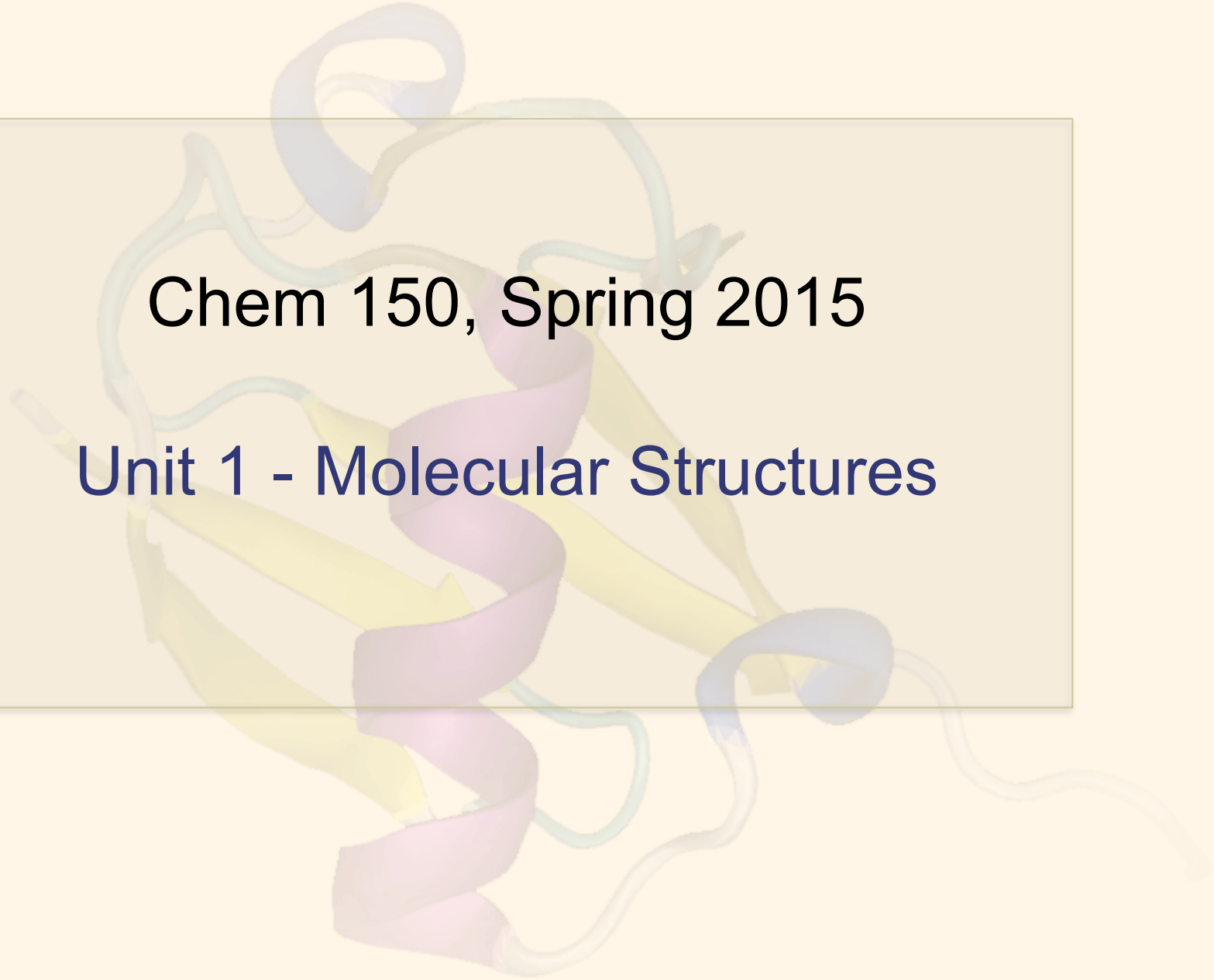
Chem 150, Spring 2015

Unit 1 - Molecular Structures

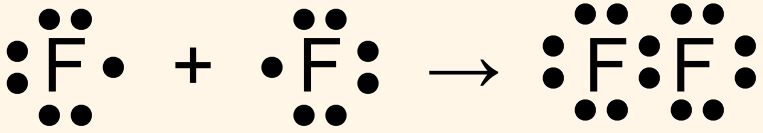


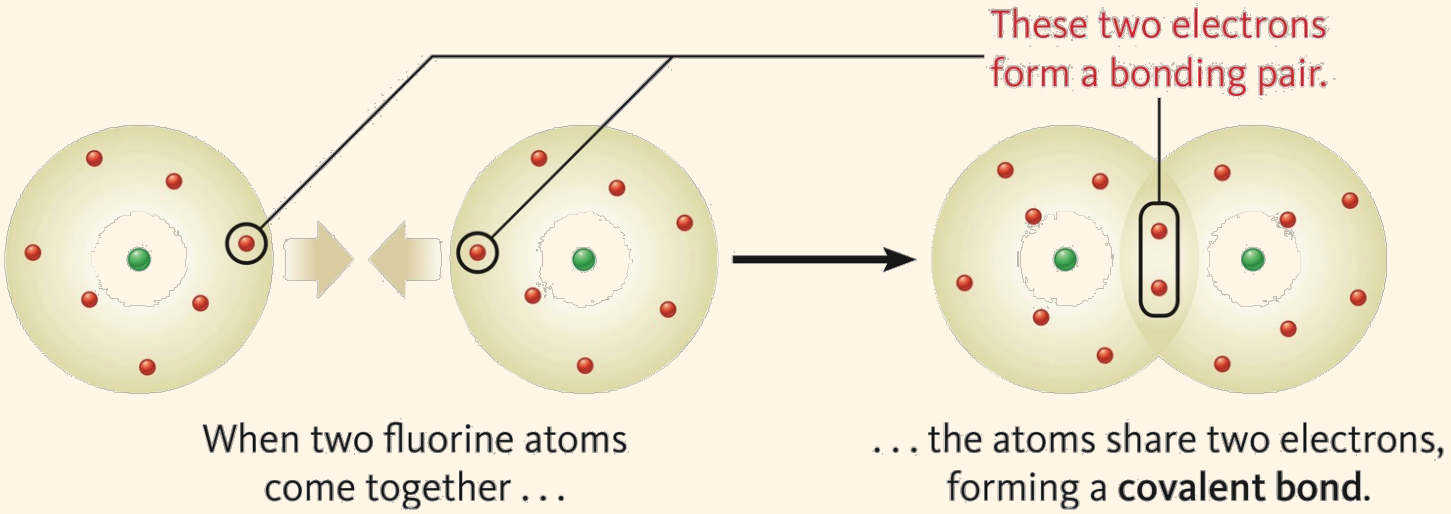
3.1 Covalent Bonds and the Octet Rule

- Group 8A elements are called Noble Gases and do not normally form chemical compounds. All of these elements also have a full valence shell, which leads to stability
- Representative elements tend to form compounds such that they fill their valence shells (octet rule).
- Known as the octet rule because this normally results in compounds in which each atom had 8 electrons in its most outer shell.

Lewis Structures and Molecules

- Fluorine has 7 valence electrons, and is found as F_2. In this form, both elements have a share in 8 electrons.
- Lewis structures can be used to represent these molecules.





Bonds

- A chemical bond occurs when two atoms are attracted enough to each other to stay together.
- A covalent bond occurs when electrons are shared between two atoms.
- A pair of shared electrons is known as a bonding electron pair.
- Lone pairs or non-bonding pairs of electrons are the electrons not involved in the covalent bond.

