Small-Scale LAB

Paper Chromatography of Food Dyes

Purpose

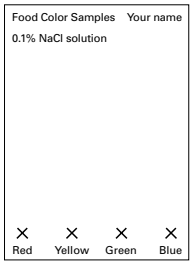
To use paper chromatography to separate and identify food dyes in various samples.

Materials

- pencil
- paper
- ruler
- scissors
- toothpicks
- 4 different colors of food coloring
- plastic cup
- 0.1% NaCl solution
- chromatography paper

Procedure

Cut a 5 cm × 10 cm strip of chromatography paper and label it with a pencil, as shown below. Use a different toothpick to place a spot of each of the four food colors on the Xs on your chromatography paper. Allow the spots to dry for a few minutes. Fill the plastic cup so its bottom is just covered with the solvent (0.1% NaCl solution). Wrap the chromatography paper around a pencil. Remove the pencil and place the chromatography paper, color-spot side down, in the solvent. When the solvent reaches the top of the chromatography paper, remove the paper and allow it to dry.



Analysis

Using your experimental data, record the answers to the following questions below your data table.

1. If a food color sample yields a single streak or spot, it is usually a pure compound. Which food colors consist of pure compounds?
2. Which food colors are mixtures of compounds?
3. Food colors often consist of a mixture of three colored dyes: Red No. 40, Yellow No. 5, and Blue No. 1. Read the label on the food color package. Which dyes do your food color samples contain?
4. Identify each spot or streak on your chromatogram as Red No. 40, Yellow No. 5, or Blue No. 1.
5. Paper chromatography separates polar covalent compounds on the basis of their relative polarities. The most polar dyes migrate the fastest and appear at the top of the paper. Which dye is the most polar? The least polar?

You're The Chemist

The following small-scale activities allow you to develop your own procedures and analyze the results.

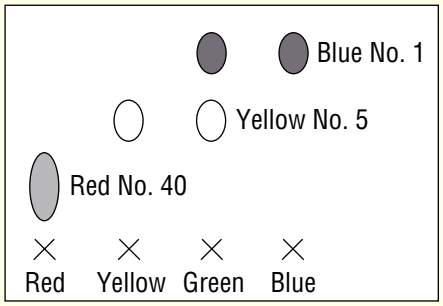
1. **Design It!** Design and carry out an experiment to identify the dyes in various colored candies.
2. **Design It!** Design and carry out an experiment to identify the dyes in various colored markers using the paper chromatography method.
3. **Design It!** Design and carry out an experiment to identify the dyes in various colored powdered drinks using the paper chromatography method.
4. **Analyze It!** Use different solvents, such as 2-propanol (rubbing alcohol), vinegar, and ammonia, to separate food colors. Does the choice of solvent affect the results?
5. **Analyze It!** Explore the effect of different papers on your results. Try paper towels, notebook paper, and coffee filters. Report your results. Examine the relative positions of Blue No. 1 and Yellow No. 5. What do you observe?

For Enrichment L3

Students could investigate how different carrier fluids affect the movement of the four dyes. For example, they might try pure water or ethanol.

Analyze

1. Red, yellow, and blue are pure.
2. Green is Yellow No. 5 plus Blue No. 1.
3. Blue No. 1; Red No. 40 (No. 3 if supplies haven't been used up); Yellow No. 5 or Yellow No. 6 if the dye appears orange.
4. See the drawing.



5. Blue is the most polar; red, the least polar.

Small-Scale LAB

Paper Chromatography of Food Dyes L2

Objective

After completing this activity, students will be able to infer differences in polarity by observing the chromatographic separation of food dyes.

Prep Time 15 minutes

Advance Prep

- To prepare 0.1% NaCl, dissolve 1.0 g NaCl in 1.0 L water.
- Jelly beans and small candy-coated chocolates are good sources of food dyes. Dissolve a package of unsweetened powdered soft drink in a small amount of water and have students use toothpicks to spot this solution on chromatography paper.
- Coffee filters can substitute for chromatography paper, but caution students not to overload their samples.

