

Atomic Theory and Bonding

Textbook pages 168–183

Before You Read

What do you already know about Bohr diagrams? Record your answer in the lines below.

What are atoms?

An **atom** is the smallest particle of any element that retains the properties of the element.

The particles that make up an atom are called **subatomic particles**. Atoms are composed of three subatomic particles: protons, neutrons, and electrons. ✓

Name	Symbol	Electric Charge	Location in the Atom	Relative Mass
Proton	p	1+	Nucleus	1836
Neutron	n	0	Nucleus	1837
Electron	e	1–	Surrounding the nucleus	1

Nuclear charge is the electric charge on the nucleus. This charge is always positive, since the protons have a positive charge and the neutrons are not charged. **Atomic number** is the number of protons. The nuclear charge or atomic number is given in the top left hand corner of the element box for each element in the periodic table.

Atomic Number	→	22	4+	← Ion charge(s)
Symbol	→	Ti	3+	
Name	→	Titanium		
Atomic Mass	→	47.9		

How does the periodic table provide information about elements?

In the periodic table, each element is listed according to its atomic number. Each row is called a **period**. Each column

Mark the Text

Identify Definitions

Highlight the definition of each word that appears in bold type.

✓ Reading Check

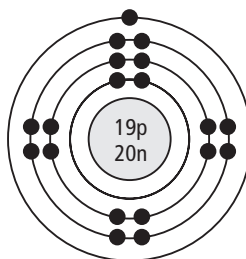
Which has a positive electric charge, a proton, a neutron, or an electron?

continued

is called a **group** or **family**. Metals are on the left side and in the middle of the table. Non-metals are in the upper right corner. The metalloids form a staircase toward the right side. The block of elements from groups 3 through 12 are the transition metals. Elements in the same chemical group or family have similar chemical properties. For example, group 17 contains very reactive non-metals known as halogens (i.e., fluorine, chlorine, bromine, etc.) Group 18 contains the non-reactive noble gases.

How do Bohr diagrams represent atoms?

A **Bohr diagram** shows the arrangement of subatomic particles in atoms and ions. Electrons are organized in “shells”. The first shell holds a maximum of two electrons; the second shell a maximum of eight. When this shell is filled, it is called a **stable octet**. The outermost shell containing electrons is called the **valence shell**. The electrons in this shell are called **valence electrons**. These electrons are involved in chemical bonding. When an atom forms a compound, it acquires a full valence shell of electrons and achieves a stable, low energy state. On the periodic table, elements in Group 1 have 1 electron in their valence shell, elements in Group 2 have 2 (a **lone pair**), elements in Group 3 have 3, and so on.



The Bohr diagram for a potassium atom

What are ionic and covalent compounds?

There are two basic types of compounds: ionic and covalent.

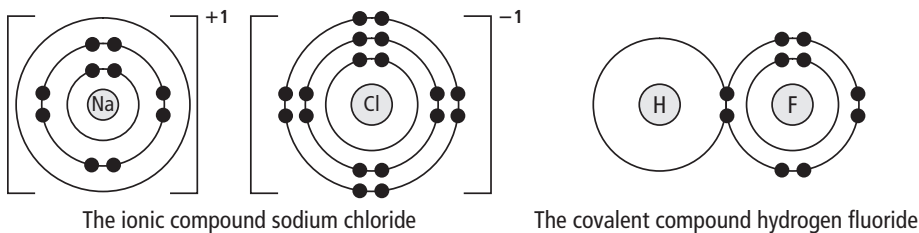
1. **Ionic compounds:** When atoms gain or lose electrons, they become electrically charged particles called **ions**. An ionic compound contains a positive ion (usually a metal) and a negative ion (usually a non-metal). In **ionic bonding**, one or more electrons transfer from each atom of the metal

to each atom of the non-metal. The metal atoms lose electrons, forming **cations**. For example, aluminum forms a 3^+ cation as a result of losing three electrons. Some metals are **multivalent** and can form ions in several ways, depending on the chemical reaction they undergo. For example, iron is multivalent because it can lose two or three electrons to become a Fe^{2+} or Fe^{3+} ion. The non-metal atoms gain electrons, forming **anions**. Chlorine gains one electron and forms a 1^- anion.

The common ions are sometimes shown in the upper right-hand corner of the element's box in the periodic table. For a multivalent metal, the most common charge is listed first.

26	3^+
Fe	2^+
Iron	
55.8	

2. Covalent compounds: In **covalent bonding**, the atoms of a non-metal share electrons with other non-metal atoms. An unpaired electron from each atom will pair together, forming a **covalent bond**. These two electrons are sometimes called a **bonding pair**.



What is a Lewis diagram?

A **Lewis diagram** illustrates chemical bonding by showing only an atom's valence electrons and its chemical symbol. Lewis diagrams can be used to represent elements, ions, and compounds. ✓



✓ Reading Check

What is a Lewis diagram?