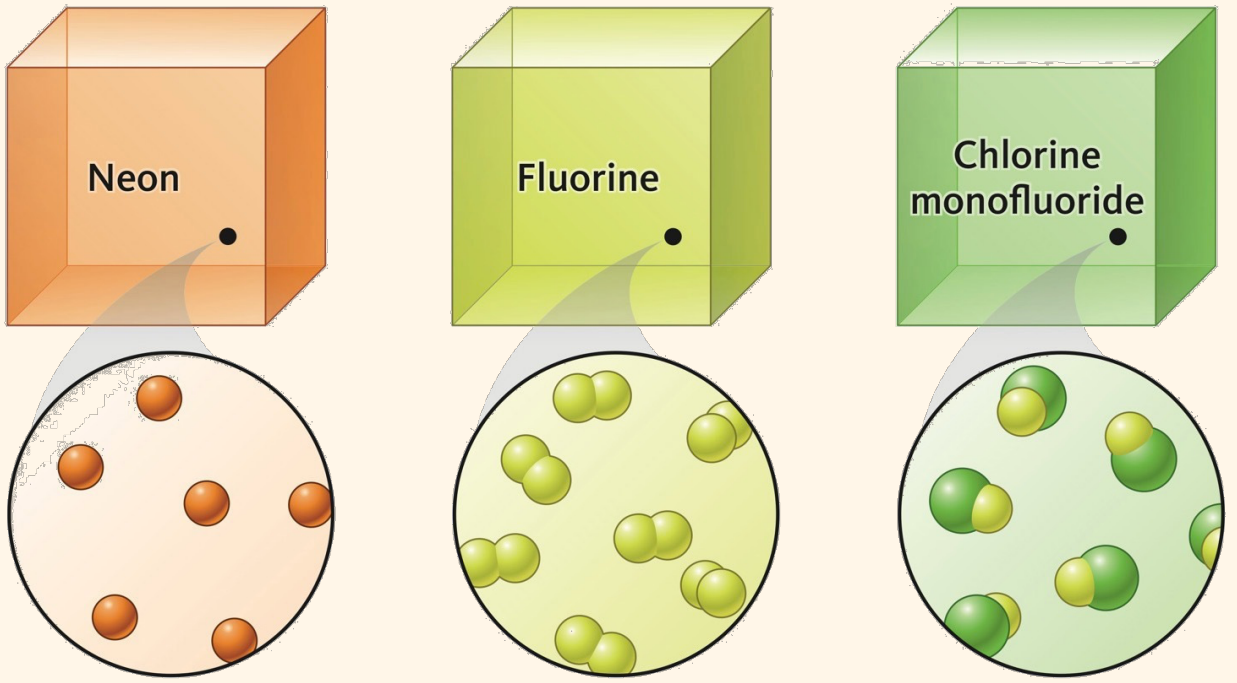
Try It!

Question:

Draw the Lewis dot structure for a molecule that contains one chlorine atom (Cl) and one fluorine (F) atom.

Atoms, Molecules and Compounds

- A group of two or more atoms (identical or different) is a molecule.
- A combination of two or more different elements is a compound.
- All compounds are molecules but not all molecules (like H_2, F_2, etc) are compounds.



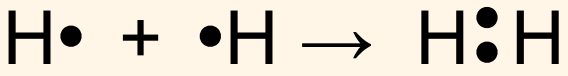
Neon is an **element**, and is made up of Ne **atoms**.

Fluorine is an **element**, and is made up of F_2 **molecules**.

Chlorine monofluoride is a **compound**, and is made up of ClF **molecules**.

Hydrogen

- Hydrogen atoms need only one electron to fill the valence shell to achieve the electron arrangement of Helium.



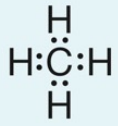
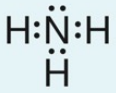
Try It!

Question:

Draw the Lewis dot structure for a molecule that contains one oxygen atom (O) and two hydrogen (H) atoms.

Covalent Bonds for All Representative Elements

TABLE 3.1 Covalent Bond Formation in Groups 4A Through 8A

	Group 4A	Group 5A	Group 6A	Group 7A	Group 8A
Number of Valence Electrons	4	5	6	7	8
Number of Empty Spaces in the Valence Shell	4	3	2	1	0
Number of Covalent Bonds Formed	4	3	2	1	0
Example of a Typical Molecule	 Methane	 Ammonia	 Water	 Hydrogen fluoride	These elements do not form molecules.

Elements with 5 or more empty spaces rarely form covalent bonds to fill their empty valence shell.

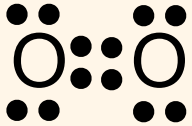
Try It!

Question:

Draw the Lewis dot structure for a molecule that contains two oxygen atoms (O).

3.2 Double and Triple Bonds

- One shared pair of electrons (2 total electrons) is a single bond.
- Double bonds form when atoms share two pairs of electrons (4 total electrons).



- Triple bonds form when atoms share three pairs of electrons (6 total electrons).
- Any atom that can form at least 2 bonds can form a double bond and any atom that can form at least 3 bonds can form a triple bond.

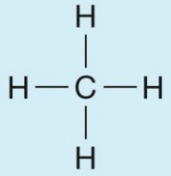
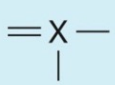
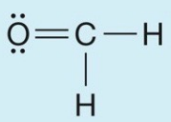
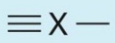
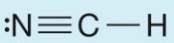
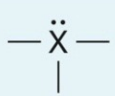
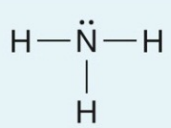
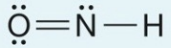
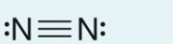
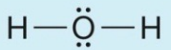
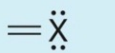
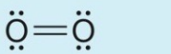
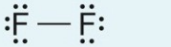
Try It!