Class Time 30 minutes

Teaching Tips Tell students to position the chromatography paper so that the lower end of the paper is in the liquid but the spots of dye are above the surface. A similar, more complete lab on chromatography is found in the Small-Scale Laboratory Manual.

Expected Outcome In order of increasing speed of travel: red, yellow, blue. Green separated into yellow and blue.

You're the Chemist

1. Wet candy, blot to remove excess water, press onto chromatography paper, and develop in 0.1% NaCl.
2. Place spots on chromatography paper. Develop in NaCl solution.
3. Use a toothpick to place spots of powdered drink solutions.
4. Rubbing alcohol moves more slowly and gives slightly better separation.
5. With some papers, the positions of Blue No. 1 and Yellow No. 5 are reversed.

CHAPTER 8

Study Guide

Study Tip

Switch Tasks When you feel yourself losing focus, switch the type of task you are working on, the subject that you are studying, or the environment you are in. Take a break and walk around a bit. Stop studying when you are no longer being productive.

Interactive Textbook

If your class subscribes to the Interactive Textbook with ChemASAP, your students can go online to access an interactive version of the Student Edition and a self-test.

with ChemASAP

CHAPTER 8

Study Guide

Key Concepts

8.1 Molecular Compounds

- Molecular compounds tend to have relatively low melting and boiling points.
- A molecular formula shows how many atoms of each element a molecule contains.

8.2 The Nature of Covalent Bonding

- Electron sharing occurs so that atoms attain the configurations of noble gases.
- An electron dot structure shows the shared electrons of a covalent bond by a pair of dots.
- Atoms form double or triple bonds by sharing two or three pairs of electrons.
- In a coordinate covalent bond, the shared electron pair comes from a single atom.
- A large bond dissociation energy corresponds to a strong covalent bond.
- In ozone, the bonding of oxygen atoms is a hybrid of the extremes represented by the resonance forms.
- The octet rule is not satisfied in molecules with an odd number of electrons, and in molecules where an atom has less, or more, than a complete octet of valence electrons.

8.3 Bonding Theories

- Just as an atomic orbital belongs to a particular atom, a molecular orbital belongs to a molecule as a whole.
- According to VSEPR theory, the repulsion between electron pairs causes molecular shapes to adjust so that the valence-electron pairs stay as far apart as possible.
- Orbital hybridization provides information about both molecular bonding and molecular shape.

8.4 Polar Bonds and Molecules

- When different atoms bond, the more electronegative atom attracts electrons more strongly and acquires a slight negative charge.
- Polar molecules between oppositely charged metal plates tend to become oriented with respect to the positive and negative plates.
- Intermolecular attractions are weaker than either an ionic or covalent bond.
- Melting a network solid requires breaking covalent bonds throughout the solid.

Vocabulary

- bond dissociation energy (p. 226)
- bonding orbital (p. 230)
- covalent bond (p. 213)
- coordinate covalent bond (p. 223)
- diatomic molecule (p. 214)
- dipole (p. 239)
- dipole interactions (p. 240)
- dispersion forces (p. 240)
- double covalent bond (p. 221)
- hybridization (p. 234)
- hydrogen bonds (p. 241)
- molecular compound (p. 214)
- molecular formula (p. 215)
- molecular orbital (p. 230)
- molecule (p. 214)
- network solids (p. 243)
- nonpolar covalent bond (p. 237)
- pi bond (p. 231)
- polar bond (p. 238)
- polar covalent bond (p. 238)
- polar molecule (p. 239)
- polyatomic ion (p. 223)
- resonance structure (p. 227)
- sigma bond (p. 230)
- single covalent bond (p. 217)
- structural formula (p. 218)
- tetrahedral angle (p. 232)
- triple covalent bond (p. 221)
- unshared pair (p. 218)
- van der Waals forces (p. 240)
- VSEPR theory (p. 232)

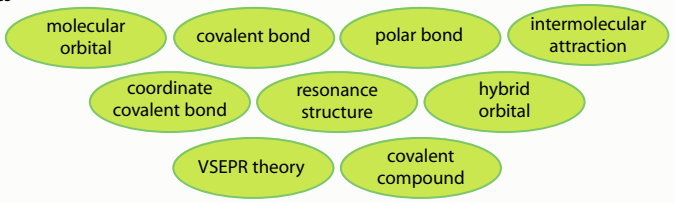
Organizing Information

Construct a concept map that organizes the major ideas of this chapter.

