These notes are posted on my site for the following reasons:

- for students to copy in their own hand-writing
  - in order to complete their class notes
  - if student did not have enough time in class
  - if student was away and missed this section
- for assistants and tutors to follow progress of the concepts taught

Photocopied/printed notes can not be used during the Unit Notebook Check in class.

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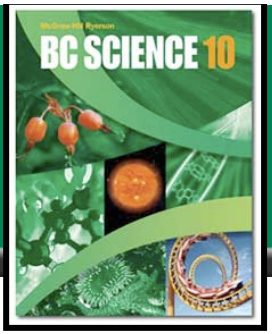
4.1 Atomic Theory and Bonding



- **An atom is the smallest particle of an element that still has the properties of that element**
  - **50 million atoms, lined up end-to-end = 1 cm**
  - **An atom = proton(s) + neutron(s) + electron(s)**

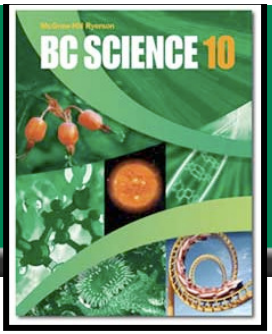
> ατομον
>
> The Greek root for the word atom, "atomon," means "that which cannot be divided." But the entities we call atoms are made from more fundamental particles!
>
> *Particle Data Group.*

- **Atoms join together to form compounds.**
  - **An element is a single molecule of a substance**
    - **The element, oxygen, is O. The oxygen molecules we breath are O_2**
  - **Compounds are also pure substances, but are made up of atoms**
  - **Oxygen and hydrogen are atoms/elements; H_2O is a compound**

- **A chemical change occurs when the arrangement of atoms in compounds change to form new compounds.**

See pages 168 - 169

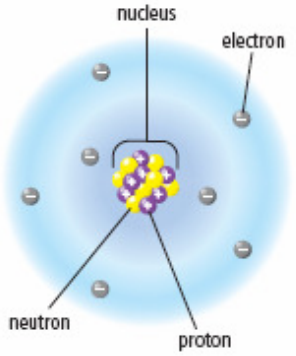
Atomic Theory



- Atoms are made up of smaller particles known as sub-atomic particles.

Name	Symbol	Charge	Location	Relative Mass
Proton	p	1+	nucleus	1836
Neutron	n	0	nucleus	1836
Electron	e	1–	area surrounding the nucleus	1

- The nucleus is at the center of an atom.
  - The nucleus is composed of protons and neutrons.
  - Electrons exist in the space surrounding the nucleus.
  - # of protons = # of electrons in every atom
  - Nuclear charge = charge on the nucleus = # of protons
  - Atomic number = # of protons = # of electrons



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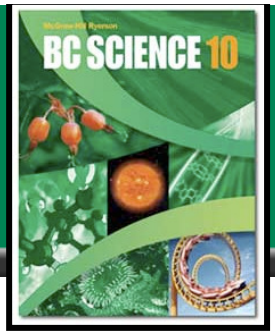
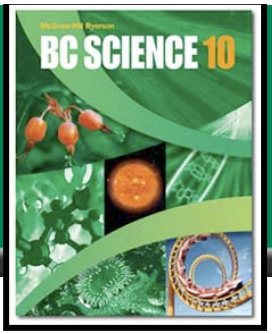
Organization of the Periodic Table



- **The periodic table organizes all known elements.**
  - Elements are listed in order by atomic number
  - Metals are on the left (the transition metals range from group 3 to group 12), non-metals are on the right, and the metalloids form a “staircase” in the middle.
  - Rows of elements (across) are called periods.
    - All elements in a period have their electrons in the same general area around their nucleus
  - Columns of elements are called groups, or families
    - All elements in a family have similar properties, and bond with other elements in similar ways
    - Group 1 = alkali metals
    - Group 2 = alkaline earth metals
    - Group 17 = the halogens
    - Group 18 = noble gases

See page 171

The Periodic Table



Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminum 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulphur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La Lantharum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium (?)	118 Uuo Ununoctium (294)

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Based on mass of C-12 at 12.00.

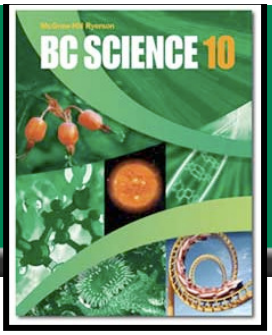
Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.

Where are the following?

- Atomic Number
- Period
- Group/Family
- Metals
- Non-metals
- Transition metals
- Metalloids
- Alkali metals
- Alkaline earth metals
- Halogens
- Noble gases

See page 172

Periodic Table and Ion Formation



- **Atoms gain and lose electrons to form bonds.**
  - **The atoms become electrically charged particles called ions.**
  - **Metals lose electrons and become positive ions (= cations)**
    - **Some metals (multivalent) lose electrons in different ways**
    - **ie. Iron, Fe, loses either 2 (Fe^{2+}) or 3 (Fe^{3+}) electrons**
  - **Non-metals gain electrons and become negative ions (= anions)**
  - **Atoms do this in an attempt to have the same number of valence electrons (electrons furthest from the nucleus) as the nearest noble gas.**

19 +	20 2+	21 3+
K	Ca	Sc
Potassium	Calcium	Scandium
39.1	40.1	45.0

~

25 2+ 3+ 4+	26 3+ 2+	27 2+ 3+
Mn	Fe	Co
Manganese	Iron	Cobalt
54.9	55.8	58.9

~

8 2–	9 –	10 0
O	F	Ne
Oxygen	Fluorine	Neon
16.0	19.0	20.2

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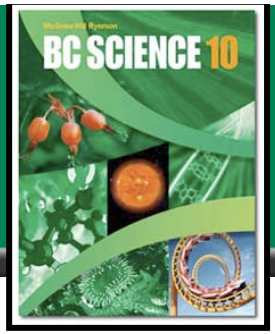
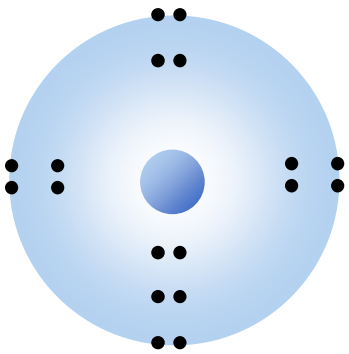
Bohr Diagrams

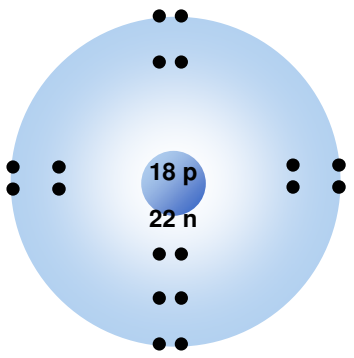


- **Bohr diagrams show how many electrons appear in each electron shell around an atom.**
  - **Each shell holds a maximum number of electrons**
  - **Electrons in the outermost shell are called valence electrons**
  - **Think of the shells as being 3D like spheres, not 2D like circles**



What element is this?

- It has 2 + 8 + 8 = 18 electrons, and therefore 18 protons
- It has 3 electron shells, so it is in period 3
- It has 8 electrons in the outer (valence) shell



Argon!

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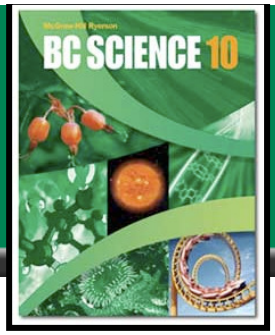
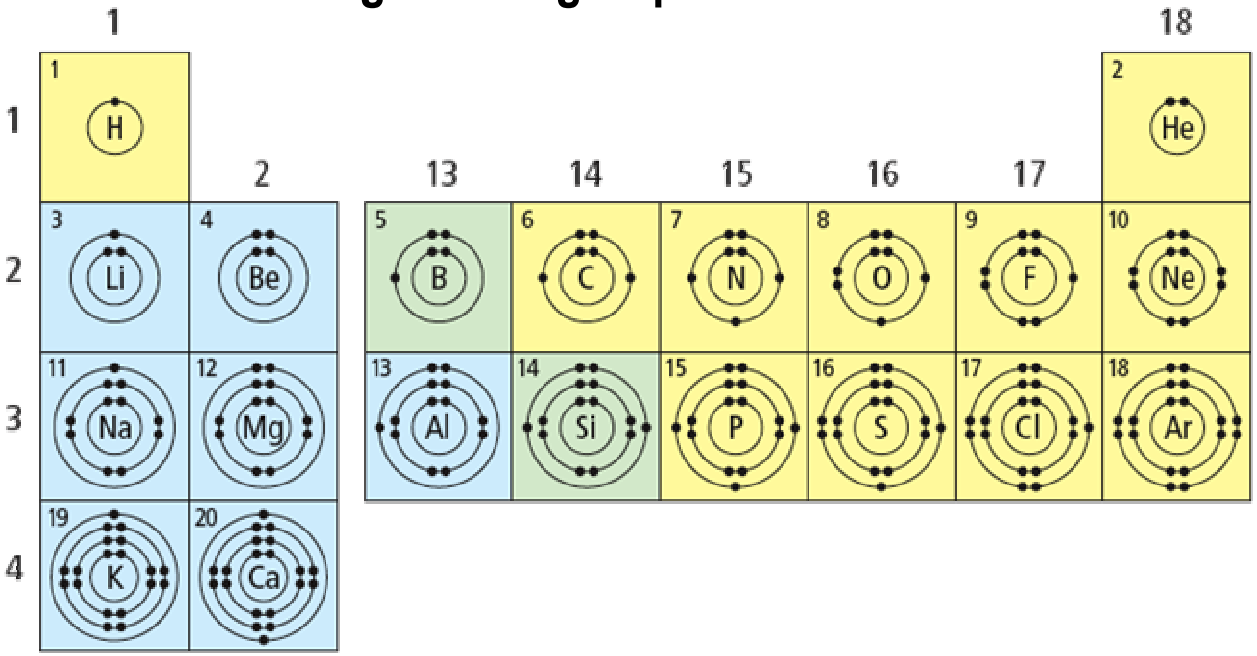
Patterns of Electron Arrangement in Periods and Groups



- Electrons appear in shells in a very predictable manner.
- There is a maximum of 2 electrons in the first shell, 8 in the 2nd shell, and 8 in the 3rd shell.
  - The period # = # of shells in the atom.
  - Except for the transition elements,

    the last digit of the group # = # of electrons in the valence shell



- The noble gas elements have full electron shells, and are very stable.

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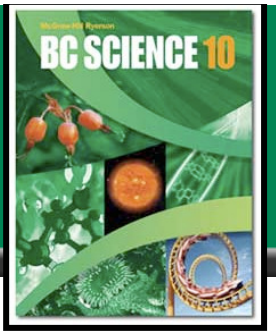
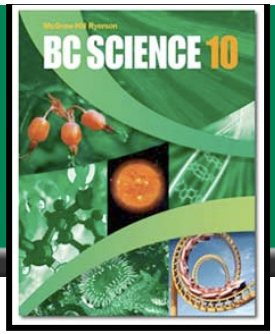
Forming Compounds



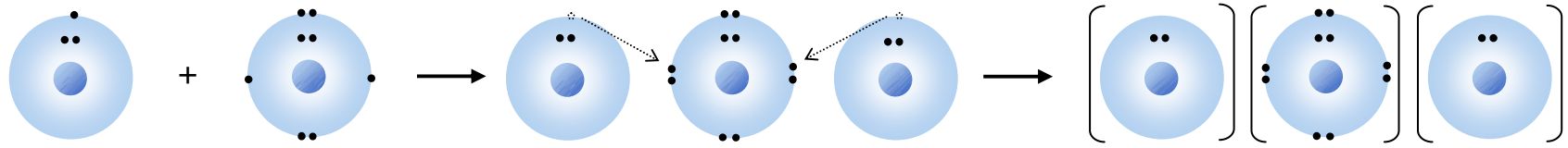
- When two atoms get close together, their valence electrons interact.
  - If the valence electrons can combine to form a low-energy bond, a compound is formed.
  - Each atom in the compound attempts to have the stable number of valence electrons as the nearest noble gas.
  - Metals may lose electrons and non-metals gain electrons, (ionic bond) OR
  - Atoms may share electrons (covalent bond)
- Ionic bonds form when electrons are transferred from cations to anions
  - Cations want to donate an electron (+) and anions want to accept more electrons (-)
- Covalent bonds form when electrons are shared between two non-metals
  - Electrons stay with their atom, but overlap with other shells

See pages 176 - 177

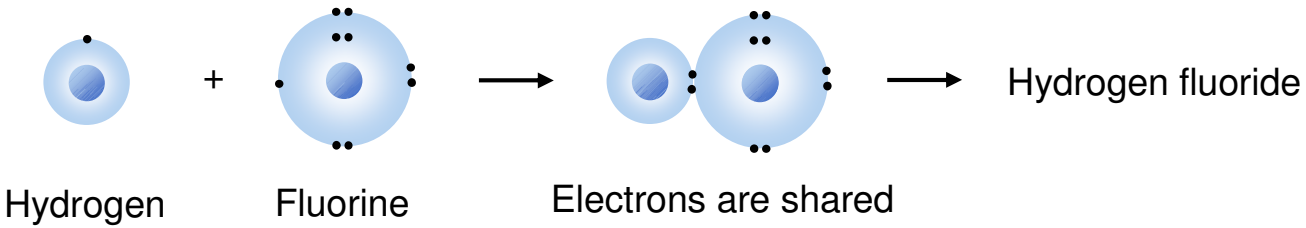
Forming Compounds (continued)



- **Ionic bonds**
  - Formed between cations (+ ions) and anions (- ions)
  - Generally, this is a metal (+) and a non-metal (-)
  - For example, lithium and oxygen form an ionic bond in the compound Li_2O



- **Covalent bonds**
  - Formed between two or more non-metals
  - Electrons are shared between atoms



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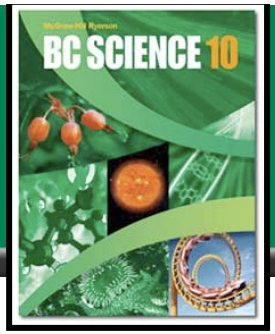
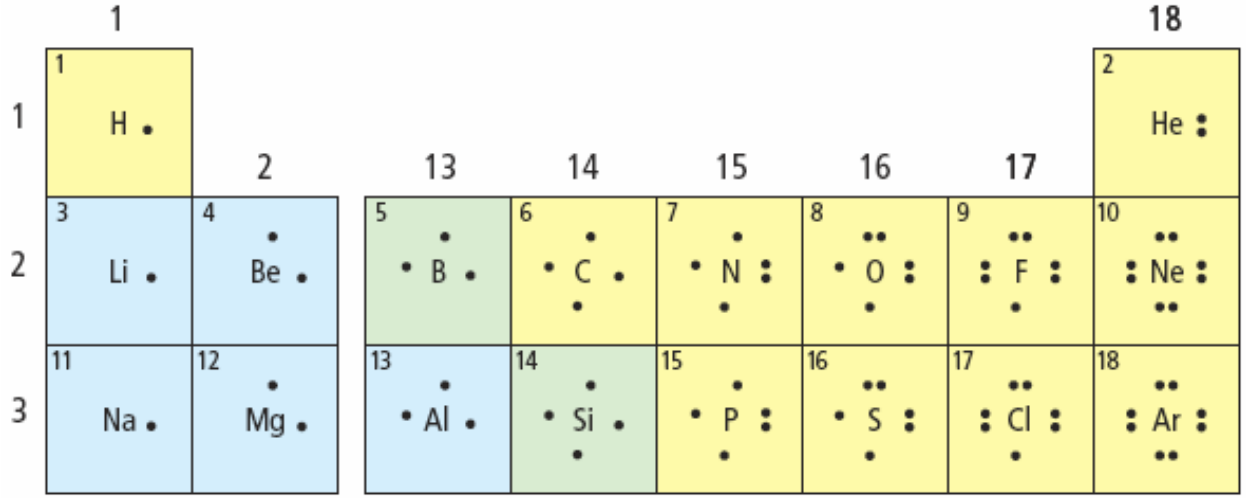
Lewis Diagrams



- **Bohr diagrams are very illustrative, but Lewis diagrams are very efficient when showing atoms and their bonding capabilities.**
  - **Only valence electrons are shown**
  - **Dots representing electrons are placed around the element symbols at the points of the compass (north, east, south, and west)**
  - **Electron dots are placed singly, until the fifth electron is reached, then they are paired.**



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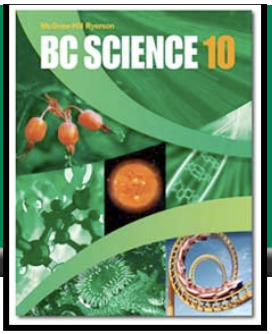
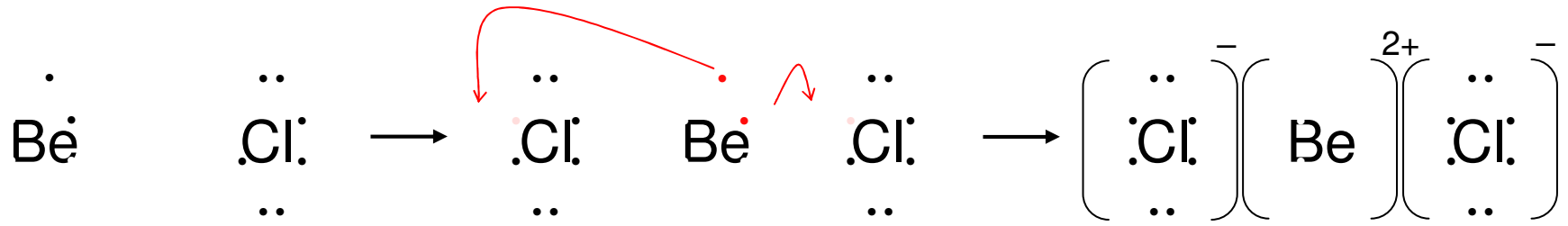
Lewis Diagrams of ions