Question:

Hydrogen cyanide is a deadly gas, which halts cellular respiration. Draw the Lewis dot structure for hydrogen cyanide.

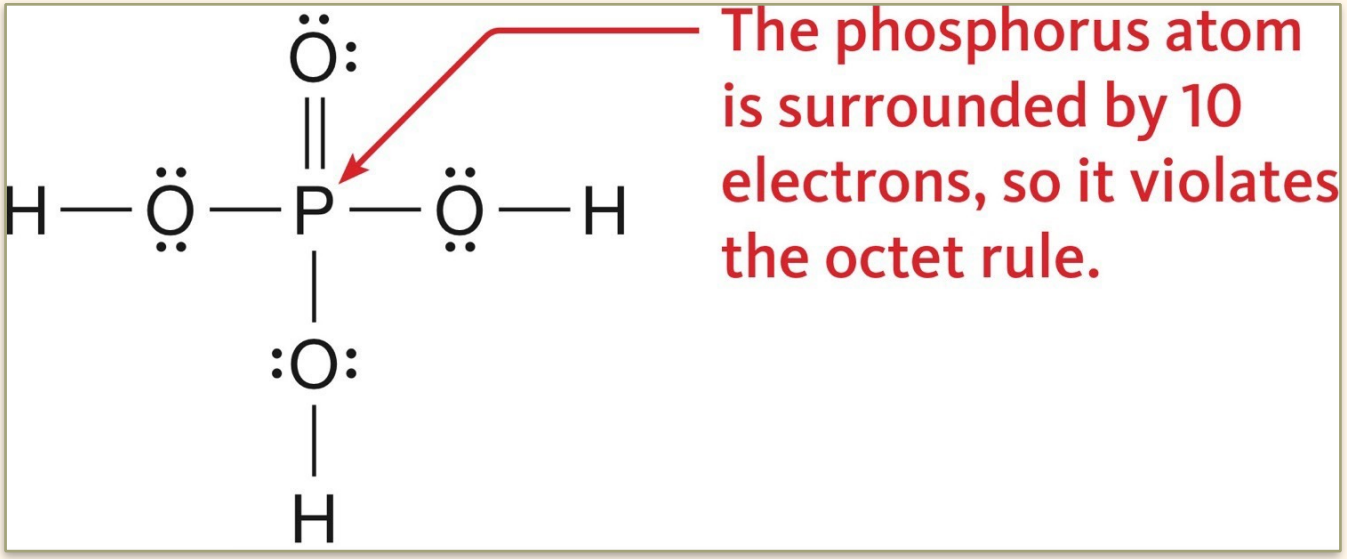
Bonding Patterns for Electrically Neutral Atoms

TABLE 3.2 Bonding Patterns for Electrically Neutral Atoms

Group Number	Normal Number of Covalent Bonds	Possible Bonding Patterns	Examples
4A	4		
			
			
5A	3		
			
			
6A	2		
			
7A	1		

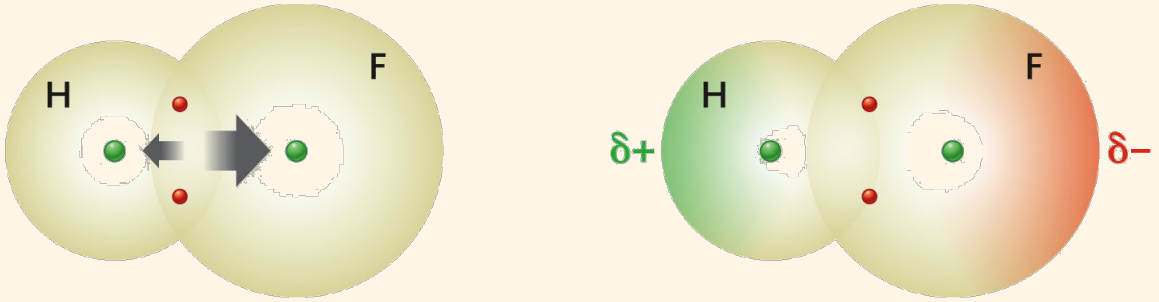
Bonding Patterns for Electrically Neutral Atoms

There are some exceptions, including non-metals in the third period and higher can violate the octet rule by sharing in more than 8 electrons.