Interactive Textbook

Concept Map 8 Solve the Concept Map with the help of an interactive guided tutorial.

with ChemASAP



Chapter Resources

Print

- **Core Teaching Resources,** Chapter 8, Practice Problems, Vocabulary Review, Quiz, Chapter Test A, Chapter Test B

Technology

- **Computer Test Bank,** Chapter 8 Test
- **Interactive Textbook with ChemASAP,** Chapter 8

CHAPTER 8

Assessment

Reviewing Content

8.1 Molecular Compounds

39. The melting point of a compound is 1240°C. Is this compound most likely an ionic or a molecular compound?

40. Identify the number and kinds of atoms present in a molecule of each compound.
a. ascorbic acid (vitamin C), $C_6H_8O_6$
b. sucrose (table sugar), $C_{12}H_{22}O_{11}$
c. trinitrotoluene (TNT), $C_7H_5N_3O_6$

41. Which of the following gases in Earth's atmosphere would you expect to find as molecules and which as individual atoms? Explain.
a. nitrogen **b.** oxygen **c.** argon

8.2 The Nature of Covalent Bonding

42. Explain why neon is monatomic but chlorine is diatomic.

43. Classify the following compounds as ionic or covalent.
a. $MgCl_2$ **b.** Na_2S **c.** H_2O **d.** H_2S

44. Describe the difference between an ionic and a covalent bond.

45. How many electrons do two atoms in a double covalent bond share? How many in a triple covalent bond?

46. Draw plausible electron dot structures for the following substances. Each substance contains only single covalent bonds.
a. I_2 **b.** OF_2 **c.** H_2S **d.** NI_3

47. Characterize a coordinate covalent bond and give an example.

48. Explain why compounds containing C—N and C—O single bonds can form coordinate covalent bonds with H^+ but compounds containing only C—H and C—C single bonds cannot.

49. Using electron dot structures, draw at least two resonance structures for the nitrite ion (NO_2^-). The oxygens in NO_2^- are attached to the nitrogen.

50. Which of these compounds contain elements that do not follow the octet rule? Explain.
a. NF_3 **b.** PCl_2F_3 **c.** SF_4 **d.** SCl_2

51. Explain what is meant by bond dissociation energy.

52. What is the relationship between the magnitude of a molecule's bond dissociation energy and its expected chemical reactivity?

8.3 Bonding Theories

53. What is a pi bond? Describe, with the aid of a diagram, how the overlap of two half-filled *p* atomic orbitals produces a pi bond.

54. Use VSEPR theory to predict the shapes of the following species.
a. CO_2 **b.** $SiCl_4$ **c.** SO_3
d. SCl_2 **e.** CO **f.** H_2Se

55. The molecule CO_2 has two carbon–oxygen double bonds. Describe the bonding in the CO_2 molecule, which involves hybridized orbitals for carbon and oxygen.

56. What types of hybrid orbitals are involved in the bonding of the carbon atoms in the following molecules?
a. CH_4 **b.** $H_2C{=}CH_2$
c. $HC{\equiv}CH$ **d.** $N{\equiv}C-C{\equiv}N$

8.4 Polar Bonds and Molecules

57. How must the electronegativities of two atoms compare if a covalent bond between them is to be polar?

58. The bonds between the following pairs of elements are covalent. Arrange them according to polarity, listing the most polar bond first.
a. H—Cl **b.** H—C **c.** H—F
d. H—O **e.** H—H **f.** S—Cl

59. What is a hydrogen bond?

60. Depict the hydrogen bonding between two ammonia molecules and between one ammonia molecule and one water molecule.

61. Why do compounds with strong intermolecular attractive forces have higher boiling points than compounds with weak intermolecular attractive forces?

CHAPTER 8 Assessment

Reviewing Content

39. ionic

40. **a.** 6 C, 8 H, 6 O **b.** 12 C, 22 H, 11 O **c.** 7 C, 5 H, 3 N, 6 O

41. Nitrogen and oxygen achieve stability as diatomic molecules. Argon exists as individual atoms because it has a stable noble-gas electron configuration.

