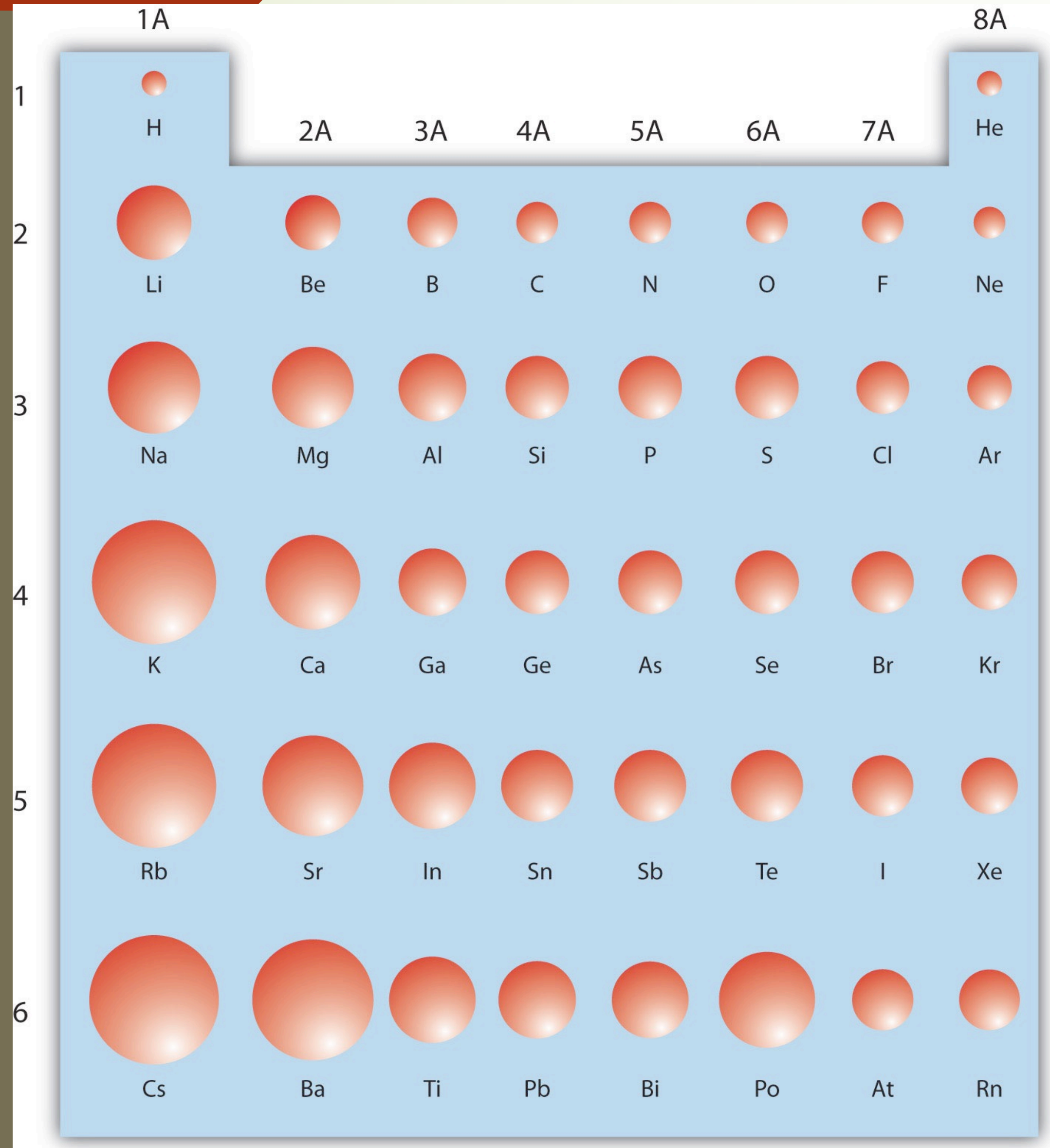
Chemical Energy

Objective: Learning about atoms, molecules and ions. Also, explore the formation of ionic and covalent compounds.

Key concepts:

- ❖ Metals, Nonmetals and Semimetals
- ❖ Electronic Structure
- ❖ Lewis Dot Diagram
- ❖ Cations and Anions
- ❖ Ionic Bonds
- ❖ Covalent Bonds.

Review: Periodic trends



Atomic Radius:

- Elements in the same row (periods) show a smooth trend toward smaller diameter (size) as you move from left to right.
- Elements in the same column (group) get bigger as you go down, due to additional electron shell.

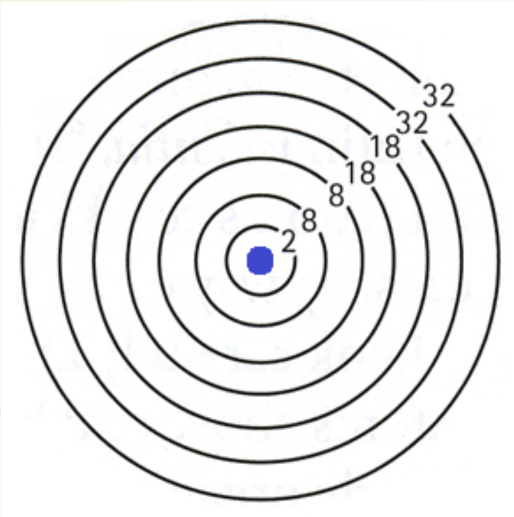
Chemical properties:

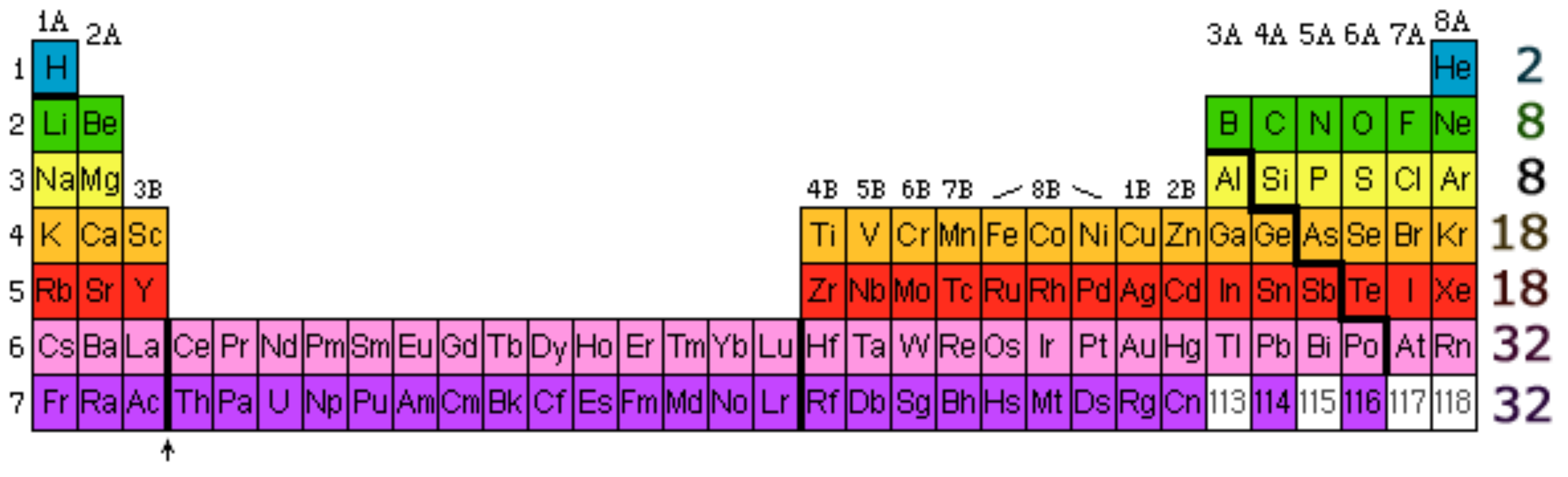
- Elements in the same column (group or family) have similar properties, such as how they react (or not) and what kinds of compounds they form.

The original arrangement of the Periodic Table came from organizing elements by their properties, which repeated in a regular pattern with a particular period (frequency). We now understand this to be a result of **the organization of electron energy levels** given by quantum mechanics.

The highest level is called the valence energy shell.

Review: Periodic trends





- Electrons fill distinct energy "shells" and each row corresponds to the filling of a shell.

- A new period starts when one of these shells is filled.

Counting valence electrons: There are never more than 8 valence electrons. *Octet Rule!*

We do not count the 10 extra electrons in rows 4 and 5 or the 24 extra electrons in rows 6 and 7.
They are not active in bonding because they have a slightly lower energy level than the 8 electrons associated with groups 1, 2, 13, 14, 15, 16, 17, and 18.
Groups **3**A, **4**A, **5**A, **6**A, **7**A, and **8**A identify the number of valence electrons for all elements in those columns. Groups with a "B" label have either 2 or 3 valence electrons.

Atoms and Molecules

ATOM: the basic particle of matter. Example: Ne = one atom of neon.

ELEMENT: simplest pure substance, **only one type of atom present.** Examples: Fe = one atom of iron, O_2 = two atoms of oxygen.

COMPOUND: pure substance formed from the chemical combination of **two or more elements in a definite ratio**. Examples: H_2O = water, H_2SO_4 = sulfuric acid, $C_6H_{12}O_6$ = sugar.

MOLECULE: neutral particle composed of **two of more atoms** chemically combined that **act as an independent unit**. Examples: H_2O = water (a compound), O_2 = oxygen (an element).

Formulas	Element or Compound	Atom or Molecule
He		
Br_2		
HCl		
CO		
Co		
Xe_2		

Metals, Nonmetals and Semimetals

Main group elements — Transition elements — Main group elements

Group 1 / Period – 1: 1 H — Atomic number, Symbol

- Metals
- Semimetals
- Nonmetals

- Alkali metals
- Alkaline earths
- Halogens
- Noble gases

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup			

Lanthanides 6	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides 7	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Metals, Nonmetals and Semimetals

Metals

- Located to left of zigzag line
- At room temperature, all except Hg are solid
- Lustrous, malleable & ductile
- Good conductors of heat & electric
- Tend to donate electrons (oxidation) to form cations (acquire positive charge)