3.3 Electronegativity and Polar Bonds

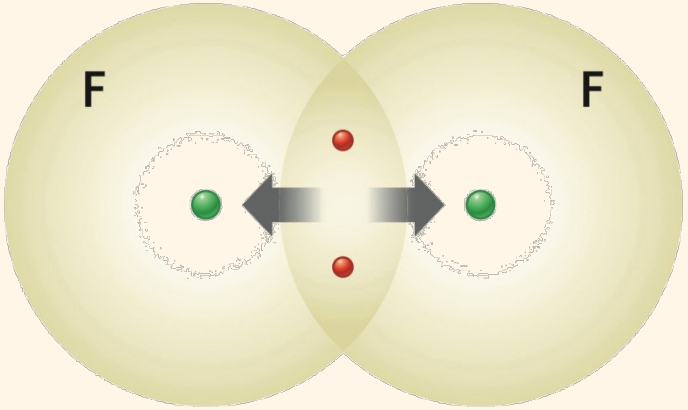
- Atoms of different elements can form polar covalent bonds.
  - Atoms of some elements are able to attract electrons in a bond stronger than others.
  - Polar bonds occur when electrons are shared unevenly.



Fluorine attracts the electrons more than hydrogen in HF, so fluorine is partially negative and hydrogen is partially positive.

Nonpolar Covalent Bonds

- Two identical atoms have equal attraction to electrons in a bond, and therefore share them equally.
- This results in the formation of a nonpolar covalent bond in which atoms are not charged.



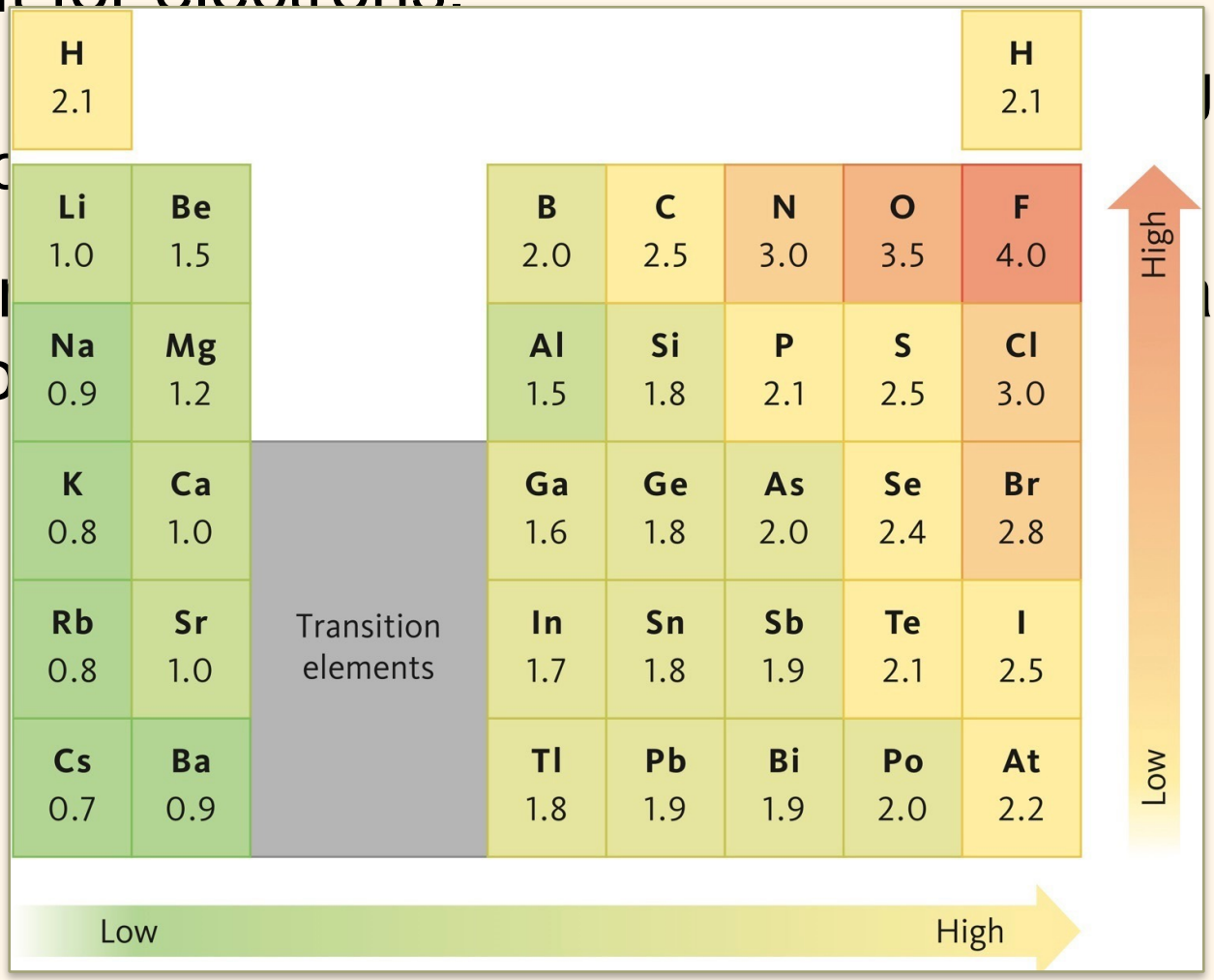
In F_2, each atom attracts the electrons equally, so neither atom is charged. F_2 has a **nonpolar covalent bond.**