- **Lewis diagrams make drawing ions, and ionic bonds much less work than Bohr diagrams.**
  - **For positive ions, one electron dot is removed from the valence shell for each positive charge of the ion.**
  - **For negative ions, one electron dot is added to each valence shell for each negative charge of the ion.**
  - **Square brackets are placed around each ion to indicate transfer of electrons**



Each beryllium has two electrons to transfer away, and each chlorine wants one more electron

Since Be^{2+} wants to donate 2 electrons and each Cl^- wants to accept only one, two Cl^- ions are necessary

Beryllium chloride

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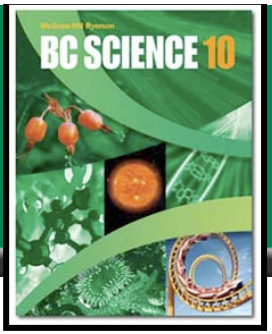
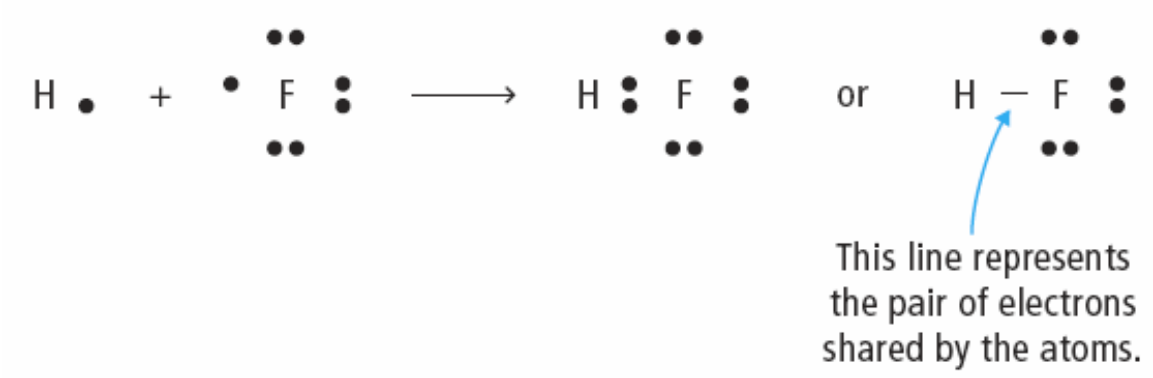
Lewis Diagrams of covalent bonds



- **Lewis diagrams of covalent bonds are also very easy.**
  - **Like Bohr diagrams, valence electrons are drawn to show sharing of electrons.**
  - **All atoms wish to have a full valence shell**
  - **The shared pairs of electrons are usually drawn as a straight line**



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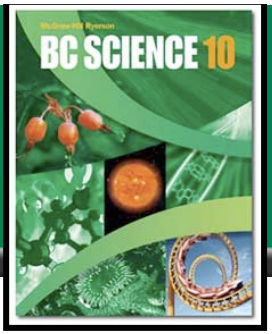
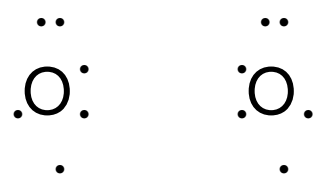
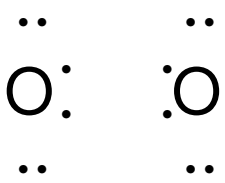
Lewis Diagrams of diatomic molecules



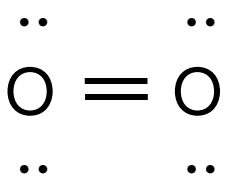
- **Diatomic molecules, like O_2, are also easy to draw in Lewis form**



Several non-metals join to form diatomic molecules



Valence electrons are shared, here in two pairs!



This is drawn as a double bond

Take the Section 4.1 Quiz

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