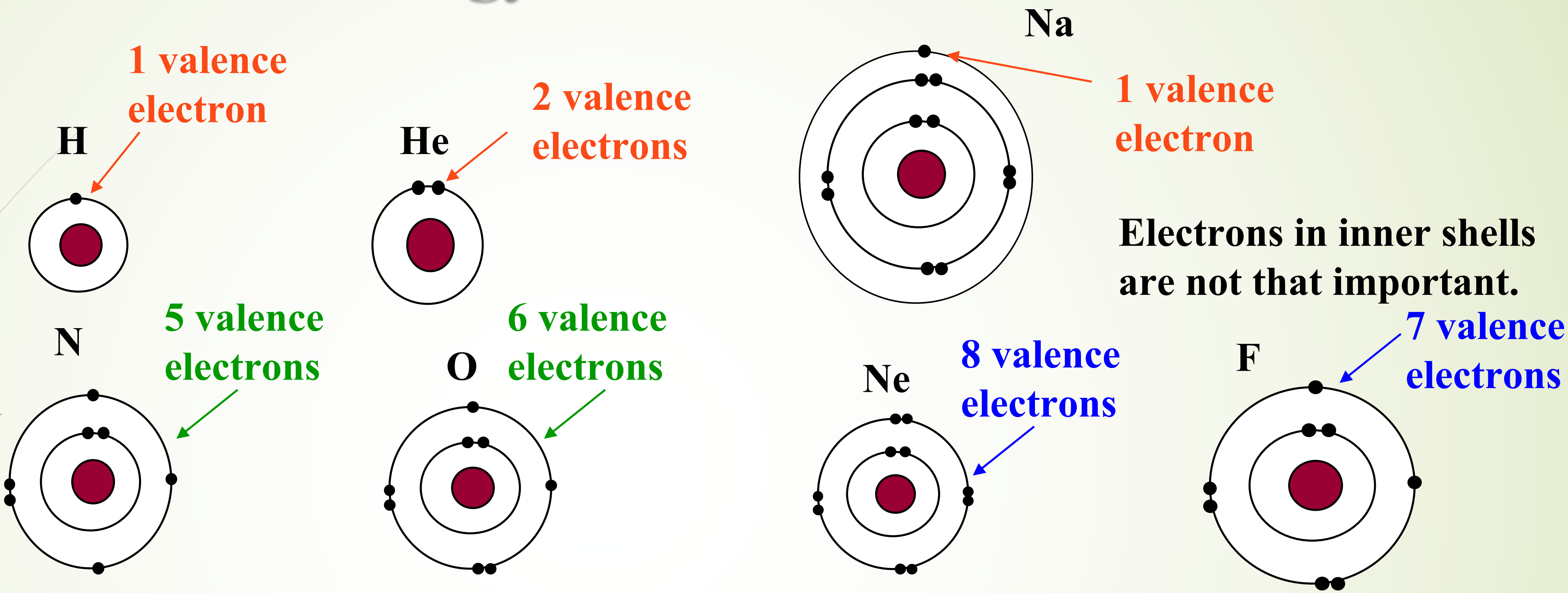
Nonmetals

- Located to right of zigzag line
- At room temperature, 11 gases, 1 liquid, 5 solids
- Poor conductors of heat & electricity
- Tend to gain electrons (reduction) to form anions (acquire negative charge)

Semimetals (Metalloids)

- Located along zigzag line
- All are solids: B, Si, As, Te, At, Ge, Sb
- Most of their physical properties resemble nonmetals.
- Several of the metalloids are semiconductors, which conduct electricity under special circumstances (Si, Ge).

Electron Energy Levels & Valence Electrons



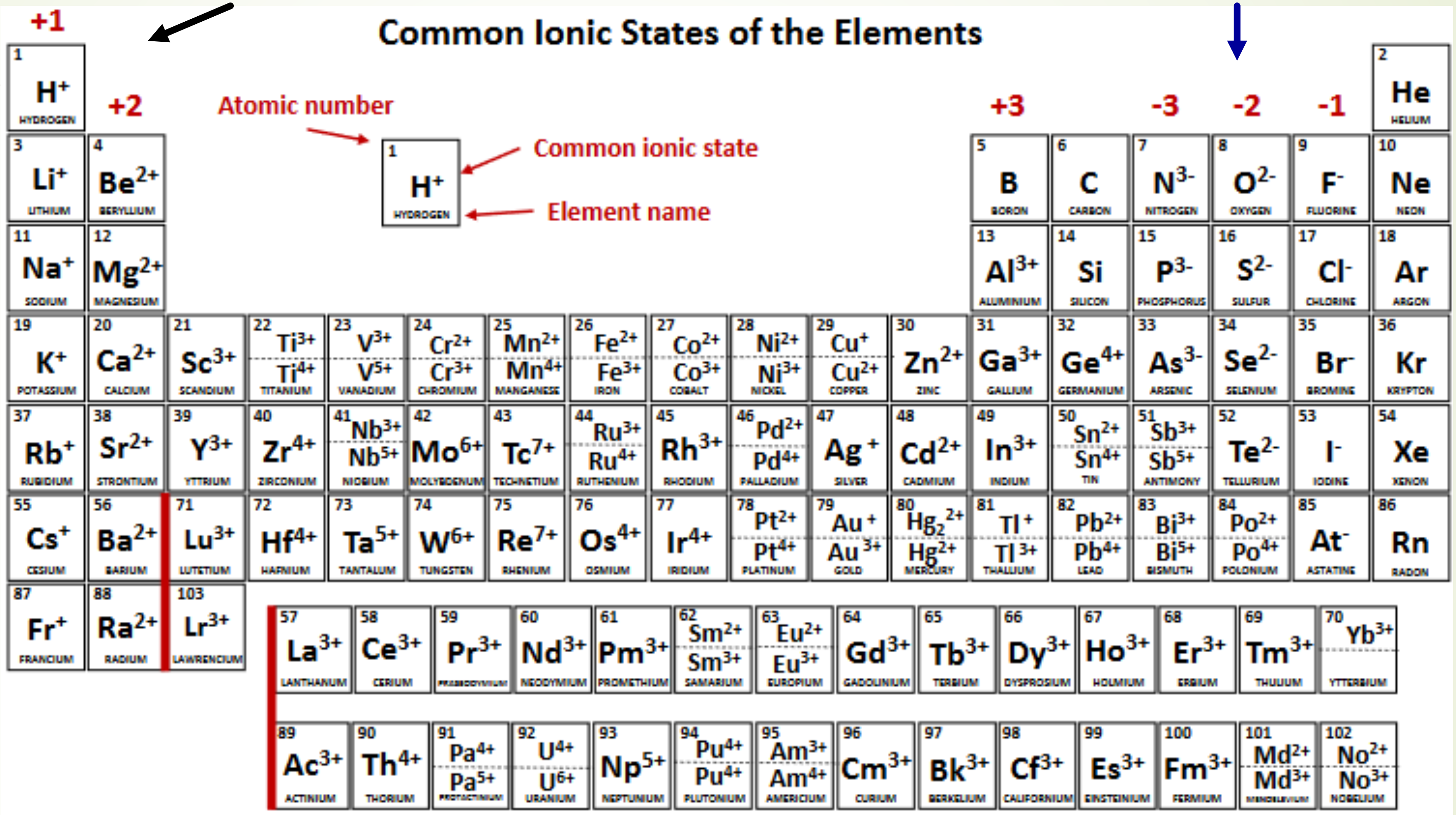
For each element, provide number of occupied electron energy levels and number of valence electrons