Periodic Table of the Elements

1 1 H Hydrogen 1.0	2 2 He Helium 4.0	NON-METALS								17 9 F Fluorine 19.0	18 10 Ne Neon 20.2										
		13 5 B Boron 10.8	14 6 C Carbon 12.0	15 7 N Nitrogen 14.0	16 8 O Oxygen 16.0	17 17 Cl Chlorine 35.5					18 18 Ar Argon 39.9										
		13 13 Al Aluminum 27.0	14 14 Si Silicon 28.1	15 15 P Phosphorus 31.0	16 16 S Sulphur 32.1					18 35 Br Bromine 79.9											
		13 31 Ga Gallium 69.7	14 32 Ge Germanium 72.6	15 33 As Arsenic 74.9	16 34 Se Selenium 79.0					18 83 Kr Krypton 83.8											
		13 49 In Indium 114.8	14 50 Sn Tin 118.7	15 51 Sb Antimony 121.8	16 52 Te Tellurium 127.6					18 86 Xe Xenon 131.3											
		13 81 Tl Thallium 204.4	14 82 Pb Lead 207.2	15 83 Bi Bismuth 209.0	16 84 Po Polonium (209)					18 85 At Astatine (210)											
		13 113 Uut Ununtrium (284)	14 114 Uuq Ununquadium (289)	15 115 Uup Ununpentium (288)	16 116 Uuh Ununhexium (292)					18 117 Uus Ununseptium (?)											
METALS ←											→										
		11 29 Cu Copper 63.5	12 30 Zn Zinc 65.4	13 47 Ag Silver 107.9	14 48 Cd Cadmium 112.4					18 126 Te Tellurium 127.6											
		11 79 Au Gold 197.0	12 80 Hg Mercury 200.6	13 78 Pt Platinum 195.1	14 77 Ir Iridium 192.2					18 126 Xe Xenon 131.3											
		11 111 Rg Roentgenium (272)	12 112 Uub Ununbium (285)	13 109 Mt Meitnerium (266)	14 108 Hs Hassium (265)					18 126 Xe Xenon 131.3											
		11 64 Gd Gadolinium 157.3	12 65 Tb Terbium 158.9	13 62 Sm Samarium 150.4	14 63 Eu Europium 152.0					18 126 Xe Xenon 131.3											
		11 96 Cm Curium (247)	12 97 Bk Berkelium (247)	13 94 Pu Plutonium (244)	14 95 Am Americium (243)					18 126 Xe Xenon 131.3											
		11 61 Pm Promethium (145)	12 60 Nd Neodymium 144.2	13 62 Sm Samarium 150.4	14 63 Eu Europium 152.0					18 126 Xe Xenon 131.3											
		11 93 Np Neptunium (237)	12 92 U Uranium 238.0	13 94 Pu Plutonium (244)	14 95 Am Americium (243)					18 126 Xe Xenon 131.3											
		11 58 Ce Cerium 140.1	12 59 Pr Praseodymium 140.9	13 62 Sm Samarium 150.4	14 63 Eu Europium 152.0					18 126 Xe Xenon 131.3											
		11 90 Th Thorium 232.0	12 91 Pa Protactinium 231.0	13 94 Pu Plutonium (244)	14 95 Am Americium (243)					18 126 Xe Xenon 131.3											
		11 88 Ra Radium (226)	12 89 Ac Actinium (227)	13 81 Tl Thallium (204.4)	14 82 Pb Lead (207.2)					18 86 Xe Xenon 131.3											

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Alkali Metals

Alkaline Earth Metals

Halogens

Noble Gases

Atomic Number → 22 4+ ←
 Symbol → **Ti** ← Ion charge(s)
 Name → Titanium
 Atomic Mass → 47.9

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.

Use with textbook pages 168–180.

The atom and the subatomic particles

1. Use the following vocabulary words to label the diagram.

Vocabulary	
common ion charge	symbol
other ion charge	atomic number
name	average atomic mass

(a) _____	22	4+	(e) _____
(b) _____	Ti	3+	(f) _____
(c) _____	Titanium		
(d) _____	47.9		

2. Examine the periodic table for the element below and complete the blanks.

35	—
Br	
Bromine	
79.9	

- (a) atomic number _____ (b) average atomic mass _____
 (c) ion charge _____ (d) number of protons _____
 (e) name of element _____ (f) number of neutrons _____

3. Complete the following table for the different atoms and ions. The first two rows have been completed to help you.

Element Name	Atomic Number	Ion Charge	Number of Protons	Number of Electrons	Number of Neutrons
potassium	19	1+	19	18	20
phosphorus	15	0	15	15	16
	3	0			
		2+	20		
nitrogen		3-			
	5	0			
argon				18	
	13			10	
chlorine		0			
			11	10	

Use with textbook pages 174–177.