Electronegativity

- Electronegativity measures the attraction of an element for electrons.
  - High electronegativity means there is a strong attraction
- Electronegativity increases from left to right and from bottom to top of the periodic table.

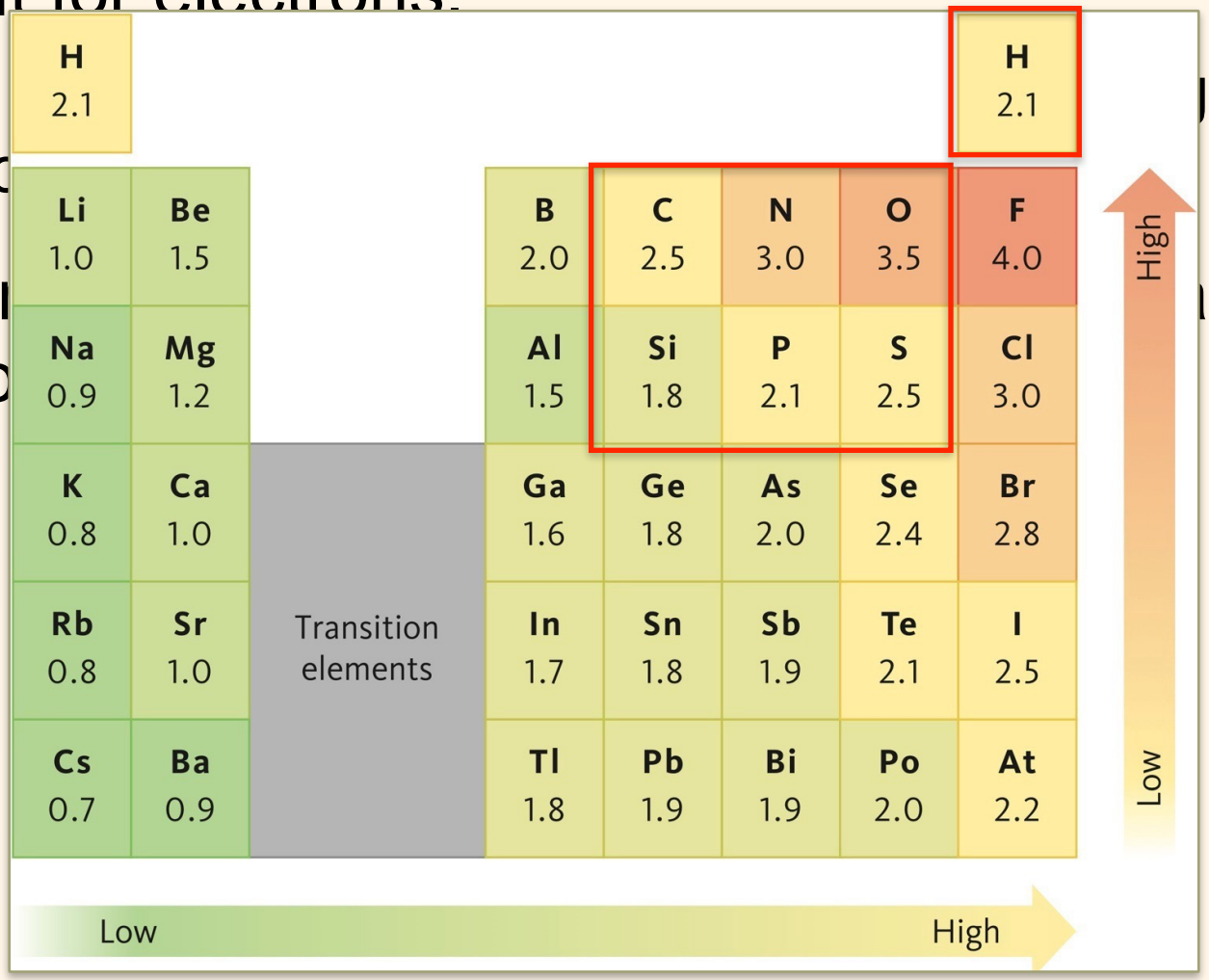
Electronegativity

- Electronegativity measures the attraction of an element for electrons.
  - High
    attrac
- Electron
  from bo



Electronegativity

- Electronegativity measures the attraction of an element for electrons.
  - High
- Electro
from bo



Electronegativity

- Electronegativity measures the attraction of an element for electrons.