42. Neon has an octet of electrons. A chlorine atom achieves an octet by sharing an electron with another chlorine atom.

43. **a.** ionic **b.** ionic **c.** covalent **d.** covalent

44. Ionic bonds depend on electrostatic attraction between ions. Covalent bonds depend on electrostatic attraction between shared electrons and nuclei of combining atoms.

45. A double covalent bond has four shared electrons (two bonding pairs); a triple covalent bond has six shared electrons (three bonding pairs).

46. **a.**  **b.** **c.** **d.**

47. One atom contributes both electrons to a coordinate covalent bond, as in CO.

48. An unshared pair of electrons is needed for a coordinate covalent bond. There are no unshared pairs in compounds with only C-H and C-C bonds.

49. 

50. b and c; assuming only single bonds, the P and S atoms each have 10 valence electrons.

51. Bond dissociation energy is defined as the energy needed to break one covalent bond.

52. Increasing bond dissociation energy is linked to lower chemical reactivity.

53. A pi bond is formed by the side-by side overlap of two half-filled *p* atomic orbitals to produce a pi molecular orbital. In a pi bond, the bonding electrons are most likely to be found in sausage-shaped regions above and below the bond. See Figure 8.15.

54. **a.** linear **b.** tetrahedral **c.** trigonal planar **d.** bent **e.** linear **f.** bent

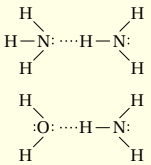
55. The 2*s* and the 2*p* orbitals form two *sp* hybrid orbitals on the carbon atom. One *sp* hybrid orbital forms a sigma bond between the carbon atom and each oxygen atom. Pi bonds between each oxygen atom and the carbon are formed by the unhybridized 2*p* orbitals.

56. **a.** sp^3 **b.** sp^2 **c.** *sp* **d.** *sp*

57. The electronegativities of the two atoms will differ by about 0.4 to 2.0.

58. c, d, a, f, b, e

59. A hydrogen bond is formed by an electrostatic interaction between a hydrogen atom that is covalently bonded to an electronegative atom, and an unshared electron pair of a nearby atom.

60. 

61. More energy is required to separate the molecules.

Understanding Concepts

62. The 3*s* and three 3*p* orbitals of phosphorus hybridize to form four sp^3 atomic orbitals. The resulting shape is pyramidal with a bond angle of 107° between the sigma bonds.

63. 

64. a. C does not have an octet.

b. One F has more than an octet.

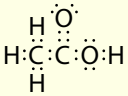
65. a. tetrahedral, 109.5°
b. trigonal planar, 120°
c. tetrahedral, 109.5°
d. bent, 105°

66. a. The percent ionic character increases as the difference in electronegativities increases.
b. 1.6
c. (1) 85% (2) 10% (3) 62% (4) 23%

67. a. 109.5°
b. 120°
c. 180°

68. a. trigonal planar
b. pyramidal
c. linear
d. tetrahedral

69. a. Phosphorus in PBr_5 has 10 valence electrons.

70. a. 

b. No, the molecule contains one carbon-oxygen double bond and one carbon-oxygen single bond.
c. polar bond
d. Yes, it has polar oxygen atoms at one end of the molecule and a nonpolar CH_3^- group at the opposite end.

Understanding Concepts

62. Devise a hybridization scheme for PCl_3 and predict the molecular shape based on this scheme.

63. The chlorine and oxygen atoms in thionyl chloride ($SOCl_2$) are bonded directly to the sulfur. Draw an acceptable electron dot structure for thionyl chloride.

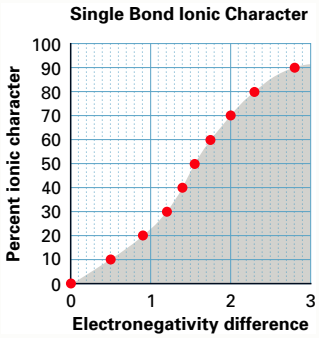
64. Explain why each electron dot structure is incorrect. Replace each structure with one that is more acceptable.

a.

b.