Elements	Number of energy levels (shells)	Valence electrons in outermost shell
Na		
Ne		
F		

Metals and Nonmetals

Metals lose electrons (cations)

Non-metals gain electrons (anions)



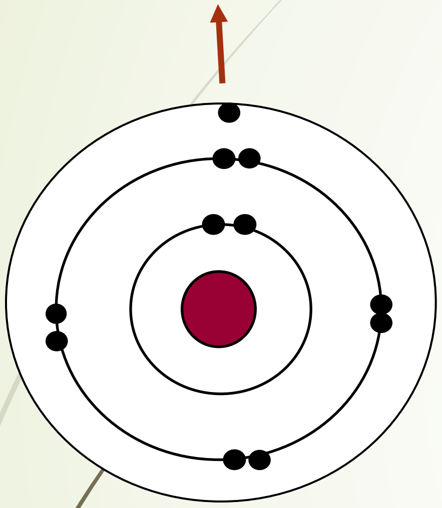
To get the stability of an inert gas,

- **metals** tend to __________ electrons to <u>empty</u> the valence shell
- **nonmetals** tend to _________ electrons to <u>fill</u> the valence shell.

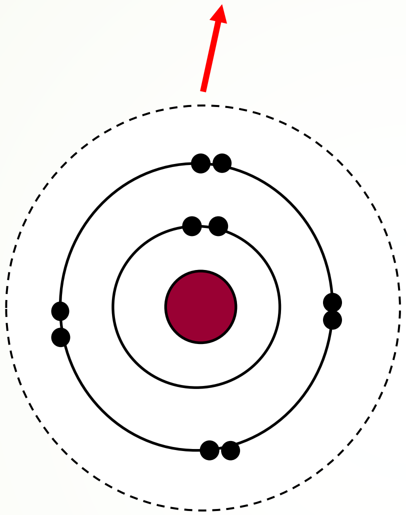
Formation of Ions

Positive ion or cation

lose the electron



vacant valance shell



Na atom

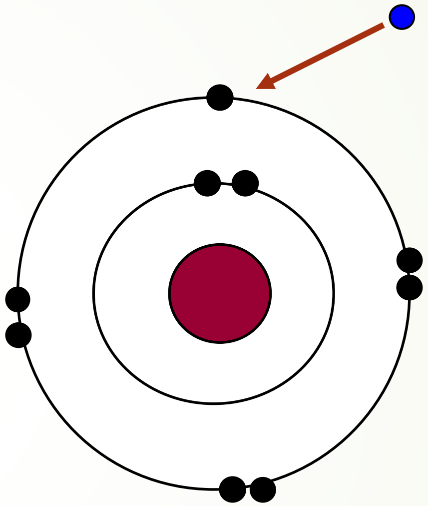
Na – 11 protons
11 electrons

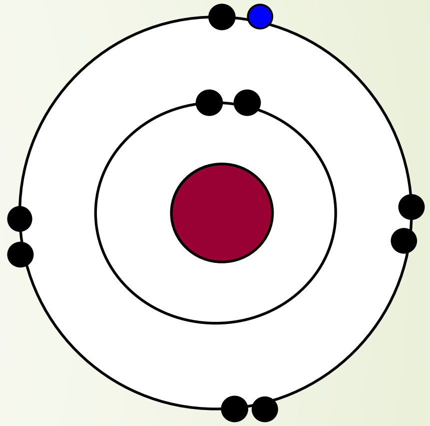
Na ion net charge +1

Na^{1+} - 11 protons
10 electrons

Negative ion or anion

gain an electron





F atom

F – 9 protons
9 electrons

F ion net charge -1

F^{1-} – 9 protons
10 electrons

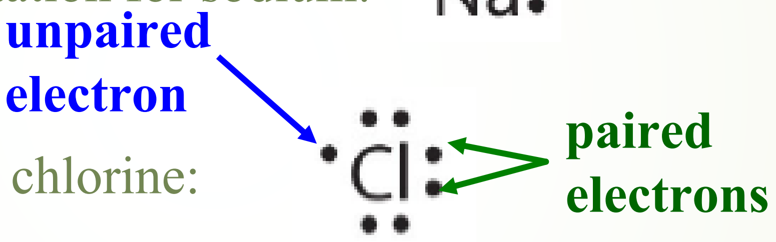
Lewis "dot" diagram

Chemists use simple diagrams to show an atom's valence electrons and how they transfer. These diagrams have two advantages over the electron shell diagrams.

