SECTION 2.4 QUESTIONS

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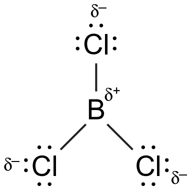
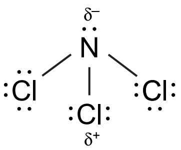
Understanding Concepts

1. Covalent bonds and ionic bonds are the forces that bond atoms and ions together within a compound — the intramolecular forces. These forces are sufficient to explain the existence of molecular and ionic compounds, and to explain many of the properties of ionic compounds, but they aren't sufficient to explain the physical state of molecular compounds. If covalent bonds were the only forces at work, molecular compounds would all be gases, as there would be no attraction between the molecules strong enough to order the molecules into solids or liquids. The concepts of the polar molecule and small charges on atoms that result in intermolecular forces help to explain why these molecular compounds are not all gases at SATP.
2. When the atoms are identical, such as in a chlorine molecule, the electrons are shared equally. However, this is not the case for a compound like hydrogen chloride, where electrons are shared between two different elements. In this situation, the sharing is unequal, as the bonding electrons in the H—Cl bond spend more time near the chlorine atom than near the hydrogen atom. This is because of chlorine's greater attraction for electrons.

3. (a) Both BCl_3 and NCl_3 are molecular compounds. By convention, compounds with bonds that have electronegativity differences less than or equal to 1.7, have covalent-type bonds and are classified as molecular compounds.
   (b) The bonds between B—Cl and N—Cl are similar in that they are both covalent-type bonds and involve the sharing of a pair of electrons. The bonds are different in that the B—Cl bonds are polar covalent bonds due to differences in electronegativities. In this situation, the sharing of electrons is unequal, as the bonding electrons in the B—Cl bond spend more time near the chlorine atom than near the boron atom. This is because of chlorine's greater attraction for electrons. Another difference is that the boron atom in BCl_3 does not have an octet in its valence shell.
   (c) BCl_3 is quite symmetrical and lacks oppositely charged ends. Thus it is not a polar molecule. Intermolecular attractions would be due to the weaker London dispersion forces. NCl_3 is a polar molecule due to having nitrogen at one end. Intermolecular attractions would be due to the stronger dipole-dipole forces.





4. Since a molecule of carbon tetrachloride, $CCl_{4(l)}$n, is quite symmetrical, it lacks oppositely charged ends and is not polar.

2.5 THE NAMES AND FORMULAS OF COMPOUNDS

PRACTICE

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Understanding Concepts

1. Substances were named in a variety of ways. In some cases, the name referred to the use of the compound; in other cases, it incorporated an obvious property, or perhaps referred to the sources of the substance.
2. (a) muriatic acid
   (b) baking soda
   (c) laughing gas
   (d) grain alcohol
3. A binary compound is composed of two kinds of elements.
4. In the formula of a binary ionic compound, the metal cation is always written first, followed by the nonmetal anion. The name of the metal is stated in full and the name of the nonmetal ion has an *-ide* suffix; for example, $NaCl_{(s)}$ is sodium chloride.

5. Most transition metals and some representative metals can form more than one kind of ion. Metals that can have more than one valence, or charge, are classified as multivalent. For example, iron can form an Fe^{2+} ion or an Fe^{3+} ion.
6. (a) CaF_2
   (b) Na_2S
   (c) AlN
   (d) $AlCl_3$
   (e) K_2O
   (f) $CaCl_2$
   (g) CuS
   (h) $PbBr_2$
   (i) AgI
   (j) Ba_3N_2
   (k) FeF_2
   (l) Hg_2O
   (m) $NiBr_2$
   (n) ZnO
   (o) $CoCl_3$
   (p) $SrBr_2$
   (q) AuF
   (r) LiCl
   (s) Sr_3N_2
   (t) $BaBr_2$
   (u) SnI_4
7. (a) sodium chloride
   (b) calcium oxide
   (c) calcium chloride
   (d) magnesium oxide
   (e) aluminum oxide
   (f) zinc sulfide
   (g) tin(IV) oxide
   (h) copper(I) sulfide
   (i) lead(IV) sulfide
   (j) iron(III) oxide
   (k) molybdenum oxide
   (l) silver sulfide
   (m) zinc oxide
8. (a) sodium oxide
   (b) tin(IV) chloride
   (c) zinc iodide
   (d) strontium chloride
   (e) aluminum bromide
   (f) lead(IV) chloride
   (g) nickel(III) oxide
   (h) silver sulfide
   (i) iron(II) chloride
   (j) potassium bromide
   (k) copper(II) iodide
   (l) nickel(II) sulfide
9. (a) SrO - strontium oxide
   (b) Na_2S - sodium sulfide
   (c) AgI - silver iodide
   (d) BaF_2 - barium fluoride
   (e) $CaBr_2$ - calcium bromide
   (f) LiCl - lithium chloride
10. (a) HgS
    (b) MoS_2
    (c) MnO_2
    (d) $NiBr_2$
    (e) $CuCl_2$
    (f) FeI_3
11. (a) iron(II) sulfide
    (b) lead(IV) bromide
    (c) tin(II) chloride

Reflecting

12. Because old systems die hard. For example, the *-ous* and *-ic* suffixes are still used extensively in industry.

PRACTICE

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Understanding Concepts

13. Tertiary compounds are composed of three different elements.
14. (a) Ionic compounds can be composed of a single ion and a polyatomic ion.
    (b) Some ionic compounds are composed of a single ion and a polyatomic ion that includes oxygen. A polyatomic ion that includes oxygen is called an oxyanion.
    (c) Ionic compounds that form crystals that contain molecules of water within the crystal structure are referred to as hydrates.
15. (a) sodium nitrate
    (b) sodium nitrite
    (c) copper(II) nitrate
    (d) copper(I) nitrate
    (e) aluminum sulfite
    (f) calcium hydroxide
    (g) lead(II) carbonate
    (h) tin(II) phosphate
    (i) iron(III) sulfate

16.	(a)	$CaCO_3$	(f)	$(NH_4)_3PO_4$
	(b)	$NaHCO_3$	(g)	$CuSO_4$
	(c)	$NaClO$	(h)	$NaOH$
	(d)	$CaSO_4$	(i)	$KmNO_4$
	(e)	NH_4NO_3		
17.	(a)	lithium chlorate	(n)	silver sulfate
	(b)	barium sulfate	(o)	mercury(II) bromate
	(c)	mercury(I) carbonate	(p)	iron(III) carbonate
	(d)	magnesium nitrate	(q)	ammonium hypochlorate
	(e)	iron(III) bromate	(r)	gold(III) nitrate
	(f)	sodium phosphate	(s)	magnesium bromate
	(g)	ammonium iodate	(t)	sodium iodate
	(h)	gold(I) acetate	(u)	zinc chlorite
	(i)	zinc phosphate	(v)	tin(II) carbonate
	(j)	antimony(V) chlorate	(w)	strontium sulfite
	(k)	manganese(II) sulfite	(x)	nickel(III) phosphate
	(l)	potassium hypobromite	(y)	copper(II) acetate
	(m)	aluminum perphosphate	(z)	barium perphosphate
18.	(a)	copper(I) hypophosphite		$CuPO_2$
	(b)	tin(IV) chlorite		$Sn(ClO_2)_4$
	(c)	iron(II) bromate		$Fe(BrO_3)_2$
	(d)	iron(III) chlorite		$Fe(ClO_2)_3$
	(e)	lead(IV) sulfate		$Pb(SO_4)_2$
19.	(a)	copper(II) pentahydrate		
	(b)	sodium sulfate decahydrate		
	(c)	magnesium sulfate heptahydrate		
20.	(a)	$Fe_2O_3 \cdot 3\ H_2O$	(d)	$Cd(NO_3)_2 \cdot 4\ H_2O$
	(b)	$AlCl_3 \cdot 6\ H_2O$	(e)	$LiCl \cdot 4\ H_2O$
	(c)	$NaS_2O_3 \cdot 5\ H_2O$	(f)	$CaCl_2 \cdot 2\ H_2O$

21. When heat is applied to a hydrate, it will decompose to produce water vapour and an associated ionic compound. When this water, called *water of hydration*, is removed, the product is referred to as *anhydrous*.

PRACTICE

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Understanding Concepts

22.	(a)	N_2	(n)	SF_4
	(b)	CO_2	(o)	PCl_5
	(c)	CO	(p)	S_2Cl_2
	(d)	NO_2	(q)	CCl_4
	(e)	NO	(r)	SO_3
	(f)	N_2O	(s)	SF_6
	(g)	N_2O_4	(t)	ClO_2
	(h)	SO_2	(u)	N_2O_5
	(i)	I_2O_5	(v)	PCl_3
	(j)	SiF_4	(w)	$SiCl_4$
	(k)	BF_3	(x)	CS_2
	(l)	PI_3	(y)	PBr_5
	(m)	P_2O_5	(z)	CF_4
23.	(a)	sulfur hexafluoride	(f)	iodine heptafluoride
	(b)	dinitrogen trioxide	(g)	boron trifluoride
	(c)	nitrogen dioxide	(h)	diphosphorus pentasulfide
	(d)	phosphorus trichloride	(i)	diphosphorus pentoxide
	(e)	phosphorus pentachloride		

PRACTICE

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Understanding Concepts

24. (a) $HCl_{(aq)}$
    (b) $HCl_{(aq)}$
    (c) $H_2SO_{4(aq)}$
    (d) $H_2SO_{4(aq)}$
    (e) $HC_2H_3O_{2(aq)}$
    (f) $HC_2H_3O_{2(aq)}$
    (g) $HNO_{2(aq)}$
    (h) $HNO_{3(aq)}$
    (i) $HBr_{(aq)}$
    (j) $H_2SO_{2(aq)}$
    (k) $HI_{(aq)}$
    (l) $HClO_{4(aq)}$

25.

	Classical	IUPAC
(a)	sulfurous acid	aqueous hydrogen sulfite
(b)	phosphoric acid	aqueous hydrogen phosphate
(c)	hydrocyanic acid	aqueous hydrogen cyanide
(d)	carbonic acid	aqueous hydrogen carbonate
(e)	hydrosulfuric acid	aqueous hydrogen sulfide
(f)	hydrochloric acid	aqueous hydrogen chloride
(g)	hydrocyanic acid	aqueous hydrogen cyanide
(h)	sulfuric acid	aqueous hydrogen sulfate
(i)	phosphoric acid	aqueous hydrogen phosphate

26. (a) potassium hydroxide
    (b) calcium hydroxide
27. (a) $Mg(OH)_{2(aq)}$
    (b) $NaOH_{(aq)}$
    (c) $Al(OH)_{3(aq)}$

SECTION 2.5 QUESTIONS

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Understanding Concepts

1. (a) NH_3, HCN
   (b) Ammonia and hydrogen cyanide are classified as covalent molecules.
   (c) Hydrogen cyanide is a polar covalent molecule that ionizes in water to form H^+, and CN^-. The ionic nature of the compound could be verified by dissolving the substance in water and testing for electrical conductivity. The covalent nature of the compound could be verified by calculating the electronegativity difference between H and C, and between C and N — the differences are not greater than 1.7.
   (d) If hydrogen cyanide is added to water, aqueous hydrogen cyanide, also known as hydrocyanic acid, is formed. The substance might cause blue litmus paper to turn red, indicating an acidic solution. (Actually, hydrocyanic acid is a very weak acid and may not turn blue litmus paper red.)
2. (a) KOH is an ionic hydroxide, and its aqueous solution is a base. The bond consists of a K^+ ion, and an OH^- ion. Chemists have discovered that all aqueous solutions of ionic hydroxides are bases. HCl as a gas is covalent, and its aqueous solution is an acid. The bond consists of an unequal sharing of a pair of electrons. When dissolved in water, the resulting aqueous solution displays a set of specific properties called acidic.
   (b) $[K]^+ \; [:\ddot{\underset{\cdot\cdot}{O}} - H]^- \rightarrow K\,OH$

   $H - \ddot{\underset{\cdot\cdot}{Cl}}: \rightarrow H - Cl$

   (c) aqueous potassium hydroxide, aqueous hydrogen chloride
   (d) Bases are reactive — for example, bases react with proteins to break them down into smaller molecules. Precautions must be taken when handling bases. Acids are reactive and can combine with many other substances. Acids must be treated with care, as they can be very corrosive and can cause serious damage to the environment.
3. The student is to write the IUPAC names and formulas for as many compounds as possible, using only the following elements: K, C, H, F, Mg, O, Cl, and Na.
   Use K as an example:
   (a) KCl, KOH, $KClO_3$

(b) KCl — potassium chloride, KOH — potassium hydroxide, $KClO_3$ — potassium chlorate.
(c) KCl — ionic, KOH — ionic, $KClO_3$ — ionic.

$[K]^+ \ [:Cl:]^- \rightarrow KCl$

$[K]^+ \ [:O — H]^- \rightarrow K\,OH$

$[K]^+ \ [:O — Cl(—:O:) — O:] \rightarrow K\,ClO_3$

(d) KCl — binary, KOH — tertiary and basic, $KClO_3$ — tertiary.
(e) KCl — ionic bonds only, KOH — ionic and covalent bonds, $KClO_3$ — ionic and covalent bonds.

CHAPTER 2 SUMMARY

Make a Summary

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The examples of NaCl and H_2O are used in the table below. The student is to include as many examples of compounds as possible for each type of intramolecular bond.

Table 1: Summarizing Bonds and Forces

Compound	Properties	Electron dot diagram/ Lewis structure	Intramolecular bond type	Polarity	Intermolecular forces
NaCl	Solid at SATP, hard and brittle, high melting point, its solution conducts electricity.	$[Na]^+ [Cl]^-$ $[Na]^+ [:Cl:]^-$	Ionic	Ionic	Locked in a regular structure, held by the balance of attractive bonds and electrical repulsion.
H_2O	Liquid at SATP, low boiling point.	H–O–H H — O — H or H–O$^{\delta-}$–H (δ^+)	Covalent	Polar	Hydrogen bonds.

Reflect on your Learning

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By the end of the chapter the student should have developed a more in-depth understanding of why atoms form compounds, an awareness of the many different compounds that are possible, the types of forces present between atoms in compounds, and how the forces that hold atoms together in a compound determine the chemical properties of the compound.

CHAPTER 2 REVIEW

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Understanding Concepts

1. When elements that are found in the "metals" position in the periodic table react with elements that are found in the "nonmetals" position in the periodic table, they form ionic compounds that have ionic bonds. When elements that are found in the "nonmetals" position in the periodic table react with elements also found in the "nonmetals" position in the periodic table, they form molecular compounds that have covalent bonds.

2. An ionic bond occurs when one or more valence electrons are transferred from a metal atom to a nonmetal atom. This leaves the metal atom as a positive ion, or cation, and the nonmetal atom as a negative ion, or anion. An ionic bond is the electrostatic attraction between positive and negative ions in a compound.

   A covalent bond arises from the simultaneous attraction of two nuclei for a shared pair of electrons. The result is a covalent bond — a shared pair of electrons held between two nonmetal atoms that hold the atoms together in a molecule.

3. (a) The properties of ionic compounds: Are solid at SATP, with hard surfaces, are brittle, have high melting points, and form solutions that conduct electricity. The properties are due to the strong ionic bonds, simultaneous forces of attraction between the positive and negative ions, which hold the ions firmly in a rigid structure. The solid state, hardness, brittleness, and the high melting point result from the strong attractions, which occur in the crystal structure. And because the ionic bonds break down in water, the resulting ions are free to move in solution and conduct electricity.

   The properties of molecular compounds: May be solids, liquids, or gases at SATP, and are soft, waxy, or flexible. Covalent bonds between the atoms are strong. However, the intermolecular forces in molecular compounds are weaker in comparison — adding a relatively small amount of heat will cause a solid molecular compound to change state from a solid to a liquid, and then to a gas.

   (b) Ionic compounds (many of which dissolve readily in water) form solutions that conduct electricity. Because the ionic bonds often break down in water, the resulting ions are free to move in solution and conduct electricity. Molecular compounds form solutions that do not generally conduct electricity.

4. (a) Intramolecular bonding is the force that bonds atoms and ions together in a compound. One main type of intramolecular bonding is ionic bonding. An example of ionic bonding is the electrostatic attraction that occurs between the $[Na]^+$ cation and the $[Cl]^-$ anion to form the ionic compound NaCl. Another main type of intramolecular bonding is covalent bonding. An example of covalent bonding is the sharing of a pair of electrons that occurs between hydrogen and chlorine to form the molecular compound HCl.

   (b) Ionic bonding results in compounds that are solid at SATP with hard surfaces, are brittle, have high melting points, and form solutions that conduct electricity. Covalent bonding results in compounds that may be solids, liquids, or gases at SATP, and are soft, waxy, or flexible. Covalently bonded compounds form solutions that do not generally conduct electricity.

5. (a) two nonmetal atoms that are sharing a pair of electrons
   (b) oppositely charged ends of polar molecules
   (c) a positive hydrogen atom of one molecule and a highly electronegative atom (F, O, or N) in another molecule
   (d) a positively charged ion (cation) of a metal and a negatively charged ion (anion) of a nonmetal

6. The chemical formulas of ionic compounds consist of a metal joined to a nonmetal. Examples are NaCl, $CuSO_4$, and $NaHCO_3$. The chemical formulas of molecular compounds consist of nonmetals combined with other nonmetals. Examples are SO_2, CO_2, and NH_3.

7. Halogens tend to form diatomic molecules because they have only one bonding electron, and thus a capacity to bond with only one other atom.

8. Students will reproduce the bonding continuum of Figure 3 on p. 84. Cl_2, with difference in electronegativities of 0, will be placed at the far right (covelent). NaCl, with an electronegativity difference of 2.1, should be placed left of centre, in the "ionic" area. Na–Cl involves an electron transfer, resulting in the formation of cations and anions that are attracted to each other. Cl–Cl involves equal sharing of a pair of electrons.

9. (a) Ca $\cdot\mathrm{Ca}\cdot$
   (b) Al $\cdot\dot{\mathrm{Al}}\cdot$
   (c) K $\mathrm{K}\cdot$
   (d) N $\cdot\underset{\cdot}{\ddot{\mathrm{N}}}\cdot$
   (e) S $:\underset{\cdot}{\ddot{\mathrm{S}}}\cdot$
   (f) Br $:\underset{\cdot}{\ddot{\mathrm{Br}}}\cdot$
   (g) Ne $:\underset{\cdot\cdot}{\ddot{\mathrm{Ne}}}:$

10. (a) covalent
    (b) polar covalent
    (c) polar covalent
    (d) ionic
    (e) ionic
    (f) ionic

11. (a) $Na_2O_{(s)}$ is ionic, $MgO_{(s)}$ is ionic, $Al_2O_{3(s)}$ is ionic, $SiO_{2(s)}$ is molecular, $P_2O_{5(s)}$ is molecular, $SO_{2(g)}$ is molecular, and $Cl_2O_{(g)}$ is molecular.