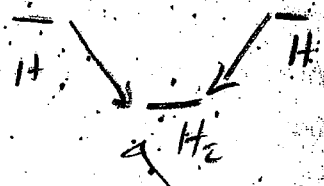
Name _____ Key _____ Class _____ Date _____

Activity 4-4
The Chemical Bond I



Introduction

1. What is a chemical bond? The Attraction of electron by 2 nucle.

2. How does potential (stored) energy change when a chemical bond is formed? energy will decrease (exothermic)

   When a chemical bond is broken? energy will increase (endo thermic)

3. Compare the potential energy of two atoms in chemically bonded condition to their energy when separated. lower when bonded

4. Generally, systems at lower potential energy are more (more/less) stable than systems at higher potential energy.

5. How is the stability of a substance related to the potential energy of that substance? less energy more stable

6. Describe two ways in which the valence electrons of atoms participate in bond formation. share or transfer

Ionic bonds

7. What is an ionic bond? electrons are transferred from metal to nonmetal The ions are then attracted to each other + (⟷) -

8. What other name is sometimes given to ionic bonds? electrovalent

9. How are positive ions formed? lose electrons

10. How are negative ions formed? gain electrons

11. When an atom loses one or more electrons to form a positive ion, energy is Absorbed (*absorbed/released*). Ionization energy ↑

12. When an atom gains one or more electrons to form a negative ion, energy is Released (*absorbed/released*).

Dot diagrams for ionic compounds

13. Choose words from the word list to fill in the blanks in the following paragraphs relating to the construction of dot diagrams for binary ionic compounds. The list pairs words that have contrasting or related meanings.

Word List

atom/ion	gain/lose	positive/negative
configuration	kernel/valence	symbol
eight	metal/nonmetal	

When atoms form ions, they usually GAIN or lose enough electrons to achieve the electron Configuration of a noble gas. Metal atoms lose electrons; nonmetal atoms GAIN electrons. The electron-dot symbols for elements can be used to construct dot diagrams for ionic compounds. Dot diagrams for monatomic ions show electrons gained or lost. In a dot diagram the Symbol for the element represents the Kernel of the ion. Square brackets are used to emphasize the fact that the structure is an Ion; not an atom. The charge is written outside the brackets.

For Positive ions, generally no electrons are indicated since all the Valence electrons have been transferred. This accounts for the Positive charge of the ion.

For nonmetal ions, generally the number of electrons shown is eight since enough electrons are transferred to the previously partially filled Valence shell of the nonmetal atom in order to form the Ion. Both metal and nonmetal ions have achieved the noble gas Configurations.

In order to represent a binary ionic compound, the appropriate number and kind of ions are used. Thus the dot diagram for the compound Mg_3N_2 is:

$[Mg]^{2+}$ $\left[\cdot\underset{\cdot}{\overset{\cdot}{\underset{\cdot}{\overset{\cdot}{N}}}}\cdot\right]^{3-}$
$[Mg]^{2+}$
$[Mg]^{2+}$ $\left[\cdot\underset{\cdot}{\overset{\cdot}{\underset{\cdot}{\overset{\cdot}{N}}}}\cdot\right]^{3-}$

Choose 5

Construct dot diagrams for the following ionic compounds.

14. NaI

Na^+ $[:\ddot{I}:]^-$

15. CaF_2

Ca^{2+} $2[:\ddot{F}:]^-$

16. $AlCl_3$

Al^{3+} $3[:\ddot{Cl}:]^-$

17. Na_2S

$2Na^+$ $[:\ddot{S}:]^{2-}$

18. BaO

Ba^{+2} $[:\ddot{O}:]^{2-}$

19. K_3P

$3K^+$ $[:\ddot{P}:]^{3-}$

20. RbBr

Rb^+ $[:\ddot{B}\ddot{r}:]^-$

21. Li_3N

$3Li^+$ $[:\ddot{N}:]^{3-}$

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Activity 4-5
The Chemical Bond II

Covalent bonds

1. What role do valence electrons play in covalent bonding? They Are shared to Achieve Noble Gas electron Config.

2. When atoms are bonded together covalently, what two kinds of structures may result? [redacted], [redacted] Network, polyatomic, molecule

3. What is a single covalent bond? 2 electron shared

4. What is a double covalent bond? 4 electrons shared

5. What is a triple covalent bond? 6 electrons shared

6. How is a coordinate covalent bond different from an ordinary covalent bond? Both of the electrons come from the same Atom to form the covalent bond

7. What kind of compound frequently shows coordinate covalent bonds? poly Atomic ions

Dot diagrams for molecules and polyatomic ions

8. Choose words from the word list to fill in the blanks in the following paragraphs relating to the construction of dot diagrams. The list groups words that have contrasting or related meanings.