65. Use VSEPR theory to predict the geometry of each of the following.
a. $SiCl_4$ **b.** CO_3^{2-} **c.** CCl_4 **d.** SCl_2

66. The following graph shows how the percent ionic character of a single bond varies according to the difference in electronegativity between the two elements forming the bond. Answer the following questions, using this graph and Table 6.2.

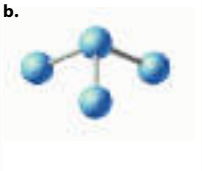


a. What is the relationship between the percent ionic character of single bonds and the electronegativity difference?
b. What electronegativity difference will result in a bond with a 50% ionic character?
c. Estimate the percent ionic character of the bonds formed between (1) lithium and oxygen, (2) nitrogen and oxygen, (3) magnesium and chlorine, and (4) nitrogen and fluorine.

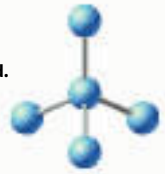
67. Give the angles between the orbitals of each hybrid.
a. sp^3 hybrids
b. sp^2 hybrids
c. *sp* hybrids

68. What is the geometry around the central atom in each of these simple molecules?

a. 

b. 

c. 

d. 

69. Which of the following molecules contains a central atom that does not obey the octet rule?
a. PBr_5
b. AlI_3
c. PF_3
d. $SiCl_4$

70. Vinegar contains the compound ethanoic acid, whose molecular formula is CH_3COOH.
a. Draw the electron dot structure of ethanoic acid.
b. Is the bonding between each of the oxygen atoms and the carbon the same?
c. Is the bonding between the carbon atom and each oxygen atom a polar or nonpolar bond?
d. Is ethanoic acid a polar molecule?

Critical Thinking

71. Make a list of the elements in the compounds found in Table 8.2 on page 224. What do the elements that form covalent bonds have in common?

72. Is there a clear difference between a very polar covalent bond and an ionic bond? Explain.

73. Although the relative positions of the atoms are correct in each of these molecules there are one or more incorrect bonds in each of the electron dot structures. Identify the incorrect bonds. Draw the correct electron dot structure for each molecule.

a. H═C═C═H
b. :F—O—H
c. : I :::Cl :
d. H—N ::: N—H

74. Ethyl alcohol and dimethyl ether each have the same molecular formula, C_2H_6O. Ethyl alcohol has a much higher boiling point (78°C) than dimethyl ether (−25°C). Propose an explanation for this difference.

75. What shape do you expect for a molecule with a central atom and the following?

a. two bonding pairs of electrons and two nonbonding pairs of electrons
b. four bonding pairs and zero nonbonding pairs
c. three bonding pairs and one nonbonding pair

76. Is this statement true or false? "As the electronegativity difference between covalently bonded atoms increases, the strength of the bond increases." Use the table below to justify your answer.

Bond	Electronegativity Difference	Bond Dissociation Energy(kJ/mol)
C — C	2.5 − 2.5 = 0.0	347
C — H	2.5 − 2.1 = 0.4	393
C — N	3.0 − 2.5 = 0.5	305
C — O	3.5 − 2.5 = 1.0	356

Concept Challenge

77. The electron structure and geometry of the methane molecule (CH_4) can be described by a variety of models, including electron dot structure, simple overlap of atomic orbitals, and orbital hybridization of carbon. Draw the electron dot structure of CH_4. Sketch two molecular orbital pictures of the CH_4 molecule. For your first sketch, assume that one of the paired $2s^2$ electrons of carbon has been promoted to the empty $2p$ orbital. Overlap each half-filled atomic orbital of carbon to a half-filled $2s$ orbital of hydrogen. What is the predicted geometry of the CH_4 molecule, using this simple overlap method? In your second sketch, assume hybridization of the $2s$ and $2p$ orbitals of carbon. Now what geometry would you predict for CH_4? Which picture is preferable based on the facts that all H—C—H bond angles in CH_4 are 109.5° and all C—H bond distances are identical?

78. There are some compounds in which one atom has more electrons than the corresponding noble gas. Examples are PCl_5, SF_6, and IF_7. Draw the electron dot structures of P, S, and I atoms and of these compounds. Considering the outer shell configuration of P, S, and I, develop an orbital hybridization scheme to explain the existence of these compounds.

79. Draw the electron dot structure of formic acid, H_2CO_2. The carbon is the central atom, and all the atoms are attached to the carbon except for a hydrogen bonded to an oxygen.

80. Oxalic acid, $C_2H_2O_4$, is used in polishes and rust removers. Draw the electron dot structure for oxalic acid given that the two carbons are bonded together but neither of the hydrogen atoms is bonded to a carbon atom.

81. Draw as many resonance structures as you can for HN_3. (*Hint:* the three nitrogen atoms are bonded in a row and the hydrogen atom is bonded to a nitrogen atom at the end of the row of nitrogens.)

82. Draw an electron dot structure for each molecule and explain why it fails to obey the octet rule.

a. BeF_2 **b.** SiF_6 **c.** ClO_2 **d.** BF_3 **e.** XeF_2

Critical Thinking

71. C, O, H, S, N, F, Cl: These elements are all nonmetals.

72. Answers will vary. Table 8.3 suggests there is no clear difference. The student's argument could be based on chemical properties, such as conductivity of the compound in the liquid state.

73. **a.** two covalent bonds to both hydrogens; double bond between carbons H:C::C:H
b. Fluorine and oxygen have only four electrons. :F:O:H
c. Halogens form one covalent bond, not three. :I:Cl:
d. Nitrogen forms three covalent bonds, not four. H:N::N:H

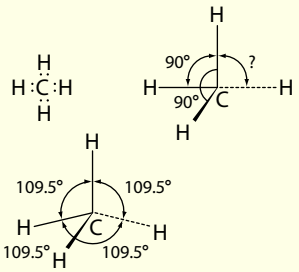
74. Ethyl alcohol can form intermolecular hydrogen bonds between its polar –OH groups, but dimethyl ether can not form hydrogen bonds.

75. **a.** bent
b. tetrahedral
c. pyramidal

76. False. The bond dissociation energies exhibit no particular trend and, in fact, are fairly constant.

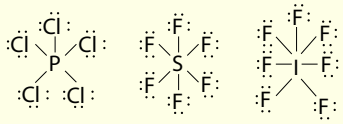
Concept Challenge

77.



The first sketch shows carbon's three *p* orbitals oriented at 90° angles, resulting in a pyramidal structure for the carbon atom with three hydrogen atoms. The 4th C-H bond, formed with carbon's 2*s* orbital and a hydrogen atom's 1s orbital, is at unspecified angles to the other three C-H bonds. The second sketch is tetrahedral. The bond angles in the first sketch are not all the same; some are 90°. The bond angles in the second sketch are all 109.5° The second sketch is correct. (Note: The wedge-shaped lines come out of the page; the dotted lines recede into the page.)

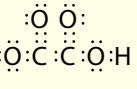
78.



P forms 5 hybrid orbitals (dsp^3), S forms 6 hybrid orbitals (d^2sp^3), and I forms 7 hybrid orbitals (d^3sp^3).

79.

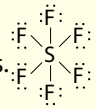
80.



81. H :N ::N :N: ⟷ H :N:N ::N:

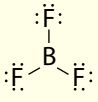
82. **a.** Be has only 4 valence electrons.
:F–Be–F:

b. S has 12 valence electrons.



c. Cl has only 7 valence electrons.

d. B has only 6 valence electrons.



e. Xe has 10 valence electrons. :F–Xe–F:

Cumulative Review

83. Name three indicators of chemical change. *(Chapter 2)*

84. Make the following conversions. *(Chapter 3)*
- **a.** 66.5 mm to micrometers
- **b.** 4×10^{-2} g to centigrams
- **c.** 5.62 mg/mL to decigrams per liter
- **d.** 85 km/h to meters per second

85. How many significant figures are in each measurement? *(Chapter 3)*
- **a.** 0.00052 m
- **b.** 9.8×10^{4} g
- **c.** 5.050 mg
- **d.** 8.700 mL

86. How many neutrons are in each atom? *(Chapter 4)*
- **a.** silicon-30
- **b.** magnesium-24
- **c.** nitrogen-15
- **d.** chromium-50

87. How do isotopes of an atom differ? *(Chapter 4)*

88. In a neutral atom, the number of which two subatomic particles must always be equal? *(Chapter 4)*

89. How many electrons are in the 2*p* sublevel of an atom of each element? *(Chapter 5)*
- **a.** aluminum
- **b.** carbon
- **c.** fluorine
- **d.** lithium

90. What happens to the wavelength of light as the frequency increases? *(Chapter 5)*

91. What does the *5* in $3d^5$ represent? *(Chapter 5)*

92. Write correct electron configurations for atoms of the following elements. *(Chapter 5)*
- **a.** sodium
- **b.** sulfur
- **c.** phosphorus
- **d.** nitrogen

93. How does the ionic radius of a typical anion compare with the radius for the corresponding neutral atom? *(Chapter 6)*

94. What criteria did Mendeleev and Moseley use to arrange the elements on the periodic table? *(Chapter 6)*

95. Give the electron configuration of the element found at each location in the periodic table. *(Chapter 6)*
- **a.** Group 1A, period 4
- **b.** Group 3A, period 3
- **c.** Group 6A, period 3
- **d.** Group 2A, period 6

96. Identify the larger atom of each pair. *(Chapter 6)*
- **a.** calcium and barium
- **b.** silicon and sulfur
- **c.** sodium and nitrogen

97. Which of these statements about the periodic table is correct? *(Chapter 6)*
- I. Elements are arranged in order of increasing atomic mass.
- II. A period is a horizontal row.
- III. Nonmetals are located on the right side of the table.

- **a.** I only
- **b.** I and II only
- **c.** I, II, and III
- **d.** I and III only
- **e.** II and III only

98. Which of the following ions has the same number of electrons as a noble gas? *(Chapter 7)*
- **a.** Al^{3+}
- **b.** O^{2-}
- **c.** Br^{-}
- **d.** N^{3-}

99. What element is likely to form an ionic compound with chlorine? *(Chapter 7)*
- **a.** iodine
- **b.** cesium
- **c.** helium

100. How many valence electrons does each atom have? *(Chapter 7)*
- **a.** argon
- **b.** aluminum
- **c.** selenium
- **d.** beryllium

101. Write the electron configuration of each ion. *(Chapter 7)*
- **a.** oxide ion
- **b.** magnesium ion
- **c.** nitride ion
- **d.** potassium ion

102. An alloy is composed of two or more elements. Is an alloy a compound? Explain your answer. *(Chapter 7)*

Cumulative Review

83. formation of a gas, a change in color or odor

84. **a.** 6.65×10^{4} micrometers
b. 4 centigrams
c. 5.62×10^{-1} decigram per liter
d. 2.4×10^{1} meters per second

85. **a.** 2
b. 2
c. 4
d. 4

86. **a.** 16
b. 12
c. 8
d. 26

87. Isotopes have the same number of protons and electrons, but different numbers of neutrons.

88. Protons and electrons must be equal.

89. **a.** 6
b. 2
c. 5
d. 0

90. The wavelength decreases as the frequency increases.

91. The *d* orbitals related to the third principal energy level contain 5 electrons.

92. **a.** $1s^2 2s^2 2p^6 3s^1$
b. $1s^2 2s^2 2p^6 3s^2 3p^4$
c. $1s^2 2s^2 2p^6 3s^2 3p^3$
d. $1s^2 2s^2 2p^3$

93. The anion is larger than the corresponding neutral atom.

94. Mendeleev arranged the elements by increasing atomic mass in vertical rows and by similarities in chemical and physical properties. Mosely arranged the elements by increasing atomic number in vertical rows and by similarities in chemical and physical properties.

95. **a.** K, $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
b. Al, $1s^2 2s^2 2p^6 3s^2 3p^1$
c. S, $1s^2 2s^2 2p^6 3s^2 3p^4$
d. Ba, $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 6s^2$

96. **a.** barium
b. silicon
c. sodium

97. **e.** II and III only

98. All have the same number of electrons as a noble gas.

99. **b.** cesium

100. **a.** 8
b. 3
c. 6
d. 2

101. **a.** $1s^2 2s^2 2p^6$
b. $1s^2 2s^2 2p^6$
c. $1s^2 2s^2 2p^6$
d. $1s^2 2s^2 2p^6 3s^2 3p^6$

102. No, an alloy is a homogeneous mixture.

Standardized Test Prep

Test-Taking Tip

Connectors Sometimes two phrases in a true/false question are connected by a word such as *because*. The word implies that one thing caused another thing to happen. Statements that include such words can be false even if both parts of the statement are true by themselves.

Select the choice that best answers each question or completes each statement.

1. A bond in which two atoms share a pair of electrons is not
- **a.** a coordinate covalent bond.
- **b.** a polar covalent bond.
- **c.** an ionic bond.
- **d.** a nonpolar covalent bond.

2. How many valence electrons are in a molecule of phosphoric acid, H_3PO_4?
a. 7 **b.** 16 **c.** 24 **d.** 32

3. Which of these molecules can form a hydrogen bond with a water molecule?
a. N_2 **b.** NH_3 **c.** O_2 **d.** CH_4

4. Which substance contains both covalent and ionic bonds?
a. NH_4NO_3 **b.** CH_3OCH_3 **c.** LiF **d.** $CaCl_2$

5. Which of these bonds is most polar?
a. H—Cl **b.** H—Br **c.** H—F **d.** H—I

Use the description and data table below to answer Questions 6–9.

The table relates molecular shape to the number of bonding and nonbonding electron pairs in molecules.

Bonding pairs	Non-bonding pairs	Arrangement of electron pairs	Molecular shape	Example
4	0	tetrahedral	tetrahedral	CH_4
3	1	tetrahedral	pyramidal	NCl_3
2	2	tetrahedral	bent	H_2S
1	3	tetrahedral	linear	HF

6. Draw the electron dot structure for each example molecule.

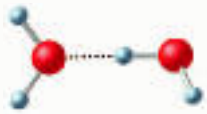
7. Explain why the arrangement of electron pairs is tetrahedral in each molecule.

8. H_2S has two hydrogen atoms bonded to a sulfur atom. Why isn't the molecule linear?

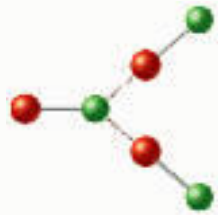
9. What is the arrangement of electron pairs in PBr_3? Predict the molecular shape of a PBr_3 molecule.

For Questions 10–12, identify the type of intermolecular bonding represented by the dotted lines in the drawings.

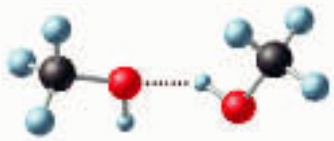
10. H_2O



11. BrCl (bromine chloride)



12. CH_3OH (methanol)



In Questions 13–15, a statement is followed by an explanation. Decide if each statement is true and then decide if the explanation given is correct.

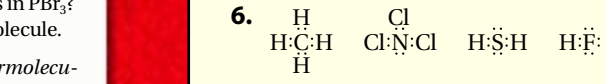
13. A carbon monoxide molecule has a triple covalent bond because carbon and oxygen atoms have an unequal number of valence electrons.

14. Xenon has a lower boiling point than neon because dispersion forces between xenon atoms are stronger than those between neon atoms.

15. The nitrate ion has three resonance structures because the nitrate ion has three single bonds.

Standardized Test Prep

1. c
2. d
3. b
4. a
5. c
6.



7. Each central atom has four pairs of electrons that, according to VSEPR theory, assume a tetrahedral shape.
8. The two nonbonding pairs repel the bonding pairs; there are still four pairs of electrons around the sulfur atom.
9. The arrangement of electron pairs is tetrahedral. The electron dot structure shows three bonding electron pairs and one non-bonding electron pair; thus, the predicted molecular shape is pyramidal.
10. hydrogen bonding
11. primarily dispersion forces
12. hydrogen bonding
13. True, True
14. False, True
15. True, False