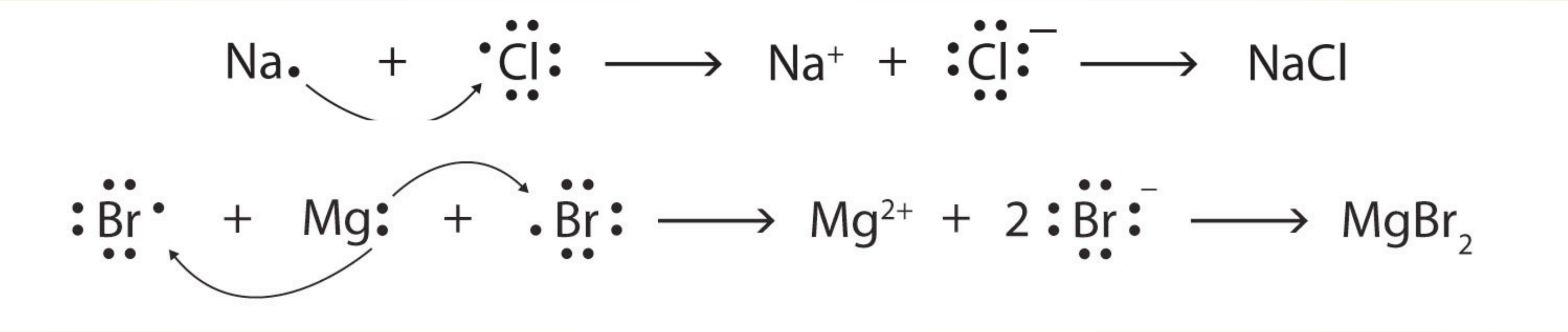
- First, they show only valence electrons.
- Second, instead of having a circle around the chemical symbol to represent the electron shell, they have up to eight dots around the symbol; each dot represents a valence electron.

For example, the representation for sodium: Na•

And the representation for chlorine:



The transfer of electrons can be illustrated easily with Lewis diagrams:



***In the final formula, the dots are omitted.

IONIC BONDING

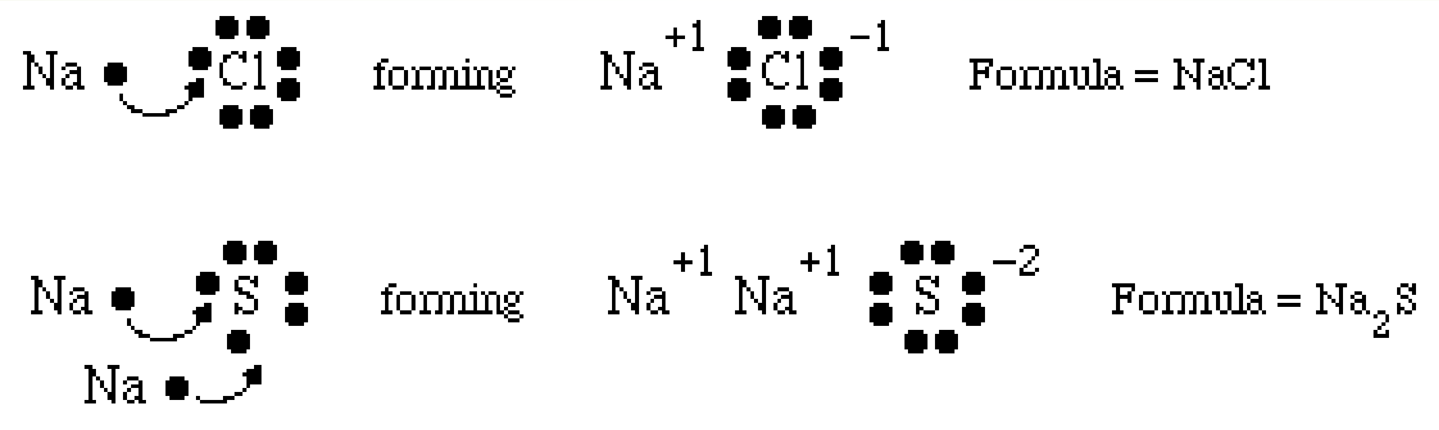
- The metal atoms give up their valence electrons and become positive ions (cations) with all inner energy levels filled.

- The non-metal atoms gain extra valence electrons and become negative ions (anions) with all energy levels filled.

- **The ions stay distinct** and are electrically attracted (bonded) to form Ionic compounds.

**By convention, the lowest whole-number ratio of the ions is used in ionic formulas. There are exceptions for certain ions, such as Hg22+

Example: A **metal atom** has valence electrons stolen by a **non-metal**. The **positive and negative ions** are then **attracted** to each other by the **coulomb force** to form an ionic compound.



IONIC BONDING

- Additionally, some ions consist of groups of atoms bonded together and have an overall electric charge. Because these ions contain more than one atom, they are called **polyatomic ions**. **Polyatomic ions** have characteristic formulas, names, and charges. Some examples of **polyatomic ions** with their charges are shown below:

NH_4^+	ammonium	OCN^-	cyanate
H_3O^+	hydronium	MnO_4^-	permanganate
OH^-	hydroxide	$C_2H_3O_2^-$	acetate (OAc^-, $CH_3CO_2^-$)
CN^-	cyanide	CO_3^{2-}	carbonate
O_2^{2-}	peroxide	HCO_3^-	hydrogen carbonate, bicarbonate
N_3^-	azide	SO_4^{2-}	sulfate
NO_3^-	nitrate	SO_3^{2-}	sulfite
NO_2^-	nitrite	$S_2O_3^{2-}$	thiosulfate
ClO_3^-	chlorate	$C_2O_4^{2-}$	oxalate
ClO_2^-	chlorite	CrO_4^{2-}	chromate
ClO^-	hypochlorite	$Cr_2O_7^{2-}$	dichromate
ClO_4^-	perchlorate	PO_4^{3-}	phosphate

IONIC BONDING

Practice: Identify each compound as ionic or not ionic.