  - High electronegativity means there is a strong attraction
- Electronegativity increases from left to right and from bottom to top of the periodic table.

Try It!

Question:

Draw the Lewis dot structure for carbon monoxide and predict whether or not it is a polar molecule.

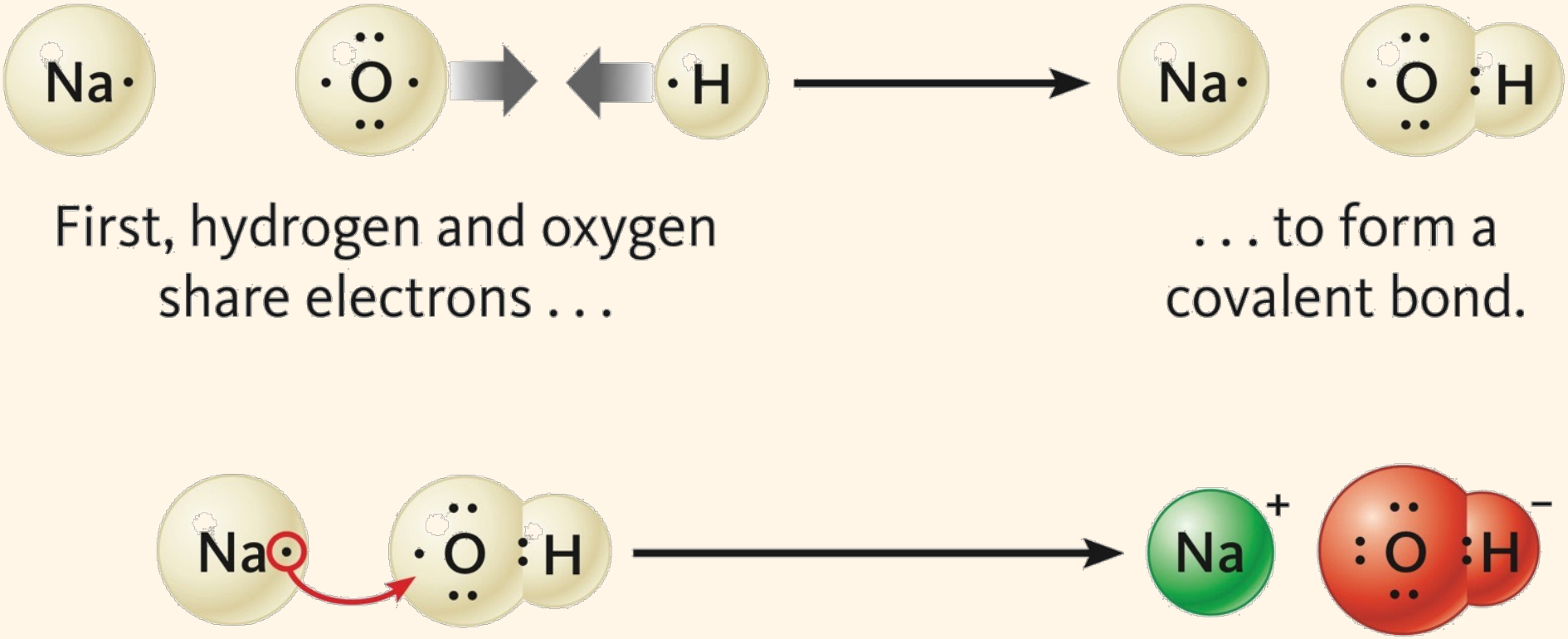
3.8 Polyatomic Ions

- Ions can be monatomic, such as Na^+ or Fe^{2+} or Cl^-.
  - For main group, or representative elements, the charge can be predicted from their location on the periodic table.
- Polyatomic ions are ions that are made up of more than one atom, which are covalently bonded together.