Word List

atom(s)/ion(s)/molecule(s)	metal/nonmetal
eight/four	O(oxygen)
error	pairs
kernel/valence	share/transfer

When atoms are held together by covalent bonds, a molecule or a polyatomic Ion is formed. The electron-dot symbols for individual atoms can

be used to construct dot diagrams for molecules and polyatomic ion. The symbol for each element represents the nucleus and Kernel electrons. When atoms form covalent (or coordinate covalent) bonds, each atom must share enough electrons to fill its valence shell with at least a share in the total of 8 electrons, that is, 4 pairs of electrons.

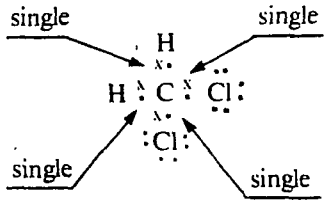
Constructing dot diagrams becomes a trial and error process until a reasonable structure is drawn. The following suggestions will help reduce the number of trials and errors.

a. Choose a central atom, generally a(n) Atom other than H or O, which is bonded to not more than 4 other atoms.

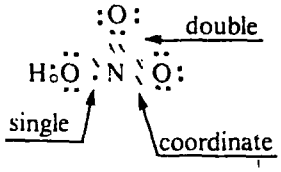
b. In ternary compounds, H atoms are generally bonded to Oxygen atoms.

c. Arrange atoms as symmetrically as possible around the central atom; try to represent the Valence electrons of all atoms as pairs of shared and unshared electrons.

The diagrams below represent CH_2Cl_2 and HNO_3.



CH_2Cl_2

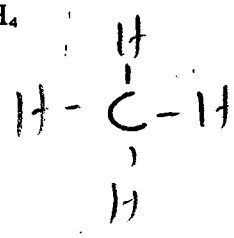


HNO_3

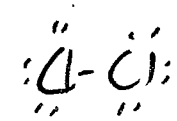
Molecules

Construct dot diagrams for the following molecules. For molecules 11, 20, 21, 25, and 27, identify bond types as shown above.

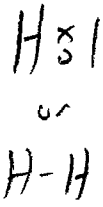
9. CH_4



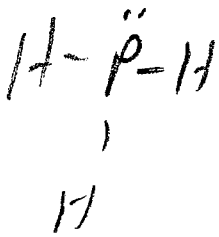
12. Cl_2



10. H_2



11. PH_3



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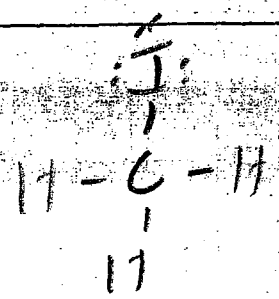
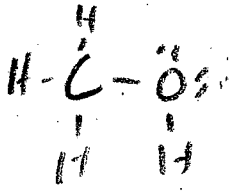
13. CHI_3

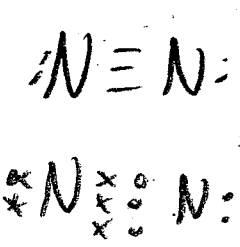


~~14.~~ $HClO_4$

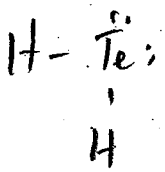
~~14.~~ CH_3OH



22. N_2

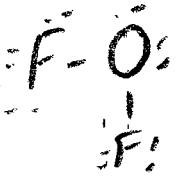


15. H_2Te

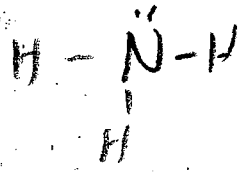


~~23.~~ H_2SO_4

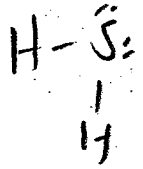
16. OF_2



24. NH_3

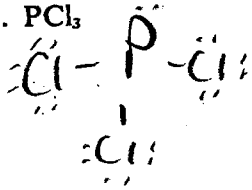


17. H_2S

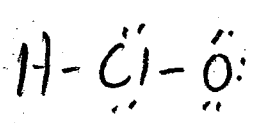


25. HCN

18. PCl_3

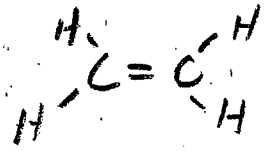


26. HClO

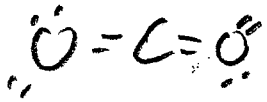


~~19.~~ SiO_2

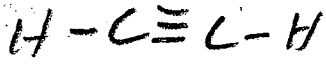
27. C_2H_4



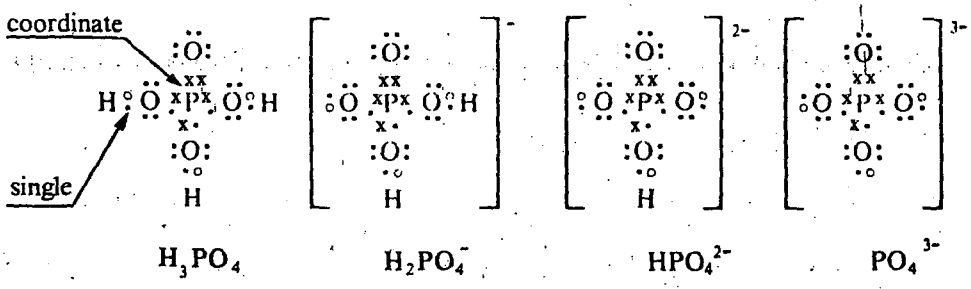
20. CO_2



28. C_2H_2



Atoms can bond together to form polyatomic ions as well as molecules. It is usually most convenient to regard polyatomic ions as derivatives of their related ternary acids. A diagram can then be constructed for the ternary acid as described above. Removal of one or more H atoms will yield the diagram for the polyatomic ion. The diagrams below represent H_3PO_4 and related polyatomic ions: $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}.



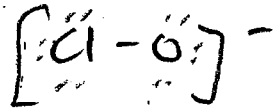
Construct dot diagrams for the following molecules and polyatomic ions. For ions 32, 34, and 38, identify bond types as shown above.

~~29.~~ $HClO_3$

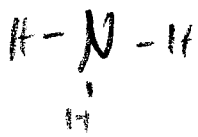
~~30.~~ ClO_3^-

~~31.~~ ClO_2^-

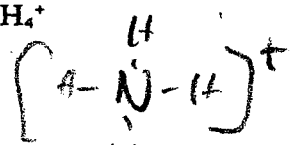
32. ClO^-



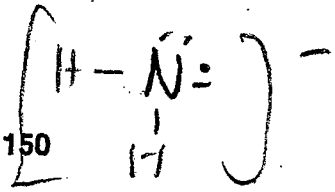
33. NH_3



34. NH_4^+

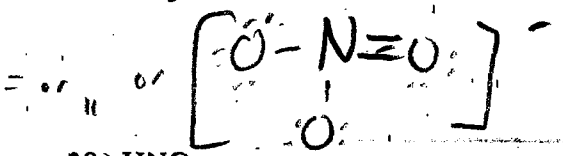


35. NH_2^-



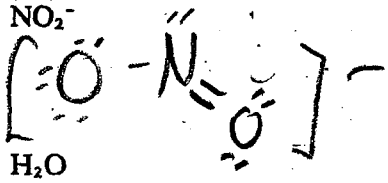
~~36.~~ HNO_3

37. NO_3^-

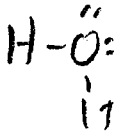


~~38.~~ HNO_2

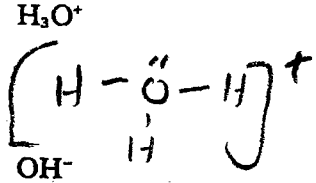
39. NO_2^-



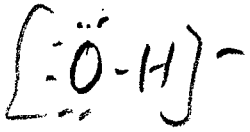
40. H_2O



41. H_3O^+



42. OH^-



Name _____ Class _____ Date _____

Activity 4-6
The Chemical Bond III

Polar bonds and polar molecules

1. How does a polar bond differ from a nonpolar bond? An electronegativity Difference btw. the 2 Atoms

2. How does a polar bond differ from an ionic bond? The electronegativity Shared unequally difference is < 1.7 for polar Co. vs. Completely transferred more for Ionic

3. How is electronegativity difference used to help predict bond type? What values separate ionic from polar covalent bonds? = 1.7 ← Ionic
0 < Polar Covalent < 1.7

4. What is a dipole (polar molecule)? When there is An Asymmetrical distribution of Charge in a molecule

5. How do polar bonds contribute to the polarity of a molecule? An imbalance of polar bonds CAUSE the Molecule to be polar

6. How can a molecule, such as CO_2 or CH_4, contain polar bonds yet still be a nonpolar substance? Symmetry the polar bonds balance each other

7. What physical properties are characteristic of dipoles? Dissolve in H_2O

8. Why does water dissolve many ionic compounds? Water is Polar & Attracts the Charged ions

Network solids

9. Describe the bonding in network solids. Strong Covalent bonds

10. What are the significant physical properties of network solids? High BP/MP insoluble in H_2O, Hard

Properties of ionic solids

11. Ionic solids have relatively _____ (high/low) melting points.
12. Describe two different conditions under which the ions of ionic solids become free to move.
in H_2O or As a liquid (melted)

13. Describe the electrical conductivity of ionic substances in the solid, liquid, and aqueous solution phases. Moving charge = electricity

14. What two kinds of elements are most likely to react with each other to form binary ionic compounds? metals w/ nonmetals

The metallic bond

15. Describe bonding in metallic solids. lattice of + ions immersed in a sea of electrons

16. What are the significant physical properties of metallic solids? Conduct electricity / heat

Hydrogen bonding

17. Draw a diagram to illustrate hydrogen bonding between molecules of HF.

H bond

HF -- H-F

18. Under what circumstances do hydrogen bonds form? Hydrogen bonded to small, highly electronegative atoms (FON)

19. What properties are associated with compounds containing hydrogen bonds? higher than expected BP's
Stronger intermolecular forces

Van der Waals forces

20. What is the source of van der Waals forces? Momentary dipole in a nonpolar molecule

21. What factors determine the magnitude of the van der Waals forces acting between molecules? mass + # of electrons in an atom
(temp + pressure also)

22. What properties of molecules are associated with van der Waals forces? Vapor pressure, BP.

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Self Test 4-B
Bonding I

Select the best answer and write its letter in the space at the right. Use the reference tables in the Appendix as needed.

1. During the formation of an ionic bond, the atom that transfers its valence electron is the atom with the
   (A) higher electronegativity value
   (B) lower electronegativity value
   (C) lower ionization energy
   (D) higher atomic mass — 1. C

2. Which type of bonding predominates in solid potassium chloride, KCl?
   (A) ionic (C) hydrogen
   (B) metallic (D) covalent — 2. A

3. What type of solid is formed when two elements with greatly different electronegativities combine?
   (A) ionic (C) covalent
   (B) molecular (D) network — 3. A

4. What type of bonds are present in magnesium metal?
   (A) covalent (C) metallic
   (B) ionic (D) van der Waals — 4. C

5. As the difference in electronegativities decreases, the tendency for elements to form covalently bonded compounds
   (A) decreases (B) increases (C) remains the same — 5. B

6. The bonding in silicon dioxide (SiO_2) can best be described as
   (A) network bonding (C) ionic bonds
   (B) van der Waals forces (D) metallic bonds — 6. A

7. Which of the following contains a coordinate covalent bond?

   (A) $H:H$

   (B) $\left[H:\ddot{O}:H \right]^+$ (with H below O)

   (C) $H:\ddot{N}:H$ (with H below N)

   (D) $:N\equiv N:$

   7. B

8. When nonmetals chemically combine, they tend to form
   (A) negative ions or covalent bonds
   (B) positive ions or covalent bonds
   (C) positive ions only
   (D) covalent bonds only — 8. A

9. What types of bonding exist in sodium hydrogen sulfate, $NaHSO_4$?
   (A) ionic only (C) both ionic and covalent
   (B) covalent only (D) both covalent and metallic — 9. C

10. When sodium and chlorine unite chemically, energy is
    (A) released, and ionic bonds are formed
    (B) released, and covalent bonds are formed
    (C) absorbed, and ionic bonds are formed
    (D) absorbed, and covalent bonds are formed — 10. A

11. Silicon compounds usually exhibit bonding which is primarily
(A) covalent (C) electrovalent
(B) ionic (D) coordinate 11. A

12. Which of the following in its solid phase contains positive ions immersed in a sea of mobile electrons?
(A) O_2 (C) Cu
(B) SiO_2 (D) CuO 12. C

13. If a pure substance is a good conductor of electricity in both its solid and its liquid phases, then the bonding in the substance is predominantly
(A) ionic (C) polar covalent
(B) metallic (D) nonpolar covalent 13. B

14. Which compound exhibits bonds having the least ionic character?
(A) CsCl 2.4 (C) KF 3.2
(B) RbBr 2.1 (D) NaI 1.5 14. B

15. A pure substance melts at 38°C and does not conduct electricity in either the solid or liquid phase. The substance is classified as
(A) ionic (C) electrovalent
(B) metallic (D) molecular 15. D

16. Which molecule is not a dipole?
(A) HBr (B) H_2O (C) NH_3 (D) CCl_4 16. D

17. Experiment shows that H_2O is a dipole while CO_2 is not a dipole. The two structures that best illustrate this fact are

(A) O=C=O H–O–H (C) O=C=O H–O–H

(B) O=C=O H–H–O (D) O=C=O H–O–H 17. A

18. Which molecule is a dipole?
(A) H_2 (B) N_2 (C) CH_4 (D) HF 18. D

19. Which molecule is polar?

(A) H–O(H) (C) O=C=O

(B) H–H (D) Cl–C(Cl)(Cl)–Cl 19. A

20. Which best explains why a methane (CH_4) molecule is nonpolar?
(A) Each carbon-hydrogen bond is polar.
(B) Carbon and hydrogen are both nonmetals.
(C) Methane is an organic compound.
(D) The methane molecule is symmetrical. 20. D

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21. Hydrogen bonds are formed between molecules in which hydrogen is covalently bonded to an element whose atomic radius and electronegativity, respectively, are
    (A) large and low (C) large and high
    (B) small and low (D) small and high 21. D
22. Multiple covalent bonds exist in a molecule of
    (A) F_2 (B) H_2 (C) N_2 (D) Cl_2 22. C
23. Which is an example of a nonpolar molecule that contains polar covalent bonds?
    (A) CCl_4 (B) N_2 (C) H_2O (D) NH_3 23. A
24. As the distance between molecules decreases, the effect of the van der Waals forces between the molecules
    (A) decreases (B) increases (C) remains the same 24. B
25. Which molecule is nonpolar?
    (A) H_2O (B) HF (C) NF_3 (D) CF_4 25. D
26. Which reaction would require the greatest amount of energy?
    (A) $Na + energy \rightarrow Na^+ + e^-$
    (B) $Mg + energy \rightarrow Mg^+ + e^-$
    (C) $Al + energy \rightarrow Al^+ + e^-$
    (D) $Si + energy \rightarrow Si^+ + e^-$ 26. D
27. In which noble gas are the van der Waals forces the greatest?
    (A) Ne (B) Ar (C) Kr (D) Xe 27. D
28. What is the nature of the bond in ICl?
    (A) ionic (C) polar covalent
    (B) nonpolar (D) coordinate covalent 28. C
29. The attraction that nonpolar molecules have for each other is primarily caused by
    (A) hydrogen bonding
    (B) high ionization
    (C) electronegativity differences
    (D) van der Waals forces 29. D
30. Xenon has a higher boiling point than neon because xenon has
    (A) smaller molecules
    (B) weaker van der Waals forces
    (C) a smaller molecular mass
    (D) more electrons per atom 30. D
31. The major attractive force between polar molecules is usually
    (A) dipole attraction (C) hydrogen bonding
    (B) electrostatic bonding (D) van der Waals forces 31. A
32. Which type of bonding accounts for the high boiling point of H_2O as compared with the relatively low boiling point of H_2S?
    (A) van der Waals forces (C) covalent bonds
    (B) hydrogen bonds (D) electrovalent bonds 32. B

Select the type of bond or binding force in Column 2 that is most closely associated with each statement in Column 1, and write its letter in the space at the right.

Column 1

33. A hydrogen nucleus combines with water to form a hydronium ion. 33. C
34. Mobility of valence electrons results in good electrical conductivity in the solid phase. 34. E
35. Nonconductors in the solid phase become electrical conductors in the liquid phase. 35. A
36. Solid iodine sublimes readily upon heating. 36. F
37. The boiling point of NH_3 is much higher than that of PH_3 or AsH_3. 37. D

Column 2

(A) ionic bonds
(B) covalent bonds (as in network solids)
(C) coordinate covalent bonds
(D) hydrogen bonds
(E) metallic bonds
(F) van der Waals forces
(G) triple covalent bonds

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Self Test 4-C
Bonding II

From the list A-F below, select the bond or attractive force that is most closely associated with each of the following phrases, and write its letter in the space at the right.

(A) ionic bonds (C) coordinate covalent bonds (E) van der Waals forces
(B) hydrogen bonds (D) metallic bonds (F) covalent bonds

1. Hold the iodine atoms together in a molecule of I_2. I-I — 1. F
2. Hold the many molecules of I_2 together in a crystal of iodine. I-I I-I — 2. E
3. Account for the relatively high boiling and freezing points of pure water. — 3. B
4. Are illustrated by the compounds formed when fluorine reacts with active metals. — 4. A
5. Hold magnesium atoms in a crystal lattice. — 5. D
6. Mobile electrons in the crystal that permit electrical conductivity in the solid state. — 6. D
7. Responsible for the extremely high melting point of diamond (above 3500°C). — 7. F (Network)
8. Permit helium and hydrogen to exist in liquid or solid phases under conditions of low temperature and high pressure. Non polar — 8. E
9. Link water molecules to neighboring water molecules. — 9. B
10. Produce substances that are nonconductors in the solid phase and conductors in the liquid phase. — 10. A
11. Are weak enough to permit solid iodine to sublime readily upon heating. — 11. E
12. Cause the boiling point of hydrogen fluoride to be much higher than that of hydrogen chloride, hydrogen bromide, or hydrogen iodide. — 12. B
13. Link the atoms within a molecule of a diatomic gaseous element. — 13. F
14. Bond noble gas atoms in the liquid phase. Non polar — 14. E
15. Account for the attraction between gas molecules in a nonideal gas. — 15. E
16. Responsible for the formation of ice crystals. — 16. B

Select the best answer and write its letter in the space at the right.

17. Among the following, the compound that has the highest degree of ionic bonding is
(A) CCl_4 (B) $MgCl_2$ (C) H_2O (D) CO_2 — 17. B
18. A compound that has polar molecules is
(A) CCl_4 (B) $MgCl_2$ (C) H_2O (D) CO_2 — 18. C
19. When compared to hydrogen chloride (HCl), hydrogen fluoride (HF) has an unusually high boiling point. This is due to the magnitude of the
(A) hydrogen bonds (C) van der Waals forces
(B) coordinate covalent bonds (D) nonpolar covalent bonds — 19. A

20. All chemical bonds are the result of the
(A) elevation of electrons to higher energy levels
(B) transfer of electrons from one atom to another
(C) attraction of electrons to each other
(D) simultaneous attraction of electrons to two nuclei — 20. D

21. The correct ranking of bonds in order of greatest to least bond strength is
(A) covalent, van der Waals, hydrogen
(B) van der Waals, hydrogen, covalent
(C) covalent, hydrogen, van der Waals
(D) hydrogen, van der Waals, covalent — 21. B

From the list A-D below, select the compound that best answers each question, and write its letter in the space at the right.

(A) $CsCl$ (B) CO_2 (C) CCl_4 (D) H_2O

22. Which compound best represents a tetrahedral molecule? — 22. C

23. Which compound would show a bent (V-shaped) molecular structure? — 23. D

24. Which compound has the highest degree of ionic bonding? — 24. A

25. Which compound probably has double bonds within its molecular structure? — 25. B

26. Which compound has polar covalent molecules? — 26. D

From the list A-D below, select the type of bond that is found between the atoms described in each phrase and write its letter in the space at the right.

(A) ionic bond (C) nonpolar covalent bond
(B) metallic bond (D) polar covalent bond

27. the hydrogen and chlorine atoms in HCl — 27. D

28. the magnesium and chlorine particles in $MgCl_2$ — 28. A

29. the nitrogen and hydrogen atoms in NH_3 — 29. D

30. the nitrogen atoms in N_2 — 30. C

31. the atoms in Cu wire — 31. B

From the list A-G below, select the formula most closely associated with each phrase, and write its letter in the space at the right.

(A) HCl (C) CH_4 (E) Cu (G) KBr
(B) N_2 (D) SiO_2 (F) Xe

32. Conducts an electric current in the molten state but not in the solid state. — 32. G

33. Its molecules contain only one atom. — 33. F

34. Mobile electrons permit electrical conductivity in the solid phase. — 34. E

35. A nonpolar covalent compound. — 35. B

36. An example of a network solid. — 36. D

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Activity 3-6
Percentage Composition

Finding percentage composition

The percentage composition, by mass, of a chemical compound can be found from experimental evidence.

Sample Problem 1 From laboratory measurements, a sample of a pure compound is known to have a mass of 3.74 grams. Analysis of the sample shows 1.10 g calcium, 0.880 g sulfur, and 1.76 g oxygen. What is the percentage composition of this compound?

Solution

$$\frac{1.10 \text{ g calcium}}{3.74 \text{ g compound}} \times 100 = 29.4\% \text{ (by mass) calcium}$$

$$\frac{0.880 \text{ g sulfur}}{3.74 \text{ g compound}} \times 100 = 23.5\% \text{ (by mass) sulfur}$$

$$\frac{1.76 \text{ g oxygen}}{3.74 \text{ g compound}} \times 100 = 47.1\% \text{ (by mass) oxygen}$$

Percentage composition may also be found by calculation from a known chemical formula.

Sample Problem 2 Calculate the percentage composition for copper (II) nitrate, $Cu(NO_3)_2$, from its formula.

Solution

1 Cu atom	1 × 63.5 u/atom	=	63.5 u
2 N atoms	2 × 14.0 u/atom	=	28.0 u
6 O atoms	6 × 16.0 u/atom	=	96.0 u
$Cu(NO_3)_2$	formula mass	=	187.5 u

Cu: $\frac{63.5 \text{ u}}{187.5 \text{ u}} \times 100 = 33.9\%$ copper by mass

N: $\frac{28.0 \text{ u}}{187.5 \text{ u}} \times 100 = 14.9\%$ nitrogen by mass

O: $\frac{96.0 \text{ u}}{187.5 \text{ u}} \times 100 = 51.2\%$ oxygen by mass

Practice problems

For each of the following, find the percentage composition from the analysis determined by experiment. Show a labeled setup in the space below each problem, and write your answers in the spaces provided.

1. A 14.80-g sample contains 3.83 g iron and 10.97 g bromine.

$\frac{3.83}{14.80} \times 100\% =$ $\frac{10.97}{14.80} \times 100\% =$

1. 25.9 % Fe
   74.1 % Br

2. A 9.14-g sample contains 4.77 g carbon, 1.19 g hydrogen, and 3.18 g oxygen.

$\frac{4.77}{9.14} \times 100 =$ $\frac{1.19}{9.14} \times 100 =$ $\frac{3.18}{9.14} \times 100 =$

2. 52.2 % C
   13.0 % H
   ~~34.7~~ % O
   34.8

3. A 2.85-g sample contains 0.82 g magnesium, 0.41 g carbon, and 1.62 g oxygen.

$\frac{0.82}{2.85} \times 100\% =$ $\frac{0.41}{2.85} \times 100 =$ $\frac{1.62}{2.85} \times 100 =$

3. 28.8 % Mg
   14.4 % C
   56.8 % O

For each of the following, calculate the percentage composition from the formula of the compound. Show a labeled setup in the space below the problem, and write your answers in the spaces provided.

4. NaBr

Na (23.0 / 102.9) × 100 =
Br (79.9 / 102.9) × 100 =
102.9

4. 22.4 % Na
   77.6 % Br

5. H_2O_2

H (2 / 34) × 100 =
O (32 / 34) × 100 =
34

5. 5.9 % H
   94.1 % O

6. CaC_2O_4

Ca (40 / 128) × 100 =
C (24 / 128) × 100 =
O (64 / 128) × 100 =

6. 31.3 % Ca
   18.8 % C
   50.0 % O

7. $Al_2(SO_4)_3$

Al (54.0 / 342.3) × 100 =
S (96.3 / 342.3) × 100
O (192.0 / 342.3) × 100
342.3

15.7
7. ~~15.7~~ % Al
   28.1 ~~18.5~~ % S
   56.1 ~~64.9~~ % O

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Activity 3-7
Empirical Formulas

The empirical formula of a compound expresses the simplest whole number ratio of elements in that compound. The empirical formula can be calculated from the percentage by mass for each element in the compound.

Sample Problem The percentage composition by mass of a compound is 56.6% potassium, 8.7% carbon, and 34.7% oxygen. Find its empirical formula.
Solution Assume that there are 100 grams of the compound. Then calculate the number of moles of atoms of each element in the sample.

$$100\text{ g compound} \times \frac{56.6\text{ g K}}{100\text{ g compound}} \times \frac{1\text{ mole K}}{39.1\text{ g K}} = 1.45\text{ moles K}$$

$$100\text{ g compound} \times \frac{8.7\text{ g C}}{100\text{ g compound}} \times \frac{1\text{ mole C}}{12.0\text{ g C}} = 0.73\text{ mole C}$$

$$100\text{ g compound} \times \frac{34.7\text{ g O}}{100\text{ g compound}} \times \frac{1\text{ mole O}}{16.0\text{ g O}} = 2.17\text{ moles O}$$

Use the number of moles as subscripts for each element to express the ratio of atoms:

$$K_{1.45}C_{0.73}O_{2.17}$$

Convert these values to a simple whole-number ratio by dividing each subscript by the smallest subscript.

$$\frac{K_{1.45}C_{0.73}O_{2.17}}{0.73\ \ 0.73\ \ 0.73} = K_2C_1O_3 \text{ or } K_2CO_3$$

If the results of this step are half-integers, multiply by 2 to convert to whole numbers. In the same way, if the results are third-integers, multiply by 3.

Practice problems

From percentage composition information in each of the following, calculate empirical formulas. Show a labeled setup below the problem, and write your answers in the spaces provided.

1. 69.6% barium, 6.1% carbon, 24.3% oxygen

1. $BaCO_3$

137.3 12 16

.51/.51 .51 1.53

1 1 3

2. 40.5% zinc, 19.9% sulfur, 39.6% oxygen

2. $ZnSO_4$

65.4 32.1 16

.62 .62 2.48

1 1 4

3. 88.8% copper, 11.2% oxygen

63.5 16

1.4 0.7

3. Cu_2O

4. 79.9% copper, 20.1% oxygen

63.5 16

1.26 1.25

4. CuO

5. 36.7% potassium, 33.3% chlorine, 30.0% oxygen

39.1 35.5 16

0.94 0.94 1.88

1 1 2

5. $KClO_2$

6. 28.2% potassium, 25.6% chlorine, 46.2% oxygen

39.1 35.5 16

0.72 0.72 2.89

6. $KClO_4$

7. 40.2% potassium, 26.8% chromium, 33.0% oxygen

39.1 52 16

1.02 0.51 2.06

7. K_2CrO_4

8. 26.6% potassium, 35.3% chromium, 38.1% oxygen

39.1 52 16

0.68 0.68 2.38

1 1 3.5

8. $K_2Cr_2O_7$

9. 56.3% oxygen, 43.7% phosphorus

16 31

$\frac{3.5}{1.41} = 2.5$ $\frac{1.4}{1.4} = 1$

9. P_2O_5

10. 90.7% lead, 9.33% oxygen

207.2 16

$\frac{0.44}{0.44} = 1$ $\frac{0.58}{0.44} = 1.33$

0.44 x3 0.44 x3

3 4

10. Pb_3O_4