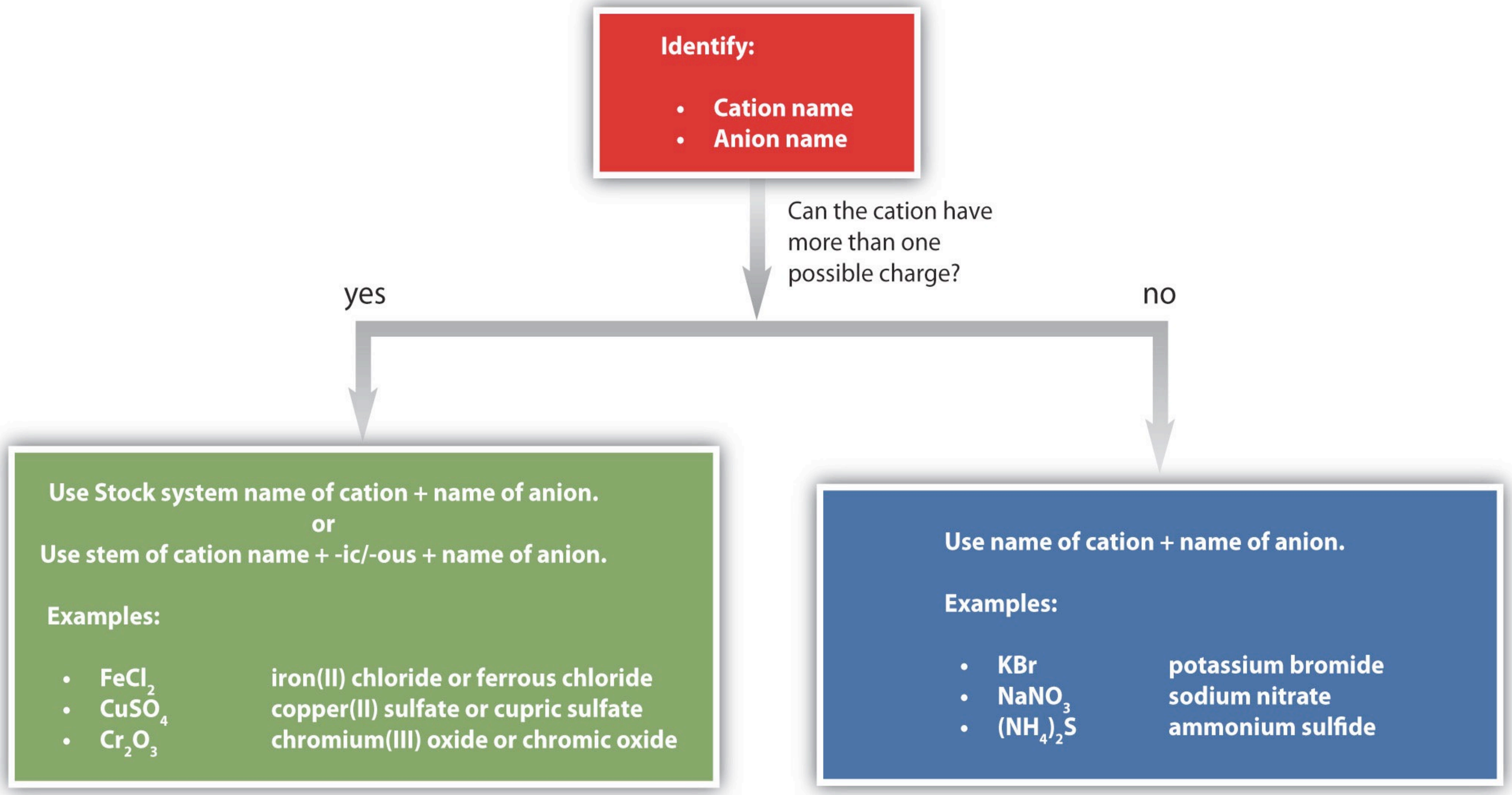
Compound	Ionic or not ionic
Na_2O	
PCl_3	
NH_4Cl	
OF_2	
N_2O	

Show the "Lewis dot diagram" and electron transfer with an arrow.