Example: NaOH consists of Na^+ and OH^-. OH^-, hydroxide ion, is a polyatomic ion.

Example: NaOH

Example: NaOH comprises Na^+ and OH^-. OH^-, an hydroxide ion, is a polyatomic ion.



Common Polyatomic Ions

TABLE 3.10 Formulas and Names of Common Polyatomic Ions

Formula	Name	Example of a Compound That Contains This Ion
NH_4^+	Ammonium	NH_4Cl (ammonium chloride: sal ammoniac)
OH^-	Hydroxide	$Mg(OH)_2$ (magnesium hydroxide: milk of magnesia)
NO_3^-	Nitrate	KNO_3 (potassium nitrate: saltpeter)
CO_3^{2-}	Carbonate	$CaCO_3$ (calcium carbonate: chalk)
SO_4^{2-}	Sulfate	$MgSO_4$ (magnesium sulfate: Epsom salt)
PO_4^{3-}	Phosphate	$Fe_3(PO_4)_2$ (iron(II) phosphate: ferrous phosphate)
HCO_3^-	Hydrogen carbonate (or bicarbonate)	$NaHCO_3$ (sodium hydrogen carbonate: sodium bicarbonate, baking soda)

Polyatomic Ions in Compounds

- Compounds with polyatomic ions should be balanced in the same way as compounds with monatomic ions.
- Polyatomic ions are treated as a unit. If there is more than one polyatomic ion, parenthesis are used.

Example: What is the formula for calcium nitrate?

Ca^{2+} and NO_3^-. We need 2 NO_3^- to balance the Ca^{2+}, so we use parenthesis.

$$Ca(NO_3)_2$$

3.9 Recognizing Ionic and Molecular Compounds

- Ionic compounds typically contain a metallic element
  - CaO, $Fe(NO_3)_3$, $NaC_2H_3O_2$
- Molecular (covalent) compounds typically contain only non-metals
  - CO_2, H_2SO_4, CH_3OH, $C_3H_5(NO_3)_3$
- NH_4^+ is an ion, so compounds that contain NH_4^+ are ionic
  - NH_4Cl, $(NH_4)_3PO_4$

Ionic and Molecular Compounds

- Hydrogen containing compounds, like HCl or H_2SO_4, are molecular structures with covalent bonds, because hydrogen is a non-metal.
- Naming conventions differ for ionic and covalent compounds, so it is important to distinguish them.
- For example:
  - $AlCl_3$ is ionic- aluminum chloride
  - PCl_3 is molecular- phosphorous trichloride

Ionic and Molecular Compounds

TABLE 3.11 A Comparison of Ionic Compounds Containing Monatomic and Polyatomic Ions

CATION	COMPOUNDS FORMED WITH −1 IONS (Cl^- and NO_3^-)		COMPOUNDS FORMED WITH −2 IONS (S^{2-} and CO_3^{2-})	
Na^+	$NaCl$ (sodium chloride)	$NaNO_3$ (sodium nitrate)	Na_2S (sodium sulfide)	Na_2CO_3 (sodium carbonate)
Mg^{2+}	$MgCl_2$ (magnesium chloride)	$Mg(NO_3)_2$ (magnesium nitrate)	MgS (magnesium sulfide)	$MgCO_3$ (magnesium carbonate)
Al^{3+}	$AlCl_3$ (aluminum chloride)	$Al(NO_3)_3$ (aluminum nitrate)	Al_2S_3 (aluminum sulfide)	$Al_2(CO_3)_3$ (aluminum carbonate)

Chapter 3—Key Health Science Notes

- In many of the health sciences, you will ***continually*** learn about the naming of medications, both the generic and brand names
  - In some medications that contain ions, the positive ion is named after the negative ion, for example:
    - The chemical name of the cholesterol-lowering medication Lipitor® is generally written *atorvastatin calcium*, although the calcium is a +2 ion

Next Up

- Unit 2 - Molecular Interactions
  - Readings Chapter 4-1,2,5 & 6 and Chapter 5-3,5 & 6
  - Homework Assignment due on 5. Feb.