2.62×10^{20} atoms

16. What is the principal advantage of the mole concept?
  a) It allows us to know the number of atoms or molecules in a sample of a known pure substance if we know the mass.
  b) It allows us to know the mass of a sample if we know the volume.
  c) It allows us to know the mass of an unknown sample if we know the number of moles.
  d) It allows us to know the volume of an unknown sample if we know the number of moles.

17. All of the following statements are true EXCEPT
  a) The proton mass is orders-of-magnitude greater than the electron mass.
  b) The nucleus occupies most of the space of an atom.
  c) The mass of an atom is mostly concentrated in the nucleus.
  d) The proton and neutron masses are almost the same.

18. It is well-known that alpha-particles are...

a) electrically neutral
b) made up of four protons
c) negatively charged
d) heavier than beta-particles

19. All of the following are associated with radioactivity except....

a) beta-particles
b) fluorescence and phosphorescence
c) elements of atomic number greater than 83
d) Becquerel and Curie

Answer Key

1. c
2. a
3. b
4. c
5. c
6. d
7. d
8. b
9. a
10. a
11. c
12. b
13. c
14. d
15. c
16. a
17. b
18. d
19. b

Elements and Compounds

1. A compound containing only H and C is completely combusted to yield 12.0 L of H_2O and 11.0 L of CO_2. What is the ratio $\frac{\text{number of H atoms}}{\text{number of C atoms}}$ for this compound?

   a) 0.545 b) 1.09
   c) 2.18 d) 4.36

2. Oxygen and element X react to form a compound that has the formula X_5O_2 and contains 11.72 g of X *per* 1.00 g of oxygen. What is the atomic mass of element X in amu?

   a) 375 amu b) 188 amu
   c) 75.0 amu d) 37.5 amu

3. Oxygen and element X react to form a product of unknown formula that contains 3.72 g of X *per* 1.00 g of oxygen. Given that the atomic mass of oxygen is 16.0, which of the following statements is correct?

   a) If the formula of the product is XO, the atomic mass of X is 3.72 amu
   b) If the formula of product is X_2O, the atomic mass of X is 119 amu
   c) If the formula of the product is X_3O_4, the atomic mass of X is 79.4 amu
   d) If the formula of the product is XO_3, the atomic mass of X is 59.5 amu

4. Two elements, A and B react in the following proportions to produce two compounds:

   Compound 1: 14.0 g A and 3.0 g B
   Compound 2: 21.0 g A and 1.50 g B

   If the formula of Compound 1 is A_2B, what is the formula of Compound 2?

   a) A_2B_3 b) AB_3
   c) A_3B_2 d) A_6B

5. Consider the following equation.

__$C_6H_{14}(l)$ + __$O_2(g)$ $\rightarrow$ __$CO_2(g)$ + __$H_2O(g)$

When this equation is properly balanced, the numbers that fill the four blanks are

a) 1, 19, 6, 7 b) 1, 19, 12, 14
c) 2, 19, 6, 7 d) 2, 19, 12, 14

6. All of the following are true about a balanced equation EXCEPT

a) It always tells the exact manner in which elements and compounds in the equation will react.
b) It is necessary for doing stoichiometric calculations.
c) It can be used for determining chemical equivalences.
d) It is a useful method for describing the nature of a chemical reaction.

7. Which of the following laws requires that equations be balanced?

a) Einstein's relationship between mass and energy, $E=mc^2$
b) The law of definite proportions
c) The law of conservation of matter
d) The ideal gas law, PV=nRT

8. What is the simplest formula of a compound that contains 53.1% C, 37.2% N, and 9.77% H by mass?

a) $C_5N_3H_{11}$ b) $C_{22}N_{15}H_4$
c) C_2NH_4 d) $C_{10}N_6H_{22}$

9. What is the simplest formula of a compound that contains 52.2% C, 34.7% O, and 13.0% H by mass?

a) C_4HO_3 b) $C_{12}H_3O_8$
c) $C_4H_{13}O_2$ d) C_2H_6O

10. All of the following are true concerning the calculation of the formula of a compound from the percentage composition of its elements only EXCEPT
    a) It is assumed that the atoms of the elements are combined in ratios of reasonably small whole numbers.
    b) The calculation can be based on the idea of starting with 100g of compound.
    c) The actual molecular formula can be calculated.
    d) The relative ratios of the numbers of the different atoms in the compound can be determined.

11. Which of the following cannot be determined from the molecular formula of the compound C_5H_{12}?
    a) The molecular mass
    b) The mass percent of the compound that is C
    c) The mass percent of the compound that is H
    d) The density of the compound

12. What is the theoretical yield of SO_2 for the reaction of 10.0 g of O_2 with sufficient S for a complete reaction?
    a) 40.0 g
    b) 30.0 g
    c) 20.0 g
    d) 10.0 g

13. Which of the following is true concerning the calculated theoretical yield of a reaction?
    a) It can be greater or less than the actual yield.
    b) It tells you exactly how much product will be produced in a reaction.
    c) It is used in the calculation of percent yield.
    d) It is higher if the reaction is run carefully.

14. O_2 will react with N_2 to form NO_2. What is the maximum yield in grams of NO_2 that can be obtained if 10.0 g of O_2 and 10.0 g of N_2 are reacted?
    a) 7.2 g
    b) 14.4 g
    c) 16.4 g
    d) 32.8 g

15. $CO(g)$ reacts with $H_2O(g)$ to form $CO_2(g)$ and $H_2(g)$. What is the percent yield if 1.8 g $H_2(g)$ gas is formed starting with 50.0 g of CO and 40.0 g of H_2O?

a) 50% b) 41%
c) 78% d) 100%

16. Which of the following is always true concerning a limiting reagent?

a) It is the reactant present in the smallest number of grams.
b) It is the reactant present in the smallest number of moles.
c) A very slight increase in the amount of the limiting reagent will result in an increase in the theoretical yield of the product.
d) Increasing the amount of the limiting reagent by any quantity will continue to increase the theoretical yield of the product.

17. A compound containing only C and H gives 0.518 g of H_2O and 2.13 g of CO_2 when fully combusted in oxygen. What is its simplest or empirical formula?

a) CH_9 b) C_5H_3
c) C_5H_6 d) C_3H_4

18. A 0.950 g sample of a compound containing C, H and O gives 0.518 g of H_2O and 2.13 g of CO_2 when fully combusted in oxygen. What is its simplest or empirical formula?

a) $C_3H_6O_2$ b) $C_5H_6O_2$
c) C_5H_4O d) $C_3H_4O_2$

19. A compound containing only phosphorus and hydrogen was fully combusted and yielded 17.9 g of P_4O_{10} and 4.80 g of H_2O. What is the empirical (simplest) formula of the compound?

a) PH_3 b) P_3H_5
c) P_6H_5 d) PH_2

20. Which of the following is true about analysis by combustion with determination of the masses of H_2O and CO_2 produced as a method for determining formula of compounds?

a) This method will work for any compound.
b) This method will give molecular formulas without any additional data.
c) This method will yield the molecular mass.
d) This method will produce a simplest or empirical formula only.

21. Which of the following is true if you carry out a combustion reaction with an unknown compound and then determine the masses of the H_2O and CO_2 produced?
    a) You can determine the molecular formula of the unknown compound without any additional data.
    b) You can determine the molecular mass of the unknown compound.
    c) You can determine only the empirical or simplest formula of the unknown compound.
    d) You cannot determine anything about the unknown compound.

22. Sulfur can be recovered from the hydrogen sulfide removed from crude oil deposits, a process known as sweetening, by roasting in air and using the sulfur dioxide initially formed to push the reaction to the final product:

$$H_2S(g) + O_2(g) \rightarrow H_2O(g) + SO_2(g)$$
$$H_2S(g) + SO_2(g) \rightarrow H_2O(g) + S(s)$$

The maximum number of kilograms of sulfur that can be isolated per kilogram of hydrogen sulfide entering the process is (Hint: Are the equations balanced?)
    a) 0.67 kg   b) 0.71 kg
    c) 0.75 kg   d) 1.5 kg

23. The reduction of carbon dioxide to carbon monoxide would best be successfully carried out by reaction with
    a) carbon   b) oxygen
    c) carbon and oxygen   d) magnesium

24. If a 1.000 g mixture of Cu_2O and CuO is quantitatively reduced to 0.865 g of Cu then the mass of Cu_2O in the original sample of the mixture must have been:
    a) 0.174 g   b) 0.250 g
    c) 0.258 g   d) 0.742 g

25. As liquid petroleum assets near depletion, natural gas can be expected to take on still greater importance in the mix of available energy resources for the 21st century. Gas chromatographic analysis reveals most natural gas samples to be largely methane and one other component. If 93% of the molecules are methane and the average molar mass is 18.0 g, then the remainder must be molecules of:

a) ethane b) propane
c) butane d) octane

26. The mass of one mole of C_{60} molecules is approximately:

a) 60 amu b) 720 amu
c) 12 g d) 720 g

27. An oxide of the element M has the formula M_2O_7 and it is known from experiments that 1.000 gram of M combines with an excess of oxygen to form 2.019 grams of oxide. The element M is

a) aluminum b) chlorine
c) manganese d) iron

28. The maximum number of kilograms (kg) of CaO produced on heating 1.0 kg of $CaCO_3$ is

a) 0.56 kg b) 0.44 kg
c) 0.40 kg d) 0.12 kg

29. When 2.70 grams of Al reacts with excess Br_2, the maximum mass of Al_2Br_6 that can be produced is

a) 8.10 g b) 26.7 g
c) 239 g d) 267 grams

30. The number of grams of O_2 required to convert 1.0 gram of H_2 to H_2O is

a) 2.0 g b) 4.0 g
c) 8.0 g d) 16.0 g

31. A sample of an iron oxide weighing 14.8 g is heated in a stream of H_2(g) until it is completely converted to iron. If the iron produced weighs 10.36 g, the percentage of oxygen in the original oxide must have been:

a) 14.3% b) 30.0%
c) 70.0% d) 85.7%

32. Boron and sulfur form two binary compounds. The first contains 0.2247 g B/1.000 g S, and the second contains 0.1348 g B/1.000 g S. If the formula for the first compound is a multiple of B_2S_3, then the second is a multiple of:

a) BS_2 b) BS_3
c) B_2S_5 d) B_2S_7

33. A sample of an unknown element has a mass of 2.14×10^{-4} g and contains 1.2751×10^{18} atoms. The element is most probably:

a) Ru b) Nb
c) Mo d) Tc

Answer Key

1. c
2. c
3. c
4. a
5. d
6. a
7. c
8. a
9. d
10. c
11. d
12. a
13. c
14. b
15. a
16. c
17. c
18. b
19. d
20. d
21. c
22. b
23. c
24. d
25. b
26. d
27. c
28. a
29. b
30. c
31. b
32. b
33. a

Gases

1. What will be the height of a column of chloroform (density = 1.49×10^3 kg/m^3) that will be supported by a pressure of 2.00×10^5 N/m^2? 1 N = 1 kg·m/s^2. The acceleration due to gravity is 9.807 m/s^2.

   a) 0.0731 m b) 0.716 m
   c) 1.40 m d) 13.7 m

2. What is atmospheric pressure if the pressure can support a column of chloroform (density = 1.49×10^3 kg/m^3) that is 13.7 m high? 1 N = 1 kg·m/s^2. The acceleration due to gravity is 9.807 m/s^2.

   a) 1.07×10^3 N/m^2 b) 1.05×10^4 N/m^2
   c) 2.05×10^4 N/m^2 d) 2.00×10^5 N/m^2

3. All of the following factors influence the height of a column of a liquid that will be supported by atmospheric pressure EXCEPT

   a) The diameter of the column
   b) The value of the existing atmospheric pressure
   c) The density of the liquid
   d) The value of acceleration due to gravity

4. Which of the following factors influences the height of a column of a liquid that will be supported by atmospheric pressure.

   a) The diameter of the column
   b) The volume of the vessel below the column
   c) The density of the liquid
   d) The depth of the vessel below the column

5. An open-ended manometer containing mercury is attached to a container of gas. The pressure of the gas in the container is known to be 991 torr (1 torr = 1 mm of mercury). The height of the mercury column is 252 mm higher on the open side than on the side connected to the container. What is the atmospheric pressure?

   a) 739 torr
   b) 991 torr
   c) 1243 torr
   d) Insufficient data are given to solve this problem.

6. A closed-ended manometer containing mercury is attached to a container of gas. The atmospheric pressure is known to be 991 torr (1 torr = 1 mm of mercury). The height of the mercury column is 252 mm higher on the closed side than on the side connected to the container. What is the pressure of the gas in the container?

a) 1243 torr	b) 739 torr
c) 252 torr	d) 991 torr

7. A closed-ended manometer containing mercury is attached to a container of gas. The pressure of the gas in the container is known to be 991 torr (1 torr = 1 mm of mercury). The height of the mercury column is 991 mm higher on the open side than on the side connected to the container. What is the atmospheric pressure?

   a) 739 torr
   b) 991 torr
   c) 1243 torr
   d) Insufficient data are given to solve this problem.

8. Consider using an open-ended and a closed-ended manometer for determining the pressure of a gas in a container. For which is it necessary to know the atmospheric pressure in order to get a meaningful pressure reading?

   a) The open-ended manometer
   b) The closed-ended manometer
   c) Both
   d) Neither

9. The density of CO gas at 1.00 atm and 323K is 1.06 g/L. What is the density of NO gas at the same temperature and pressure?

a) 0.989 g/L	b) 1.06 g/L
c) 1.14 g/L	d) 22.4 g/L

10. The density of CO gas at 1.00 atm and 323K is 1.06 g/L. The density of a second gas is 1.74 g/L at the same temperature and pressure. What is the molar mass of the second gas?
    a) 72 g/mol b) 46 g/mol
    c) 92 g/mol d) 36 g/mol

11. All of the following are equivalent to a statement of Avogadro's hypothesis EXCEPT
    a) Equal volumes of gases at the same temperature and pressure have the same number of particles.
    b) Equal volumes of gases at the same temperature and pressure have the same number of moles.
    c) For gases at the same temperature and pressure, the number of particles is proportional to the volume.
    d) The number of particles in one liter of gas is always the same.

12. Which of the following is a consequence of Avogadro's hypothesis?
    a) The density of a gas is proportional to its atomic or molar mass.
    b) The density of a gas is proportional to the size of the sample in moles.
    c) The density of a gas is proportional to the temperature.
    d) The density of a gas is inversely proportional to the temperature.

13. All of the following are a consequence of Charles's law EXCEPT
    a) A balloon filled with hot air will rise.
    b) If the absolute temperature of an ideal gas is doubled, its volume will double as long as the pressure remains constant.
    c) Increasing the pressure on a gas will decrease its volume.
    d) An ideal gas would have a volume of 0 L at 0 K regardless of the pressure.

14. Which of the following is a consequence of Charles's law?
   a) Increasing the amount of gas in a container of constant volume increases the pressure.
   b) A gas will expand to a larger volume if the pressure is decreased.
   c) The lower the density of the liquid in a barometer, the higher the column of that liquid will be.
   d) The density of a gas held at constant pressure decreases when the temperature is increased.

15. All of the following are a consequence of Boyle's law EXCEPT
   a) Doubling the volume of a sample of ideal gas will halve its pressure at constant temperature.
   b)For an ideal gas at constant pressure, the product of the pressure times the volume is a constant.
   c) If all the gas in a highly compressed gas cylinder is released, the volume of the gas at atmospheric pressure will be greater than the volume of the cylinder.
   d) Increasing the pressure on a gas will raise its temperature.

16. Which of the following is a consequence of Boyle's law?
   a) The density of a gas increases when the pressure is increased.
   b) The density of a gas decreases when the temperature is increased.
   c) The density of a gas increases when the molecular mass is increased.
   d) The density of a gas increases when the temperature is increased.

17. What is the molar mass of a gas which has a density of 13.5 g/L at a pressure of 1.50 atm and a temperature of 27…C?
   a) 20.0 g/mol   b) 44.9 g/mol
   c) 222 g/mol   d) 499 g/mol

18. What is the density of N_2O_4 at a pressure of 1.50 atm and a temperature of 27…C?

a) 5.6 g/L b) 3.7 g/L
c) 62 g/L d) 41 g/L

19. What is the temperature of a sample of $NO_2(g)$ if it has a pressure of 1.63 atm and its density is measured to be 2.60 g/L?

a) 351K b) 2380K
c) 56.2K d) 2.36K

20. All of the following will cause the density of a fixed mass of a gas to increase EXCEPT

a) Increasing its pressure (temperature held constant)
b) Decreasing its volume (temperature held constant)
c) Increasing its temperature (pressure held constant)
d) All of the above will increase the density of the gas.

21. Which of the following will cause the density of a fixed mass of a gas to increase?

a) Increasing its pressure (temperature held constant)
b) Increasing its volume (temperature held constant)
c) Increasing its temperature (pressure held constant)
d) Increasing its temperature (volume held constant)

22. Water reacts with lithium to produce H_2 gas and LiOH. This reaction is run at 27…C and a pressure of 0.75 atm. What is the mass of the lithium sample if 3.4 L of H_2 are produced using an excess of HCl?

a) 0.36 g b) 0.72 g
c) 3.99 g d) 7.98 g

23. What mass of Al is required to react with an acid and produce 1.00 L of $H_2(g)$ at 700 torr and 350K?

a) 0.0320 g b) 0.577 g
c) 0.865 g d) 1.30 g

24. A gas mixture of N_2(g) and CO_2(g) contained in a volume of 10.0 L has a total pressure of 0.750 atm at a temperature of 273K. The mixture is known to contain 3.00 g N_2(g). What is the partial pressure of CO_2(g) in the mixture?

a) 0.120 atm b) 0.240 atm
c) 0.510 atm d) 0.630 atm

25. A gas mixture of N_2(g) and CO_2(g) contained in a volume of 10.0 L has a total pressure of 0.750 atm at a temperature of 273K. The mixture is known to contain 2.00 g N_2(g). What is the mass of the CO_2(g) in the mixture?

a) 0.2632 g b) 3.12 g
c) 11.58 g d) 14.70 g

26. A gas mixture contains 2.00 g of N_2(g) and 4.00 g of CO_2(g) in a volume of 25.0 L and a temperature of 300K. What is the total pressure of the gas mixture?

a) 0.070 atm b) 0.090 atm
c) 0.130 atm d) 0.160 atm

27. A gas mixture of N_2(g) and an unknown gas contained in a volume of 10.0 L has a total pressure of 0.850 atm at a temperature of 298K. The mixture is known to contain 3.00 g N_2(g) and 10.6 g of the unknown gas. What is the molar mass of the unknown?

a) 44 g/mol b) 22 g/mol
c) 28 g/mol d) 88 g/mol

28. All of the following are true about Dalton's law of partial pressures EXCEPT

a) It is true for any gas.
b) It states that the total pressure of a gas mixture is equal to the sum of the partial pressures of the components of the mixture.
c) The states the partial pressure of a gas in a mixture is equal to the mole fraction of the gas times the pressure of the mixture.
d) It states that each gas in a mixture has its own partial pressure.

29. Which of the following is a necessary assumption for Dalton's law of partial pressures?
    a) The gas must be ideal.
    b) The gas must have a low molar mass.
    c) The total pressure of the gas mixture must be less than 1 atm.
    d) The partial pressures of all gases in the mixture must be about the same.

30. What is pressure calculated by van der Waals s equation for 1.00 mole of $Cl_2(g)$ in a volume of 1.00 L at a temperature of 200K? The values of the van der Waals's constants for Cl_2 (g) are a = 6.493 $L^2 \cdot atm/mol^2$ and b = 0.5622 L/mol.
    a) 9.93 atm
    b) 16.4 atm
    c) 31.0 atm
    d) 37.5 atm

31. What will be the temperature calculated using the van der Waals equation for 1.00 moles of Cl_2 (g) in a volume of 1.00 L at a pressure of 31.0 atm? The values of the van der Waal's constants for $Cl_2(g)$ are a = 6.493 $L^2 \cdot atm/mol^2$ and b = 0.5622 L/mol.
    a) 16.4K
    b) 200K
    c) 377K
    d) 365K

32. Which of the following is true about a real gas?
    a) Its pressure is always less than that calculated for an ideal gas.
    b) Its pressure is always greater than that calculated for an ideal gas.
    c) Its pressure is always different from that calculated for an ideal gas.
    d) Its particles have volume and have forces of attraction or repulsion for other particles.

33. The van der Waals constants for Ar are a = 1.345 L^2Æatm/mol^2 and b = 0.03219 L/mol. The same constants for O_2 are a = 1.360 L^2Æatm/mol^2 and b = 0.03183 L/mol. Which of the following is correct in a comparison between Ar and O_2?

a) Attractions between Ar particles are stronger and the effective size of the Ar particle is greater.
b) Attractions between O_2 particles are stronger and the effective size of the O_2 particle is greater.
c) Attractions between O_2 particles are stronger but the effective size of the Ar particle is greater.
d) Attractions between Ar particles are stronger but the effective size of the O_2 particle is greater.

34. The Cl_2 molecule is larger than the N_2 molecule and Cl_2 has a higher boiling point than N_2. Which of the following would be true about the van der Waals constants for the two gases.

a) a and b for Cl_2 are larger than a and b for N_2
b) a and b for Cl_2 are smaller than a and b for N_2
c) a is larger for Cl_2 but b is larger for N_2
d) a is larger for N_2 but b is larger for Cl_2

35. At how many different pressures can the compressibility factor, Z, of a real gas equal exactly 1?

a) None
b) One only
c) One or two
d) Z is always equal to 1.

36. A gas has a compressibility factor of 2.50 at a pressure of 65.0 atm. What is the temperature of 2.00 moles of this gas in a volume of 1.00 L at 65.0 atm pressure?

a) 158K
b) 317K
c) 396K
d) 990K

37. A plot of the compressibility factor (Z) vs. pressure for some gas has a value of 1 at zero pressure; Z drops and then rises again crossing the Z = 1 line as the pressure is increased. What is the situation that prevails at that pressure at which the compressibility is just crossing the Z=1 line?
    a) The attraction between particles is the predominant factor causing non-ideal behavior.
    b) The volume of the particles is the predominant factor causing non-ideal behavior.
    c) The effects of attraction between particles and the volume of the particles are exactly canceling each other out.
    d) The gas is behaving like an ideal gas.

38. What will be the likely value of the compressibility factor, Z, of a real gas if attraction between particles is the predominant factor causing non-ideal behavior?
    a) Z will be greater than 1 b) Z will be less than 1
    c) Z will be equal to 1 d) Z will be equal to 0

39. What is the root-mean-square speed of a CO_2 (g) particle at a temperature of 250 K?
    a) 1.18 cm/s b) 3.76×10^4 cm/s
    c) 1.42×10^9 cm/s d) Not enough data are available

40. At what temperature will a sample of O_2 have a root mean square speed of 3.68×10^4 cm/s? Assume a pressure of exactly one atm.
    a) 0.00472K b) 174K
    c) 521K d) 17600K

41. All of the following are assumptions made in deriving the equation for the root mean square speed of the particles of a gas EXCEPT
    a) Collisions are perfectly elastic.
    b) The gas particles are in constant motion.
    c) Gas particles collide with the walls of the container but not with each other.
    d) Pressure is the result of the gas particles colliding with the container walls.

42. All of the following are true about the speed of a gas according to the kinetic theory EXCEPT
   a) The root-mean-square speed of a gas depends on the pressure.
   b) The particles move at different speeds.
   c) The root mean square speed of a gas is proportional to the square root of the temperature.
   d) Particles with high molar masses in a gas mixture move more slowly than those with low molecular masses.

43. Which of the following will increase the root-mean-square speed of a gas in a container?
   a) Change to a gas with a higher molar mass.
   b) Increase the pressure
   c) Increase the temperature
   d) Increase the volume

44. $H_2(g)$ effuses though a tiny opening ______ times as fast as $O_2(g)$ under the same conditions.
   a) 1.3 b) 4.0
   c) 5.6 d) 32

45. A gas diffuses through a tiny opening at 1.37 times the rate of $O_2(g)$. What is the molar mass of the gas?
   a) 23.4 b) 43.8
   c) 17.0 d) 60.1

46. The rate of effusion through a tiny opening is measured for each of the following combinations. In which of these combinations does the gas effuse through the opening most rapidly assuming that all start at the same pressure?
   a) CO_2 at 273K b) CO_2 at 373K
   c) O_2 at 273K d) O_2 at 373K

47. The Kelvin temperature scale was created from the Celsius scale, because
   a) Kelvin invented a simpler and more precise thermometer.
   b) Negative temperature on the Celsius scale has no physical meaning.
   c) It was found experimentally that all gases extrapolated to an apparent zero volume at minus 273.15… Celsius.
   d) The mathematics are easier if negative temperatures are not considered.

48. A closed flask contains equal molar amounts of F_2, $^{16}O_2$, $^{18}O_2$, and UF_6 at room temperature. If a small hole is cut in one side, and the speed of the gas molecules escaping into a vacuum is measured, which of the following statements is TRUE?
   a) The speeds are the same because the temperature is the same.
   b) The two oxygen molecules have the same speed.
   c) UF_6 is slowest because it is the heaviest.
   d) The speeds depend upon the gas kinetic collision rate, and hence on the total pressure inside.

49. The density of molecules in the normal atmosphere at room temperature and P = 1 atm is about:
   a) 6.02×10^{23} molecules / cm^3
   b) 2.5×10^{19} / cm^3
   c) It depends upon the presence or absence of species such as NO, nitrogen dioxide, and sulfur dioxide.
   d) It can not be calculated from the ideal gas law.

50. He gas at a pressure of 100 atmospheres is stored in a 1 liter steel tank cooled by liquid nitrogen at 77K. The gas is expanded in a 200-L glass flask at 14…C, just below room temperature. What is the final pressure?
   a) 2 atm b) 5 atm
   c) 16.6 atm d) 400 atm

51. What is the density of carbon dioxide gas at 0…C temperature and 1 atmosphere pressure?
   a) 0.54 g/L b) 1.25 g/L
   c) 1.43 g/L d) 1.96 g/L

52. A flask of 0.5 L volume contains one atmosphere of nitrogen gas at 295K temperature. A vacuum pump exhausts the flask to a pressure of 1×10^{-7} atm. About how many molecules of nitrogen remain in the flask?

a) 2.5×10^{12} molecules   b) 1.25×10^{15} molecules
c) 2.5×10^{19} molecules   d) 1.25×10^{22} molecules

53. In an isotopic enrichment effusion apparatus, $^{238}UF_6$ and $^{235}UF_6$ gases at 23…C escape from a small hole into a vacuum. If the initial mole fraction ratio of the two gases is 1:1 , calculate the mole fraction ratio $^{235}UF_6/^{238}UF_6$ in the escaping gases.

a) 1.0086   b) 1.0043
c) 0.99147   d) 0.98740

54. All of the following statements about gases are true, EXCEPT

a) At 23…C an $^{18}O_2$ gas has a higher pressure than an $^{16}O_2$ gas because the heavier molecule exerts a greater force per collision on the wall.
b) In the absence of other molecules, a single molecule travels in a straight line trajectory.
c) At high pressure, a single molecule travels in a random trajectory because of multiple collisions with other molecules.
d) In a gas at 23…C and P = 1 atm, the average distance between molecules is much greater than a molecular diameter.

55. If the sun were to suddenly begin to emit more far UV light of wavelength less than 200 nm, then:

a) the ozone at the earth's surface would be photodissociated faster and thus decrease
b) the earth would heat up, and the human skin cancer rate would increase due to increased ultraviolet light
c) more NO (nitric oxide) would form in the polluted air of big cities due to reactions by O atoms from photodissociation
d) in the ozone layer at 30 km, the oxygen atom concentration would increase first and then ozone concentration would increase

56. Two elements react as follows:

$$1 \text{ L of A} + 2 \text{ L of B} \rightarrow 1 \text{ L of product}$$

Which of the following is a formula for the product that is consistent with the data?

a) AB
b) A_2B
c) AB_2
d) All of the above are consistent

Answer Key

1. d
2. d
3. a
4. c
5. a
6. c
7. d
8. a
9. c
10. b
11. d
12. a
13. c
14. d
15. d
16. a
17. c
18. a
19. a
20. c
21. a
22. a
23. b
24. c
25. c
26. d
27. a
28. a
29. a
30. c
31. b
32. d
33. c
34. a
35. c
36. a
37. c
38. b
39. b
40. b
41. c
42. a
43. c
44. b
45. c
46. d
47. c
48. c
49. b
50. a
51. d
52. b
53. b
54. a
55. a
56. c

Atomic Structure

1. What is the frequency of light with a wavelength of 7.5×10^{-5} cm?
   a) 2.5×10^{-13} s^{-1} b) 2.5×10^{-8} s^{-1}
   c) 4.0×10^{12} s^{-1} d) 4.0×10^{7} s^{-1}

2. What is the energy of a photon of light that has a frequency of 3.0×10^{14} s^{-1}?
   a) 2.0×10^{-19} J b) 5.0×10^{18} J
   c) 1.0×10^{6} J d) 1.0×10^{-8} J

3. Which of the following is not a form of electromagnetic radiation?
   a) Light b) Radiated heat
   c) Sound d) Microwaves

4. Which of the following has the most energy per photon?
   a) X-rays b) Ultraviolet rays
   c) Visible light d) Infrared radiation

5. The maximum wavelength of light that can remove electrons from zinc is 310 nm. What is the work function for zinc?
   a) 1.1×10^{-18} J b) 2.0×10^{-40} J
   c) 6.4×10^{-19} J d) 2.0×10^{-23} J

6. The work function for copper is 7.17×10^{-19} J. What is the kinetic energy of electrons expelled from a copper surface by radiation with a wavelength of 250 nm?
   a) 7.9×10^{-19} J b) 7.8×10^{-20} J
   c) 7.2×10^{-19} J d) 2.5×10^{-17} J

7. A beam of light with a wavelength of 450 nm is expelling electrons from a lithium surface. What will be the effect of doubling the intensity of this light, that is, employing two lamps instead of one?
   a) No effect
   b) Increase in the kinetic energy of expelled electrons
   c) Increase in intensity of expelled electron beam (more electrons expelled per unit time)
   d) Increase of kinetic energy and intensity of expelled electron beam

8. Which of the following transitions in the hydrogen spectrum will radiate the highest frequency?
   a) From n=3 to n=1 b) From n=2 to n=1
   c) From n=3 to n=2 d) From n=4 to n=2

9. What is the frequency emitted when a hydrogen atom in the n=4 state drops to the n=2 state?
   a) 8.18×10^{14} s^{-1} b) 2.01×10^{6} s^{-1}
   c) 3.06×10^{15} s^{-1} d) 6.13×10^{14} s^{-1}

10. Which of the following is the result when single atoms in gases are energized?
    a) Line spectra b) Continuous spectra
    c) Only ultraviolet radiation d) Band spectra

11. What is the minimum information needed to use the Rydberg equation can be used to calculate the frequency of a specific transition in the hydrogen spectrum?
    a) The quantum number of the lower energy level and the Rydberg constant.
    b) The quantum number of the higher energy level and the Rydberg constant.
    c) The quantum numbers of the higher energy level and the lower energy level and the Rydberg constant.
    d) The quantum numbers of the upper energy level and the lower energy level, the Rydberg constant and the atomic mass.

12. All of the following are assumptions made in the Bohr theory EXCEPT
    a) The forces of circular motion and coulombic attraction exactly balance.
    b) The electron in its orbit neither absorbs or emits energy.
    c) The electron can occupy only certain orbits.
    d) The nucleus consists of protons and neutrons.

13. Which of the following is NOT true of the Bohr theory of the atom?
   a) The Bohr theory quite accurately reproduces the spectrum of the hydrogen atom.
   b) The Bohr theory involves quantum numbers.
   c) The Bohr theory is useful for reproducing the emission spectra of small atoms such as He and Li.
   d) The orbiting electron in the ground state of a hydrogen atom maintains a constant distance from the nucleus.

14. What is the energy necessary to remove the one electron from the He^+ ion?
   a) 2.16×10^{-18} J   b) 4.33×10^{-18} J
   c) 8.66×10^{-18} J   d) 1.73×10^{-17} J

15. What is the energy necessary to remove the one electron from the Be^{3+} ion?
   a) 2.17×10^{-18} J   b) 8.68×10^{-18} J
   c) 1.95×10^{-17} J   d) 3.47×10^{-17} J

16. What is the de Broglie wavelength of an electron moving at a speed of 3.00×10^8 cm/s?
   a) 2.42×10^{-8} cm   b) 2.42×10^{-15} cm
   c) 4.13×10^7 cm   d) 7.26×10^{-16} cm

17. What is the mass of a particle having a de Broglie wavelength of 2.42×10^{-10} m and moving at 1.00×10^{-7} m/s?
   a) 2.42×10^{-8} kg   b) 2.74×10^{-17} kg
   c) 4.13×10^7 kg   d) 7.26×10^{-16} kg

18. Why do we not observe wave behavior for a moving Greyhound bus?
   a) Its speed is too slow.   b) Its mass is too great.
   c) It has no charge.   d) It is not a pure substance.

19. What is the minimum uncertainty in the speed of a particle if its mass is 1.0×10^{-27} kg and its position is known with an uncertainty of 1.0×10^{-7} m?
   a) 1.52×10^{-34} m/s   b) 0.16 m/s
   c) 3.5×10^7 m/s   d) 54 m/s

20. Why is the Bohr model of the atom forbidden by the Heisenberg uncertainty principle?
    a) The Bohr model fails to predict the fine structure in the hydrogen spectrum.
    b) The Bohr model is useful only for one-electron systems.
    c) The Bohr electron is moving in a fixed orbit at a fixed speed.
    d) The direction of the orbiting electron is not known.

21. What is the longest wavelength of vibration that can occur on a string that is held between to points 30 cm apart?
    a) 10 cm   b) 15 cm
    c) 30 cm   d) 60 cm

22. The wave model of the electron of the hydrogen atom produces which of the following results?
    a) An exact tracking of the movement of the electron
    b) Quantization of the angular momentum of the electron
    c) The exact speed of the electron
    d) A new value for Planck's constant

23. How many different states (combinations of l, m_l and m_s) are possible if n, the major quantum number is 2?
    a) 3   b) 4
    c) 6   d) 8

24. How many different states (combinations of l, m_l and m_s) are possible if n, the major quantum number is 3?
    a) 8   b) 9
    c) 18   d) 36

25. Why does the spin quantum number m_s arise?
    a) The spin of the nucleus
    b) The orbiting of the electron
    c) The overall spin of the atom
    d) The spin of the electron

26. Which of the following is the correct electron configuration of Ca?
    a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$ b) $1s^2 2s^2 2p^6 2d^2 3s^2 3p^6$
    c) $1s^2 2s^2 2p^6 3s^2 3p^8$ d) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

27. Which of the following is the correct electron configuration of Pb?

a) $[Xe]6s^2 5d^{10} 4f^{14} 6p^2$
b) $[Xe]6s^2 4f^{14} 6s^2$
c) $[Xe]6s^2 5d^{10} 4f^{14} 5d^{10} 6p^2$
d) $[Xe]5d^{10} 4f^{14} 6p^2$

28. Which element has the ground state electron configuration of $[Xe]6s^2 5d^{10} 4f^{14} 6p^2$?

a) Tl
b) Sn
c) Pb
d) Bi

29. What is the principal assumption that is made in the build-up of electronic structures of atoms?

a) The masses of the different atoms are so small that the differences are negligible.
b) All atoms are approximately the same size
c) The orbitals calculated for hydrogen can be used for all the rest of the atoms.
d) All atoms have similar reactivity.

30. What is the effect on an orbital of an atom if the nuclear charge is increased?

a) The size of the orbital decreases and its energy becomes lower.
b) The size of the orbital increases and its energy becomes higher.
c) The size of the orbital decreases and its energy becomes higher.
d) The size of the orbital increases and its energy becomes lower.

31. How many 3d orbitals are there?

a) 1
b) 5
c) 10
d) 12

32. There are two 2p electrons in carbon. How are there spins related to each other?

a) In one orbital and in the same direction
b) In one orbital and in opposite directions
c) In two orbitals and in the same direction
d) In two orbitals and in opposite directions

33. The most stable monatomic ion of phosphorus will have a charge of:

a) —1
b) +1
c) +2
d) —3

34. The correct order of increasing frequency is:
   a) X-ray, ultraviolet, microwave
   b) ultraviolet, X-ray, microwave
   c) ultraviolet, microwave, X-ray
   d) microwave, ultraviolet, X-ray

35. The total number of orbitals (excluding spin) in the n = 3 states of the H-atom are:
   a) 32   b) 16
   c) 9   d) 5

36. The total spin of the electrons in the ground state of a calcium atom is
   a) 2   b) 1
   c) 0   d) 1/2

37. A noble gas configuration is
   a) ns   b) ns^2np
   c) ns^2np^6 d) $ns^2np^6(n + 1)s^2$

38. A thermal neutron in a reactor has a mass of 1.675×10^{-27} kg, a velocity of 800. m/s, and h = 6.662×10^{-34} JÆs. The de Broglie wavelength of this thermal neutron is
   a) 0.0530 nm   b) 4.97×10^{-13} m
   c) 0.497 nm   d) 0.530 nm

39. Respectively, red light has a (higher or lower) frequency and a (longer or shorter)wavelength than blue light.
   a) higher, longer   b) higher, shorter
   c) lower, longer   d) lower, shorter

40. When high energy ultraviolet light falling on a metal surface causes electrons to be ejected, as the intensity of the light is increased
   a) the kinetic energy of the ejected electrons increases
   b) the kinetic energy of the ejected electrons decreases
   c) the number of ejected electrons increases
   d) the number of ejected electrons decreases

41. Following are three states for fluorine:

$1s^2 2s^1 2p^6$ $1s^2 2s^2 2p^5$ $1s^2 2s^2 2p^4 2d^1$

They are, respectively:

a) ground, excited, impossible
b) ground, impossible, excited
c) excited, impossible, ground
d) excited, ground, impossible

42. The energy sublevel that can contain the most electrons is specified by which of the following quantum number descriptions?

a) $n = 2, l = 1$ b) $n = 3, l = 2$
c) $n = 4, l = 3$ d) $n = 5, l = 0$

43. Imagine a universe that is the same as ours in all ways except the value of Planck s constant is different. A scientist in this universe measures the wavelength of an Si atom (assume atomic mass is 28 amu) traveling at 100 m/sec to be 3×10^{-5} m. What is the value of Planck s constant in JÆs that can be obtained from these measurements?

a) 6.62×10^{-34} b) 1.39×10^{-28}
c) 4.21×10^{-28} d) 5.67×10^{-31}

44. Which of the following atoms has the largest number of unpaired spins?

a) C b) P
c) K d) F

45. Which of the following orbitals in a many-electron atom has the lowest (i.e. most negative) energy?

a) 3s b) 3p
c) 3d d) 4d

46. All one of the following statements about the Bohr atom are true, EXCEPT

a) Electrons travel in circular orbits with only specific values of the angular momentum allowed.
b) The uncertainty principle can be derived from the Bohr atom.
c) The Bohr atom correctly predicts the energy levels of the hydrogen atom.
d) The Bohr atom is not a complete and accurate theory of quantum mechanics.

47. All of the following statements about a hydrogenic 4s orbital are true, EXCEPT

a) The probability of finding an electron in this orbital 10m from the nucleus is zero.
b) The orbital has three radial nodes.
c) The energy of the orbital is higher (less negative) than that of the 3s orbital.
d) The spatial extent of the orbital is (on average) greater than that of a 2s orbital.

48. What is the wavelength of green light?

a) ~370 nm b) ~540 nm
c) ~700 nm d)~1020 nm

49. All of the following are correctly stated underlying principles used to build up the configuration of a many electron atom, EXCEPT

a) Pauli principle: no two electrons can have an identical set of quantum numbers.
b) Aufbau principle: atomic orbitals are filled with electrons from lowest energy to higher energies.
c) Hund s rule: electrons in degenerate orbitals are arranged to minimize the number of unpaired spins.
d) All of the above statements are correct.

50. A molecule of N_2 has a velocity of 3000 m/sec. Calculate the de Broglie wavelength of the molecule

a) 7.88×10^{-39} m b) 1.58×10^{-38} m
c) 4.75×10^{-12} m d) 9.5×10^{-12} m

51. A hydrogen atom in its ground state (n=1) absorbs a photon of frequency 3.223×10^{15}/sec. It then emits a photon of frequency 2.98×10^{14}/sec. What state (i.e. what value of n) of the hydrogen atom is the electron in after emitting the photon?

a) 1 b) 2
c) 3 d) 4

52. A scientist in an alternate universe decides to measure the value of Planck s constant in that universe. She takes a metal with work function $W=1 \times 10^{—10}$ J and varies the frequency of light used to irradiate the metal until an electron is ejected. The smallest frequency causing ejection of the electron is 4×10^{15}/sec. What is the value of Planck s constant determined from this experiment?

a) $6.62 \times 10^{—34}$ JÆs　　b) $2.5 \times 10^{—26}$ JÆs
c) 4.0×10^{5} JÆs　　d) 4×10^{25} JÆs

53. Consider an electron which must reside in one of two boxes, A and B. The volumes of A and B are identical and the wavefunction of the electron is constant inside of each box. The values of the wavefunction for the two boxes are as follows:

ψ_A (x,y,z) = 0.5
ψ_B (x,y,z) = 0.866

An experiment is carried out to locate the electron. The experiment is repeated many times. What percentage of the time will the electron be found in box A?

a) 0%　　b) 25%
c) 33%　　d) 75%

54. The Bohr radius of the hydrogen atom is 5.29×10^{-11} m; this is approximately the size of the hydrogen atom when the electron is in its 1s ground state as calculated with accurate quantum mechanics. Suppose we tried to construct a quantum mechanical state in which an electron was confined to within $10^{—15}$ m of the hydrogen nucleus. Which of the following statements about this state is correct?

a) It is impossible to prepare such a state because it violates the uncertainty principle.
b) If such a state were prepared, it would have very high energy due to the presence of very large kinetic energy components arising from the uncertainty principle.
c) If such a state were prepared, it would have very high energy due to unfavorable Coulomb interactions caused by the electron being very close to the nucleus.
d) Such a state would have very low energy, lower than the normal hydrogen 1s state.

55. Only one of the following sets of quantum numbers for the H atom does not violate the quantum number rules. Which one is it?

a) $n = 0, l = 0, m = 0, m_s = 1/2$
b) $n = 3, l = 2, m = 3, m_s = -1/2$
c) $n = 4, l = 5, m = -2, m_s = 1/2$
d) $n = 6, l = 7, m = -5, m_s = -1/2$

56. All of the following statements about X-rays are true EXCEPT

a) X-rays are emitted by excited atoms.
b) X-rays are particles with a measurable e/m ratio
c) X-rays are dangerous at high intensities.
d) X-rays are a form of electromagnetic radiation.

57. Calculate the minimum uncertainty in the position of a baseball moving the x direction only of mass 0.5 kg whose uncertainty in velocity is 1.0×10^{-5} m/sec.

a) 1.05×10^{-29} m
b) 1.32×10^{-28} m
c) 4.22×10^{-34} m
d) 6.63×10^{-34} m

58. An atom has a velocity of 75 m/sec and a de Broglie wavelength of 2.199×10^{-10} m. Which of the following is the atom (hint: the atomic masses in the Periodic Table average over the masses of isotopes. To answer this question, just round off the numbers in the Periodic Table to the nearest integer).

a) H
b) C
c) Mg
d) Ti

59. The photoelectric effect involves shining light on a metal surface in an attempt to eject an electron. Which of the following statements about the photoelectric effect is TRUE?

a) Classical mechanics predicts that light impinging on a metal surface could never eject an electron, no matter what the intensity or frequency of the light.
b) Quantum mechanics predicts that light with a frequency less than a critical value ν_0 cannot eject an electron from the surface, no matter what the intensity of the light.
c) Classical mechanics predicts that light with a frequency less than a critical value ν_0 cannot eject an electron from the surface, no matter what the intensity of the light.
d) Quantum mechanics predicts that light impinging on a metal surface could never eject an electron, no matter what the intensity or frequency of the light.

60. What happens when a hydrogen atom makes a transition from a 5s state to a 3p state?

a) The atom absorbs a photon of frequency of 2.34×10^{14}/sec
b) The atom absorbs a photon of frequency of 4.387×10^{14}/sec
c) The atom emits a photon of frequency of 2.34×10^{14}/sec
d) The atom emits a photon of frequency of 4.387×10^{14}/sec

61. Which of the following BEST describes the ground state electronic configuration of the P atom?

a) $[Ne]3s^2 3p_x^2 3p_y^1$
b) $[Ne]3s^1 3p_x^2 3p_y^2$
c) $[Ne]3s^2 3p_x^1 3p_y^1 3p_z^1$, two p spins of +1/2, one p spin of —1/2
d) $[Ne]3s^2 3p_x^1 3p_y^1 3p_z^1$, three p spins of +1/2

62. What shell of the periodic table is being filled by the series In....Xe?

a) 4p b) 4d
c) 5p d) 5d

63. Which of the following atoms is never observed to have an oxidation state of +2?

a) Sn b) Be
c) Ca d) F

64. A beam of incoming cosmic radiation has a frequency of 2.0×10^{23} s^{-1}. Calculate the wavelength of this radiation.

a) 1.0×10^{-15} m
b) 1.5×10^{-15} m
c) 2.0×10^{-15} m
d) 2.5×10^{-15} m

Answer Key

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

Properties of Molecules

1. Which of the following bonds would you expect to be the most polar?

   a) N-Bi b) N-Sb
   c) N-As d) N-P

2. Which of the following molecules should have the longest bond?

   a) F_2 b) Cl_2
   c) Br_2 d) I_2

3. Given the following bond lengths:

H-H	0.754
Cl-Cl	1.99
Br-Br	2.28

   What would the length of the H-Br bond be?

   a) Less than 1.52 b) In the range of 1.52 to 2.28
   c) 3.03 d) Greater than 3.03

4. Which of the following has the smallest ionic radius?

   a) Cl^{-} b) O^{2-}
   c) S^{2-} d) N^{3-}

5. The Lewis structure of SO_2 has ____ lone pairs of electrons and ____ double bonds. (Note that in SO_2 the O atoms are not bonded together.)

   a) 6, 1 b) 6, 2
   c) 8, 1 d) 8, 2

6. The Lewis structure of SO_3 has ____ lone pairs of electrons and ____ double bonds. (Note that in SO_3 the O atoms are not bonded together.)

   a) 6, 1 b) 6, 2
   c) 8, 1 d) 8, 2

7. The Lewis structure of NH_3 has ____ lone pairs of electrons and ____ double bonds.

    a) 2,0　　b) 1,0
    c) 0,1　　d) 0,2

8. The Lewis structure of SF_2 has ____ lone pairs of electrons and ____ double bonds.

    a) 8,0　　b) 6,0
    c) 4,1　　d) 2,2

9. The Lewis structure of N_2H_4 has ____ lone pairs of electrons and ____ double bonds.

    a) 2,0　　b) 1,0
    c) 0,1　　d) 0,2

10. All of the following statements are true about the Lewis structures of covalent molecules EXCEPT

    a) Only one possible Lewis structure can be drawn for any compound.
    b) The structural features in a Lewis structure include single, double and triple bonds and lone electron pairs.
    c) A Lewis structure is necessary to calculate formal charges.
    d) The number of electrons shown in a Lewis structure of a compound must equal the total number of valence electrons in the compound.

11. All of the following are structural features that may be observed in Lewis structures of covalent molecules EXCEPT

    a) Double bonds　　b) Triple bonds
    c) Melting points　　d) Lone pairs of electrons

12. The formal charge on N in HNO_3 is which of the following? (Note that the O atoms in HNO_3 are not bonded together and H is bonded to O.)

    a) —1　　b) 0
    c) +1　　d) +2

13. The formal charge on N in HNO_2 is which of the following? (Note that the O atoms in HNO_2 are not bonded together and H is bonded to O.)

a) —1 b) 0
c) +1 d) +2

14. The formal charge on S in SO_2 is which of the following? (Note that the O atoms in SO_2 are not bonded together)

a) —1 b) 0
c) +1 d) +2

15. All of the following statements are true about formal charges EXCEPT

a) Formal charges are calculated on the assumption that electrons in covalent bonds are shared equally.
b) Formal charges give an indication of which of several possible Lewis structures is most likely to be correct.
c) The total of the formal charges on a neutral molecule can range from —3 to +3.
d) Lewis structures of some compounds have formal charges of zero on every atom.

16. Which of the following do formal charges help evaluate?

a) Which of two or more Lewis structures is most likely to be correct.
b) What possible ions can be formed by a compound.
c) What the molecular mass of a compound is.
d) What possible ions can be formed by an element.

17. The Lewis structure of ClO_2^- has ____ lone pairs of electrons and ____ double bonds. (Note that oxygen atoms are not bonded together in this ion.)

a) 8, 0 b) 7, 1
c) 6, 1 d) 4, 2

18. The Lewis structure of ClO_3^- has ____ lone pairs of electrons and ____ double bonds. (Note that oxygen atoms are not bonded together in this ion.)

a) 10, 0 b) 8, 1
c) 10, 1 d) 6, 2

19. The correct name of KNO_2 is

a) Potassium nitrate
b) Potassium nitric
c) Potassium nitrite
d) Potassium nitrous

20. The Lewis structure of H_2CO_3 has ____ lone pairs of electrons and ____ double bonds.

a) 8, 0
b) 6, 1
c) 5, 2
d) 4, 3

21. All of the following represent a possible type of reaction for hydrogen EXCEPT

a) Gain of an electron to form the H^{-} ion.
b) Gain of two electrons to form the H^{2-} ion.
c) Loss of an electron to form the H^{+} ion.
d) Sharing of an electron with another atom to form a covalent single bond.

22. Which of the following elements or compounds would you expect to have the highest boiling point?

a) H_2
b) F_2
c) HF
d) HCl

23. Which of the following elements would you expect to have the highest boiling point?

a) F_2
b) Cl_2
c) Br_2
d) I_2

24. What is the shape of the plot of potential energy as a function of the decreasing internuclear distance between two atoms that bond?

a) Close to zero at a long distance and then decreasing to lower and lower values.
b) Close to zero at a long distance and then increasing to higher and higher values.
c) Close to zero at a long distance, then increasing to a maximum and then steadily decreasing to lower and lower values.
d) Close to zero at a long distance, then decreasing to a minimum and then steadily increasing to higher and higher values.

25. Which of the following kinds of bonds are the strongest?
    a) covalent
    b) hydrogen bonds
    c) permanent dipole-dipole interactions
    d) induced dipole-dipole interactions

26. Which of the following atoms should have a larger atomic radius than arsenic (As)?
    a) S b) Se
    c) P d) Ge

27. Which of the following ions is expected to have a smaller ionic radius than O^{2-}?
    a) S^{2-} b) P^{3-}
    c) F^{-} d) Se^{2-}

28. Which of the following bonds is expected to be the longest?
    a) C=C b) C-C
    c) N-N d) O-O

29. Using the following bond enthalpies, calculate the approximate enthalpy change for the reaction below. F-F 155 kJ/mol; H-F 565 kJ/mol; H-H 431 kJ/mol

$$F_2(g) + H_2(g) \rightarrow 2HF(g)$$

    a) —544 kJ/mol b) 21 kJ/mol
    c) 1151 kJ/mol d) 1716 kJ/mol

30. Which of the following bonds would you expect to be the weakest?
    a) H-H b) N-H
    c) O-H d) F-H

31. Which of the following bonds would you expect to be the strongest?
    a) C-C b) C=C
    c) Si-H d) Ge-Ge

32. Why does carbon tetrachloride (CCl_4) have a dipole moment of zero?

a) Because C and Cl have the same electronegativity
b) Because the bond dipoles cancel out
c) Because the compound is covalently bonded
d) Because all of the bonds have partial ionic character

33. Which of the following compounds exhibits resonance?

a) CO_2 b) NH_3
c) SO_3 d) SF_6

34. All of the following are the result of an electronegativity difference between two atoms bonded to each other EXCEPT

a) shorter bond length b) stronger bond
c) longer bond length d) a dipole moment

35. Each of the following molecules contains one type of carbon-carbon bond. Which one has the largest bond energy?

a) CF_2 b) C_2H_4
c) C_6H_6 d) C_2H_6

36. What is the oxidation state of the S atom in the compound SF_6 (the six F atoms are bonded to the S)?

a) —2 b) +2
c) +4 d) +6

37. In which of the following molecules (all linear and linked together as written) is the carbon an sp^2 hybrid?

a) FCCF b) OCCO
c) NCCN d) none of the above

38. Which of the following diatomic molecules has the smallest percentage of ionic character?

a) O_2 b) OH
c) LiF d) NO

39. Which of the following molecules would have the largest bond length?

a) Li_2 b) F_2
c) K_2 d) Br_2

40. Consider the following list of atmospheric gases and determine which are greenhouse gases (absorb infrared radiation):

(1) Ar, (2) CO_2, (3) $N_{2,}$ (4) CH_4, (5) $H_2O(g)$

a) (1) and (2) b) (2) and (5)
c) only (2) d) (2), (4), and (5)

Answer Key

1. a	21. b
2. a	22. c
3. a	23. d
4. d	24. d
5. a	25. a
6. c	26. d
7. b	27. c
8. a	28. b
9. a	29. a
10. a	30. b
11. c	31. b
12. c	32. b
13. b	33. c
14. c	34. c
15. c	35. c
16. a	36. d
17. a	37. b
18. a	38. a
19. c	39. c
20. b	40. d

Theories of Chemical Bonding

1. In the Lewis dot structure of PF_5, the P atom is surrounded by ____ bonding electron pairs and ____ lone pairs.

   a) 5, 0 b) 5, 1
   c) 5, 3 d) 4, 2

2. In the Lewis dot structure of SF_4, the S atom is surrounded by ____ bonding electron pairs and ____ lone pairs.

   a) 5, 0 b) 4, 1
   c) 3, 3 d) 4, 2

3. Which of the following best describes the VSEPR structure of SF_6?

   a) T-shaped b) Seesaw shaped
   c) Trigonal bipyamidal d) Octahedral

4. Which of the following best describes the VSEPR structure of IF_4^-??

   a) Tetrahedral b) Seesaw shaped
   c) Square planar d) Octahedral

5. Which of the following best describes the VSEPR structure of SF_4?

   a) T-shaped b) Seesaw shaped
   c) Trigonal bipyamidal d) Octahedral

6. For which of these compounds is it impossible to explain the correct structure without hybridized orbitals?

   a) H_2 b) CH_4
   c) NH_3 d) H_2O

7. What is the hybidization of the I atom in IF_5?

   a) sp^2 b) sp^3
   d) sp^3d d) sp^3d^2

8. If orbitals are not hybridized, what is the predicted formula for the carbon-hydrogen compound containing one carbon atom?

   a) CH b) CH_2
   c) CH_3 d) CH_4

9. What is the bond order of the carbon-oxygen bonds in the $CO_3^{2—}$?
   a) One with bond order 2 and two with bond order 1.
   b) All three with bond order 1
   c) All three with bond order 4/3
   d) All three with bond order 3/2

10. What is the bond order of the nitrogen-oxygen bonds in the $NO_2^{—}$?
   a) One with bond order 2 and one with bond order 1.
   b) Both with bond order 1
   c) Both with bond order 4/3
   d) Both with bond order 3/2

11. All of the following are a result of the pi-bonding that occurs in H_2CCH_2 EXCEPT
   a) The carbon-carbon bond is shortened.
   b) The H-C-H angle is 109….
   c) The carbon-carbon bond is strengthened.
   d) Rotation around the carbon-carbon bond is easier.

12. What would be the bond order of a diatomic system with a total of three 1s electrons?
   a) 0 b) 1/2
   c) 3/4 d) 1

1. How many unpaired electrons would you expect in a diatomic molecule with the following electron configuration?
   $(2s\sigma)^2(2s\sigma^*)^2(2p_x\sigma)^2(2p_y\pi)^2(2p_z\pi)^2(2p_y\pi^*)^1(2p_z\pi^*)^1$
   a) 0 b) 1
   c) 2 d) 4

14. In the CS_2 molecule (the carbon is bonded to both sulfurs), the bonding between the carbon and a sulfur consists of:
   a) one σ bond b) one σ bond and one π bond
   c) two σ bonds d) two π bonds

15. Even though carbon is known to be ___, valence bond theory predicts it to be ___.
   a) divalent, monovalent b) tetravalent, divalent
   c) divalent, tetravalent d) tetravalent, monovalent

16. When carbon is bonded in a molecule such as methane, CH_4, which of its electrons do not participate in the bonding?
    a) 1s electrons b) 2s electrons
    c) 2p electrons d) they all participate

17. When s and p orbitals are hybridized, how many sp^3 hybrid orbitals are formed?
    a) 1 b) 2
    c) 3 d) 4

18. The hybridization of the oxygen atom in water is
    a) sp b) sp^2
    c) sp^3 d) sp^3d

19. Benzene molecules, C_6H_6, actually contain
    a) six carbon-carbon single bonds
    b) six carbon-carbon double bonds
    c) three carbon-carbon single bonds and carbon-carbon double bonds
    d) six equivalent carbon-carbon bonds that are in between single and double bonds

20. Rank O_2, N_2, F_2 in order of increasing bond dissociation energy:
    a) $O_2 < N_2 < F_2$ b) $F_2 < N_2 < O_2$
    c) $N_2 < O_2 < F_2$ d) $F_2 < O_2 < N_2$

21. Phase overlap of s atomic orbitals produces a _____ molecular orbital.
    a) σ b) σ^*
    c) π^* d) π

22. Elemental oxygen, O_2, has _____ unpaired electrons and therefore is _____
    a) no, diamagnetic b) 1, paramagnetic
    c) 2, paramagnetic d) 3, paramagnetic

23. The bond order of the bond in elemental oxygen is
    a) 1 b) 2
    c) 4 d) 6

24. A molecule that has equal numbers of electrons in bonding and antibonding molecular orbitals has a bond order of

a) 1	b) 1/2
c) 0	d) 2

Answer Key

1. a	13. c
2. b	14. b
3. d	15. b
4. c	16. a
5. b	17. d
6. b	18. c
7. d	19. d
8. b	20. d
9. c	21. a
10. d	22. c
11. b	23. b
12. b	24. c

Periodic Properties

1. Which of the following elements has the highest ionization energy?
   a) Al b) Ga
   c) Si d) Ge

2. What is the correct order of electronegativites of the elements He, N, O and Ne?
   a) He > N > O > Ne b) He > Ne > O > N
   c) Ne > He > N > O d) He > Ne > N > O

3. Which of the following elements has the highest ionization energy?
   a) K b) Ca
   c) Rb d) Sr

4. What will be the likely combination of ionization energy and electron affinity for an element that has a very low electronegativity?
   a) High ionization energy, high electron affinity
   b) High ionization energy, low electron affinity
   c) Low ionization energy, high electron affinity
   d) Low ionization energy, low electron affinity

5. Which of the following bonds would you expect to be the most polar?
   a) N-Bi b) N-Sb
   c) N-As d) N-P

6. All of the following statements are true EXCEPT
   a) The elements in the periodic table are listed by increasing atomic mass.
   b) The periodic table has been used to predict the properties of unknown elements.
   c) Metals and nonmetals are generally located in different parts of the periodic table.
   d) Elements close to each other in the periodic table generally have similar properties.

7. The number of valence electrons on an aluminum atom is
   a) one b) two
   c) three d) four

8. The most stable ion of cesium will have a charge of:

a) —2 b) —1
c) +1 d) +2

9. The most stable ion of magnesium will have a charge of:

a) —2 b) —1
c) +1 d) +2

10. Which of the following is not true about the formation of monatomic ions?

a) Hydrogen forms only the ion H^+.
b) An element tends to form an ion with the same number of electrons as the nearest noble gas.
c) Both positive and negative ions can be formed.
d) The charges of ions normally range between +3 and —3.

11. What is the correct formula for barium oxide?

a) BaO b) BaO_2
c) BaO_3 d) Ba_2O_3

12. What is the correct formula for barium nitride?

a) Ba_3N_2 b) BaN_2
c) BaN_3 d) Ba_2N_3

13. Which of the following is not true about the naming of binary salts?

a) The name of the metal always precedes the name of the nonmetal.
b) The name of the metal appears unchanged in the name of the salt.
c) The name of the nonmetal appears with the suffix -ide in the name of the salt.
d) The prefixes mono-, di-, tri- etc. are used to indicate the ratios of atoms in the formula of the salt.

14. All of the following combinations of reagents will lead to the preparation of $BaCl_2$ EXCEPT

a) $Ba(OH)_2$ and HCl b) Ba and HCl
c) Ba and Cl_2 d) $Ba(OH)_2$ and Cl_2

15. All of the following are important methods of preparing binary salts EXCEPT
    a) Direct combination of the elements
    b) Reaction of an acid and a base
    c) Reaction of a binary acid with a base
    d) Reaction of an oxy acid with a base

16. What is the correct name for IF_5?
    a) Fluorine (V) iodide
    b) Iodine (V) fluoride
    c) Iodine pentafluoride
    d) Iodine fluoride

17. What is the correct name for BrF_3?
    a) Bromine trifluoride
    b) Bromine fluoride
    c) Fluorine bromide
    d) Bromine fluorine

18. Which of the following is a common method for preparing binary covalent compounds?
    a) Reaction of a binary acid with a metal
    b) Reaction of a binary acid with a base
    c) Reaction of a metal with a nonmetal
    d) Reaction of one nonmetal with another nonmetal

19. Which of the following combinations of substances is the most likely preparation of SCl_4?
    a) $S + Cl_2$
    b) $S + HCl$
    c) $H_2S + NaOCl$
    d) $S + NaOCl$

20. All of the following reactions are an important step in the degradation of atmospheric ozone EXCEPT
    a) $Cl(g) + O_3(g) \rightarrow O_2(g) + ClO(g)$
    b) $NO(g) + O_3(g) \rightarrow O_2(g) + NO_2(g)$
    c) $ClO(g) + O(g) \rightarrow O_2(g) + Cl(g)$
    d) $Cl(g) + O(g) + H(g) \rightarrow HClO(g)$

21. Which of the following is a reason why chlorofluorocarbons (CFC's) are postulated to be a danger to the ozone layer?
    a) CFC's decompose in the lower atmosphere.
    b) CFC's decompose upon absorbing high energy radiation in the upper atmosphere to form fluorine atoms.
    c) Decomposition of CFC's in the upper atmosphere forms chemical species that can react over and over to convert O_3 to O_2.
    d) CFC's react directly with $O_2(g)$ in the lower atmosphere.

22. Which of the following is thought to be the active catalyst in the destruction of the ozone layer caused by chlorofluorocarbons (CFC's)?
    a) F atoms
    b) F_2 molecules
    c) Cl atoms
    d) Cl_2 molecules

23. What is the oxidation state of Cr in $K_2Cr_2O_7$?
    a) 2
    b) 4
    c) 6
    d) 8

24. Which of the following would you expect to be the stable state of NaH at room temperature?
    a) solid
    b) liquid
    c) gas
    d) none of the above

25. Which of the following is the strongest acid?
    a) HClO
    b) $HClO_2$
    c) $HClO_3$
    d) $HClO_4$

26. Which of the following is the weakest acid?
    a) HClO
    b) $HClO_2$
    c) $HClO_3$
    d) $HClO_4$

27. Which of the following is a product when NaH(s) reacts with water?
    a) Na(s)
    b) $O_2(g)$
    c) $H_2(g)$
    d) $Na_2O(s)$

28. Which of the following would you expect to form the strongest bonds to carbon?

a) Li b) Na
c) K d) Rb

29. Which of the following sets of properties BEST describes the Group IA metals?

a) high density, soft, react by losing electrons, electrical conductor
b) low density, hard, react by losing electrons, electrical conductor
c) high density, soft, react by gaining electrons, electrical insulator
d) low density, soft, react by losing electrons, electrical conductor

30. Silicon does NOT form a gaseous oxide as carbon does because

a) The atomic weight of silicon is too high.
b) The oxide of silicon is too unstable.
c) Silicon does not form double bonds.
d) Too many Si-Si bonds are formed.

31. What is the relationship between the electronegativities of Pb(IV) [lead in oxidation state +4] and Pb(II) [lead in oxidation state +2]?

a) They both have the same electronegativity.
b) Pb(II) is more electronegative.
c) Pb(IV) is more electronegative.
d) Lead does not have an electronegativity because it is a metal.

32. Which of the following is the best reason to explain why silicon forms -Si-O-Si-O-Si- chains but not -Si-Si-Si-Si-Si- chains?

a) The bond enthalpy of the Si-Si bond is greater than the bond enthalpy of the Si-O bond.
b) The bond enthalpy of the Si-Si bond is less than the bond enthalpy of the Si-O bond.
c) The bond enthalpies of the Si-Si bond and the Si-O bond are both very high.
d) The bond enthalpies of the Si-Si bond and the Si-O bond are both very low.

33. Which of the following compounds should be the most stable?

a) PF_5 b) PCl_5
c) PBr_5 d) PI_5

34. The fluorine-oxygen bond is relatively weak because

a) there are repulsions between the lone pairs of each atom
b) the atomic radius of oxygen is large
c) fluorine has a high electronegativity
d) the bond is ionic

35. Which of the following compounds would you expect to be the most stable if it could be prepared?

a) KrF_2 b) $XeCl_2$
c) XeF_2 d) RnF_2

36. All of the following statements concerning many electron atoms are true, EXCEPT

a) As one goes across a row of the periodic table, ionization energy increases.
b) As one goes down a column of the periodic table, the electron affinity decreases.
c) As one goes across a row of the periodic table, atomic size decreases.
d) As one goes down the periodic table, the orbital energy of the 1s orbital increases (becomes more positive).

37. All of the following statements about the first transition metal series, X-Y, are true, EXCEPT

a) The 3s and 4p states lie very close in energy, with the 4p sometimes going below the 3d.
b) Transition metal atoms appear in a wide variety of oxidation states.
c) The series is generated by filling the 3d shell.
d) The ionization potential of Y is higher than that of X.

38. In the winter, it is warmer on a cloudy night than on a clear night because
    a) Clouds occur when a warm front is approaching.
    b) Clouds block sunlight reflected by the moon.
    c) Clouds absorb and reflect infrared light emitted by the earth.
    d) Atmospheric CO reacts with water vapor in clouds to produce CO_2.

39. If the sun were to suddenly begin to emit more far UV light of wavelength less than 200 nm, then
    a) the ozone at the earth's surface would be photodissociated faster and thus decrease
    b) the earth would heat up, and the human skin cancer rate would increase due to increased ultraviolet light
    c) more NO (nitric oxide) would form in the polluted air of big cities due to reactions by O atoms from photodissociation
    d) in the ozone layer at 30 km, the oxygen atom concentration would increase first and then ozone concentration would increase

40. Which of the following pairs of elements correctly specify the first and last elements in filling the 4d shell?
    a) Sc, Zn
    b) K, Kr
    c) Rb, Xe
    d) Y, Cd

41. Which of the following true statements concerning atomic properties is NOT explained by shielding effects?
    a) The 2s orbital is lower in energy than the 2p orbital.
    b) The electronegativity of the F atom is larger than that of the Li atom.
    c) The 3d and 4s orbitals are close in energy for some transition metals.
    d) All of the above can be explained by shielding effects.

42. Which of the following has the highest boiling point?
    a) Ne
    b) Ar
    c) Kr
    d) Xe

43. Which of the following ions is least likely to be found in nature?

a) Li^+ b) F^-
c) Ni^{2+} d) Ne^-

44. Which of the following statements is true?

a) The carbon dioxide in the atmosphere has increased by a factor of about 10 since 1960.
b) The carbon dioxide concentration is now about the same as the oxygen concentration in the atmosphere.
c) Natural geological cycles, as well as increasing carbon dioxide and freon in the atmosphere, might cause the atmosphere to warm.
d) The ozone layer absorbs some visible sunlight and helps prevent global warming.

45. Freon molecules cause a decrease of atmospheric ozone because

a) One Cl atom made by photolysis can catalyze the destruction of many ozone molecules in a chain reaction, without being consumed itself.
b) Freon reacts directly with ozone, with a low activation barrier at 240K.
c) The freon concentration is so high at 30 km that it absorbs all the sun's UV light that otherwise would photodissociate O_2.
d) Freon absorbs infrared radiation from the earth and thus heats the ozone.

46. All of the following statements are true EXCEPT

a) Ozone, if present in the atmosphere, is stable against thermal decomposition to O_2 due to a high bond energy.
b) Ozone is made naturally from O_2 by lightning.
c) Ozone is normally not present at the earth's surface because far-ultraviolet photolysis of O_2 does not occur at the earth's surface.
d) Ozone is removed from the atmosphere by reaction with N_2.

47. One allotropic form of element **Q** is a crystalline solid at room temperature and atmospheric pressure. The reaction of the substance **Q** with an excess of oxygen produces a colorless, odorless gas at standard conditions. This gaseous product dissolves in cold water to yield a weakly acidic solution. The element is:

a) phosphorus b) chlorine
c) sulfur d) carbon

48. You are given three samples of mixtures of different substances:
Sample **P** is a mixture of ^1H and ^2H.
Sample **Q** is a mixture of S_8 and plastic sulfur, S_x, where x is a large number.
Sample **R** is a mixture of NH_4OCN and NH_2CONH_2, both of which have the same empirical (simple) formula, N_2H_4CO.
P, **Q**, and **R** are, respectively, mixtures of

a) isomers, allotropes, and isotopes
b) allotropes, isotopes, and isomers
c) isotopes, allotropes, and isomers
d) isomers, isotopes, and allotropes

49. The following compounds can all be prepared by direct oxidation of the respective elements: P_4O_{10}, MgO, CO_2, SO_2, and WO_3. The five compounds can be best described as

a) alkaline oxides b) acidic oxides
c) oxides d) amphoteric oxides

50. A mole of HX, a diatomic molecule, is a gas at room temperature and dissolves in water to form a strongly acidic solution. X must therefore be:

a) a Group IA element (alkali metal)
b) a Group IIA element (alkaline earth metal)
c) a Group VIIA element (halogen family)
d) a Group VIA element (oxygen family)

51. All of the following elements are molecular at room temperature and atmospheric pressure EXCEPT

a) mercury b) bromine
c) phosphorus d) sulfur

52. All of the following are good electrical conductors EXCEPT

a) tungsten b) graphite
c) water d) aqueous salt solutions

53. Which of the following orbitals would you expect to have the largest ionization energy (i.e., which orbital will require the most energetic photon to eject an electron)?

a) 1s orbital of Si
b) 3p orbital of Si
c) 1s orbital of C
d) 3p orbital of C

54. Which of the following statements about the electron affinities of Mg and S is TRUE?

a) The electron affinity of Mg is larger than that of S because an electron added to Mg would see a larger effective nuclear charge than an electron added to S.
b) The electron affinity of S is larger than that of Mg because an electron added to S would see a larger effective nuclear charge than an electron added to Mg.
c) The electron affinity of Mg is larger than that of S because an electron added to Mg is in a higher shell (larger value of n) than an electron added to S.
d) The electron affinity of S is larger than that of Mg because an electron added to S is in a higher shell (larger value of n) than an electron added to Mg.

55. The impurity in coal that leads to acidic rain is

a) sulfur
b) benzene
c) nitrogen dioxide
d) all of the above

56. Carbon dioxide is increasing in the atmosphere because

a) Plants liberate less carbon dioxide as we prevent deforestation of the earth.
b) Mankind creates carbon dioxide in the burning of fuels.
c) Carbon dioxide bubbles out of the oceans as the climate warms.
d) All of the above.

57. The "greenhouse effect" works on the following principle

a) Glass transmits visible light from the sun, but absorbs infrared light from the soil.
b) An enclosed glass house prevents the escape of warm gases from plant photosynthesis.
c) Glass reflects some direct sunlight and thus cools the interior.
d) The glass house retains heat from the furnace, yet allows sunlight to enter.

58. In the photodissociation of H_2 which of the following statements is TRUE?

a) The large energy splitting between the bonding σ orbital and the antibonding σ^* orbital causes H_2 to absorb in the ultraviolet, yet be transparent at visible wavelengths.
b) The energy splitting between σ and σ^* is equal to the H_2 bonding energy.
c) After absorption of a photon, electronic potential energy is converted into high kinetic energy as the molecule dissociates.
d) Both a and c above.

59. Which of the following species has the ability to absorb infrared radiation?

a) Ar
b) H_2
c) CO_2
d) None of the above.

60. In an automobile engine exhaust nitric oxide (NO) is present because

a) The combustion temperature at which gasoline is burned is far higher than 25¡C, allowing N_2 and O_2 to react.
b) Nitrogen containing compounds are impurities in gasoline.
c) Nitric oxide is naturally present in the reagent air that the car engine uses for combustion.
d) At high temperatures the carbon dioxide made by combustion sequentially reacts with N_2 to make NO.

61. Mankind is thought to be increasing carbon dioxide in the atmosphere by

a) Cutting down trees that naturally take up carbon dioxide as they grow.
b) Burning fuels that create carbon dioxide as a product.
c) Releasing freon molecules that, when photolyzed by ultraviolet light, catalyze natural production of carbon dioxide in the atmosphere
d) Both a and b above.

Answer Key

1. c
2. d
3. b
4. d
5. a
6. a
7. c
8. c
9. d
10. a
11. a
12. a
13. d
14. d
15. d
16. c
17. a
18. d
19. a
20. d
21. c
22. c
23. c
24. a
25. d
26. a
27. c
28. a
29. d
30. c
31. c
32. b
33. a
34. a
35. d
36. d
37. a
38. c
39. b
40. d
41. d
42. d
43. d
44. c
45. d
46. d
47. d
48. c
49. c
50. c
51. a
52. c
53. a
54. b
55. a
56. b
57. a
58. d
59. c
60. a
61. d

Liquids and Solutions

1. A water solution contains 90.0 g of glucose, $C_6H_{12}O_6$. It has a density of 1.10 g/cm^3 and a total volume of 900 mL. What is the molality of the solution.

   a) 0.495 m b) 0.556 m
   c) 0.500 m d) 0.100 m

2. How many grams of glucose, $C_6H_{12}O_6$, are necessary to prepare 656 mL of a solution with a concentration that is 0.550 molar?

   a) 0.00200 g b) 64.9 g
   c) 151 g d) 214 g

3. What is the volume of a solution of sucrose, ($C_{12}H_{22}O_{11}$) in water that contains 123 g of sucrose and is 0.55 molar?

   a) 66 mL b) 220 mL
   c) 340 mL d) 650 mL

4. Which of the following units of concentration will change in value for a particular solution if the temperature changes?

   a) mole fraction b) molarity
   c) molality d) none of these will change

5. Which of the following is the minimum information necessary for calculating the molality of a solution?

   a) The mass of the solute and the volume of the solvent
   b) The mass of the solute, the volume of the solvent, and the density of the solvent
   c) The mass of the solute, the volume of the solvent and the molecular mass of the solute
   d) The mass of the solute, the volume of the solvent, the molecular mass of the solute, and the density of the solvent

6. A closed vessel contains an inert gas at 500 torr and 60…C. What is the total pressure (in torr) inside the vessel after a few drops of liquid B are injected and equilibrium is established at 60…C with B present as both liquid and vapor? The vapor pressure of liquid B at 60…C is 80 torr.

   a) 420 torr b) 500 torr
   c) 560 torr d) 580 torr

7. A closed vessel contains an inert gas at 500. torr and 60…C. A few drops of liquid B are injected and the pressure rises to 580 torr when equilibrium is established at 60…C with B present as both liquid and vapor? What is the vapor pressure of liquid B at 60…C.

   a) 80 torr b) 500 torr
   c) 560 torr d) 580 torr

8. The equilibrium vapor pressure of a given liquid will increase if

   a) the surface area of the liquid is increased
   b) the temperature is increased
   c) the volume of the vapor phase is decreased
   d) the volume of the liquid is increased

9. Which of the following statements is true?

   a) The rates of evaporation and condensation of a substance can never be equal.
   b) Increasing the external pressure on a gas increases its vapor pressure.
   c) The rate of condensation of a gas decreases when the temperature is raised.
   d) The rate of evaporation of a liquid increases when the temperature is raised.

10. The normal boiling point of chlorine is —34.6…C. If pure liquid chlorine is sealed in a vessel and the temperature is then raised to 0…C and held at that temperature until equilibrium is reached, which of the following statements is true about the pressure in the container.

   a) It is exactly one atmosphere.
   b) It is changing only very slowly.
   c) It is a less than one atmosphere.
   d) It is greater than one atmosphere.

11. The normal boiling point of diethyl ether is 34.6…C. Consider a sealed vessel containing only diethyl ether. What is the pressure in the vessel if it is heated to 34.6…C and held at that temperature until equilibrium is reached?

   a) It is exactly one atmosphere.
   b) It is changing only very slowly.
   c) It is a less than one atmosphere.
   d) It is greater than one atmosphere.

12. The normal boiling point of a liquid is
    a) 100…C at 1 atm
    b) the temperature at which the vapor pressure is 1 atm
    c) the temperature at which liquid and vapor are at equilibrium
    d) the temperature at which the vapor pressure equals the external pressure

13. The triple point in the phase diagram of a certain substance is at 0.76 atm and 203K. What phase change occurs in going from 180K to 220K while holding the pressure at 0.50 atm?
    a) melting
    b) boiling
    c) subliming
    d) can not tell without further data

14. Which of the following is true at the triple point of a substance?
    a) The temperature is not changing.
    b) Only solid and gas are present.
    c) The amount of liquid present can be changing slowly.
    d) The pressure of the gas phase is zero.

15. Which of the following must be true about any pure substance that sublimes at ordinary atmospheric pressure?
    a) Its triple point occurs at a temperature higher than 298K.
    b) Its triple point occurs at a pressure lower than atmospheric pressure.
    c) Its triple point occurs at a temperature higher than 298K.
    d) Its triple point occurs at a pressure higher than atmospheric pressure.

16. The critical temperature of nitrogen is 126K. A flask of nitrogen at 123K contains
    a) only liquid
    b) only vapor
    c) a mixture of liquid and vapor
    d) can not tell without further data

17. Which of the following is true of a supercritical fluids?
   a) They have diffusing and effusing properties similar to gases.
   b) They do not fill the container the way a gas does.
   c) They include all substances above their critical temperatures.
   d) They have no practical applications.

18. When NaI(s) is dissolved in water, the liquid cools. If a solution of NaI is in equilibrium with solid NaI, what will be the effect on the solubility of NaI if the temperature is raised?
   a) The solubility will decrease.
   b) The solubility will remain unchanged.
   c) The solubility will increase.
   d) No definite statement on the solubility can be made.

19. When Li_2CO_3(s) is dissolved in water the liquid warms. If a solution of Li_2CO_3 is in equilibrium with solid Li_2CO_3, what will be the effect on the solubility of Li_2CO_3 if the temperature is raised?
   a) The solubility will decrease.
   b) The solubility will remain unchanged.
   c) The solubility will increase.
   d) No definite statement on the solubility can be made.

20. What is the reason that NaCl is freely soluble in water?
   a) Water and NaCl have similar structures.
   b) Water has a high dielectric constant.
   c) Water and NaCl have similar molar masses.
   d) The water can combine with the NaCl molecule to form a stable new compound.

21. What is the reason that CH_3OH is freely soluble in water?
   a) Water and CH_3OH have similar structural features.
   b) Water has a high dielectric constant.
   c) Water and CH_3OH have similar molar masses.
   d) The water can combine with the CH_3OH molecule to form a stable new compound.

22. What is the vapor pressure of 1000. g of a water solution at 25…C that contains 124.0 g of the nonvolatile solute ethylene glycol, $C_2H_6O_2$? The vapor pressure of pure water at this temperature is 23.76 torr. Assume an ideal solution.

a) 0.94 torr	b) 22.8 torr
c) 23.7 torr	d) 24.6 torr

23. Raoult's law holds exactly across the entire range of concentrations only for ideal solutions. For real solutions, at which values of the mole fraction of a nonvolatile solute does Raoult's law hold exactly?

a) 0.0 and 0.5
b) 0.5 and 1.0
c) 0.0 and 1.0
d) Raoult's law does not hold exactly at any of these values

24. Consider a solution of water and a nonvolatile solute at some temperature. What combination of conditions would be sure to increase the vapor pressure of the solution?

a) Raise the temperature and add more solute
b) Lower the temperature and add more solute
c) Lower the temperature and add more water
d) Raise the temperature and add more water

25. If 4.27g of sucrose, $C_{12}H_{22}O_{11}$ are dissolved in 15.2 g of water, what will be the boiling point of the resulting solution? (K_b for water = 0.512K/m. The normal boiling point of water is 100.00…C.)

a) 101.64…C	b) 100.42…C
c) 99.626…C	d) 100.73…C

26. How many moles of sugar must be added to 100 g of water to lower the freezing point of the solution by 1…C? The value of K_f for water is —1.86K/m.

a) 0.54 mol	b) 0.27 mol
c) 0.054 mol	d) 0.027 mol

27. Maximum precision in the calculation of the molar mass of an unknown compound using the depression of freezing point will be achieved by choosing a solvent with which of the following characteristics?
    a) A low absolute value of the freezing point constant
    b) A high absolute value of the freezing point constant
    c) A low molecular weight
    d) A high molecular weight

28. Which of the following is the minimum information needed to calculate the freezing point depression for a solution of a nondissociating solute?
    a) The molal concentration of the solution
    b) The molal concentration of the solution and the freezing point depression constant of the solute
    c) The molal concentration of the solution and the freezing point depression constant of the solvent
    d) The molal concentration of the solution and the freezing point depression constants of the solute and the solvent

29. A water solution containing 2.5 g of a polymer in a total volume of 100. mL has an osmotic pressure of $1.0 \times 10^{—3}$ atm at 20…C. What is the molar mass of the polymer?
    a) 6.0×10^2 g/mol b) 4.2×10^4 g/mol
    c) 6.0×10^5 g/mol d) 2.1×10^6 g/mol

30. What osmotic pressure will be produced if 10. g of $C_{12}H_{22}O_{11}$ is dissolved in enough water to produce 400. mL of solution at 298K?
    a) 250 atm b) 1.8 atm
    c) 0.71 atm d) 0.0060 atm

31. For a particular mass of some nondissociating solute and a particular mass of water, the osmotic pressure will be the greatest for which of the following combinations of conditions?
    a) A high temperature and a solute with a high molar mass
    b) A high temperature and a solute with a low molar mass
    c) A low temperature and a solute with a high molar mass
    c) A low temperature and a solute with a low molar mass

32. Which of the following statements is true regarding osmotic pressure?
    a) Osmotic pressures are always extremely small.
    b) The osmotic pressure does not depend on the concentration of the solute.
    c) Measurement of osmotic pressure cannot be used to determine small molar masses.
    d) Measurement of osmotic pressure can be used to determine very large molar masses.

33. What is the theoretical ratio of the boiling point elevation observed for the salt Na_3PO_4 compared with the same molal concentration of sugar?
    a) 0.50 b) 4
    c) 6 d) 8

34. Compared to a soluble but nondissociating solute, an equal number of moles of a soluble salt in solution will always result in a(n) __________ osmotic pressure.
    a) smaller b) equal
    c) greater d) No general statement can be made

35. The vapor pressure of water at 25…C is 23.8 torr and the vapor pressure of ethanol, C_2H_6O, is 44.5 torr at the same temperature. What is the total pressure of a solution at 25…C composed of 2.0 mol of water and 3.0 mol of ethanol? Assume an ideal solution.
    a) 36.2 torr b) 34.2 torr
    c) 18.1 torr d) 68.3 torr

36. Condensation of the vapor above an ideal solution of two volatile components gives a new solution that has which composition compared to the original solution?
    a) the same
    b) richer in the component that was in higher concentration in the original solution
    c) richer in the component that has the lower vapor pressure when pure
    d) richer in the component that has the higher vapor pressure when pure

37. Consider a solution of two volatile liquids, A and B. This solution has a higher vapor pressure than would be predicted if the solution were ideal. Which of the following statements is true about this solution?
   a) Attractions between molecules of A and B are stronger than attractions between A and A, and B and B.
   b) Formation of the solution will absorb heat.
   c) A and B must have the same boiling points.
   d) A and B probably have almost identical chemical structures.

38. Consider a solution of two volatile liquids, A and B. This solution has a lower vapor pressure than would be predicted if the solution were ideal. Which of the following statements is true about this solution?
   a) Attractions between molecules of A and B are stronger than attractions between A and A, and B and B.
   b) Formation of the solution will be absorb heat.
   c) A and B must have the same boiling points.
   d) A and B probably have almost identical chemical structures.

39. If the normal boiling point of SO_2 is 263.1K and that of NH_3 is 239.7K then at 40ºC
   a) ammonia has the greater vapor pressure
   b) sulfur dioxide has the greater vapor pressure.
   c) the vapor pressures would be equal.
   d) the vapor pressure of NH_3 is 760 mmHg.

40. For CO_2, the critical temperature is 31.1ºC and the critical pressure is 73 atm. These data imply that CO_2 can be liquified at
   a) 31.1ºC and 72.0 atm
   b) 32.0ºC and 73.0 atm
   c) 30.0ºC and 73.0 atm
   d) 32.0ºC and 74.0 atm

41. A pure substance, above its melting point, is in a high pressure cylinder. Upon opening a valve on the cylinder a gas escapes. A pressure gauge on the cylinder shows a pressure of 56.5 atm. at 20ºC before opening the valve. After removing 10 ft^3 of the gas, measured at standard conditions, the pressure in the cylinder reads 56.5 atm at 20ºC. The pressure gauge is in good working order. Which best explains these observations?
   a) The cylinder and contents will weigh the same before and after opening the valve.
   b) The substance in the cylinder is in the gaseous state.
   c) The substance in the cylinder is mostly in the liquid state.
   d) The substance in the cylinder has diatomic molecules when in the gaseous state.

42. A cellophane bag, which acts as a membrane permeable only to water, contains a 2 M sucrose solution. When immersed in a 1 M sucrose solution
   a) the bag will soon contain more solution that will be more concentrated than 2 M
   b) the bag will soon contain more solution that will be less concentrated than 2 M
   c) the bag will lose sugar and the solution in it will become less concentrated
   d) the bag will lose water and the solution in it will become more concentrated

43. The likely formula for a completely ionized salt if an aqueous 0.10 M solution of that salt has a freezing point of –0.74ºC is: (K_f for water = 1.86ºC·c/*m*)
   a) MX   b) M_2X
   c) M_2X_3 d) MX_3

44. A 2.00 g sample of a non-electrolyte is dissolved in 100. g H_2O. If the resulting solution freezes at –0.186ºC, what is the molar mass of the compound?
   (K_f for water = 1.86ºC·c/*m*)
   a) 18.0 g/mole   b) 18.6 g/mole
   c) 20.0 g/mole   d) 200. g/mole

45. A proposed method for desalinating sea water is to submerge a long tube, its bottom closed with a semipermeable membrane, to a depth such that the hydrostatic pressure overbalances the osmotic pressure and forces pure water through the membrane. Taking a model for sea water to be a 0.50 M aqueous solution of NaCl at 17°C, what is the pressure at which this process will begin? Remember that Π = cRT and R = 0.08205 LÆatm/molÆK

a) 1.4 atm b) 6.0 atm
c) 12 atm d) 24 atm

46. Assuming ideal behavior, what is the vapor pressure of a solution of 16.0 mol of carbon tetrachloride and 4.00 mol of dioxane at 23°C?

Vapor Pressures at 23ºC	
carbon tetrachloride	100. mmHg
dioxane	38.0 mmHg

a) 50.4 mmHg b) 62.8 mmHg
c) 74.2 mmHg d) 87.6 mmHg

47. A cylinder fitted with a movable piston contains liquid water in equilibrium with water vapor at 25ºC. Which would cause a ***decrease*** in the equilibrium vapor pressure?

a) moving the piston downward a short distance
b) removing a small amount of vapor
c) removing a small amount of the liquid water
d) dissolving salt in the water

48. A prune, a carrot, and a raw egg from which the shell has been carefully removed (leaving the membrane intact), are placed in the same salt solution, in separate beakers. The prune swelled, the carrot shriveled, and not much seemed to happen to the egg. On that basis, you might best conclude the relative concentration of the solutions that constitute the cellular fluids of these common food items is

a) prune < carrot < egg b) prune < egg < carrot
c) carrot < egg < prune d) egg < carrot < prune

49. Which water solution has the lowest freezing point?

a) 0.1 *m* Na_2SO_4 b) 0.1 *m* NaCl

c) 0.1 *m* KNO_3 d) 0.1 *m* $C_{12}H_{22}O_{11}$ (sugar)

50. Beaker A contains 0.100 L of a 0.20 M KOH solution; beaker B contains 0.100 L of a 0.20 M HCl solution. The contents of the two beakers are thoroughly mixed together in a sufficiently large, third beaker. The molarity, M, of the resulting salt solution is

a) 0.05 M b) 0.10 M

c) 0.20 M d) 0.40 M

51. A victim's gastric juices contained 3.20 mg of arsenic/liter of solution. What was the concentration of arsenic in moles/liter?

a) 7.49×10^{-3} mol/L b) 4.27×10^{-5} mol/L

c) 3.28×10^{-6} mol/L d) 3.20×10^{-2} mol/L

Answer Key

1. b
2. b
3. d
4. b
5. d
6. d
7. a
8. b
9. d
10. d
11. a
12. d
13. d
14. a
15. d
16. d
17. a
18. c
19. a
20. b
21. a
22. b
23. c
24. d
25. b
26. c
27. b
28. b
29. c
30. b
31. b
32. d
33. b
34. c
35. a
36. d
37. b
38. a
39. a
40. c
41. c
42. b
43. d
44. d
45. d
46. d
47. d
48. c
49. a
50. b
51. b

Chemical Equilibrium

1. The following reaction is endothermic. What combination of changed conditions would cause it to proceed more to the right as written?

$$2CO_2(g) \rightarrow 2CO(g) + O_2(g)$$

a) raising the temperature and increasing the pressure
b) raising the temperature and decreasing the pressure
c) lowering the temperature and increasing the pressure
d) lowering the temperature and decreasing the pressure

2. Consider the following reaction. What combination of changed conditions would cause it to proceed more to the right as written?

$$CS_2(g) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g) \qquad \Delta H\ldots = —1110 \text{ kJ/mol}$$

a) raising the temperature and increasing the pressure
b) raising the temperature and decreasing the pressure
c) lowering the temperature and increasing the pressure
d) lowering the temperature and decreasing the pressure

3. Which of the following is true of chemical equilibrium?

a) It can only be approached starting with the reactants of a chemical process.
b) Many systems are not spontaneously approaching equilibrium.
c) It results in a system that appears to be under no change.
d) It is the result of the process stopping at a microscopic level.

4. Select the correct equilibrium expression for the reaction:

$$C(s) + 2H_2O(g) \rightarrow CO(g) + 2H_2(g)$$

a) $K_p = \dfrac{(pCO)\cdot(pH_2)^2}{(pH_2O)^2\cdot(pC)}$ b) $K_p = \dfrac{(pCO)}{(pH_2O)^2}$

c) $K_p = \dfrac{(pCO)}{(pH_2O)^2\cdot(pC)}$ d) $K_p = \dfrac{(pCO)\cdot(pH_2)^2}{(pH_2O)^2}$

5. Select the correct equilibrium expression for the reaction:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

a) $K_p = \dfrac{(pNH_3)}{(pN_2)(pH_2)}$ b) $K_p = \dfrac{(pNH_3)^2}{(pN_2)(pH_2)^3}$

c) $K_p = (pNH_3)(pN_2)(pH_2)$ d) $K_p = \dfrac{1}{(pNH_3)(pN_2)(pH_2)}$

6. For a reaction that proceeds almost completely to products:

   a) K = 1 b) K > 1
   c) K < 1 d) requires more information

7. For a reaction in which there are comparable amounts of reactants and products present when equilibrium is reached:

   a) K ~ 1 b) K >> 1
   c) K = 1 d) K < 0

8. Using the equilibrium constants given for reactions (1) and (2), what is the equilibrium constant for reaction (3)?

   1) $2NO(g) + O_2(g) \rightarrow N_2O_4(g) \quad K_p = 1.49 \times 10^{13}$
   2) $2NO(g) + O_2(g) \rightarrow 2NO_2(g) \quad K_p = 1.66 \times 10^{12}$
   3) $N_2O_4(g) \rightarrow 2NO_2(g)$

   a) 0.0123 b) 0.111
   c) 8.98 d) 80.3

9. Using the equilibrium constants given for reactions (1) and (2), what is the equilibrium constant for reaction (3)?

   1) $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g) \quad K_p = 3.80$
   2) $C(s) + CO_2(g) \rightarrow 2CO(g) \quad K_p = 2.66$
   3) $CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$

   a) 1.42 b) 3.80
   c) 0.263 d) 7.77

10. Consider two reactions that are combined together to produce a third reaction. The first and second reactions both proceed almost completely to products. Which of the following is true about the equilibrium constant of the third reaction?

    a) K >> 1
    b) K << 1
    c) K = 1
    d) More data are needed to answer this question

11. The equilibrium constant for the following reaction at 600K is 38.6. What is the reaction quotient for this reaction if the partial pressures of all three gases are measured to be 2.0 atm?

$2HI(g) \rightarrow H_2(g) + I_2(g)$

a) 1.0 b) 2.0
c) 19.3 d) 38.6

12. The value of K_p for the following reaction is 3.80. What will be the spontaneous direction of this reaction if some carbon is present and the partial pressures of all three gases are measured to be 2.0 atm?

$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$

a) toward the right b) no reaction will occur
c) toward the left d) cannot tell without more data

13. The value of K_p for the following reaction is 1.3×10^{14}. What will be the spontaneous direction of this reaction if some carbon is present and the partial pressure of CO_2 is determined to be 1.3×10^{-6} atm and the partial pressure of CO is 2.5×10^{4} atm?

$CO_2(g) + C(s) \rightarrow 2CO(g)$

a) toward the right b) toward the left
c) no reaction will occur d) cannot tell without more data

14. Which of the following chemical systems are subject to spontaneous change.

a) only systems in which the reaction quotient is greater than the equilibrium constant
b) only systems in which the reaction quotient is less than the equilibrium constant
c) all systems in which the reaction quotient is not equal to the equilibrium constant
d) all systems in which the reaction quotient is equal to the equilibrium constant

15. The equilibrium constant for the following reaction at 550…C is 67.0. What is the partial pressure of $H_2O(g)$ at equilibrium if the system starts with the only substances present being CoO(s) and Co(s), as well as $H_2(g)$ at a partial pressure of 0.100 atm?

$CoO(s) + H_2(g) \rightarrow Co(s) + H_2O(g)$

a) 0.015 atm b) 0.099 atm
c) 1.0 atm d) 6.7 atm

16. Which of the following statements is true about the relationship between the values of K_p and K_c for a gas phase reaction?
    a) K_p is always larger than K_c
    b) K_p is always smaller than K_c.
    c) K_p is always equal to K_c.
    d) None of the general statements given above is correct

17. What is the solubility of CaF_2 in water in mols of CaF_2 per L of solution? K_{sp} for CaF_2 is 1.7×10^{-10}.
    a) 9.2×10^{-6} M b) 1.3×10^{-5} M
    c) 3.5×10^{-4} M d) 5.5×10^{-4} M

18. What is the relationship between the solubility of a salt and the value of its solubility product?
    a) The solubility is directly proportional to the solubility product.
    b) The solubility is proportional to the square root of the solubility product.
    c) The solubility is inversely proportional to the square root of the solubility product.
    d) None of the above is a general statement that is true of all salts.

19. Suppose the following four salts all have the same numerical value of K_{sp}, which is much less than one. Which will have the highest solubility?
    a) AB b) AB_2
    c) AB_3 d) A_2B_3

20. What is the solubility in mol/L of BaF_2 in 0.10M MgF_2? K_{sp} for $BaF_2 = 1.7 \times 10^{-6}$.
    a) 1.7×10^{-4} M b) 1.7×10^{-5} M
    c) 4.3×10^{-5} M d) 8.5×10^{-6} M

21. Addition of which of the following substances to an equilibrium mixture of water and AgCl will raise the solubility of the AgCl in water?
    a) NaCl b) $AgNO_3$
    c) AgCl d) None of the above

22. A solution of sodium sulfate is mixed with a solution of barium chloride. Which of the following is the correct net ionic equation for the reaction that takes place?

a) $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(s)$

b) $2Na^+(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + 2Cl^-(aq) \rightarrow 2NaCl(s) + Ba^{2+}(aq) + SO_4^{2-}(aq)$

c) $2Na^+(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + 2Cl^-(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + BaSO_4(s)$

d) $SO_4^{2-}(aq) + Ba^{2+}(aq) \rightarrow BaSO_4(s)$

23. Iron(II) sulfate decomposes thermally according to the following equation:

$$2\ FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

At 650…C, the total pressure of the gases present is 0.80 atm and both solids are present. K_p for this reaction at the indicated temperature is

a) 0.16 b) 0.40

c) 0.64 d) 0.80

24. A reaction vessel is filled initially with p = 0.50 atm each of SO_2, SO_3, NO, and NO_2. For the reaction at 1000K, K_p is equal to 1/9.

$$SO_3(g) + NO(g) \rightarrow SO_2(g) + NO_2(g)$$

At equilibrium, $p(SO_3)$ is:

a) 0.111 b) 0.250

c) 0.500 d) 0.750

25. The correct ordering of the relative solubility of AgCl(s) in water and aqueous solutions of 0.1M silver nitrate and 0.1M ammonia is:

(a) in pure water; (b) in 0.1M $AgNO_3$; c) in 0.1M aq NH_3

a) a>c>b b) b>c>a

c) c>a>b d) c>b>a

26. A saturated solution of lanthanum iodate, $La(IO_3)_3$, in pure water has a concentration of iodate ion equal to 2.07×10^{-3} M at 25¡C. What is the solubility product of lanthanum iodate?

a) 2.07×10^{-4} b) 1.43×10^{-6}

c) 1.84×10^{-11} d) 6.12×10^{-12}

27. The solubility product constant of $Fe(OH)_2$ in pure water is $K_{sp} = 1.6 \times 10^{-14}$. The concentration of Fe^{2+} when $Fe(OH)_2$ is dissolved in pure water is

a) 1.6×10^{-5} M b) 2.5×10^{-5} M
c) 3.2×10^{-7} M d) 1.6×10^{-14} M

28. The amino acid glycine can exist in aqueous solution in several different states - as a neutral molecule (NH_2CH_2COOH); as a conjugate base ($NH_2CH_2COO^-$); as a conjugate acid ($^+NH_3CH_2COOH$); and as *zwitter*ions ($^+NH_3CH_2COO^-$). Given the K_a values for the dissociations determine the concentration of the zwitterion ($^+NH_3CH_2COO^-$) in a solution prepared by dissolving 0.01 mole of glycine (NH_2CH_2COOH)in enough water to make one liter of solution. Hint: In order to do that, you will first have to find the equilibrium constant for the reaction

$$NH_2CH_2COOH \rightarrow {}^+NH_3CH_2COO^-$$

$$NH_2CH_2COOH + H_2O \rightarrow H_3O^+ + NH_2CH_2COO^- \quad K_a(1) = 4.6 \times 10^{-3}$$
$$^+NH_3CH_2COO^- + H_2O \rightarrow H_3O^+ + NH_2CH_2COO^- \quad K_a(2) = 2.5 \times 10^{-6}$$

a) 0.01 M b) 0.10 M
c) 0.001 M d) 0.05 M

29. Nitrogen and hydrogen react to form ammonia by the following reaction:

$$1/2N_2(g) + 3/2H_2(g) \rightarrow NH_3(g) \qquad \Delta H = -46 \text{ kJ/mol}$$

The reaction goes to equilibrium under an external pressure P. An inert gas such as argon is introduced into the reactor and the external pressure is maintained at P. The effect of the addition of the inert gas is to

a) increase the yield of ammonia
b) decrease the yield of ammonia
c) leave the yield unchanged
d) not enough information to tell

30. In a different experiment, the same reaction as in problem 29 is allowed to come to equilibrium in a closed container of volume V. Argon gas is introduced. Assuming all the gases behave ideally, then the effect of the addition of inert gas is to

a) increase the yield of ammonia
b) decrease the yield of ammonia
c) leave the yield unchanged
d) not enough information to tell

31. A particular reaction goes much more favorably (with a larger equilibrium constant in the forward direction) at a higher temperature. Which of the following statements are likely to be true?
(1) the reaction is endothermic; (2) the reaction is exothermic; (3) the enthalpy change for the reaction is positive; (4) the enthalpy change for the reaction is negative; (5) the products have greater bond strengths than the reactants, assuming that bond energy differences dominate the enthalpy of reaction; (6) the products have lesser bond strengths than the reactants, assuming that bond energy differences dominate the enthalpy of reaction

a) 1, 3 and 6 b) 2, 4 and 6
c)1, 4 and 6 d) 2, 3 and 5

32. With respect to the following reaction, what conditions would make SO_3 most stable. Assume that only these components, and no other gases, are present.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g) + \text{Heat}$$

a) High pressure and high temperature
b) High pressure and low temperature
c) Low pressure and high temperature
d) Low pressure and low temperature

Answer Key

1. b
2. c
3. c
4. d
5. b
6. b
7. a
8. b
9. a
10. a
11. a
12. a
13. b
14. c
15. b
16. d
17. c
18. d
19. d
20. c
21. d
22. d
23. a
24. d
25. c
26. d
27. a
28. a
29. c
30. b
31. a
32. b

Acids and Bases

1. Which of the following solutions at 0.01 M in a conductivity apparatus should cause a light bulb to burn the most brightly? (All these substances are freely soluble in water.)
   a) NaCl b) $CaCl_2$
   d) NH_3 d) HCN

2. A solution of an electrolyte conducts an electric current because of
   a) The movement of cations only
   b) The movement of anions only
   c) The movement of both anions and cations
   d) The movement of electrons in the spaces between solvent molecules

3. Which of the following is one of the principal gases that is responsible for acid rain?
   a) CH_4 b) SF_6
   c) Cl_2 d) SO_2

4. What is the concentration of OH^- in a water solution of 0.0015 M HCl?
   a) 6.7×10^{-12} M b) 1.5×10^{11} M
   c) 1.5×10^{-3} M d) 6.7×10^{2} M

5. The autoionization of water has a small equilibrium constant because
   a) of the low solubility of the products of the reaction
   b) a strong acid and a weak base combine to form a weak acid and a strong base
   c) a strong acid and a strong base combine to form a weak acid and a weak base
   d) a weak acid and a weak base combine to form a strong acid and a strong base

6. H_2S can autoionize according to the reaction, $2H_2S \rightarrow H_3S^+ + HS^-$. Which of the following describes the value of the equilibrium constant that you would expect for this reaction?
   a) $K \sim 1$ b) $K >> 1$
   c) $K << 1$ d) More information is required

7. What is the pH of a solution that has an H_3O^+ concentration of 2.0×10^{-3}M?

a) 7.0 b) 2.0
c) 2.7 d) 3.0

8. What is the pH of a solution that has an OH^- concentration of 5.0×10^{-5}M?

a) 9.7 b) 4.3
c) 5.0 d) 12.0

9. What is the pH of a solution that contains 0.0010 moles of HCl in a total volume of 1.00 L?

a) 1.0 b) 7.0
c) 1.3 d) 3.0

10. What effect will the addition of pure water to a water solution of an acid have on the pH of the acid solution?

a) Raise it b) Lower it
c) Leave it unchanged d) Cannot say without further data

11. Which of the following is not a strong acid?

a) HF b) HCl
c) HBr d) HNO_3

12. What is the pH of a solution of 0.100M HCN? K_a for HCN = 7.2×10^{-10}.

a) 4.6 b) 5.1
c) 9.1 d) 10.1

13. What is the pH of a solution of 0.0500M NH_3? K_b for NH_3 = 1.8×10^{-5}.

a) 3.0 b) 8.0
c) 11.0 d) 11.6

14. Which of the following situations will result in a solution with the lowest value of the pH?

a) A low concentration of an acid with a low value of K_a
b) A high concentration of an acid with a low value of K_a
c) A low concentration of an acid with a high value of K_a
d) A high concentration of an acid with a high value of K_a

15. Which of the following situations will result in a solution with the highest value of the pH?
    a) A low concentration of a base with a low value of K_b
    b) A high concentration of a base with a low value of K_b
    c) A low concentration of a base with a high value of K_b
    d) A high concentration of a base with a high value of K_b

16. What is the pH of a 1.00 L solution that contains 0.100 moles of HCN and 0.050 moles of the freely soluble salt NaCN? K_a for HCN = 7.2×10^{-10}.
    a) 10.3 b) 9.1
    c) 8.8 d) 4.6

17. If a salt of a weak acid is added to a water solution of that same weak acid (problem #16) the pH of the acid solution will
    a) Increase b) Decrease
    c) Stay the same d) Not possible to predict

18. What is the concentration of S^{2-} (aq) in equilibrium with 1.00 M H_2S (aq)? $K_{a1} = 9.1 \times 10^{-8}$, $K_{a2} = 1.2 \times 10^{-15}$.
    a) 3.0×10^{-4} M b) 3.4×10^{-8} M
    c) 9.1×10^{-8} M d) 1.2×10^{-15} M

19. The second ionization constant for an acid will always be _______ the first ionization constant.
    a) smaller than b) equal to
    c) greater than d) No general statement can be made.

20. What is the concentration of NH_4^+ ion when a solution that is initially 0.050 M in NH_3 comes to equilibrium? K_b for NH_3 is 1.8×10^{-5}.
    a) 4.2×10^{-3} M b) 9.5×10^{-4} M
    c) 1.8×10^{-5} M d) 9.0 t 10^{-7} M

21. What is the pH of a solution that is initially 0.015 M in NH_3 when it comes to equilibrium? K_b for NH_3 is 1.8×10^{-5}.
    a) 2.4 b) 3.3
    c) 10.7 d) 11.6

22. Which of the following situations would produce the lowest pH in a water solution that contained NH_3 and NH_4Cl?
    a) A high concentration of NH_3 and a high concentration of NH_4Cl
    b) A high concentration of NH_3 and a low concentration of NH_4Cl
    c) A low concentration of NH_3 and a high concentration of NH_4Cl
    d) A low concentration of NH_3 and a low concentration of NH_4Cl

23. A 0.10 M solution of which of the following is most basic?
    a) $NaNO_3$ b) $NaNO_2$
    c) NaCl   d) Na_2SO_4

24. What is the equilibrium constant for the reaction of the Bronsted acid HCN with the Bronsted base NO_2^-? K_a for HCN = 7.2×10^{-10}, K_a for HNO_2 = 4.5×10^{-4}.
    a) 6.2×10^5 b) 1.6×10^{-6}
    c) 7.2×10^{-10} d) 3.2×10^{-13}

25. What is the equilibrium constant for the reaction of the Bronsted acid HNO_2 with the Bronsted base F^-? K_a for HF = 6.8×10^{-4}. K_a for HNO_2 = 4.5×10^{-4}.
    a) 1.5   b) 0.66
    c) 6.8×10^{-4} d) 4.5×10^{-4}

26. All of the following statements are consistent with the Bronsted concept of acids and bases EXCEPT
    a) The stronger a Bronsted acid is, the weaker is its conjugate base.
    b) A Bronsted acid-base reaction proceeds so as to produce the weaker conjugate acid and the weaker conjugate base.
    c) Any complete Bronsted acid-base reaction must have two conjugate acid-base pairs.
    d) It is possible to have a Bronsted acid-base reaction in which two strong Bronsted acids react to form two weak Bronsted bases.

27. Which of the following pairs is not a Bronsted conjugate acid-base pair?
    a) H_2O and H_3O^+ b) H_2O and OH^-
    c) OH^- and O^{2-} d) H^+ and OH^-

28. All of the following statements are consistent with the Bronsted concept of acids and bases EXCEPT
    a) A Bronsted acid must contain an H atom.
    b) A Bronsted base must contain an OH.
    c) Water can be either an acid or a base in Bronsted acid base reactions.
    d) The $Cl^{—}$ ion can only be a base in a Bronsted acid-base reaction.

29. What is the pH of a 1.00 L solution of water and 0.10 moles of NaCN? K_a for HCN = $7.2 \times 10^{—10}$.
    a) 3.9 b) 5.1
    c) 9.1 d) 11.1

30. What is the concentration of $OH^{—}$ in a 1.00 L solution that contains 0.010 moles of NaOCl? K_a for HOCl = $3.7 \times 10^{—8}$.
    a) 5.2×10^{-4} M b) 1.9×10^{-4} M
    c) 5.2×10^{-5} M d) 1.9×10^{-5} M

31. Which of the following will give the highest concentration of $OH^{—}$?
    a) 0.100 M solution of NaCl.
    b) 0.100 M solution of NH_4Cl
    c) 0.100 M solution of $NaNO_2$
    d) 0.100 M solution of HNO_2

32. Which of the following will form a basic solution when dissolved in water?
    a) The salt of a strong acid and a strong base
    b) The salt of a weak acid and a strong base
    c) The salt of a strong acid and a weak base
    d) None of the above

33. What is the ratio of acid concentration to anion concentration needed to produce a buffer of pH = 10.0 using HCN and NaCN? K_a for HCN = $7.2 \times 10^{—10}$.
    a) 10.0 b) 0.14
    c) 1.0 d) 7.2

34. What will be the pH of a buffer produced by dissolving 0.010 moles of HCN and 0.070 moles of NaCN in sufficient water to make 1.00 L of solution? K_a for HCN $= 7.2 \times 10^{-10}$.

a) 8.30 b) 9.14
c) 9.99 d) 11.14

35. The pH of a buffer NOT change

a) When acid is added to the buffer
b) When base is added to the buffer
c) When pure water is added to the buffer
d) All of the above circumstances

36. 25.0 mL of a monoprotic unknown acid is titrated to an end point with 0.100 M NaOH at 32.2 mL. At the point where 16.1 mL of base has been added, the pH of the solution is 5.5. What is the value of K_a for the unknown acid?

a) 1.6×10^{-6} b) 3.2×10^{-6}
c) 6.4×10^{-6} d) 1.3×10^{-5}

37. What information can be obtained by the titration of an unknown acid?

a) Its concentration
b) Its acid dissociation constant
c) Whether it is monoprotic or diprotic
d) All of the above

38. 26.7 mL of an acid known to be 0.105 M exactly neutralizes 20.0 mL of an unknown base. What is the concentration of the base?

a) 0.00525 M b) 0. 0786 M
c) 0.267 M d) 0.140 M

39. An unknown student takes an unknown mass of an unknown weak monoprotic acid and dissolves it in an unknown amount of water. The unknown student then divides the aqueous solution into two equal volumes, titrates one volume to a phenolphthalein endpoint, and then adds the other volume to the titrated solution. The pH of the combined volumes turns out to be 4.67. The K_a of the weak acid is

a) 0.33×10^{5} b) 1.8×10^{-5}
c) 2.14×10^{-5} d) 4.67×10^{-5}

40. A saturated aqueous solution of CO_2 is (basic, acidic) while a saturated aqueous solution of H_2S is (basic, acidic)

a) basic, basic b) basic, acidic
c) acidic, basic d) acidic, acidic

41. On adding 0.100 M sulfuric acid to a barium hydroxide solution, at the equivalence point

a) The solution conducts, as evidenced by a glowing light bulb.
b) The solution does not conduct, as evidenced by the extinction of a light bulb
c) The solution is acidic, due to hydrolysis
d) The solution is basic, due to hydrolysis

42. At 60…C, the autoprotolysis constant (K_w) of water is $9.6 \times 10^{—14}$. What is the pH of an aqueous solution that has an $OH^{—}$ concentration of $5.0 \times 10^{—5}$ M at 60…C?

a) 5.7 b) 6.7
c) 7.7 d) 8.7

43. What effect will the addition of pure water to an aqueous solution of a base have on the pH of the basic solution?

a) Raise it
b) Lower it
c) Leave it unchanged
d) Cannot say without more information

44. What is the pH of the resulting solution when 50.0 mL of a 0.10 M HCl solution is added to 100 mL of a 0.20 M NaOH solution?

a) 14 b) 13
c) 12 d) 11

45. What effect will dilution of a simple solution of a buffer most likely have on its pH value?

a) Lower it b) Raise it
c) No change d) Cannot conclude

46. Which of the following solutions results in a buffer of pH = 4.0? Assume that the K_a value for benzoic acid is 6.5×10^{-5}.

a) 0.10M benzoate and 0.21M benzoic acid
b) 0.25M benzoate and 0.16M benzoic acid
c) 0.11M benzoate and 0.50M benzoic acid
d) 0.16M benzoate and 0.25 M benzoic acid

47. Benzoic acid ($C_6H_5CO_2H$) has a pK_a of 4.2, and nitric acid (HNO_3) has pK_a = —1.3. What is the equilibrium constant for the following reaction?

$$C_6H_5CO_2H(aq) + NO_3^-(aq) \rightarrow C_6H_5CO_2^-(aq) + HNO_3(aq)\ ?$$

a) $10^{(-5.5)}$ b) 2.9
c) 5.5 d) $10^{(2.9)}$

48. The pH of a 1.0×10^{-4} M $Ba(OH)_2$ solution at 25…C is

a) 1.0 b) 3.69
c) 4.0 d) 10.3

49. Given that $K_b(F^-) = 1.5 \times 10^{-11}$ at 25…C, then $K_a(HF)$ must be

a) 3.3×10^{-7} b) 6.7×10^{-5}
c) 6.7×10^{-4} d) 3.3×10^{-3}

50. Given $K_b(CN^-) = 1.6 \times 10^{-5}$ and $K_b(F^-) = 1.5 \times 10^{-11}$, then the equilibrium constant for the following reaction must be

$$HF + CN^- \rightarrow HCN + F^-$$

a) 2.4×10^{-16} b) 4.1×10^{-12}
c) 9.4×10^{-7} d) 1.1×10^{6}

51. The pK_a for formic acid is 3.74. What is the pH of the solution resulting from addition of 0.50 moles of formic acid (HCOOH) and 0.30 mole sodium formate ($HCOO^-$) to enough water to create a final volume of 1.0 L?

a) 2.18 b) 2.78
c) 4.35 d) 3.52

52. If the above solution (problem #51) is diluted by the addition of 0.50 L of pure water, the pH will

a) decrease b) increase
c) stay the same d) become neutral

53. If you were to construct a buffer solution from phosphoric acid and its salts that operated in the range of pH 1-3, you would choose

a) 0.1 M H_3PO_4 / 0.1 M NaH_2PO_4
b) 0.1 M NaH_2PO_4 / 0.1 M Na_2HPO_4
c) 0.1 M Na_2HPO_4 / 0.1 M Na_3PO_4
d) all of these will work

54. Which of the following solutions would produce the highest pH in an aqueous solution that contained NH_3 and NH_4Cl?

a) A high concentration of NH_3 and a high concentration of NH_4Cl
b) A high concentration of NH_3 and a low concentration of NH_4Cl
c) A low concentration of NH_3 and a high concentration of NH_4Cl
d) A low concentration of NH_3 and a low concentration of NH_4Cl

55. HX and HY are both weak acids. HX is a somewhat stronger acid than HY. Which is the stronger base, NaX or NaY?

a) NaX is the stronger base
b) NaY is the stronger base
c) Neither is a base
d) Both form buffers

Answer Key

1. b
2. c
3. d
4. a
5. d
6. c
7. c
8. a
9. d
10. a
11. a
12. b
13. c
14. d
15. d
16. c
17. a
18. d
19. a
20. b
21. c
22. c
23. b
24. b
25. b
26. d
27. d
28. d
29. d
30. c
31. c
32. b
33. b
34. c
35. c
36. b
37. d
38. d
39. c
40. d
41. c
42. d
43. b
44. b
45. d
46. d
47. a
48. d
49. c
50. d
51. d
52. c
53. a
54. b
55. b

Heat, Work and Energy

1. What is the final water temperature if 100. g of water at 15.0°C is thoroughly mixed with 250. g of water at 50.0°C? Assume that the vessel in which the mixing occurs is perfectly insulated.
   a) 31.4°C b) 40.0°C
   c) 44.0°C d) 50.0°C

2. Water has a higher specific heat than mercury. All of the following statements are consistent EXCEPT?
   a) It takes more heat to warm one pound of water by 15°C than to warm the same mass of mercury by 15°C.
   b) More heat will by given off when one pound of water is cooled by 15°C than when the same mass of mercury is cooled by15°C.
   c) One pound of water cooled from 80°C to 20°C will give off the same amount of heat as one pound of mercury cooled between the same temperatures.
   d) If one pound of mercury and one pound of water initially at the same temperature are each exposed to the same amount of heat, the temperature of the mercury will rise more.

3. All of the following can be obtained from the value of the specific heat of a metal EXCEPT
   a) The amount of heat it will take to increase the temperature of 10 g of a metal by 10 K.
   b) The amount of heat that will be given off when 10 g of a metal cools from 100°C to 25°C.
   c) The approximate density of a metal.
   d) The approximate atomic mass of a metal.

4. Which of the following statements is TRUE?
   a) Temperature is the same as heat.
   b) Heat is the same as internal energy.
   c) Heat is the same as work.
   d) Internal energy is related to temperature.

5. What is the internal energy (E) in J of a system that consists of 2.50 moles of neon behaving as an ideal gas at 298K?

a) 3720 J   b) 9290 J
c) 13900 J   d) 18600 J

6. What is the temperature of a system that consists of 4.00 moles of argon behaving as an ideal gas with an internal energy of 15500 J?

a) 599K   b) 937K
c) 2500K   d) 299K

7. How many of the following variables can be used to specify the state of a system?

Heat; Pressure; Temperature; Volume; Work

a) two   b) three
c) four   d) five

8. How many of the following variables can be used to specify the state of a system?

Internal energy; Composition; Pressure; Temperature; Volume; Work

a) three   b) four
c) five   d) six

9. Which of the following is a path function?

a) heat   b) temperature
c) energy   d) pressure

10. What is the value of w for a process in which a gas expands from 3.00 L to 10.00 L against a constant external pressure of 2.00 atm?

a) —20. LÆatm   b) —14 LÆatm
c) +14 LÆatm   d) +20. LÆatm

11. What is the constant external pressure being applied to a gas if it takes 14.0 L·atm of work to compress the gas from 15.0 L to 10.0 L?

a) 2.80 atm   b) 0.357 atm
c) 70.0 atm   d) 210. atm

12. What will be the final volume of a gas sample if 12.0 L·atm of work are done on the gas sample and the constant external pressure is 2.50 atm? The initial volume of the gas is 20.0 L.

a) 4.80 L   b) 24.8 L
c) 19.8 L   d) 15.2 L

13. What is the temperature of a gas sample if the gas does 25.0 L·atm of work against a constant external pressure of 3.57 atm when expanding from 14.0 L to 21.0 L?

a) 2304K
b) 608K
c) 913K
d) More information is required.

14. What are the minimum conditions necessary for $w = —P_{ex}\Delta V$ to hold?

a) constant external pressure
b) constant external pressure and an ideal gas
c) constant external pressure and constant temperature
d) constant external pressure, an ideal gas and constant temperature

15. What is the change in internal energy (ΔE) for a system in kJ if 2550 kJ of heat are absorbed by the system and the system performs 1900 kJ of work on the surroundings?

a) —4450 kJ
b) —650 kJ
c) 650 kJ
d) 4450 kJ

16. What is the work for a system in kJ if 1900 kJ of heat are absorbed by the system and the change in internal energy (ΔE) is +2550 kJ?

a) —4450 kJ
b) —650 kJ
c) 650 kJ
d) 4450 kJ

17. Under what conditions does the first law of thermodynamics apply?

a) Constant temperature processes only
b) Processes involving ideal gases only
c) Adiabatic processes only
d) All processes

18. What is the value of ΔE in L·atm for the adiabatic expansion of a gas from 1.0 L to 2.0 L against a constant external pressure of 5.0 atm?

a) —10 L·atm
b) —5 L·atm
c) 5 L·atm
d) 10 L·atm

19. What is the value of ΔE in LÆatm for the adiabatic compression of a gas from 12.0 L to 1.0 L by a constant external pressure of 5.0 atm?

a) —55 L·atm
b) —12 L·atm
c) +12 L·atm
d) +55 L·atm

20. Which of the following is true for all adiabatic processes?
    a) $\Delta E = 0$
    b) $\Delta E = w$
    c) $\Delta E = q$
    d) None of the above is true for all adiabatic processes

21. Consider opening a compressed gas cylinder in a room at atmospheric pressure. Define the system as the cylinder and the gas contained in it. Assume that the gas is ideal and that the process is adiabatic. Which of the following is true?
    a) The temperature of the system will decrease.
    b) The temperature of the system will stay the same.
    c) The temperature of the system will increase.
    d) No prediction can be made about the temperature of the system.

22. What is the value of q in L·atm for the isothermal compression of an ideal gas from 10.0 L to 1.0 L by a constant external pressure of 10.0 atm?
    a) —90 b) —10
    c) 10 d) 90

23. Which of the following is true for an isothermal process?
    a) $q = —w$ for any isothermal process
    b) $q = —w$ for an isothermal process only if the process is the change of volume of an ideal gas
    c) $q = 0$
    d) $w = 0$

24. What is the change in temperature ΔT in K when 1 mol of an ideal gas at a pressure of 10.0 atm is discharged adiabatically into a vacuum?
    a) —1.2K b) —0.8K
    c) 0.0K d) +0.8K

25. Which of the following is true when a gas moves freely from one part to another part of a rigid system?
    a) Work is zero because the external pressure is zero.
    b) Work is zero because ΔV of the system is zero.
    c) Work is zero only if the temperature is held constant.
    d) Work is zero only if the external pressure is held constant.

26. Which of the following is true when a gas is discharged into a vacuum?
    a) Work is zero because the external pressure is zero
    b) Work is zero because ΔV of the system is zero
    c) Work is zero only if the temperature is held constant
    d) Work is zero only if the gas is assumed to be ideal

27. What is the value of w in J for the reversible compression of 1.00 mol of an ideal gas from a pressure of 1.0 atm to a pressure of 10.0 atm at a temperature of 298K?
    a) —5700 J   b) —2200 J
    c) +5700 J   d) +22000 J

28. What is the value of w in L·atm for the reversible expansion of 1.00 mol of an ideal gas from a volume of 7.0 L to a volume of 10.0 L at a temperature of 298K?
    a) +8.7 L·atm   b) +3.0 L·atm
    c) —3.0 L·atm   d) —8.7 L·atm

29. The value of ΔH for the following reaction is +52.0 kJ/mol at 298K. What is the value of ΔE in kJ/mol at the same temperature?
    $6C(s) + 3H_2(g) \rightarrow C_6H_6(l)$
    a) 44.6 kJ/mol   b) 52.0 kJ/mol
    c) 54.5 kJ/mol   d) 59.4 kJ/mol

30. The value of ΔE for the following reaction is —59.4 kJ/mol at 298K. What is the value of ΔH in kJ/mol at the same temperature?
    $C_6H_6(l) \rightarrow 6C(s) + 3H_2(g)$
    a) +7.37 kJ/mol   b) —44.6 kJ/mol
    c) —52.0 kJ/mol   d) —59.4 kJ/mol

31. What is the minimum information necessary in order to determine ΔE for a chemical reaction that consumes one mole of reactant and that takes place at a constant volume and a constant temperature?

    a) The value of q
    b) The value of q and the temperature
    c) The value of q and the balanced chemical equation
    d) The value of q, the balanced chemical equation, and the temperature.

32. What is the minimum information necessary in order to determine ΔH for a chemical reaction that consumes one mole of reactant and that takes place at a constant volume and a constant temperature?

    a) The value of q
    b) The value of q and the temperature
    c) The value of q and the balanced chemical equation
    d) The value of q, the balanced chemical equation and the temperature.

33. A 0.500 mole sample of CO(g) is combusted in a constant pressure calorimeter to CO_2(g). The temperature is observed to rise from 25.00°C to 27.50°C. The heat capacity of the calorimeter (calorimeter constant) is 56.6 kJ/K. What is ΔH in kJ/(mole of CO) for the reaction?

    a) —283 kJ/mol b) —282 kJ/mol
    c) +282 kJ/mol d) +283 kJ/mol

34. Suppose you are given ΔH in kJ/mol for a chemical process that has taken place in a constant pressure calorimeter. What minimum additional information will you need to be able to determine ΔE in kJ/mol for the process?

    a) The temperature only
    b) The temperature and the balanced equation for the reaction only
    c) The temperature, the balanced equation, and the external pressure only
    d) The temperature, the balanced equation, the external pressure, and the volume of the calorimeter at P_{ex} = 1 atm

35. What is the enthalpy change of the third reaction in terms of the enthalpy changes of the first two reactions?

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ ΔH_1

$4NH_3(g) + 3O_2(g) \rightarrow 6H_2O(l) + 2N_2(g)$ ΔH_2

$4NH_3(g) \rightarrow 6H_2(g) + 2N_2(g)$ ΔH_3

a) $\Delta H_3 = \Delta H_2 — \Delta H_1/2$ b) $\Delta H_3 = \Delta H_2/2 — 3\Delta H_1$
c) $\Delta H_3 = \Delta H_2 — \Delta H_1$ d) $\Delta H_3 = \Delta H_2 — 3\Delta H_1$

36. Hess's law states that the overall enthalpy change ΔH of a cyclic process is zero. Why is this true?

a) Because pressure is constant
b) Because volume is constant
c) Because ΔH = ΔE
d) Because ΔH is a state function

37. Determine ΔH… in kJ/mol for the following reaction:

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

The standard enthalpy of formation of NO(g) is 90.4 kJ/mol and the standard enthalpy of formation of $NO_2(g)$ is 33.9 kJ/mol.

a) —113 kJ/mol b) —56.5 kJ/mol
c) +56.5 kJ/mol d) +113 kJ/mol

38. Calculate ΔH_f… of $C_2H_5OH(l)$ from the following data:

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

ΔH… = —1365 kJ, ΔH_f… for $CO_2(g)$ is —393 kJ/mol, ΔH_f… for $H_2O(g)$ is —242 kJ/mol

a) —680 kJ/mol b) +680 kJ/mol
c) —297 kJ/mol d) Cannot be answered without knowing ΔH_f… of $O_2(g)$

39. 10. g of ice at 0.0°C is dropped into 30. g of liquid water at 80°C. ΔH_{fusion} of water at 0.0°C is 6.00 kJ/mol. What is the final temperature?

a) 40°C b) 43°C
c) 46°C d) More information is required.

40. Which of the following have standard enthalpies of formation of zero?
a) All pure substances
b) All pure elements
c) All pure substances in their standard states
d) All pure elements in their standard states

41. Which of the following statements is true?
a) The standard enthalpy of formation of a compound is the enthalpy of the formation of the compound from the atoms that compose it.
b) The standard enthalpy of formation of a compound is the enthalpy of the formation of the compound in its standard state from the elements that compose it in their standard states.
c) The standard enthalpy of formation of a compound is always a negative number.
d) The standard enthalpy of formation of an element is zero regardless of what state it is in.

42. An unknown gas has $C_p = 20.7$ J/mol·K and $C_v = 12.5$ J/mol·K. Which of the following is true about this gas?
a) It is monatomic and behaving like an ideal gas.
b) It is polyatomic and behaving like an ideal gas.
c) It is monatomic and not behaving like an ideal gas.
d) It is polyatomic and not behaving like an ideal gas.

43. Which of the following is true for a gas,
a) The heat capacity at constant volume is always less than the heat capacity at constant pressure
b) The heat capacity at constant volume is always greater than the heat capacity at constant pressure
c) The heat capacities at constant pressure and constant volume are always equal
d) No general statement can be made about the relative values of the heat capacities at constant volume and constant pressure for a gas. It depends what gas it is.

44. All of the following are statements of problems encountered when using hydrogen as fuel EXCEPT
   a) The enthalpy change per gram for the combustion of hydrogen is too small
   b) Stored hydrogen gas requires takes up large volumes
   c) Hydrogen atoms migrate into metals making them brittle
   d) Production of hydrogen gas requires high quantities of energy

45. A pile of copper shot (pellets) weighing 25.0 grams is heated to 165°C and is then immersed in water at a temperature of 85.0°C. Assuming no loss of heat to the surroundings, after thermal equilibrium is achieved, the final temperature of the system (copper plus water) could be
   a) <85.0°C   b) >165°C
   c) 85°C – 165°C   d) none of the above

46. Given the following thermochemical data, the standard enthalpy of formation of naphthalene, $C_{10}H_8(s)$ can be shown to be
   $\Delta H^o_{combustion}$ for naphthalene is −5154 kJ/mol
   $\Delta H^o_{formation}$ of $CO_2(g)$ is −393 kJ/mol
   $\Delta H^o_{formation}$ of $H_2O(l)$ is −286 kJ/mol
   a) −5833 kJ/mol   b) −79.9 kJ/mol
   c) +79.9 kJ/mol   d) +4475 kJ/mol

47. The reduction of carbon dioxide with magnesium powder and turnings releases energy and is therefore (exothermic, endothermic) and the expanding of carbon dioxide from an extinguisher is (isothermal, adiabatic).
   a) exothermic, isothermal   b) exothermic, adiabatic
   c) endothermic, isothermal   d) endothermic, adiabatic

48. One kg of hot oil at 80°C is poured onto two kg of methanol at 0°C. The heat capacity of the oil is half that of the methanol. What will be the final temperature?
   a) 8°C   b) 16°C
   c) 40°C   d) 60°C

49. The heats of formation of $SO_2(g)$ and $SO_3(g)$ are −296.8 kJ/mol and −395.7 kJ/mol, respectively. The enthalpy change of the following reaction in kJ is:

$$SO_2(g) + 1/2O_2(g) \rightarrow SO_3(g)$$

a) −901.2 kJ b) −901.2 kJ
c) + 98.9 kJ d) −98.9 kJ

50. The heat of combustion of methane is about 1000 kJ/mol and about 160 grams is required to heat 20 gallons of water from ambient room temperature to about 45…C for the purposes of bathing. If butane (CH_4), the compressible fluid used in a variety of burners and lighters, is available to you in place of methane, the grams required to accomplish the same task is estimated to be

a) 16 g b) 44 g
c) 58 g d) 160 g

51. Calculate the amount of heat needed to bring 10.00 g of ice from —15°C to 110°C. Assume that the heat of fusion is 80.00 cal/g, the heat of vaporization is 540.0 cal/g, the heat capacity of liquid water is 1.00 cal/g · K, and that of steam and ice are both 0.500 cal/g · K.

a) 7.325 cal b) 7.450 cal
c) 7.325 kcal d) 7.450 kcal

52. A piece of metal at 20°C that weighs 60.0 g is dropped into 200. g of water at 100°C. The specific heat capacity of the metal is 0.389 J/g·K and that of water is 4.22 J/g·K. Calculate the final temperature reached by the water.

a) —10.1°C b) 22.1°C
c) 35.2°C d) 97.8°C

53. The following reaction is environmentally significant. Both CO and CO_2 are combustion products of hydrocarbon fuels. At constant T and P, which of the following statements is correct?

$$2CO(g) + O_2 \rightarrow 2CO_2(g)$$

a) $\Delta H = \Delta E$
b) $\Delta H < \Delta E$
c) $\Delta H > \Delta E$
d) T must be known in order to properly select an answer

54. An ice cube at 0.00°C and weighing 18.0 grams is placed in 180. grams of water at 25.0°C in an isolated system. What is the temperature of the system at equilibrium, given that the heat of fusion for ice is −6,007 J/mol and the specific heat for water is 4.184 J/gÆK?

a) 5.00…C	b) 15.6°C
c) 17.1°C	d) 24.0°C

Answer Key

1. b
2. c
3. c
4. d
5. b
6. a
7. b
8. c
9. a
10. b
11. a
12. d
13. d
14. a
15. c
16. c
17. d
18. b
19. d
20. b
21. a
22. a
23. b
24. c
25. b
26. a
27. c
28. d
29. d
30. c
31. a
32. d
33. a
34. b
35. d
36. d
37. c
38. d
39. d
40. d
41. b
42. a
43. a
44. a
45. c
46. c
47. b
48. b
49. d
50. d
51. c
52. d
53. b
54. b

Spontaneous Change

1. All of the following are reversible processes EXCEPT
   a) Liquid water interconverting with solid ice at the normal freezing point, 0°C and one atm
   b) A chemical reaction in which the reaction quotient Q is equal to the equilibrium constant K
   c) A gas expanding against a constant external pressure of one atmosphere at a constant temperature of 298K
   d) The interconversion of solid, liquid and gaseous bromine at its triple point

2. Which of the following is a reversible process?
   a) The free expansion of a gas.
   b) The isothermal expansion of a gas against a constant pressure
   c) Water boiling at 100°C and one atm pressure
   d) The heating of water from 0°C to 100°C at the rate of one degree per hour.

3. Which of the following statements is true regarding reversible and spontaneous processes?
   a) A reversible process is any process that can be caused to proceed in the opposite direction.
   b) If the process from State A to State B is spontaneous, then the process from State B to State A cannot be caused to be spontaneous.
   c) A process is not spontaneous if it requires work to be done on the system.
   d) A reversible process proceeds infinitely slowly.

4. Calculate the total work for a two step process where an ideal gas sample, originally at a volume of 1.00 L, a temperature of 298K, and an internal pressure of 1.00 atm, is isothermally compressed, first by a constant external pressure of 2.00 atm (internal pressure goes to 2.00 atm) and then by a constant external pressure of 3.00 atm (internal pressure goes to 3.00 atm).
   a) 0.667 L·atm b) 1.10 L·atm
   c) 1.50 L·atm d) 2.00 L·atm

5. Which of the following statements is true regarding the isothermal change in volume of an ideal gas?
   a) The reversible path requires about three steps.
   b) The reversible path will have a lower value of ΔE than any irreversible path.
   c) The reversible path will have a lower value of w than any irreversible path.
   d) The reversible path will have a lower value of q than any irreversible path.

6. What is the value of $\Delta S_{surroundings}$ in J/K for a process conducted at 298K for which w for the process is 2000. J and q for the process is 3000. J?
   a) —10.1 J/K
   b) —6.71 J/K
   c) 6.71 J/K
   d) more data are required

7. Which of the following statements is true?
   a) $\Delta S_{universe}$ can be positive or negative.
   b) ΔS_{system} can be positive only
   c) ΔS_{system} can be negative only
   d) $\Delta S_{surroundings}$ can be positive or negative

8. What is ΔS_{system} for a reversible, isothermal compression of 0.0409 moles of an ideal gas at 298K from 1.000 L to 0.500 L?
   a) —0.236 J/K
   b) —1.156 J/K
   c) +1.156 J/K
   d) +0.236 J/K

9. Which of the following is always zero for a reversible, isothermal change in volume of an ideal gas?
   a) ΔS_{system}
   b) $\Delta S_{surroundings}$
   c) q
   d) $\Delta S_{universe}$

10. Which of the following is always zero for an adiabatic change in volume of an ideal gas?
   a) ΔS_{system}
   b) w
   c) q
   d) $\Delta S_{universe}$

11. What is the value of ΔS_{system} in J/K for the expansion of 1.00 moles of an ideal gas from a 12.23 L to 24.46 L against a constant external pressure of 1.00 atm at 298K

    a) —5.76 J/K b) —4.16 J/K
    c) +4.16 J/K d) +5.76 J/K

12. What is $\Delta S_{surroundings}$ for the isothermal expansion of 0.0409 moles of an ideal gas at 298K from 0.500 L to 1.000 L against a constant external pressure of 1.00 atm?

    a) —0.404 J/K b) +0.404 J/K
    c) +0.236 J/K d) —0.168 J/K

13. An ideal gas is isothermally and irreversibly compressed by a constant external pressure. Which of the following is true?

    a) $\Delta S_{system} = 0$ b) $\Delta S_{system} > 0$
    c) $\Delta S_{surroundings} = 0$ d) $\Delta S_{surroundings} > 0$

14. What is the value of ΔS_{system} in J/K for the adiabatic expansion of 1.00 mol of an ideal gas from 1.00 L to 2.00 L at 298K against no opposing pressure?

    a) —1717 J/K b) —5.8 J/K
    c) +5.8 J/K d) +1717 J/K

15. Which of the following is true for the free expansion of an ideal gas?

    a) $\Delta S_{system} = 0$ b) $\Delta S_{surroundings} = 0$
    c) $\Delta S_{universe} = 0$ d) All of the above are true

16. Which of the following is always zero for the adiabatic free expansion of an ideal gas?

    a) ΔS_{system}
    b) $\Delta S_{surroundings}$
    c) $\Delta S_{universe}$
    d) All of the above are zero for this process.

17. What is the entropy change of the system in J/K for the reversible cooling of one mole of copper metal from 200°C to 150°C? The heat capacity of copper is 24.7 J/molÆK.

    a) —7.10 J/K b) —2.76 J/K
    c) +2.76 J/K d) +7.10 J/K

18. All of the following equations are useful for making calculations involving the heating or cooling of a substance EXCEPT

a) $q = C\Delta T$
b) $\Delta E = q + w$
c) $\Delta S = q_{rev}/T$
d) None of the above

19. What is the entropy change of a system in J/K for the melting of one mole of aluminum at its normal melting point of 660.°C? The value of ΔH_{fusion} of aluminum at this temperature is 10660 J/mol.

a) —16.2 J/K
b) —11.4 J/K
c) +11.4 J/K
d) +16.2 J/K

20. What is the entropy change of a system in J/K for vaporizing 2.00 moles of a substance? The value of $\Delta H_{vaporization}$ of the substance at this temperature is 152100 J/mol.

a) 10.7 J/K
b) 88.0 J/K
c) 93.0 J/K
d) More data are required

21. Trouton's rule states that many substances have entropies of vaporization close to 88 J/molÆK. Which of the following is the best rationale for Trouton's rule?

a) Most substances have similar enthalpies of vaporization.
b) Most substances have similar boiling points.
c) The change in disorder in going from one mole of liquid to one mole of gas is similar for many substances.
d) Entropy changes for most processes are about 88 J/molÆK.

22. Which of the following is true for $\Delta S_{universe}$ for the freezing of water at —10°C and 1.00 atm?

a) $\Delta S_{universe} < 0$
b) $\Delta S_{universe} = 0$
c) $\Delta S_{universe} > 0$
d) More data are necessary

23. Which of the following would be true for $\Delta S_{universe}$ for the process of converting liquid water to water vapor at 100°C and 1.00 atm?

a) $\Delta S_{universe} < 0$
b) $\Delta S_{universe} = 0$
c) $\Delta S_{universe} > 0$
d) More data are required

24. What is (are) the driving forces for the conversion of liquid water to water vapor at 110°C and 1.00 atm?
    a) The drive to achieve higher disorder
    b) The drive to achieve lower potential energy
    c) Both the drive to achieve higher disorder and the drive to achieve lower potential energy
    d) There is no driving force because the process is not spontaneous under these conditions.

25. What is the standard entropy change for the following reaction in J/molÆK? Values of absolute entropy are given below the reaction.

$$2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$$

	S°, J/molÆK
Zn(s)	41.6
$O_2(g)$	205
ZnO(s)	43.9

a) —203 J/molÆK b) —200 J/molÆK
c) +2.0 J/molÆK d) +4.0 J/molÆK

26. Which of the following statements is true?
    a) All crystals at absolute zero have an entropy of zero.
    b) Only perfect crystals of pure substances at absolute zero have an entropy of zero.
    c) Only perfect crystals of pure elements at absolute zero have an entropy of zero.
    d) There is no actual zero of entropy.

27. Which of the following determinations takes advantage of the third law of thermodynamics?
    a) Calculation of the enthalpy of fusion of a substance
    b) Calculation of the absolute entropy of a substance
    c) Calculation of the enthalpy change of a process
    d) Calculation of the change in internal energy of a process

28. What is the value of ΔG for a chemical reaction in which the equilibrium constant K is equal to the reaction quotient Q?
    a) $\Delta G < 0$
    b) $\Delta G = 0$
    c) $\Delta G > 0$
    d) ΔG can have any value under these conditions

29. If ΔG for a chemical reaction is less than zero, which is greater, the equilibrium constant K or the reaction quotient Q?
    a) K is greater
    b) Q is greater
    c) K = Q
    d) More data are required

30. Under what minimum conditions (besides constant temperature) can ΔG be used to tell if a chemical reaction is spontaneous?
    a) Constant
    b) Constant P
    c) Constant V and P
    d) Constant P and 298K

31. What is the value of ΔG for a process conducted at 298K that has a ΔH of —600. kJ and a ΔS of 100. J/K?
    a) —30400 kJ
    b) —630 kJ
    c) +570 kJ
    d) +630 kJ

32. A reaction is exothermic and has a positive value of ΔS. Under what conditions of temperature will this reaction be spontaneous?
    a) high temperatures only
    b) low temperatures only
    c) essentially all temperatures
    d) it will not be spontaneous at any temperature

33. What is the value of $\Delta G°$ at 298K for a reaction that has an equilibrium constant of 3.82 at that temperature?
    a) —9460 J
    b) —3320 J
    c) +3320 J
    d) +9460 J

34. What can be said about the value of the equilibrium constant, K, for a chemical process that has a negative value of ΔG°?

a) The value of K is negative.
b) The value of K is zero.
c) The value of K is less than one but greater than zero.
d) The value of K is greater than one.

35. A reaction has ΔH° = +193 kJ/mol and ΔS° = +112 J/molÆK. At what temperature is the value of ΔG° equal to zero?

a) 1.72K b) 298K
c) 580K d) 1720K

36. Which of the following statements is correct about a reaction for which the value of ΔG° is equal to zero at 300K?

a) The reaction is at equilibrium at 300K only if all reactants and products are at standard conditions.
b) The reaction is at equilibrium at 300K no matter what the partial pressures or concentrations of the reactants and products.
c) The reaction can be made to proceed fully to products by raising the temperature.
d) There are no conditions under which this reaction can be made to proceed spontaneously to products.

37. Calculate the value of K at 550K for the following reaction assuming that ΔH… and ΔS… are independent of temperature in the range 298K to 550K.

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ ΔH° = —113.0 kJ/mol
ΔS° = —145 J/molÆK

a) $4.9 \times 10^{—19}$ b) 1.44×10^{3}
c) 4.1×10^{28} d) $7.0 \times 10^{—4}$

38. What information is necessary to calculate the value of $\Delta G°$ for a chemical reaction at a temperature other than 298K without assuming that $\Delta H°$ and $\Delta S°$ are independent of temperature within the appropriate temperature range?

a) $\Delta H°$ and $\Delta S°$ at 298K only
b) $\Delta H°$ and $\Delta S°$ at 298K and the heat capacities of the products only
c) $\Delta H°$ and $\Delta S°$ at 298K and the heat capacities of the reactants and the products
d) It is impossible to make this calculation.

39. For a reaction that is exothermic and has a negative value of ΔS

a) higher temperatures favor product formation
b) lower temperatures favor product formation
c) product formation is favored at all temperatures
d) the reaction will not be product-favored at any temperature

40. What is the value of $\Delta G°$ at 298K for a reaction that has an equilibrium constant of 3.82 at that temperature?

a) —9460 J
b) —3320 J
c) +3320 J
d) +9460 J

41. Based on comparison of $\Delta G°$ values at 298K, *trans*-2-butene is more stable than *cis*-2-butene by about 4 kJ/mol. Therefore, the equilibrium constant for the isomerization at that temperature must be.

cis-2-butene $\rightarrow$ *trans*-2-butene

a) 0.02
b) 0.20
c) 5.0
d) 41

42. What are the signs of ΔS and ΔG, respectively, for the combustion of propane, an exothermic reaction?

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

a) + and —
b) — and +
c) + and +
d) – and –

43. Given that ΔG°_f = +98.2 kJ/mol for $N_2O_4(g)$ and ΔG° for the decomposition of N_2O_4 according to the following equation is +5.4 kJ, all at 298K

$$N_2O_4(g) \rightarrow 2NO_2(g)$$

Calculate ΔG°_f for $NO_2(g)$.

a) +46.4 kJ/mol b) +51.8 kJ/mol
c) +92.8 kJ/mol d) +103.6 kJ/mol

44. For which of the following reactions is $\Delta S>O$?

a) $NH_4NO_3(s) \rightarrow NH_4NO_3(aq)$
b) $Cl_2(g) \rightarrow Cl_2(liq)$
c) $2NO_2(g) \rightarrow N_2O_4(g)$
d) $H_2O(g) \rightarrow H_2O(s)$

45. The algebraic signs of ΔH° and ΔS° for the electrolysis of liquid water at 298K to give gaseous oxygen and hydrogen are

a) $\Delta H^\circ > 0, \Delta S^\circ > 0$ b) $\Delta H^\circ > 0, \Delta S^\circ < 0$
c) $\Delta H^\circ < 0, \Delta S^\circ < 0$ d) $\Delta H^\circ < 0, \Delta S^\circ > 0$

Answer Key

1. c
2. c
3. d
4. c
5. c
6. a
7. d
8. a
9. d
10. c
11. d
12. d
13. d
14. c
15. b
16. b
17. b
18. c
19. c
20. d
21. c
22. c
23. b
24. a
25. b
26. b
27. b
28. b
29. a
30. b
31. b
32. c
33. b
34. d
35. d
36. a
37. b
38. c
39. b
40. b
41. c
42. a
43. b
44. a
45. a

Electrochemistry

1. What is the oxidation state of Cr in $K_2Cr_2O_7$?

   a) +2 b) +4
   c) +6 d) +8

2. How many OH^- ions appear on one side or the other once the equation below is balanced?

   $$Al(s) + IO_3^-(aq) \rightarrow H_2AlO_3^-(aq) + I^-(aq)$$

   a) 2 b) 4
   c) 6 d) 8

3. Consider the following half-cells connected in a spontaneous (galvanic) cell,

   $Mn^{2+} + 2e^- \rightarrow Mn$ —1.18 V
   $Ni^{2+} + 2e^- \rightarrow Ni$ —0.250 V

   Which of the following describes the Mn electrode correctly?

   a) Anode and positively charged
   b) Cathode and positively charged
   c) Anode and negatively charged
   d) Cathode and negatively charged

4. What moves between the two half-cells of a galvanic cell?

   a) Electrons only
   b) Ions only
   c) Ions and electrons
   d) The cells are separated from each other so that there will be no transfer between them.

5. Consider a cell in which one half-cell has a lead electrode immersed in a 1M Pb^{2+} solution and the other has an iron electrode immersed in a 1M Fe^{3+} solution. Pertinent reduction potentials are:

   $Pb^{2+} + 2e^- \rightarrow Pb$ —0.126 V
   $Fe^{3+} + 3e^- \rightarrow Fe$ —0.037 V

   What will be the cell potential if the cell proceeds spontaneously?

   a) 0.089 V b) 0.163 V
   c) 0.304 V d) 0.489 V

6. Which of the following statements is true?
   a) Oxidations always have positive potentials and reductions have negative potentials.
   b) Half-reactions that have negative half-cell potentials cannot be part of a galvanic (spontaneous) cell under standard conditions.
   c) An unreactive metal like gold is very difficult to oxidize. Therefore, it is also very difficult to reduce gold ions to gold metal.
   d) Assigning a potential of 0 V to the hydrogen ion/hydrogen gas electrode is purely arbitrary and it could have been assigned any other value.

7. What is the electrical work that can be done by 3.00 moles of electrons at a potential of 1.75 V?
   a) 1.71 J b) 5.25 J
   c) 1.65×10^5 J d) 5.07×10^5 J

8. What does it mean if a cell reaction has a standard potential of zero?
   a) The value of the equilibrium constant is zero.
   b) It is not possible to change the concentrations of the electrolytes in such a way the observed potential will be positive.
   c) The reaction is at equilibrium if all concentrations are 1M.
   d) The reaction is spontaneously approaching equilibrium.

9. Which of the following is the minimum list of conditions required for the equation $\Delta G^\circ = - nFE^\circ$ to hold?
   a) Standard conditions and constant pressure
   b) Standard conditions, constant pressure, and constant temperature
   c) Standard conditions, constant pressure, constant temperature, and a reversible process
   d) Standard conditions, constant pressure, constant temperature, constant volume, and a reversible process

10. The standard potential at 298K for the following reaction is 0.467 V.

$$2Cr(s) + 3Co^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Co(s)$$

What is the potential if the concentration of Co^{2+} is 0.0000100M and the concentration of Cr^{3+} is 0.100M ?

a) 0.263 V b) 0.339 V
c) 0.428 V d) 0.509 V

11. Which of the following describes a concentration cell that has run spontaneously until the process stops?

a) Positive potential; concentrations equal in both half—cells
b) Negative potential; concentrations equal in both half—cells
c) Negative potential; concentrations not equal in both half—cells
d) Zero potential; concentrations equal in both half—cells

12. A galvanic cell has a copper electrode dipping into a 1M Cu^{2+} solution and a hydrogen electrode (H_2 pressure = 1 atm) dipping into an unknown solution. The cell potential is 0.478 V. What is the pH of the unknown solution?

$Cu^{2+}(aq) + 2e^{—} \rightarrow Cu(s)$ $E° = +0.153$ V
$2H^{+}(aq) + 2e^{—} \rightarrow H_2(g)$ $E° = 0.000$ V

a) 2.7 b) 4.0
c) 5.5 d) 8.1

13. What current would be necessary to deposit 5.00 g of Fe(s) from a solution of $Fe^{3+}(aq)$ in 1.00 hr?

a) 2.40 A b) 2.68 A
c) 24.0 A d) 26.8 A

14. What potential needs to be applied to change the direction of a reaction in a spontaneous cell process?

a) The same potential as that generated by the spontaneous process
b) Somewhat more than the potential generated by the spontaneous process
c) The voltage depends on the current applied; the more amperes of current, the lower the potential that is needed
d) One volt is satisfactory under any conditions

15. In the equation for the reaction of potassium iodide (KI) and sulfuric acid (H_2SO_4), which statement is TRUE?

$8KI(aq) + 9H_2SO_4(aq) \rightarrow 4I_2(s) + 8KHSO_4(aq) + H_2S(g) + 4H_2O(l)$

a) The reducing agent is H_2SO_4
b) The oxidizing agent is KI
c) The substance reduced is H_2SO_4
d) The substance oxidized is $KHSO_4$

16. In the electrolysis of aqueous (sodium chloride, sodium sulfate) solutions respectively, the anode reaction produces

a) oxygen, oxygen
b) oxygen and chlorine, oxygen
c) chlorine, oxygen
d) chlorine and hydrogen, oxygen

17. The reduction of aqueous copper (II) with iron metal has a ΔE¡ value of 0.78 V.

$Fe(s) + Cu^{2+}(aq, 1\ M) \rightarrow Fe^{2+}(aq, 1\ M) + Cu(s)$

If the standard reduction potential for Cu^{2+} + 2e— $\rightarrow$ Cu(s) is 0.34 V, then the standard reduction potential for Fe^{2+}/Fe(s) must be:

a) 0.44 V
b) —0.44 V
c) 0.22 V
d) —0.22 V

18. A given amount of electric charge deposits 2.159 g of silver from an Ag^+ solution. What mass of copper from a Cu^{2+} solution will be deposited by the same quantity of electric charge?

Atomic Molar Masses: Ag 107.9 g/mol; Cu 63.5 g/mol

a) 0.635 g
b) 1.27 g
c) 1.97 g
d) 2.54 g

19. Based on the following information, which statement is correct?

$[H^+]$ = 1.0 M initially, P_{O2} = 1.0 atm

4e— + $O_2(g) + 4H^+(aq) \rightarrow 2H_2O(l)$ E¡ = 1.23 V

a) n = l, since one mole of oxygen is being considered.
b) Addition of base should result in an E¡ value which is less than 1.23 V
c) $Q = [H_2O]^2/[O_2]^0[H^+]$
d) $Q = 1/[H^+]$

20. The gold plating process involves the following reaction: $Au^{3+}(aq) + 3e^{-} \rightarrow Au(s)$. If 0.6 g of Au is plated onto a metal, how many coulombs are used? Assume that the numerical value of the Faraday constant is 96,487 C/mol and the molecular mass of gold is 197 g/mol.

a) 3.2×10^{-8} C b) 880 C
c) 5.8×10^{4} C d) 8800 C

Answer Key

1. c	11. d
2. a	12. c
3. c	13. a
4. c	14. b
5. a	15. c
6. d	16. c
7. d	17. b
8. c	18. a
9. c	19. b
10. c	20. b

Chemical Kinetics

1. In a reaction where A and B go to products, what is the rate law if the following rates are observed?

[A] mol/L	[B] mol/L	rate M/s
0.020	0.010	0.278
0.040	0.010	0.556
0.030	0.020	1.67
0.040	0.020	2.22

a) rate = k[A][B] b) rate = $k[A]^2[B]$
c) rate = $k[A][B]^2$ d) rate = $k[A]^2[B]^2$

2. If the rate is given as $—\Delta[O_2]/\Delta T$ for a reaction, for the following reaction, what is the same rate given in terms of $[H_2O]$?

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

a) $\Delta[H_2O]/\Delta t$ b) $\Delta[H_2O]/2\Delta t$
c) $2\Delta[H_2O]/\Delta t$ d) $—2\Delta[H_2O]/\Delta t$

3. Which of the following is true about an elementary process?
a) A reaction involving only atoms is an elementary process.
b) A reaction that proceeds in only one step is an elementary process.
c) A reaction with a zero order rate law is an elementary process.
d) All chemical reactions are elementary processes.

4. What is the specific rate constant for a 1st order reaction with a half-life of 45 min 30 s?
a) $2.54 \times 10^{—4}$ $s^{—1}$ b) $3.66 \times 10^{—4}$ $s^{—1}$
c) 1.89×10^{3} $s^{—1}$ d) 3.66×10^{4} $s^{—1}$

5. The radioactive isotope, ^{14}C, has a half-life of 5720 years. As a result of the natural abundance of ^{14}C, a 1.00 g sample of carbon from a living organism undergoes 15 disintegrations per minute. How old is a 10.0 g sample for which the rate of disintegrations is 91 per minute?
a) 2900 yr b) 8250 yr
c) 3470 yr d) 4120 yr

6. Which of the following ranges of time would give the most accurate age of an object for a radioactive nuclide with a half-life of 1000 years?

a) 1 to 10 years　b) 10 to 100 years
c) 100 to 5000 years　d) 5000 to 50,000 years

7. What is the energy of activation for a reaction that has a specific rate constant equal to 3.6×10^{-2} s^{-1} at 273K and a specific rate constant = 7.2×10^{-2} s^{-1} at 373 K?

a) 706 J/mol　b) 8470 J/mol
c) 4230 J/mol　d) 5870 J/mol

8. How do you explain the increased rate observed when a reaction is heated?

a) The entropy increases.
b) The activation energy decreases.
c) A faster pathway can be found.
d) A higher fraction of molecules have enough kinetic energy to surmount the activation energy barrier.

9. Which of the following represents the minimum possible information to establish the mechanism of a chemical reaction beyond doubt?

a) The rate constant
b) The chemical equation
c) The rate law
d) None of the above is sufficient to establish the mechanism beyond a doubt.

10. Which of the following can be changed for a reaction if a catalyst is added?

a) ΔH　b) ΔG
c) E_a　d) K

11. In the formation of HCl from H_2 and Cl_2, what kind of step is the following?

$H\cdot + Cl\cdot \rightarrow HCl$

a) Initiation　b) Propagation
c) Termination　d) None of the above

12. If a catalyst increases the rate of a reaction what happens to $k_{forward}$, the rate constant for the forward reaction, and to $k_{reverse}$, the rate constant of the reverse reaction?

a) $k_{forward}$ increases and $k_{reverse}$ increases
b) $k_{forward}$ increases and $k_{reverse}$ decreases
c) $k_{forward}$ increases and $k_{reverse}$ remains unchanged
d) $k_{forward}$ remains unchanged and $k_{reverse}$ decreases

13. A propane-oxygen flame, once lighted, burns continuously because

a) the heat released in the reaction raises the temperature of the reactants
b) the visible light of the flame photodissociates the reactant O_2
c) all reactions that release heat (ΔH) occur without a collisional activation barrier
d) this specific reaction has no collisional activation barrier

14. If two H atoms collide with each other at 23°C, which of the following statements is TRUE?

a) They can recombine if they are going slowly enough.
b) They can recombine if a third body in the collision takes away part or all of the H_2 bond energy.
c) The kinetic energy of the two H atoms increases as they speed up towards each on the bonding sigma curve.
d) Both b and c above.

15. Which of the following statements is TRUE?

a) Chemical energy, ΔH, is released if molecules with strong bonds form molecules with weak bonds.
b) Chemical energy is released only if a reaction begins with photodissociation.
c) Chemical energy released cannot be large if the initial activation barrier, E_a, is very high.
d) Chemical energy released, ΔH, can be zero even if the collisional activation energy, E_a, is not zero.

16. All of the following reactions have high collisional activation barriers EXCEPT

a) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

b) $^{16}O_2 + {}^{18}O_2 \rightarrow 2\,{}^{16}O\text{-}{}^{18}O$

c) $NO + O_2 \rightarrow NO_2$

d) $N_2 + O_2 \rightarrow 2NO$

17. A propane-oxygen flame needs to be lighted with a match because

a) The heat of the match balances the heat absorbed by the reaction.

b) The visible light of the flame creates free O atoms by photodissociation of reactant O_2

c) The gas company adds an additive to prevent a fast reaction and to make propane a safer fuel.

d) This specific reaction only starts if the reagent temperature is much higher than 25°C.

18. A reaction has an activation energy of 4.82×10^2 cal/mol. If the rate constant is 8.82×10^{-5} at 275K, what is the rate constant at 567K?

a) 6.25 b) 5.17×10^2

c) 1.39×10^{-4} d) 2.36×10^{-3}

19. For a given reaction, it was found that the activated complex had an energy that was 45 J higher than the energy of the products and 198 J higher in energy than the reactants. The energy of activation of this reaction is

a) 45 J b) 198 J

b) 153 J d) 243 J

20. Which one of the following is an example of homogeneous catalysis?

a) the destruction of ozone gas in the stratosphere by gaseous nitrogen oxides

b) the breakdown of sugars in an animal cell

c) the hydrogenation of oils to margarine with a palladium catalyst

d) the reaction of gaseous hydrogen with gaseous bromine to form gaseous hydrogen bromide

21. All of the following are true about knock inhibitors in fuels EXCEPT

a) They inhibit uncontrolled chemical reactions during the compression and heating phases in the engine.
b) Tetraethyl lead functions very well in this application.
c) Tetraethyl lead is used extensively in this application in the United States.
d) They have lead to the existence of high levels of lead in the environment.

Answer Key

1. c
2. b
3. b
4. a
5. d
6. c
7. d
8. d
9. d
10. c
11. c
12. a
13. a
14. d
15. d
16. b
17. d
18. c
19. b
20. a
21. c

CHAPTER SIXTEEN

Solids

1. All of the following are true about crystals EXCEPT
   a) A crystal softens and melts over a wide range of temperature.
   b) A crystal tends to shatter along defined planes.
   c) Crystals generally have a specific shape for a specific substance.
   d) Crystals usually have a high degree of symmetry.

2. All of the following are logical consequences of the observed macroscopic properties of crystals EXCEPT
   a) The atoms or molecules of a crystal are arranged in a regularly repeating pattern.
   b) The forces holding the atoms in a metal crystal are the same for essentially every atom except at the surface.
   c) The distances between adjacent atoms or molecules vary greatly.
   d) Some defects are present in crystals.

3. Which of the following has the largest number of lattice points per unit cell?
   a) The primitive (simple) cubic lattice
   b) The face centered cubic lattice
   c) The body centered cubic lattice
   d) All these lattices have the same number of lattice points per unit cell.

4. All of the following are true about lattice points in a crystal structure EXCEPT
   a) The first lattice point can be placed at any location.
   b) All lattice points have identical environments.
   c) The corners of unit cells are located at lattice points.
   d) Atoms are always located on lattice points.

5. Lead (Pb) crystallizes in a face-centered cubic lattice with a unit cell edge of 4.941 . What is the density of lead? (1 = 10^{-8} cm)
   a) 2.78×10^{-14} g/cm^3 b) 2.85 g/cm^3
   c) 5.70 g/cm^3 d) 11.4 g/cm^3

6. Tantalum (Ta) crystallizes in one of the cubic lattices with a unit cell edge of 3.281 . The density of tantalum is 17.0 g/cm^3. In which of the following lattices does tantalum crystallize? (1 $=10^{-8}$ cm)
   a) Primitive (simple) cubic b) Body-centered cubic
   c) Face-centered cubic d) It cannot be crystallized in a cubic lattice.

7. All of the following statements are true EXCEPT
   a) The face-centered cubic lattice is identical to the cubic closest packed lattice.
   b) The body-centered cubic lattice is identical to the hexagonal closest packed lattice.
   c) The cubic closest packed and hexagonal closest packed structures have identical fractions of space which are occupied by atoms.
   d) The density of a metal sample is independent of the size of the sample considered.

8. Which of the following represents the minimal amount of data necessary to determine the atomic mass of a metal?
   a) Avogadro’s number and the density of the metal
   b) Avogadro’s number, the density of the metal and the length of the unit cell edge
   c) Avogadro’s number, the density of the metal, the length of the unit cell edge and the type of lattice
   d) Avogadro’s number, the density of the metal, the length of the unit cell edge, the type of lattice and the atomic radius of the metal

9. Uranium crystallizes in a body-centered cubic lattice with a unit cell edge of 3.43 . What is the atomic radius of uranium? (1 $= 10^{-8}$ cm)
   a) 1.21 b) 1.48
   c) 1.72 d) 5.94

10. Silver (Ag) has an atomic radius of 1.44 and crystallizes in a cubic lattice with a unit cell edge of 4.0776 . In which of the following lattices does silver crystallize? (1 $= 10^{-8}$ cm)
   a) Simple cubic b) Body-centered cubic
   c) Face-centered cubic d) None of the above

11. Mn crystallizes in a body-centered cubic lattice with a unit cell edge of 8.894 .
Which of the following metals would have a greater atomic radius than Mn?
   a) A metal that crystallizes in a face-centered unit cell with a unit cell edge of 8.894
   b) A metal that crystallizes in a body-centered unit cell with a cell edge smaller than 8.894 .
   c) A metal that crystallizes in a body-centered unit cell and has a lower atomic mass than Mn but a higher density
   d) A metal that crystallizes in a primitive cubic unit cell with a unit cell edge of 8.894

12. Which of the following is assumed when calculating atomic radii of metals from crystallographic data?
   a) The atoms are soft spheres that are deformed in the structure.
   b) The atoms are almost perfect cubes.
   c) The atoms are of different sizes and the value calculated for the radius is an average.
   d) The atoms in the structure are touching.

13. What is the usual relationship between the number of valence electrons and the number of nearest neighbors of a metal atom in a solid metal?
   a) The number of valence electrons is less than the number of nearest neighbors.
   b) The number of valence electrons is greater than the number of nearest neighbors.
   c) The number of valence electrons is equal to the number of nearest neighbors.
   d) The number of valence electrons can be less than, greater than, or equal to the number of nearest neighbors.

14. All of the following are consequences of the theory of the structure of metals EXCEPT
   a) Metals conduct electricity b) Metals are malleable
   c) Metals are ductile. d) Metals break easily when they are bent.

15. Which of the following is the reason that metals conduct electricity.
    a) The metal atoms are close together.
    b) There are no empty spaces in metal structures.
    c) Electrons in the structure can move freely.
    d) Electrons and protons in the structure can move freely.

16. What fraction of the volume of a metal with a body-centered cubic lattice is occupied by metal atoms?
    a) 0.74 b) 0.68
    c) 0.52 d) 1.00

17. Which of the following is the reason why salts stay bonded in the solid state?
    a) There are strong covalent bonds between the ions.
    b) The structure consists of salt molecules that bind tightly to other salt molecules.
    c) They are held together by electrostatic attractions and the structure includes no electrostatic repulsions.
    d) There are both electrostatic attractions and repulsions within the structure but the total of the attractions is greater.

18. All of the following are possible crystal defects EXCEPT
    a) An atom or ion out of its regular position and occupying a normally empty hole.
    b) A crystal in which the only defect is one pair of ions of the same charge which are missing.
    c) An electron occupying a site that is normally occupied by a —1 anion.
    d) A crystal containing some ion sites empty and some ions not bearing the expected charge.

19. Which of the following is the most important explanation for the conductivity of metals?
    a) They are almost all solids.
    b) Their coordination numbers are high.
    c) Their numbers of valence electrons are high.
    d) Their densities are high.

20. Which of the following pairs is isoelectronic?
    a) AlS and P b) GeAs and Se
    c) GeAs and GaSe d) Al and SiP

21. Which of the following is always the same for allotropes of the same element?
   a) the atomic mass b) the molar mass
   c) the structure d) the chemical and physical properties

22. The semiconductor crystalline Si has a low electrical conductivity in the dark because
   a) crystalline Si is a molecular solid
   b) the band gap energy is much greater than 3RT at 23…C
   c) the chemical bonding in the crystal is strong in all three dimensions
   d) Si has fewer valence electrons than elements that form metallic solids

23. A laser pointer is composed of a doped semiconductor junction (*i.e.*, a region of Al doped semiconductor bonded to a region of P doped semiconductor) with a flowing current due to an applied voltage from a battery. Which of the following statements is TRUE?
   a) The color of the light is determined by the semiconductor band gap.
   b) The device works better warm rather than cold because the number of thermally generated electrons is higher.
   c) Light is emitted at the interface when a hole from the Al region combines with an electron from the P region.
   d) Both (a) and (c).

24. In order to dope crystalline Si with extra electrons, which element should be incorporated into the lattice?
   a) P b) Al
   c) C d) O

25. All of the following statements about the NaCl crystalline lattice are true, EXCEPT

a) Every Cl is surrounded by 4 Na at equal bond lengths, and vice versa.
b) The structure along the x, y, and z axes of the unit cell is all the same.
c) If the length of one side of the unit cell and the atomic weights of Na and Cl are known, then the density can be calculated.
d) The unit cell is cubic even though the Na and Cl ions have different ionic radii.

26. All of the following statements about the different forms of solid C are true, EXCEPT

a) Diamond is transparent and shows no color because its band gap is quite large.
b) Graphite slides easily because the C atoms are strongly bonded in only two dimensions.
c) In diamond the structure around each C atom is due to C sp^3 hybridization.
d) Diamond is hard yet brittle because the band gap is large.

Answer Key

1. a
2. c
3. b
4. d
5. d
6. b
7. b
8. c
9. b
10. c
11. d
12. d
13. a
14. d
15. c
16. b
17. d
18. b
19. b
20. c
21. a
22. b
23. d
24. a
25. a
26. a

Materials

1. Which of the following types of materials generally has the characteristics of: brittleness, hardness, poor conductivity of heat and electricity, resistance to high temperatures?
   a) Ceramics
   b) Metals
   c) Polymers
   d) Composites

2. Which of the following types of materials has bonds that are the most highly directional?
   a) Ionic ceramics
   b) Metals
   c) Polymers
   d) Glasses

3. What is the microscopic explanation for elastic deformation when a material is stressed?
   a) Bonds are compressed and stretched.
   b) Planes of atoms move against each other along slip planes.
   c) Weak intermolecular forces are broken.
   d) Like charges are brought adjacent to each other

4. What is the microscopic explanation for plastic deformation of a metal?
   a) Bonds are compressed and stretched.
   b) Planes of atoms move against each other along slip planes.
   c) Weak intermolecular forces are broken.
   d) Like charges are brought adjacent to each other.

5. What is the microscopic explanation for plastic deformation of a polymer?
   a) Bonds are compressed and stretched.
   b) Planes of atoms move against each other along slip planes.
   c) Weak intermolecular forces are broken.
   d) Like charges are brought adjacent to each other.

6. What is the microscopic explanation for the shattering of an ionic solid when it is stressed?
   a) Bonds are compressed and stretched.
   b) Planes of atoms move against each other along slip planes.
   c) Weak intermolecular forces are broken.
   d) Like charges are brought adjacent to each other.

7. Which of the following describes a polymer that would be very rigid.

a) Long straight chains
b) Short straight chains
c) Branched chains
d) Crosslinked structure

8. Which of the following treatments is the most likely to produce a glass?

a) Removing all impurities from a molten substance and then cooling it.
b) Cooling a molten substance very rapidly
c) Cooling a molten substance very slowly
d) Storing a crystalline substance for a very long time

9. All of the following are true about alloys EXCEPT

a) They are solid solutions.
b) They contain small amounts of compounds.
c) Their composition is easily varied over a large range.
d) Very few metals form alloys.

10. All of the following are true about ceramics EXCEPT

a) They are composed of compounds or ions.
b) They usually contain nitrogen.
c) They are highly resistant to corrosion.
d) They are resistant to reactions with oxidizing acids.

11. The load imposed on a material divided by the original cross sectional area is called the:

a) twist
b) strain
c) stress
d) shear

12. A nylon fishing line with a circular cross section of diameter 0.11mm was tied to a support at one end and a 4.93 kg mass was tied to the other end. What was the stress on the line?

a) 4.93 kg
b) 44.8 kg/mm
c) 89.6 kg/mm
d) 519 kg/mm^2

13. All of the following are true concerning the experimental determination of the modulus of elasticity EXCEPT
    a) The instrument records the force needed to pull the two ends of the sample apart at a constant rate.
    b) The active portion of the sample is called the gauge length.
    c) Rectangular samples are typically used to promote uniform strain.
    d) The modulus is usually calculated from the region where the stress to strain ratio is constant.

14. A material that has the ability to stretch a great deal and then return to its original dimensions is called a(n)
    a) polymer b) elastomer
    c) plastic d) monomer

15. Which one of the following is an example of a thermoset polymer?
    a) formica b) polyethylene
    c) polystyrene d) poly(vinyl)chloride

16. All of the following are Hume-Rothery rules for predicting if two metals will dissolve in each other such that the lesser component is at least 10%, EXCEPT
    a) The atomic radii of the two metals must be within 15% of each other.
    b) The two metals should be from the same group.
    c) The metals should have similar electronegativities.
    d) The two metals should have the same crystal structure.

17. What is the relationship between stress and strain for a material showing perfectly elastic behavior?
    a) They are unrelated
    b) Strain is zero no matter what the stress.
    c) They are directly proportional
    d) They are inversely proportional

18. Calculate the atomic packing factor for the body centered cubic structure.
    a) 0.52 b) 0.68
    c) 0.74 d) 1.0

19. You are about to go on a long boat ride in the ocean. Keeping in mind the rocky beaches and the salt water, what material would you like to have for the bottom of the boat and the motor blade (the piece under the water) made, respectively?

a) wood, ceramic
b) composite, metal
c) glass, metal
d) composite, composite

20. Plastic deformation of a crystal occurs to a greater extent in crystals containing defects because the defect

a) creates a hole for atoms to fall into
b) lowers the slip stress
c) increases the elasticity
d) allows greater interaction between an atom at the defect site with surrounding atoms

21. Which of the following could be a cyclic silicate ion?

a) $Si_5O_{15}^{10-}$
b) $Si_5O_{16}^{12-}$
c) $Si_4O_{13}^{10-}$
d) $Si_6O_{12}^{14-}$

Answer Key

1. a	11. c
2. c	12. d
3. a	13. c
4. b	14. b
5. c	15. a
6. d	16. b
7. d	17. c
8. b	18. b
9. d	19. d
10. b	20. b
	21. a

Properties of Polymers

1. The compound most likely to polymerize and form macromolecules of high molecular mass is:
   a) CH_3CH_3 (ethane)
   b) CH_3CH_2OH (ethanol)
   c) $CH_2{=}CH{-}CH{=}CH_2$ (1,3-butadiene)
   d) C_6H_6 (benzene)

2. The polymer molecule made by co-polymerizing a dicarboxylic acid (which contains 2 -COOH groups) and a diamine (which contains 2 $-NH_2$ groups) would be expected to:
   a) contain amide bonds b) be highly cross-linked
   c) be low molecular weight d) be monomeric

3. What makes polymeric materials unique is their
   a) chain length b) fiber-forming ability
   c) film-forming ability d) all of the above

4. If the average molecular mass of a particular polyethylene oxide $-(OCH_2{-}CH_2)_n-$ is 836,000 amu, the degree of polymerization (n) is
   a) 1 b) 1,000
   c) 19,000 d) 30,000

5. The simplest compound that will polymerize is
   a) ethanol (CH_3CH_2OH)
   b) ethylene glycol ($HOCH_2CH_2OH$)
   c) chloroethane (CH_3CH_2Cl)
   d) ethyl amine ($CH_3CH_2NH_2$)

6. When butadiene ($CH_2{=}CH{-}CH{=}CH_2$) polymerizes to form polybutadiene (synthetic rubber), the polymer molecules have an average of how many double bonds per monomer unit?
   a) one b) two
   c) three d) four

7. The degree of polymerization can be calculated as the total mass of the polymer relative to the mass of a single monomer. In general, this is a measure of the
   a) mass of a hyperbranched polymer
   b) chain length
   c) the weight-average molecular mass
   d) the number average molecular mass

8. The difference between an alternating copolymer and a block copolymer is
   a) An alternating copolymer has long segments of repeating monomer residues while a block copolymer has repeating units (AB) that always repeat in the same periodicity.
   b) An alternating copolymer has repeating units that are randomly distributed along the polymer chain and a block copolymer has long segments of repeating monomer residues.
   c) An alternating copolymer has repeating units (AB) that always repeat with the same (short) periodicity and a block copolymer has long segments of repeating monomer residues.
   d) An alternating copolymer is highly branched and a block copolymer is typically linear.

9. All of the following are polymerization mechanisms EXCEPT
   a) radical b) condensation
   c) chain growth d) substitution

10. Determine the mass-average and number average molecular masses for a mixture of 5 polymers with masses of 20 000, 30 0000, 30 000, 30 000 and 40 000.
   a) M_n = 30 000 amu and M_w = 31 000 amu
   b) M_n = 31 000 amu and M_w = 30 000 amu
   c) M_n = 6 500 amu and M_w = 6 000 amu
   d) M_n = 30 000 amu and M_w = 30 000 amu

11. The mass-average molecular mass for a polymer is larger than the number average molecular mass EXCEPT
   a) when the polymer is branched
   b) when the number of polymer molecules is equal to the mass of a single polymer
   c) when the chain length of every polymer is different
   d) when all of the polymers have the same molecular mass

12. If a polymer distribution is said to be polydisperse it implies that
    a) there is a narrow distribution of molecular masses
    b) all of the polymers contain the same number of monomer units
    c) there is a broad distribution of molecular masses
    d) the number average molecular mass is equal to the mass average molecular mass

13. Thermoset polymers are very rigid while elastomers can be stretched and then returned to their original state. On a molecular level, thermoset polymers are different from elastomers because of the
    a) number of monomer units in the chain
    b) mass of the polymer
    c) level of crosslinking within each polymer
    d) intermolecular interactions between sheets of the polymer

14. In the process of vulcanization, natural rubber is heated with sulfur. This process changes the structure of the polymer by
    a) crosslinking the polymer strands through new carbon-carbon bonds
    b) crosslinking the polymer through disufide bonds
    c) breaking apart crosslinks in the polymer with the evolution of SO_2
    d) heating up the polymer so the strands become disordered

15. A crystalline polymer undergoes a sharp glass transition at 60…C. At what temperature will it melt?
    a) < 59…C   b) 60…C
    c) > 61…C   c) not enough information

16. Molding and extrusion are examples polymer fabrication techniques. All of the following are true EXCEPT

    a) Extrusion is used to make polymer pipes and tubes whereas molding involves the solidification of a polymer within a container.
    b) Compression molding involves putting a thermoset polymer in a mold and placing it under heat and pressure causing it to flow and fill the mold.
    c) Expansion molding involves the use of steam to expand polymer beads and then fuse them together into the shape of the mold.
    d) Thermoset plastics that have been subjected to compression molding have undergone an irreversible process

17. The recycling of plastics is important because it cuts down on solid waste. Approximately half of the mass of all plastics to be recycled is PET (polyethylene terphthalate). However, a single PVC (polyvinyl chloride) bottle in 20 000 PET bottles is enough contamination to prevent successful recycling. The molecular mass of the PET monomer is 236 g/mol. If 1×10^4 monomers are used in both types of bottles, what concentration (in ppm) of contamination is required to complicate the recycling process?

    a) 13 ppm   b) 130 ppm
    c) 1.3×10^{-5} ppm   c) 1.3×10^5 ppm

18. A polymerization was done in a laboratory. The monomer unit had a molecular mass of 168 g/mol. Two separate reaction conditions were employed where under the first type of conditions 100% of the polymerization proceeded by condensation and under the second type of conditions all of the polymerization occurred by addition reactions. The molecular mass of the polymer after 1 000 reactions by condensation was ____ g/mol and by addition was ___ g/mol, respectively

    a) 168,000; 150,000   b) 150,000; 168,000
    c) 318,000; 300,000   d) 318,000; 300,000

19. In a step-growth polymerization, a small percentage of monofunctional molecules was added among the difunctional molecules used to prepare a homopolymer. The effect on the polymerization be

a) increased chain branching b) a long block copolymer
c) increased termination d) increased chain propagation

20. What is the degree of polymerization for a polyethylene oxide polymer having an average molecular mass of 8.8×10^5. The monomer unit has a molecular mass of 44 amu.

a) 20,000 b) 80,000
c) 44 d) 3.9×10^7

Answer Key

1. c	11. d
2. a	12. c
3. d	13. c
4. c	14. b
5. c	15. c
6. a	16. d
7. b	17. a
8. c	18. b
9. d	19. c
10. a	20. a

Transition Metals

1. Which of the following transition metal elements has only a single 4s electron?
   a) Ti b) V
   c) Cr d) Mn

2. Which of the following accounts for the irregularities in the electron configurations of the 3d elements, Sc to Zn?
   a) The tendency to half-filled or fully-filled d subshells
   b) The tendency to half-filled or fully-filled s subshells
   c) The tendency to having an odd number of d electrons
   d) The ionic radii of the ions

3. What is the formula for sodium diaquatetrachloroaluminate(III)?
   a) $Na_3[Al(H_2O)_2Cl_4]$ b) $Na_3[Al(OH)_2Cl_4]$
   c) $Na_2[Al(H_2O)(ClO_4)_5]$ d) $Na[Al(H_2O)_2Cl_4]$

4. Which of the following can have no octahedral complexes that are paramagnetic?
   a) Fe^{3+} b) Ni^{2+}
   c) Cu^{2+} d) Cu^{+}

5. Which of the following numbers of unpaired electrons is possible for an octahedral complex of Cr^{2+}?
   a) 3 b) 4
   c) 5 d) 6

6. Which of the following will tend to cause high spin octahedral complexes?
   a) Low ionic charge
   b) High spin pairing energy
   c) High energy of octahedral splitting, Δ_o
   c) Low position in spectrochemical series

7. If ligand **A** gives a complex ion that is red in water solution, and ligand **B** gives a blue solution with the same metal in the same oxidation state. What can you say about the relative positions of these two ligands on the spectrochemical series? (The larger the octahedral splitting caused by a ligand, the higher its position on the spectrochemical series.)
   a) **A** is higher on the series than **B**
   b) **B** is higher on the series than **A**
   c) Both ligands occupy the same position on the series
   d) More information is needed to answer this question.

8. Ethylene diamine ($H_2NCH_2CH_2NH_2$) forms more stable complexes than NH_3 for which of the following reasons?
   a) Ethylene diamine has carbon ions available to complex metals
   b) Ethylene diamine has the higher boiling point.
   c) The reaction of ethylene diamine with an aquated metal does not change the total number of ions and molecules.
   d) In the reaction of ethylene diamine with an aquated metal the total of ions and molecules is greater for the products than the reactants.

9. The addition of a large excess of aqueous ammonia to an aqueous solution of silver nitrate, results predominantly in the silver-containing species:
   a) $Ag^+(aq)$ b) $AgNO_3$
   c) $[Ag(NH_3)_2]^+$ d) $[Ag(NH_4)_2]^+$

10. A compound has the empirical formula $CoCl_3$Æ$4NH_3$. One mole of the compound yields one mole of silver chloride when treated with silver nitrate. Ammonia is not removed by treatment of the compound with concentrated sulfuric acid. The formula for the compound is best represented by
   a) $Co(NH_3)_4Cl_3$ b) $[Co(NH_3)_4Cl]Cl_2$
   c) $[Co(NH_3)_3Cl_3]NH_3$ d) $[Co(NH_3)_4Cl_2]Cl$

11. The absorption spectrum of a coordination compound has a maximum absorbance at ~680 nm. The color of this coordination compound would appear to be closest to
   a) violet b) green
   c) yellow d) orange

12. The number of *cis—trans* isomers possible for $[Pt(NH_3)_2ClBr]$ is:

a) 1 b) 2
c) 3 d) 4

13. Which of the following complex ions is capable of *cis—trans* isomerization?

a) square planar $[PtBrCl_3]^{2-}$ b) octahedral $[Fe(CN)_6]^{3-}$
c) tetrahedral $[ZnBrCl_3]^{2-}$ d) octahedral $[CrBr_2(NH_3)_4]^{+}$

14. One of the original octahedral complexes investigated by Alfred Werner, the founder of the field of coordination chemistry (for which he was given the Nobel Prize for Chemistry in 1913) was $[Pt(NH_3)_5Cl]Cl_3$. The oxidation state (or "primary valency" as Werner called it) for platinum in this coordination complex is

a) +3 b) +4
c) +5 d) +6

15. All of the following are true EXCEPT

a) The value of Δ decreases on going from the second to the third transition series.
b) Higher oxidation states result in higher value of Δ.
c) Almost all complexes of second and third transition series elements are low spin.
d) The larger d orbitals of the second and third transition series elements more effectively overlap orbitals of ligands.

16. Chelating ligands

a) are usually monodentate
b) form more stable complexes than non-chelating ligands
c) only form one bond with the metal atom
d) are nonflexible

17. All of the following are true about ethylenediaminetetraacetic acid EXCEPT

a) It is also known as EDTA.
b) It is a hexadentate ligand.
c) It is used in treatment of heavy metal poisoning.
d) It forms tetrahedral complexes with most metal ions.

18. Rank the following in order of increasing strength:

(1) ferromagnetism; (2) diamagnetism; (3) paramagnetism

a) 1< 2< 3 b) 3< 2< 1
c) 2<1<3 d) 2<3<1

19. A student prepared a $Ti(H_2O)_6^{3+}$ complex and found it to absorb light at 550 nm. The color of light absorbed is ____ and the color observed by the student is ____

a) green, purple b) red, blue
c) yellow, violet d) yellow, green

20. The Gouy balance measures magnetic susceptibility. The observed increase in the mass in the presence of a magnet is caused by

a) the attraction of the sample to a magnet caused by paramagnetism
b) the attraction of the sample to a magnet caused by diamagnetism
c) the repulsion of the sample to the magnet caused paramagnetism
d) none of the above

21. Crystal field theory assumes all of the following EXCEPT

a) All bonding is assumed to be the result of electrostatic attractions.
b) All ligands are assumed to have a negative charge or dipole.
c) All bonding to metals occurs in octahedral or trigonal fields.
d) All charges are assumed to be located at points.

Answer Key

1. c
2. a
3. d
4. d
5. b
6. b
7. b
8. d
9. d
10. d
11. b
12. b
13. d
14. b
15. a
16. b
17. d
18. d
19. a
20. a
21. c

Metallurgy

1. For which of the following reactions would you expect the standard free energy to have the greatest response to temperature.
   a) Carbon reacting with Fe_2O_3 to produce iron and carbon dioxide.
   b) Carbon reacting with Fe_2O_3 to produce iron and carbon monoxide.
   c) Hydrogen reacting with Fe_2O_3 to produce iron and water vapor.
   d) Sodium metal reacting with potassium chloride to produce potassium metal and sodium chloride. (all reactants and products are in the gaseous state.)

2. Lithophiles are _____ and atmophiles are____, respectively
   a) Elements that appear as oxides and halides in the Earth s crust; elements found as sulfides in the crust
   b) Elements that appear as oxides and halides in the Earth s crust; elements found as volatile gases in the atmosphere or ocean
   c) Elements found as metallic alloys in the Earth s crust; elements that appear as oxides and halides in the Earth s crust
   d) Elements found as volatile gases in the atmosphere or ocean; elements found as metallic alloys in the Earth s crust

3. The separation of elements from their ores is a complicated process. Of selective settling, flotation, and oxidation followed by roasting, which would you choose to separate mineral waste from the desired oily, particulate matter?
   a) flotation
   b) selective settling
   c) oxidation followed by roasting
   d) not enough information to decide

4. Which of the following components can be separated from silicon dioxide (SiO_2) because of its magnetic properties?
   a) Fe_3O_4 b) Benzene (C_6H_6)
   c) Natural rubber (polyisoprene) d) ZnO

5. A plot of ΔG… vs. temperature for many metals yields a straight line with an upwards slope. At 1000 K, Ag has ΔG… = +50 kJ/mol and Ti has ΔG… = —550 kJ/mol. If a metal of one is heated with the oxide of the other, in which combination will a reaction that releases O_2 occur?
   a) Ag, TiO_2,
   b) Ti, AgO
   c) Ag, TiO_2
   d) not enough information to decide

6. An overvoltage is the voltage required beyond the calculated voltage to create spontaneous conditions. It results from
   a) the adsorption of metal oxides to electrodes
   b) a nonconductive material, iron ore, dissolved in solution
   c) the change in concentration that develops as the reaction proceeds in the region of the electrodes
   d) the change in potential because of very large, negative values of ΔG

7. Napoleon used gold and silver tableware for guests and reserved aluminum tableware for special guests. At that time, why was aluminum so valued?
   a) Aluminum metal is unreactive and is difficult to purify.
   b) Aluminum is easily reduced.
   c) Aluminum is rarely found in the Earth s crust.
   d) Aluminum is highly reactive and is difficult to purify.

8. Gold resists oxidation and does not tarnish. Gold can be separated from gold ore concentrate through several means. All of the following are methods of separation EXCEPT
   a) Gold amalgam sticks to the surface of a drum coated with mercury which can then be easily isolated by distillation.
   b) Gold amalgam consists of Au, Al and Si, and the gold can be easily separated from the other metals through reduction of Al and Si.
   c) An amalgam of gold is highly reactive with oxygen resulting in pure gold.
   d) Extraction of low-grade ores occurs through complexation of gold with cyanide ions and subsequent reduction by Zn.

9. Iron ore contains SiO_2 impurities. In order to separate Fe from Si, all of the following reactions occur in the separation process EXCEPT
   a) $3Fe_2O_3(s) + CO(g) \rightarrow 2Fe_3O_4(s) + CO_2(g)$
   b) $Fe_3O_4(s) + CO(g) \rightarrow 3FeO(s) + CO_2(g)$
   c) $FeCO_3(s) + H_2O(g) \rightarrow FeO(s) + H_2CO_3(s)$
   d) $FeO(s) + CO(g) \rightarrow Fe(l) + CO_2(g)$

10. Limestone ($CaCO_3$) can be decomposed in a furnace to yield CaO(s) and CO_2(g). If the furnace used a water filter as a purification method to trap emitted gases, what would happen to the pH of the water over time?
   a) increase b) decrease
   c) remain constant d) more information is required

11. Copper can be separated from several impurities by flotation. What is the function of a collector in flotation process?
   a) The collector binds to polar particles to aid in the separation.
   b) The collector binds to nonpolar particles to aid in the separation.
   c) The collector is a physical device that separates the copper by magnetic effects.
   d) The collector separates the impurities from the copper by size and density.

12. Final separation of copper is accomplished by electric refining. If Cu is contaminated with Ag, Zn and Ni and electrolysis is carried out, in what order (first to last) will the metals precipitate out of solution leaving only Cu?
   $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ $E^o = -0.337$ V
   $Ag(s) \rightarrow Ag^+(aq) + e^-$ $E^o = -0.799$ V
   $Zn(s) \rightarrow Zn^+(aq) + 2e^-$ $E^o = +0.763$ V
   $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$ $E^o = +0.250$ V
   a) Ag > Zn > Ni
   b) Zn > Ni > Ag
   c) Ni > Ag > Zn
   d) All of the metals cannot be separated in this manner.

13. Why is the purification of Ti expensive?
    a) TiO_2 is difficult to mine
    b) The use of Mg or Na are required as reducing agents
    c) Very high temperatures (>3000K) must be used
    d) Chemical oxidation of the TiO_2 does not have high yields

14. All of the properties listed below make tungsten ideal for use in electric light filaments, electrical contacts, and arcing point EXCEPT
    a) extremely high melting point
    b) extremely high boiling point
    c) very high density
    d) very easily oxidized

15. Steel is an exceptionally versatile alloy. All of the following list a type of steel and a main component (other than iron) of steel EXCEPT
    a) Corrosion-resistant steel: Cr
    b) Magnetic steel: Co
    c) Magnetic steel: Zn
    d) Corrosion-resistant steel: Ni

16. The degree of spontaneity of the reaction of one metal with the oxide of another is largely independent of temperature because
    a) $\Delta H = \Delta G$
    b) ΔH is negative because of the formation of the strong metal-oxygen interaction
    c) ΔS… of the process is similar for most metals
    d) ΔG has a large, positive value at all of the temperatures

17. Which one of the following compounds can be used as a collector?
    a) NiCl
    b) benzene
    c) dodecylammonium chloride (a soap)
    d) ZnO

18. What mass of Cu metal will be deposited in the electrolytic refining of metal using a current of 1.5 A for 10 hours? Consider the process to be a 2 electron reduction, the molecular mass of Cu to be 63.55 g/mol, and F = 96500 C/mol.

a) 0.28 g   b) 4.4×10^{-3} g
c) 4.4×10^{5} g   d) 1.9×10^{3} g

19. What is the ΔG… for the decomposition of 5 moles of ZnO(s) to elements based on the reaction and information below?

$ZnO(s) \rightarrow Zn(s) + \_O_2(g)$

ΔH…$_f$(ZnO) = —350 kJ/mol   S…(Zn) = 41. J/K·mol
S…(O_2) = 205 J/K·mol   S…(ZnO) = 44 J/K·mol

a) 1.6×10^{3} kJ   b) 3.2×10^{3} kJ
c) 350 kJ   d) 1.6×10^{-3} kJ

20. Chalcophiles are:

a) elements found as sulfides in the Earth's crust
b) elements found as oxides in the Earth's crust
c) volatile gases found in the atmosphere
d) metallic alloys found in the ocean

Answer Key

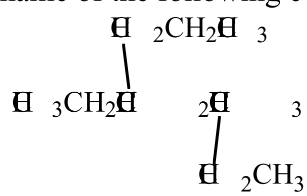
1. b	11. a
2. b	12. d
3. a	13. b
4. a	14. d
5. c	15. c
6. c	16. b
7. d	17. c
8. b	18. b
9. c	19. a
10. b	20. a

Organic Chemistry

1. How many isomers are there of the chlorinated alkane with the formula $C_3H_6Cl_2$?

    a) 2 b) 3
    c) 4 d) 5

2. What is the correct name of the following compound?



    a) 2-ethyl, 4-propyl hexane b) 3-methyl, 5-ethyl octane
    c) 2, 4-diethyl heptane d) 3-methyl, 5-propyl heptane

3. Which of the following react most readily with Br_2?

    a) Straight chain alkanes b) Branched alkanes
    c) Alkenes d) Aromatic compounds

4. Which of the following will be the products in the reaction of benzene (C_6H_6) and Br_2 in the presence of a catalyst?

    a) C_6H_5Br only b) C_5H_6Br and HBr
    c) C_5H_6Br only d) C_6H_5Br and HBr

5. Oxidation of which of the following compounds can lead to an aldehyde?

    a) A primary alcohol b) A secondary alcohol
    c) A tertiary alcohol d) An ether

6. Oxidation of which of the following compounds can lead to ketone?

    a) A primary alcohol b) A secondary alcohol
    c) A tertiary alcohol d) An ether

7. Hydrolysis of an ester leads to two compounds. Which of the following pairs compounds is formed from such a hydrolysis?

    a) An alcohol and an aldehyde
    b) Two alcohols
    c) An alcohol and a carboxylic acid
    d) A ketone and a carboxylic acid

8. Which of the following compounds would you expect to be the most soluble in water?

a) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
b) $CH_3CH_2CH_2OH$
c) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$
d) $CH_3CH_2CH_2$-O-$CH_2CH_2CH_3$

9. Which of the following is the best definition of the chemical nature of soap?

a) A soap is a very long molecule.
b) A soap is a long chain carboxylic acid.
c) A soap is an ester of glycerol and a long chain carboxylic acid.
d) A soap is a salt of a long chain carboxylic acid.

10. The molecule among those in the following list that can be classified as an amide is

a) CH_3NH_2 b) CH_3CONH_2
c) CH_3CHO d) CH_3COOH

11. How many isomers are there for trichlorobenzene?

a) 1 b) 2
c) 3 d) 4

12. Which of the following would react most vigorously with bromine water?

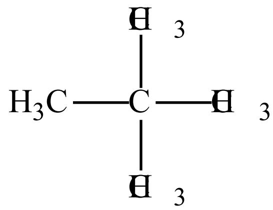
a) cyclohexane b) n-pentane
c) benzene d) ethylene

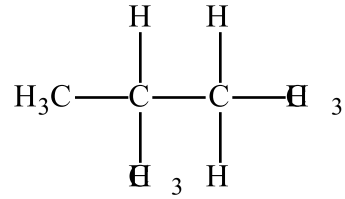
13. To form an amide, you would be best advised to react which of the following?
(1) CH_3COOH, (2) CH_3OH, (3) CH_3CHO, (4) CH_3CONH_2, (5) CH_3NH_2

a) 1 with 2 b) 1 with 3
c) 1 with 4 d) 1 with 5

14. The true isomers among the following hydrocarbons are:

1) $CH_3CH_2CH_2CH_2CH_3$

2) 

3) 

4) $CH_3CH_2CH_2CH_3$

5) $CH_3CH_2CH_2CH{=}CH_2$

a) 1, 4 and 5
b) 2 and 3
c) 1 and 5
d) 1, 2 and 3

15. The smallest cycloalkane is

a) cyclomethane
b) cycloethane
c) cyclopropane
d) cyclobutane

16. The reaction of methane with chlorine to form methyl chloride follows a free radical chain reaction mechanism. The first step in this reaction mechanism is

a) abstraction of a hydrogen from a methane molecule by a chlorine molecule
b) homolytic splitting of the chlorine molecule into chlorine atoms
c) photochemical splitting of one of the C-H bonds in methane
d) reaction of a hydrogen from methane with a chlorine molecule to form HCl which then catalyzes the reaction

17. All of the following are true about alkynes EXCEPT

a) They contain one or more carbon-carbon triple bonds.
b) They have the general formula C_nH_{2n}.
c) They contain at least two sp hybridized carbons.
d) The simplest one, acetylene, can be made by the reaction of water and calcium carbide.

18. When benzene reacts with chlorine, a(n) ____ reaction occurs whereas when cyclohexene reacts with chlorine a(n) ____ reaction occurs.

a) oxidation, reduction
b) addition, oxidation
c) substitution, oxidation
d) substitution, addition

19. When compound X was added to a dilute solution of potassium permanganate at room temperature, the solution immediately turned from purple to a murky brown color. Which one of the following compounds could compound X be?

a) methane	b) ethylene
c) propane	d) 5-chlorodecane

20. When a straight chain alkene undergoes sulfuric acid catalyzed hydration, the primary product is a

a) primary alcohol	b) secondary alcohol
c) tertiary alcohol	d) quaternary alcohol

Answer Key

1. c
2. b
3. c
4. d
5. a
6. b
7. c
8. b
9. d
10. b
11. c
12. d
13. d
14. d
15. c
16. b
17. b
18. d
19. b
20. b

Nuclear Chemistry

1. In an experiment using a cathode ray tube and a magnetic field to deflect the electron beam, the following equation can be derived to determine the ratio of charge to mass for the electron, e/m = v/BÆr. Which of the following parameters in this equation cannot be measured without performing another experiment?
   a) v, the speed of the electrons
   b) B, the magnetic field strength
   c) r, the radius of curvature of the path of the deflected beam
   d) All of the parameters, v, B and r, can be measured in this experiment

2. Consider Millikan's oil drop experiment, which was performed to determine the charge on the electron. Which of the following statements is not true?
   a) The oil drops were ionized (charged) by an x-ray beam.
   b) The mass of an oil drop was determined by its rate of fall with the electric field turned off.
   c) The electric field was balanced so that the drop neither rose nor fell.
   d) The charge on the oil drop was assumed to be the same as the charge on an electron.

3. Which of the following is true regarding the reason that isotopes such as ^{16}O and ^{17}O are considered to be the same element?
   a) They have the same number of protons and protons determine the chemistry of an atom.
   b) They have the same number of neutrons and neutrons determine the chemistry of an atom.
   c) They have the same number of electrons and electrons determine the chemistry of an atom.
   d) The give off the same emissions when they undergo nuclear decay

4. The stable isotope of arsenic is ^{75}As. What would be the expected products of the disintegration of the unstable isotope, ^{70}As?
   a) β^{-} and ^{70}Ge b) β^{-} and ^{70}Se
   c) β^{+} and ^{70}Ge d) $^{4}_{2}He$ and ^{66}Ga

5. All of the following are true about stable nuclides EXCEPT
   a) The number of neutrons is always equal to the number of protons.
   b) In general, the greater the number of protons, the greater the number of neutrons.
   c) At high numbers of neutrons, the number of neutrons is greater than the number of protons.
   d) At low numbers of neutrons, the number of neutrons is approximately equal to the number of protons.

6. Calculate the total binding energy of one ^4He nucleus. The masses of the electron, proton, and neutron are 0.000549 amu, 1.007276 amu, and 1.008665 amu, respectively. The atomic mass of ^4He is 4.002059 amu. The speed of light is 2.9979×10^{10} cm/sec. 1 erg = 1 gÆcm^2/sec^2.
   a) 2.7×10^{-19} erg b) 4.6×10^{-5} erg
   c) 4.6×10^{5} erg d) 2.7×10^{19} erg

7. Except for the H atom, the mass of the nucleus of an atom:
   a) Is always less than the total mass of the protons and neutrons that compose it
   b) Is always the same as the total mass of the protons and neutrons that compose it
   c) Is always greater than the total mass of the protons and neutrons that compose it
   d) May be less than, the same as, or greater than the total mass of the protons and neutrons that compose it.

8. What is the binding energy per nucleon for ^{17}O? The masses of the electron, proton, and neutron are 0.000549 amu 1.007276 amu and 1.008665 amu, respectively. The atomic mass of ^{17}O is 16.99903 amu. The speed of light is 2.9979×10^{10} cm/sec. 1 erg = 1 gÆcm^2/sec^2.
   a) 1.24×10^{-5} erg/nucleon b) 1.32×10^{-5} erg/nucleon
   c) 2.11×10^{-4} erg/nucleon d) 7.48×10^{18} erg/nucleon

9. If the binding energy per nucleon is plotted as a function of atomic mass, the curve that results will have which of the following shapes?
   a) A straight line with a positive slope.
   b) A straight line with a negative slope
   c) A curved line that starts low, reaches a maximum, and then goes to increasingly lower values
   d) A curved line that starts high, reaches a minimum, and then goes to increasingly higher values

10. A plot of binding energy per nucleon as a function of atomic mass does NOT explain which of the following?
   a) Light atoms tend to undergo fusion.
   b) Heavy atoms tend to undergo fission.
   c) Most elements have several isotopes.
   d) Iron has a very high abundance

11. Which of the following correctly fills the blank in this nuclear reaction?
   ${}^{9}_{4}Be + {}^{1}_{1}H \rightarrow$ ____ $+ {}^{2}_{1}H$
   a) ${}^{8}Li$ b) ${}^{8}Be$
   c) ${}^{9}B$ d) ${}^{10}B$

12. Which of the following correctly fills the blank in this nuclear reaction?
   ${}^{19}_{9}F + {}^{4}_{2}\alpha \rightarrow$ ____ $+ {}^{1}_{1}H$
   a) ${}^{24}Mg$ b) ${}^{23}Na$
   c) ${}^{22}F$ d) ${}^{22}Ne$

13. Accelerators are necessary for most synthetic nuclear reactions because
   a) The reacting particles attract each other
   b) The reacting particles repel each other
   c) The reacting particles are unstable
   d) The product particles are unstable

14. What is the additional product in a fission reaction in which one neutron strikes a ${}^{235}U$ nucleus giving off three neutrons and ${}^{90}Br$?
   a) ${}^{143}Cs$ b) ${}^{143}La$
   c) ${}^{145}La$ d) ${}^{145}Pr$

15. What are the additional products in a fission reaction in which one neutron strikes a ^{235}U nucleus giving off ^{143}La and ^{90}Br?

a) no additional products b) two protons
c) two neutrons d) three neutrons

16. Which of the following describes typical products of a neutron induced reaction in a fission chain?

a) Two nuclei with quite different atomic numbers only
b) Two nuclei with quite different atomic numbers plus one or more neutrons
c) Two nuclei of approximately the same atomic number only
d) Two nuclei of approximately the same atomic number plus one or more neutrons

17. Which answer completes the following reaction?

$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H +$ _______

a) $^{4}_{2}He$ b) β^{-}
c) β^{+} d) $^{1}_{0}n$

18. Which of the following is a prediction of the theories of the "big bang" and stellar nucleogenesis?

a) The principal elements of the universe are hydrogen and helium.
b) The elements with even atomic numbers are generally rare.
c) $^{7}_{3}Li$ is the third most common element.
d) Elements with atomic numbers below that of nickel are rare.

19. When a nuclide undergoes beta-decay

a) the mass number remains unchanged and the atomic number increases by one
b) the atomic number remains unchanged and the mass number increases by one
c) the mass number remains unchanged and the atomic number decreases by one
d) the atomic number remains unchanged and the mass number decreases by one

20. An atom which undergoes a nuclear reaction resulting in an increase in atomic number has emitted

    a) an alpha particle   b) a beta particle
    c) a neutron   d) a positron

21. If an unstable nucleus decays by successive alpha, beta, beta emissions, the overall change in the atomic number and the mass number are respectively

    a) —4 and 0   b) +2 and —2
    c) 0 and —4   d) —2 and —4

22. To answer the following question, you will need to recall for the ^{14}C isotope found in living matter t_ = 5720 years and the decay rate is 15 decays/g¥min. If 2.0 grams of charcoal scrapings from the wall of a prehistoric cave dwelling are decaying at a rate of 2.0 disintegrations/minute then the writings must be

    a)1500 years old   b) 5720 years old
    c)11,000 years old   d) 22,000 years old

23. Given the mass defect for the triton (tritium nucleus) to be 0.00910 amu, calculate the binding energy per nucleon: 1 amu = 931.4 MeV.

    a) 2.119 MeV   b) 2.825 MeV
    c) 4.238 MeV   d) 8.476 MeV

24. It is well-known that alpha-particles are

    a) electrically neutral.   b) made up of four protons.
    c) negatively charged.   d) heavier than beta-particles.

Answer Key

1. a
2. d
3. c
4. c
5. a
6. b
7. a
8. a
9. c
10. c
11. b
12. d
13. b
14. b
15. d
16. b
17. c
18. a
19. c
20. b
21. c
22. d
23. b
24. d