Mg F

Formula: ________

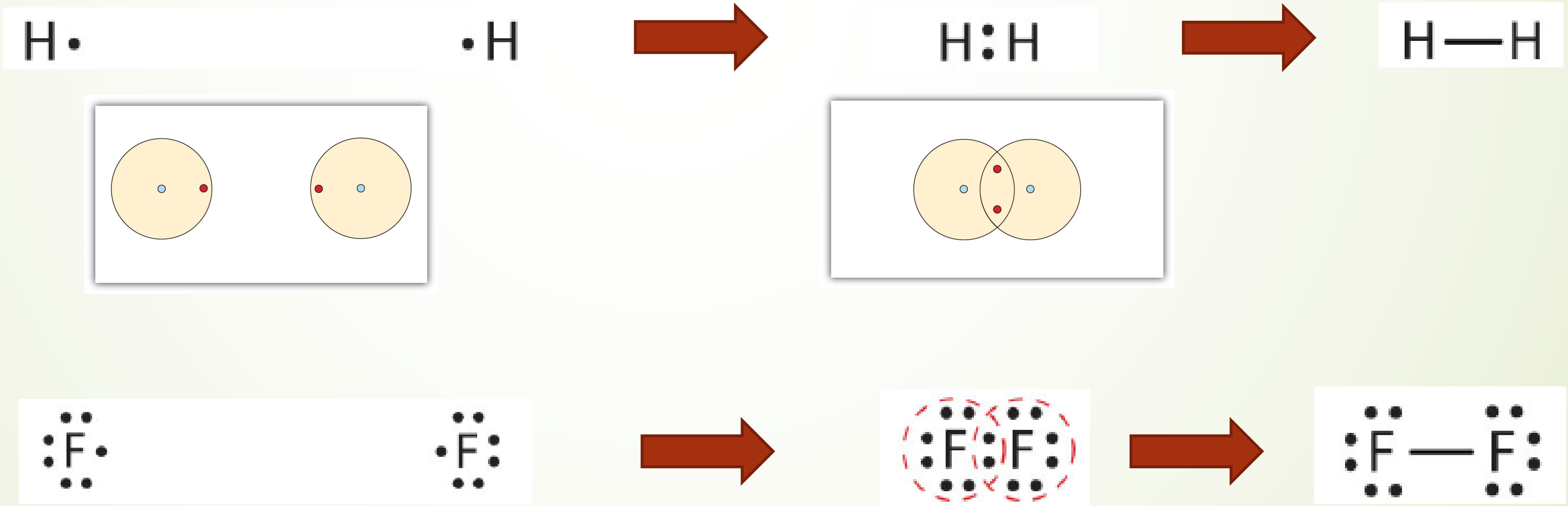
A Guide to Naming Simple Ionic Compounds



COVALENT BONDING

- An unpaired electron in one atom is **shared** with an unpaired electron in another atom. Each atom is happy when it thinks it has a full set of ***8 valence electrons*** even though some electrons actually belong to a different atom and are just being shared with it.
- Specific formula resulting in molecules. The formula is determined by the number of unpaired valence electrons.

This is where the **Lewis dot diagrams**, which show us how the valence electrons are organized, are most useful. We put atoms with unpaired electrons next to each other and then put a line between the electrons to show the bonded pair.

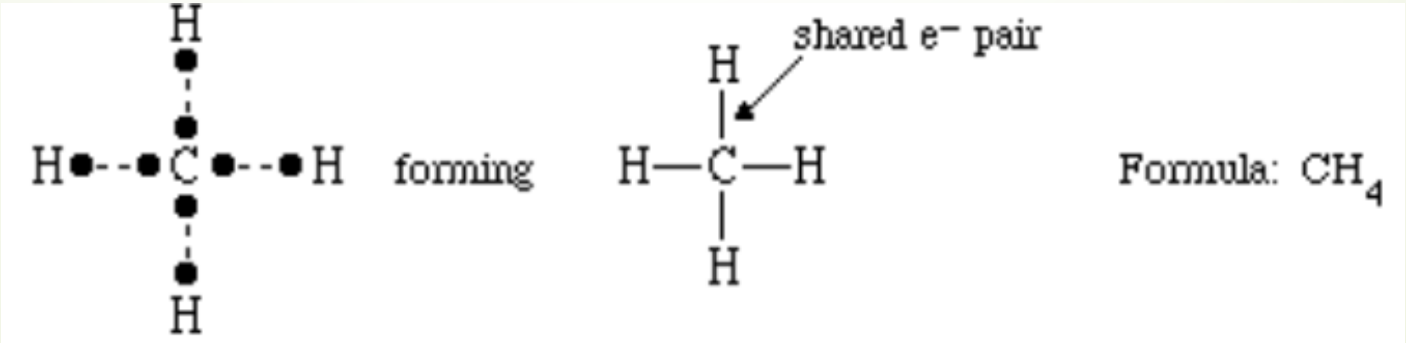


COVALENT BONDING

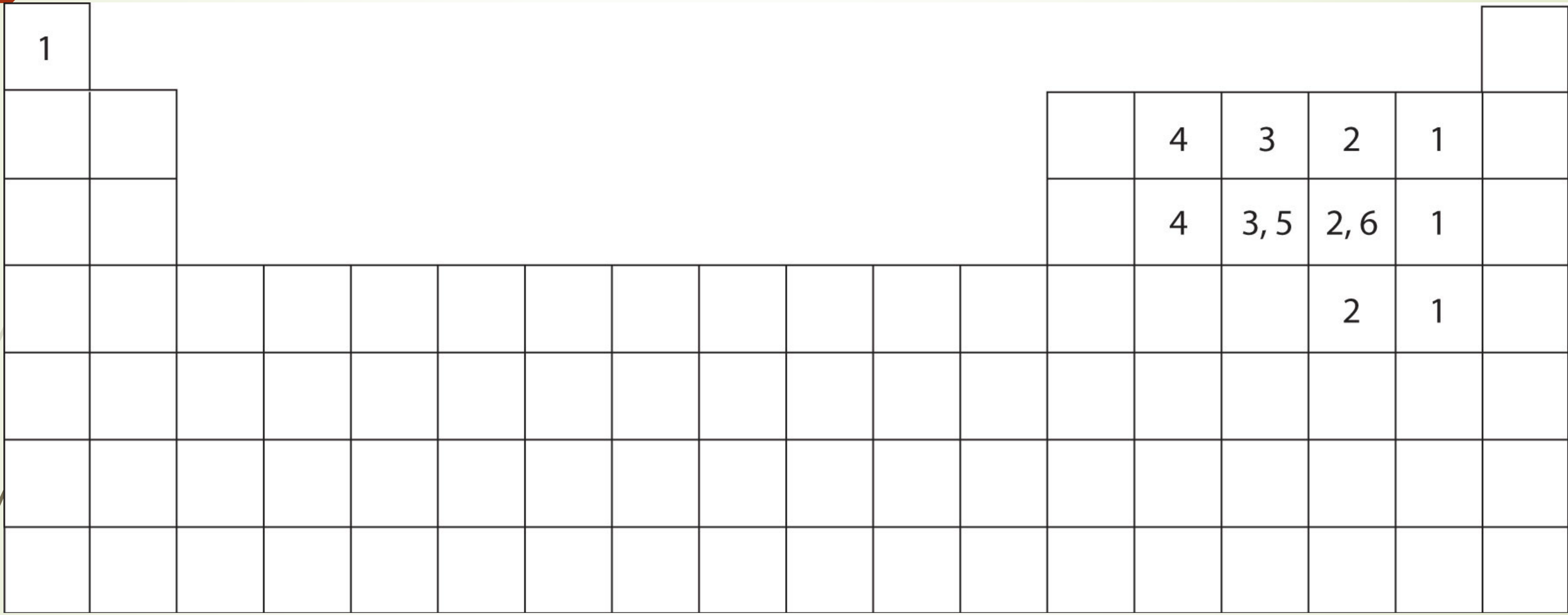
Covalent Bonds between Different Atoms: Consider a molecule composed of one hydrogen atom and one fluorine atom.