Bohr diagrams

1. Define the following terms:

- (a) Bohr diagram _____
- (b) stable octet _____
- (c) valence shell _____
- (d) valence electrons _____

2. Complete the following table.

Atom/ion	Atomic Number	Number of Protons	Number of Electrons	Number of Neutrons	Number of Electron Shells
neon atom					
fluorine atom					
fluorine ion					
sodium atom					
sodium ion					

3. Use the table above to draw the Bohr model diagram for each of the following atoms and ions.

neon atom	fluorine atom	fluorine ion	sodium atom	sodium ion

4. Draw the Bohr model diagram for each of the following compounds.

carbon dioxide (CO ₂)	ammonia (NH ₃)	calcium chloride (CaCl ₂)

Name _____

Date _____

Use with textbook pages 176–180.

Lewis diagrams

1. Define the following terms:

(a) Lewis diagram

(b) lone pair _____

(c) bonding pair _____

2. Draw Lewis diagrams for each of the following elements.

(a) boron

(b) nitrogen

(c) aluminium

(d) chlorine

3. Draw Lewis diagrams for each of the following ionic compounds.

(a) sodium oxide

(b) potassium chloride

(c) magnesium bromide

4. Draw Lewis diagrams for each of the following covalent compounds.

(a) carbon dioxide, CO_2 (b) phosphorus trifluoride, PF_3 (c) silicon tetrachloride, SiCl_4

5. Draw Lewis diagrams for each of the following diatomic molecules.

(a) chlorine, Cl_2

(b) nitrogen, N_2

(c) hydrogen, H_2

Use with textbook pages 168–180.

Atomic theory and bonding

Match the Term on the left with the best Descriptor on the right. Each Descriptor may be used only once.

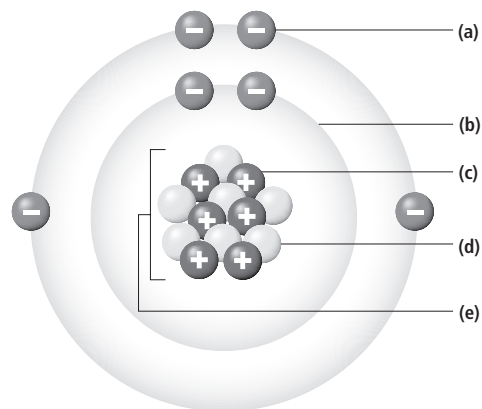
Term	Descriptor
1. _____ shell	A. a horizontal row on the periodic table
2. _____ period	B. a vertical column on the periodic table
3. _____ family	C. an area around the nucleus where electrons exist
4. _____ ionic bonding	D. chemical bonding that results from a sharing of valence electrons
5. _____ covalent bonding	E. chemical bonding that results when one or more electrons transfers from each atom of a metal to each atom of a non-metal

6. Which of the following is the smallest particle of an element that can exist by itself?
- A.** ion
B. atom
C. molecule
D. compound
7. Which of the following correctly matches the subatomic particle with its charge and location in an atom?

	Subatomic Particle	Location	Charge
A.	proton	nucleus	neutral
B.	neutron	nucleus	positive
C.	electron	shell	positive
D.	electron	shell	negative

8. Which of the following are responsible for bonding?
- A.** nuclei
B. protons
C. neutrons
D. electrons

Use the following diagram of an atom to answer questions 9 to 11.



9. Which labelled part in the diagram represents a neutron?
- A.** (a)
B. (b)
C. (c)
D. (d)
10. What is the number of subatomic particle (c) equivalent to?
- A.** atomic number
B. mass number – atomic number
C. mass number + atomic number
D. number of electrons + number of protons
11. How many valence electrons are there in this atom?
- A.** 2
B. 4
C. 6
D. 7

Name _____

Date _____

12. Which of the following describes structure (e)?

	CHARGE	SUBATOMIC PARTICLE(S) PRESENT
A.	neutral	electrons and neutrons
B.	positive	protons and neutrons
C.	positive	protons and electrons
D.	negative	electrons

13. Which of the following describes a cation?

I.	examples include Ca^{2+} and Al^{3+}
II.	a metal atom that has lost electrons
III.	has equal numbers of electrons and protons

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II, and III

14. Which row of the table is completed correctly for an atom of potassium?

	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons
A.	19	39	19	20	19
B.	19	39	39	20	20
C.	19	39	20	20	19
D.	39	19	19	19	20

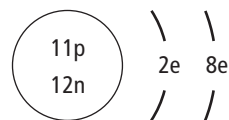
Use the following Lewis diagrams of four hypothetical elements to answer question 15.



15. Which of the hypothetical elements shown above represents a metal?

- A. Ma
- B. Di
- C. So
- D. Nh

Use the following Bohr model of an element to answer question 16.



16. Which of the following does the Bohr model represent?

- A. a neon atom
- B. a sodium ion
- C. a sodium atom
- D. a fluorine atom