Each atom needs one additional electron to complete its valence shell. By each contributing one electron, they make the following molecule:

Larger molecules are constructed in a similar fashion, with some atoms participating in more than one covalent bond. For example, methane (CH_4), with one carbon atom and four hydrogen atoms, can be represented as follows:



How Many Covalent Bonds Are Formed?

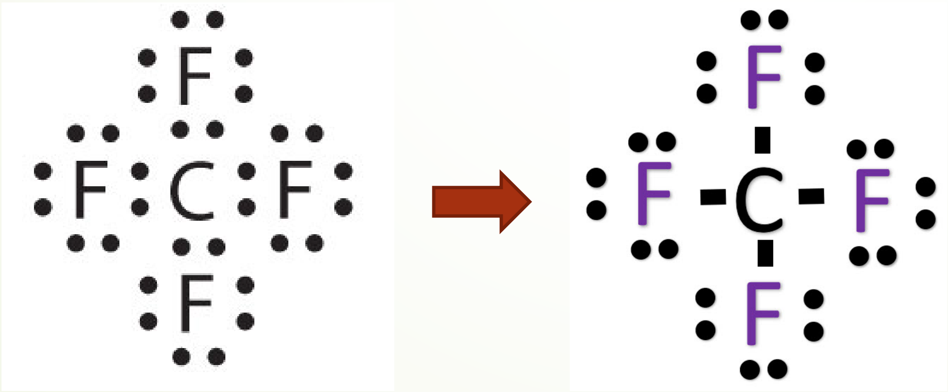


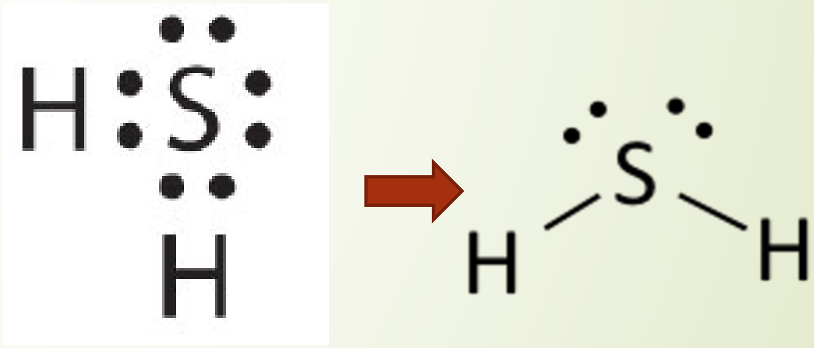
In molecules, there is a pattern to the number of covalent bonds that different atoms can form. Each block with a number indicates the number of covalent bonds formed by that atom in neutral compounds.

COVALENT BONDING

- Always start by drawing the dot diagram for the atom at the center of the group. (*We tell you what that is*)
- The formula tells you how many of the other atoms need to be added to find a partner for every unpaired atom.
- A dash connects paired electron dots to show the bond.

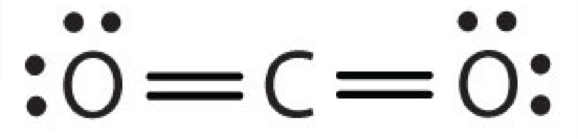
Example: CF_4 H_2S





Multiple Covalent Bonds

- Two pairs of electrons shared between two atoms make a **double bond** between the atoms, which is represented by a double dash:

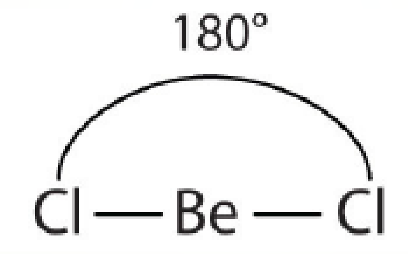


- Some molecules contain **triple bonds**, covalent bonds in which *three* pairs of electrons are shared by two atoms. A simple compound that has a triple bond is acetylene (C_2H_2), whose Lewis diagram is as follows:

Molecular Shape: VSEPR Theory

Unlike ionic compounds, covalent molecules are discrete units with specific 3-D shapes. The shape of a molecule is determined by the fact that covalent bonds, which are composed of negatively charged electrons, tend to repel one another. This concept is called the **Valence Shell Electron Pair Repulsion (VSEPR)** theory.

For example, the two covalent bonds in $BeCl_2$ stay as far from each other as possible, ending up 180° apart from each other. The result is a *linear molecule*:



The three covalent bonds in BF3 repel each other to form 120° angles in a plane, in a shape called *trigonal planar*: