Ch09

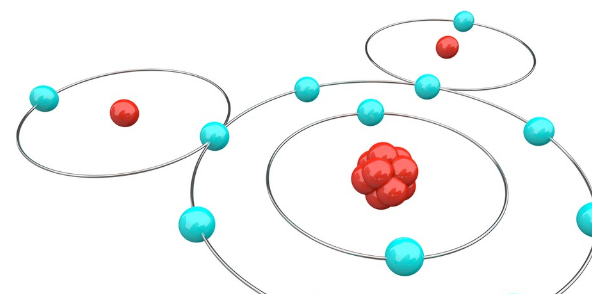
Chemical Bonds

How atoms connect to form ... everything.

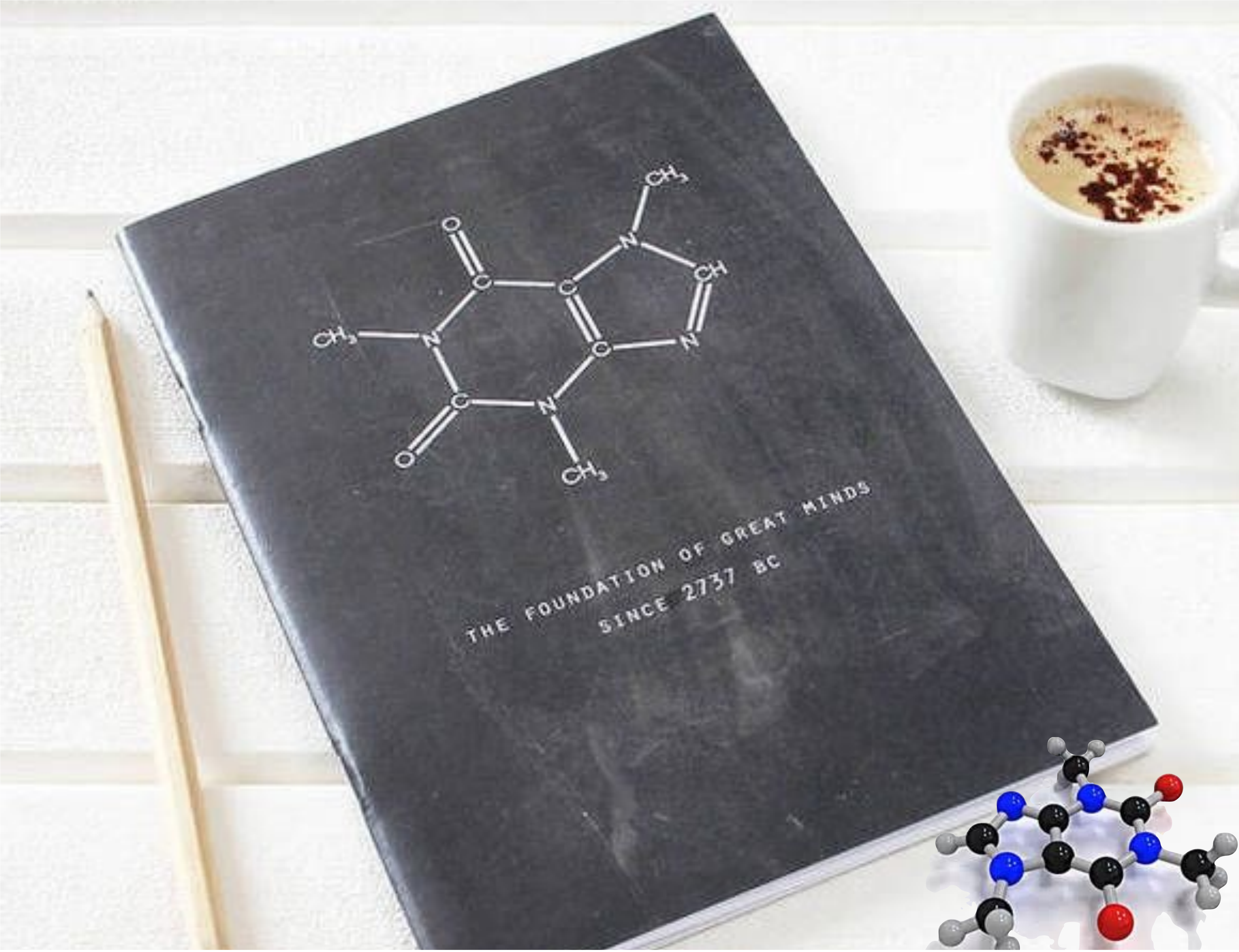
“When carbon, oxygen and hydrogen atoms bond in a certain way to form sugar, the resulting compound has a sweet taste.

The sweetness resides neither in the C, nor in the O, nor in the H; it resides in the pattern that emerges from their interaction.”

— F. Capra 2002

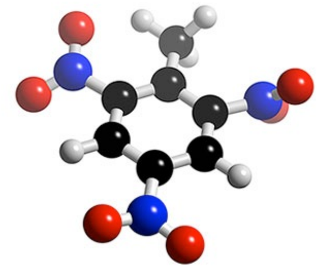


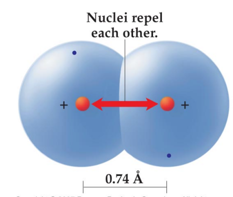
version 1.5


THE FOUNDATION OF GREAT MINDS
SINCE 2737 BC

Chemical Bonds

- Atoms forming Molecules
  - Composition, Connectivity & Shape
- Types of Connectivity (Bonding)
  - ionic - stealing electrons
  - covalent - sharing electrons
  - metallic - swimming in electrons
- Lewis Dot Notation
  - Lewis Symbols
    - elemental symbol surrounded by valence electrons
  - The Octet Rule
    - Why it's a reliable predictor.
- Ionic Bonding
  - Forming Ions to Bond Atoms
  - Thermodynamics
    - Born-Haber cycle
    - Lattice energy
      - trends: by size & charge
  - Checking the Model
- Covalent Bonding
  - Sharing Electrons to Bond Atoms
  - Thermodynamics
  - Lewis Structures
    - Identifies Lone Pairs
    - Predicts Bond Order
  - Checking the Model

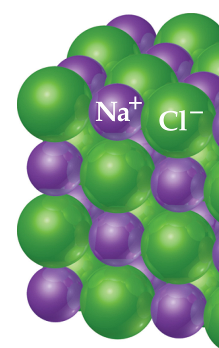


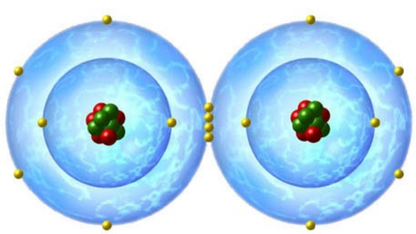


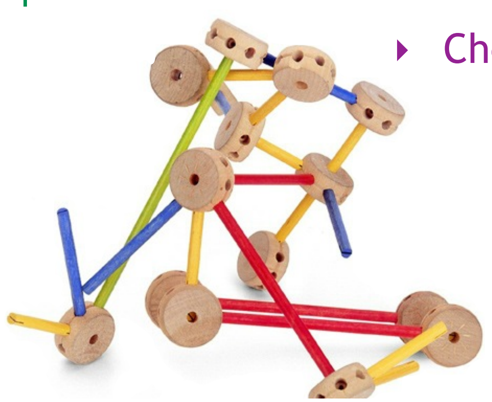
N

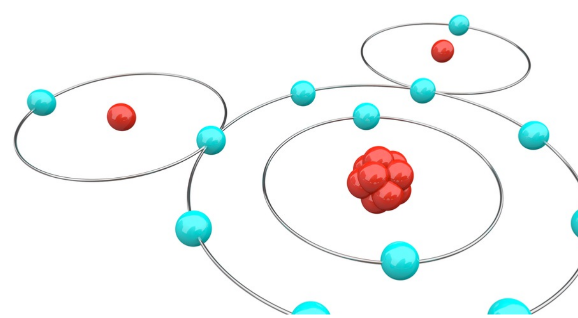
C

H : O : H









A model for understanding connectivity.

Composition

(What's in it.)

CCl_4

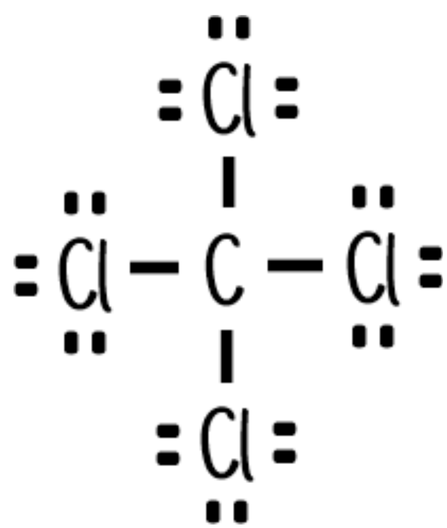
1 Carbon
4 Chlorine

Chemical Symbols

Molecular Formula

Connectivity

(What's connected to what.)



Lewis Dot Structure

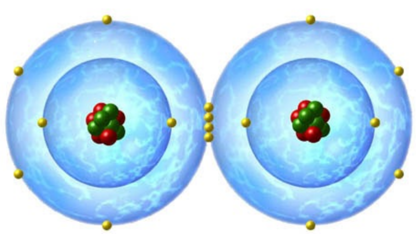
Shape

(Bond Angles & Distances)

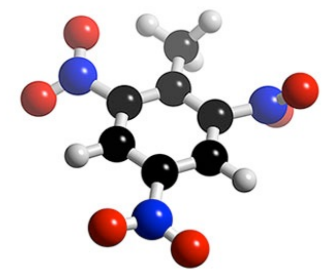
(Chapter 10)

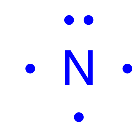
Chemical Bonds

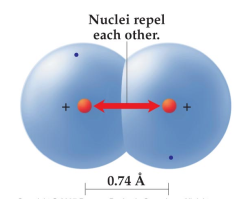
- Atoms forming Molecules
  - Composition, Connectivity & Shape
- Types of Connectivity (Bonding)
  - ionic - stealing electrons
  - covalent - sharing electrons
  - metallic - swimming in electrons
- Lewis Dot Notation
  - Lewis Symbols
    - elemental symbol surrounded by valence electrons
  - The Octet Rule
    - Why it’s a reliable predictor.

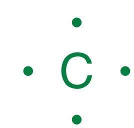


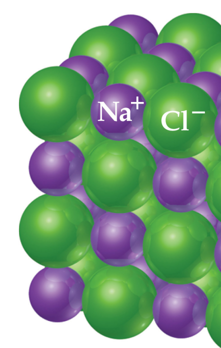
- Ionic Bonding
  - Forming Ions to Bond Atoms
  - Thermodynamics
    - Born-Haber cycle
    - Lattice energy
      - trends: by size & charge
  - Checking the Model
- Covalent Bonding
  - Sharing Electrons to Bond Atoms
  - Thermodynamics
  - Lewis Structures
    - Identifies Lone Pairs
    - Predicts Bond Order
  - Checking the Model

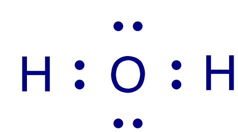


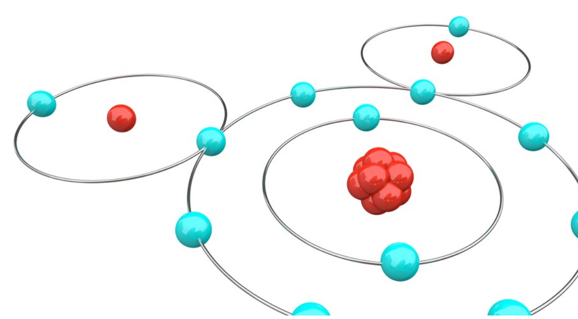






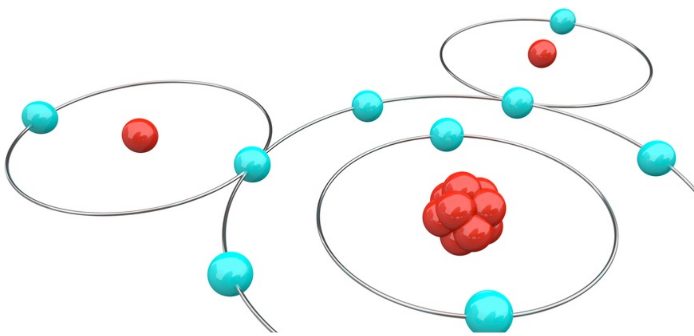






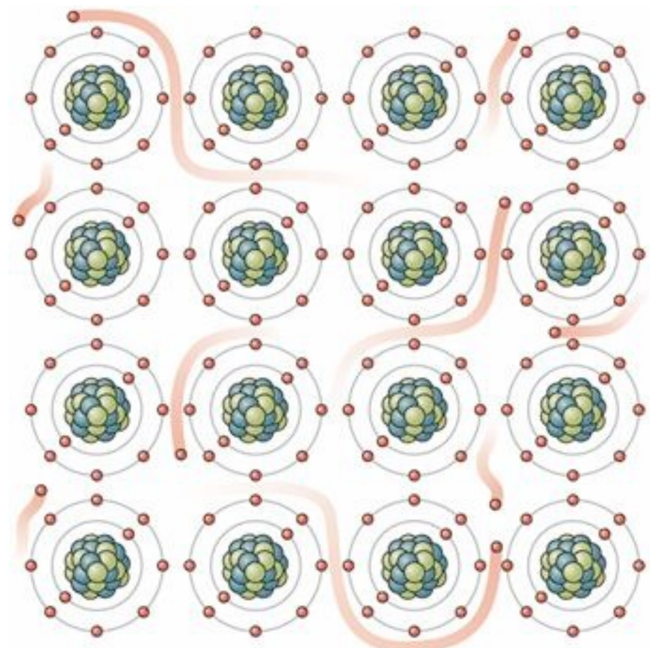
Chemical Bonds

- The properties of many materials can be understood in terms of their microscopic properties.
- Microscopic properties of molecules include:
  - Composition: what atoms it's made of (Ch 03)
  - Connectivity: which atoms are stuck to which atoms (bonds)
  - Shape: is it flat, a pyramid, a cylinder? (thinking 3-D).
- When atoms or ions are strongly attracted to one another, we say that there is a chemical bond between them.
- In chemical bonds, electrons are the glue.
- Types of chemical bonds include:
  - metallic bonds
    - metal nuclei floating in a sea of electrons, e.g., Na — atoms swimming in electrons
  - ionic bonds
    - electrostatic forces holding ions together, e.g., NaCl — atoms transferring electrons
  - covalent bonds
    - the sharing of electrons between atoms, e.g., Cl_2 — atoms sharing electrons



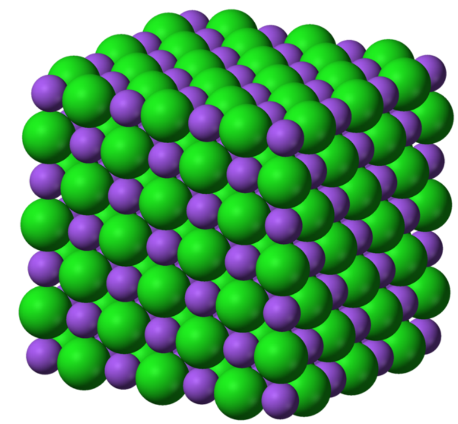
Chemical Bonds

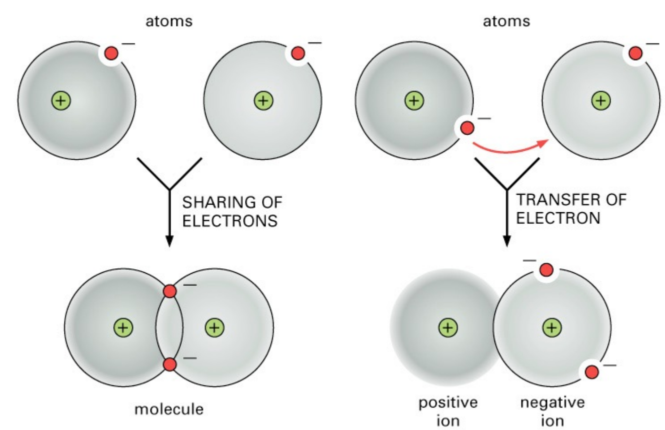
- Metallic Bonding:
  - In bulk metals (Fe, Au, Co) electrons break off and float between the atoms.
  - These free flowing electrons make metals extremely good conductors of electricity.
  - Metal atoms pull on the electrons flowing between them causing the mass to stick together.

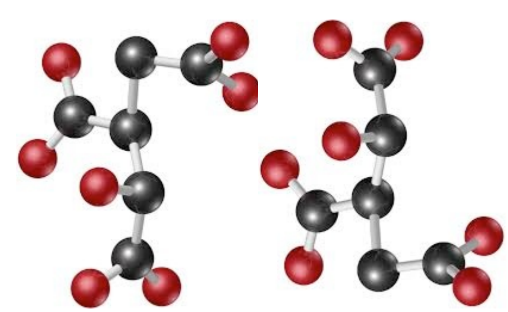


Chemical Bonds

- Metallic Bonding:
  - In bulk metals (Fe, Au, Co) electrons break off and float between the atoms.
  - These free flowing electrons make metals extremely good conductors of electricity.
  - Metal atoms pull on the electrons flowing between them causing the mass to stick together.
- Ionic Bonding:
  - In mixtures of metals and non-metals electrons break off from metals and are captured by non-metals.
  - This creates positively and negatively charged particles.
  - These ions clump together in simple, large complexes.
  - Ionic bonds are extremely strong.
- Covalent Bonding:
  - Nonmetals pull on each others electrons.
  - If neither non-metal pulls hard enough to remove the electron from the other, the two end up sharing a pair of electrons.
  - The shared electrons are localized between two atoms, creating bond between those atoms.

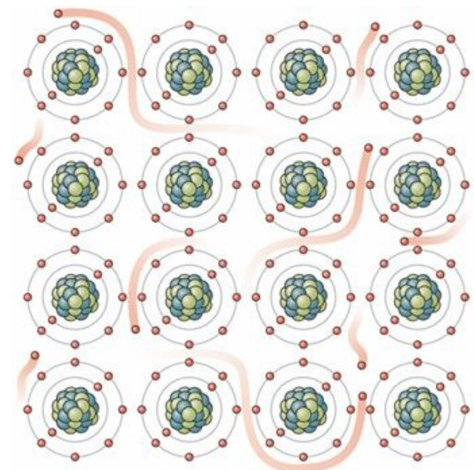




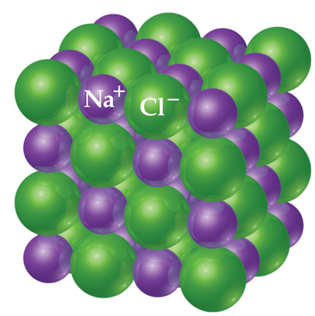


Chemical Bonds

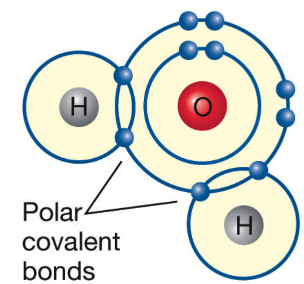
- Metallic Bonding:
  - In bulk metals (Fe, Au, Co) electrons break off and float between the atoms.
  - These free flowing electrons make metals extremely good conductors of electricity.
  - Metal atoms pull on the electrons flowing between them causing the mass to stick together.
- Ionic Bonding:
  - In mixtures of metals and non-metals electrons break off from metals and are captured by non-metals.
  - This creates positively and negatively charged particles.
  - These ions clump together in simple, large complexes.
  - Ionic bonds are extremely strong.
- Covalent Bonding:
  - Nonmetals pull on each others electrons.
  - If neither non-metal pulls hard enough to remove the electron from the other, the two end up sharing a pair of electrons.
  - The shared electrons are localized between two atoms, creating bond between those atoms.



75-1000 kJ/mol



400-4000 kJ/mol

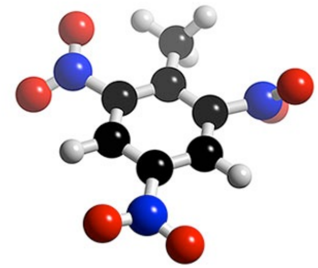


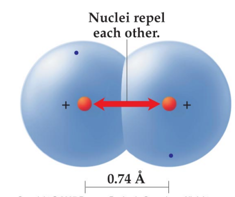
150-1100 kJ/mol

Chemical Bonds

- Atoms forming Molecules
  - Composition,
    Connectivity & Shape
- Types of Connectivity (Bonding)
  - ionic - stealing electrons
  - covalent - sharing electrons
  - metallic - swimming in electrons
- Lewis Dot Notation
  - Lewis Symbols
    - elemental symbol surrounded by valence electrons
  - The Octet Rule
    - Why it's a reliable predictor.

- Ionic Bonding
  - Forming Ions to Bond Atoms
  - Thermodynamics
    - Born-Haber cycle
    - Lattice energy
      - trends: by size & charge
  - Checking the Model
- Covalent Bonding
  - Sharing Electrons to Bond Atoms
  - Thermodynamics
  - Lewis Structures
    - Identifies Lone Pairs
    - Predicts Bond Order
  - Checking the Model

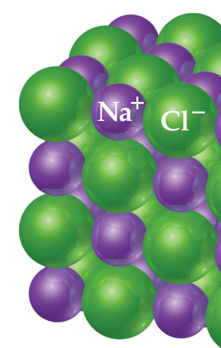


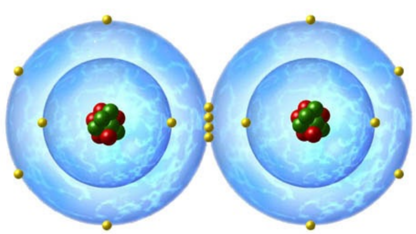


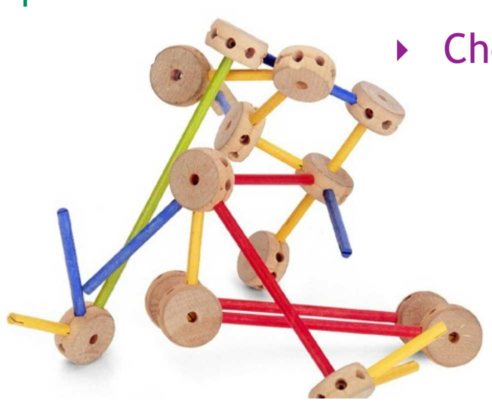
N

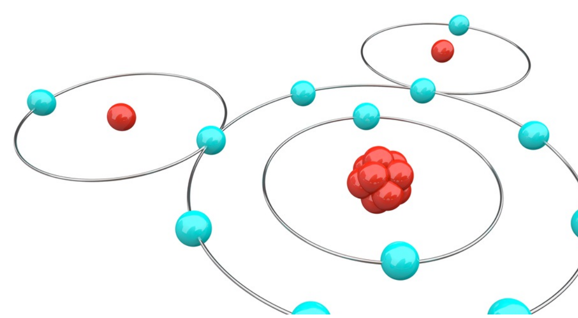
C

H : O : H



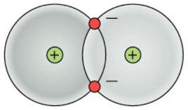






Gilbert N. Lewis

- Discovered the Covalent Bond
  - The basis for all organic chemistry.



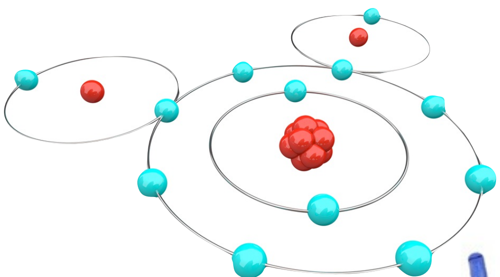
- Coined the term Photon

  - Although Planck and Einstein advanced the concept of quanta, Einstein did not use the word photon in his early writings and as far as my reading goes, he never did. The word "photon" originated from Gilbert N. Lewis years after Einstein's photoelectric paper and appeared in a letter to the editor of Nature magazine.
  - "I therefore take the liberty of proposing for this hypothetical new atom, which is not light but plays an essential part in every process of radiation, the name photon." -Gilbert N. Lewis, 1926
    (Nature Vol. 118, Part 2, December 18, 1926, page 874-875)

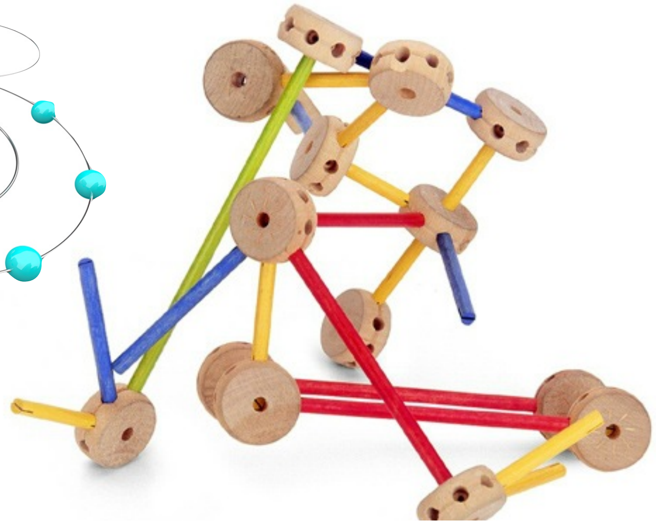
(1875-1946)

- Formalized the electron pair theory of Acids & Bases which is why we call them "Lewis Acids"

- Developed the process for purifying Heavy Water (^2H_2O)
  - Which was essential to the Manhattan project.
- Professor at UC Berkeley for 34 years
  - Lewis Hall,the Chemistry building at UC Berkeley, is named after G.N. Lewis

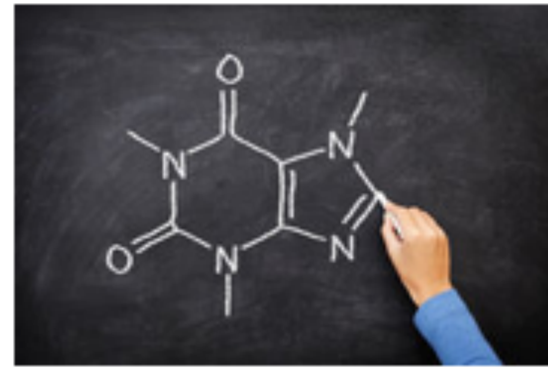


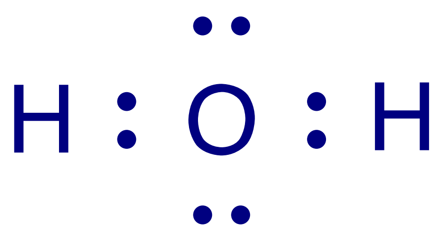
- Nominated for a nobel prize 35 times
  (Mahatma Gandhi was only nominated 5 times)
  - *He never received one.*
- Lewis was found dead at his lab bench at UC Berkeley in 1946, his death may have been due to poisoning from chemicals in his experiment. The coroner listed it as a heart attack.
- Developed Valence Shell Notation
  - more commonly known as Lewis Dot Structures

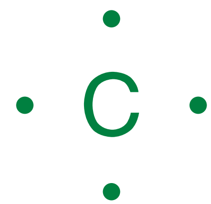


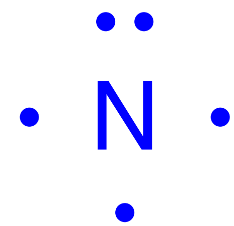
It starts with Lewis Symbols

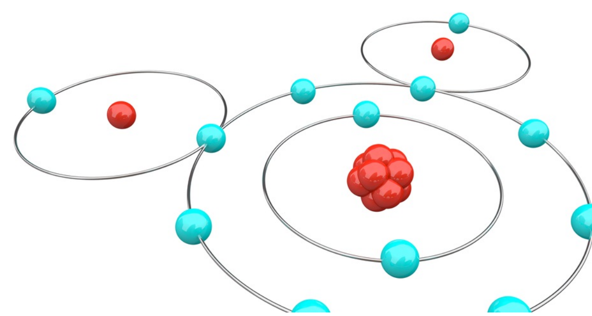
- Lewis notation is how we described the connectivity of all covalent compounds (molecules).
- It's how we show the difference between compounds that have the same composition (molecular formula).
- Lewis notation starts with understanding the Lewis symbols for each atom or ion.
- Symbols that communicate the valence structure of the electronic configuration of those particles.



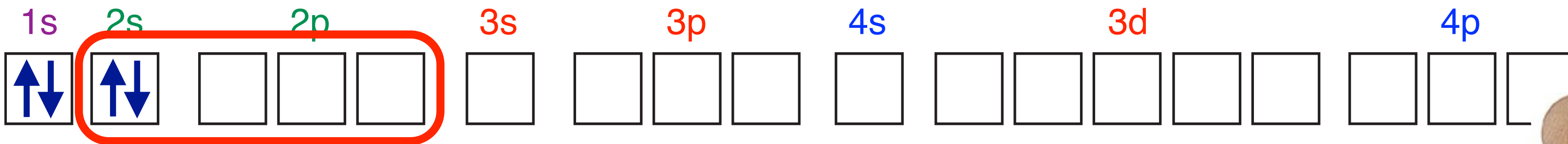








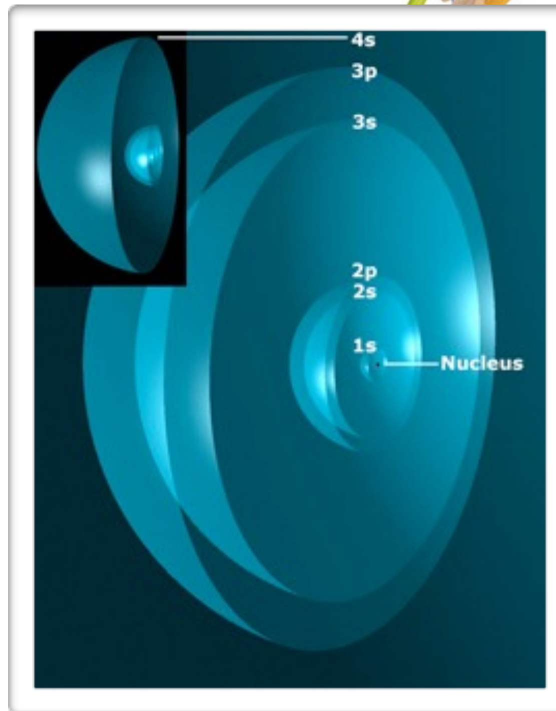
Lewis Symbols



- The electrons involved in bonding are called valence electrons.
- Valence electrons are found in the incomplete, outermost shell of an atom. The valence shell.
- As a pictorial understanding of where the electrons are in an atom, we represent the electrons as dots around the symbol for the element.
- The number of valence electrons available for bonding are indicated by unpaired dots.
- We generally place the electrons on four sides of a square around the element's symbol.

Be

- These symbols are called Lewis symbols or Lewis electron-dot symbols.



We won't discriminate between ground state and excited states in Lewis structures. If you're asked for the Lewis structure anyone of these is fine.

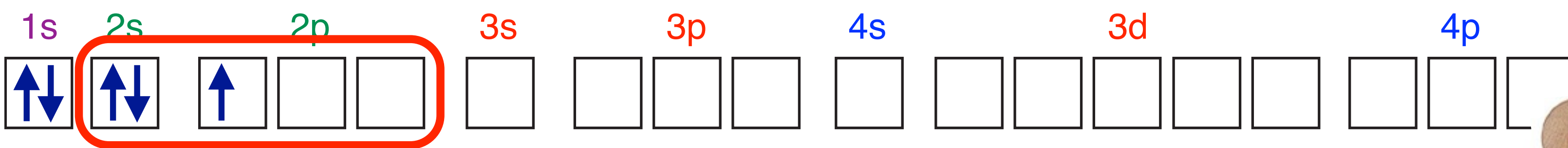
ground state

excited state

$1s^2 2s^2$

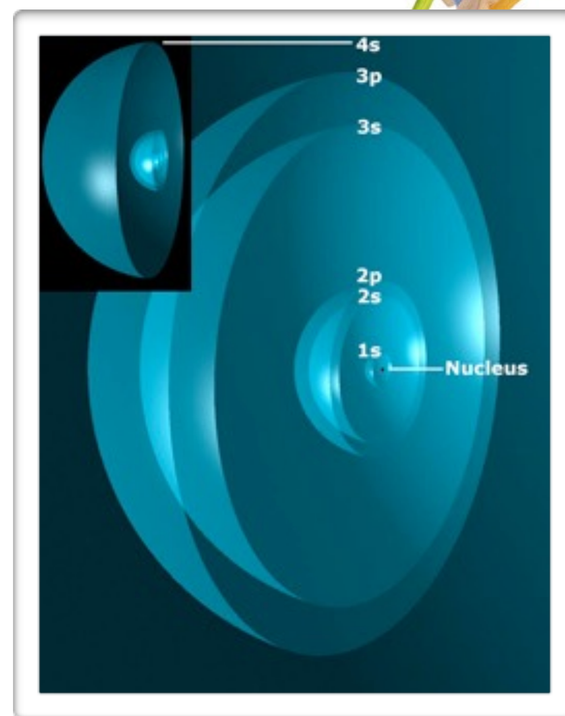
4 electrons
2 valence electrons

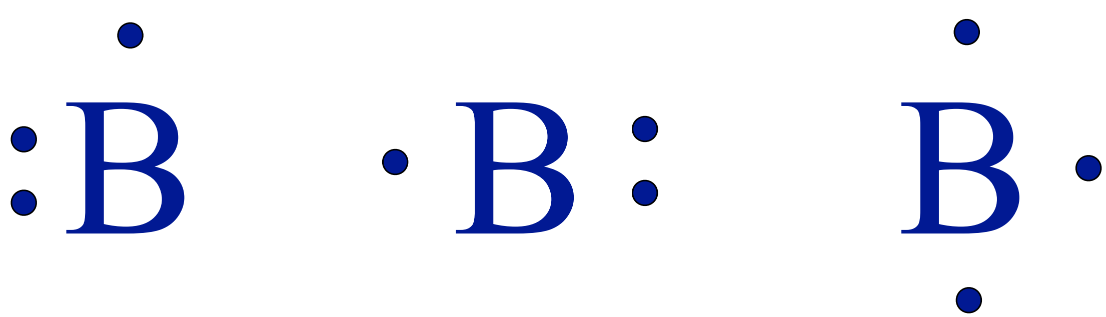
Lewis Symbols



- The electrons involved in bonding are called valence electrons.
- Valence electrons are found in the incomplete, outermost shell of an atom. The valence shell.
- As a pictorial understanding of where the electrons are in an atom, we represent the electrons as dots around the symbol for the element.
- The number of valence electrons available for bonding are indicated by unpaired dots.
- We generally place the electrons on four sides of a square around the element's symbol.
- These symbols are called Lewis symbols or Lewis electron-dot symbols.

B





ground state

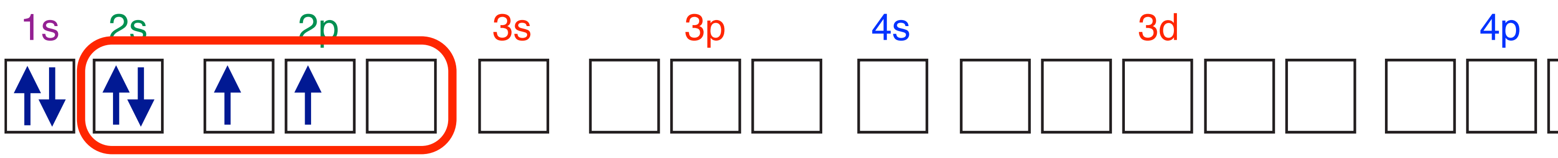
excited state

$1s^2 2s^2 2p^1$

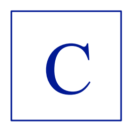
5 electrons

3 valence electrons

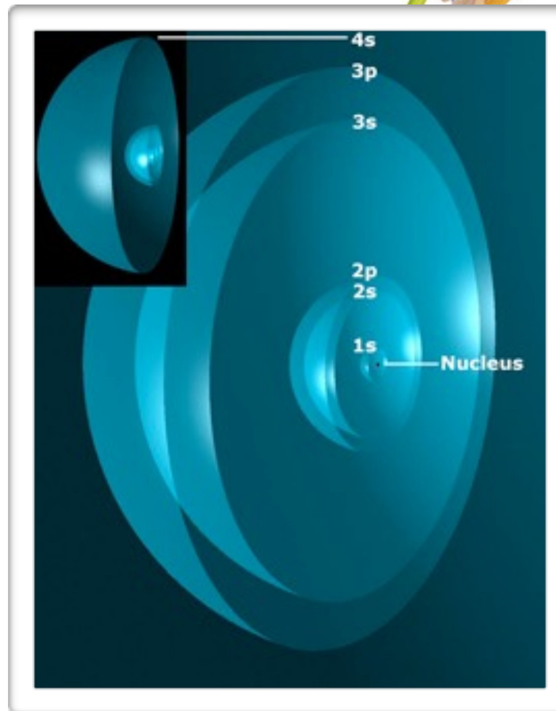
Lewis Symbols

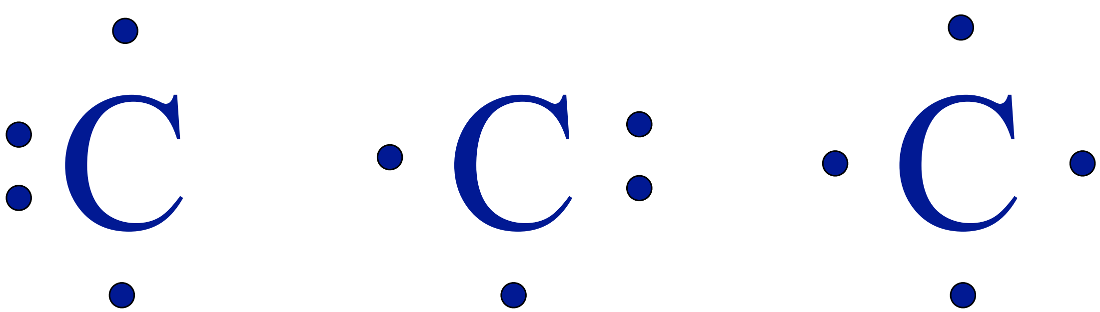


- The electrons involved in bonding are called valence electrons.
- Valence electrons are found in the incomplete, outermost shell of an atom. The valence shell.
- As a pictorial understanding of where the electrons are in an atom, we represent the electrons as dots around the symbol for the element.
- The number of valence electrons available for bonding are indicated by unpaired dots.
- We generally place the electrons on four sides of a square around the element's symbol.



- These symbols are called Lewis symbols or Lewis electron-dot symbols.





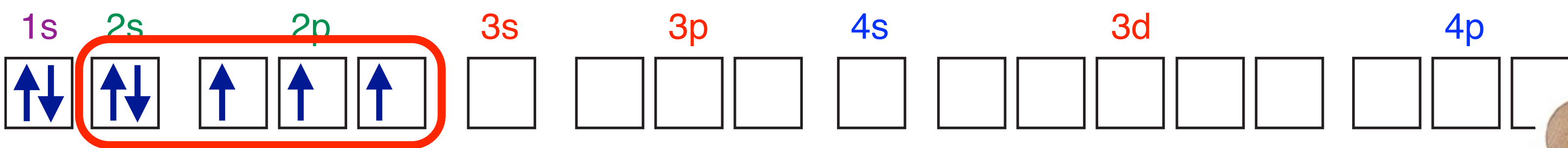
ground state

excited state

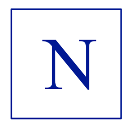
$1s^2 2s^2 2p^2$

6 electrons
4 valence electrons

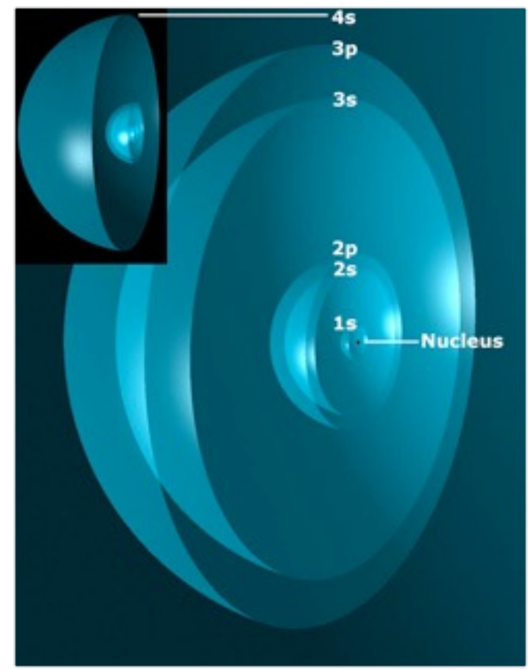
Lewis Symbols

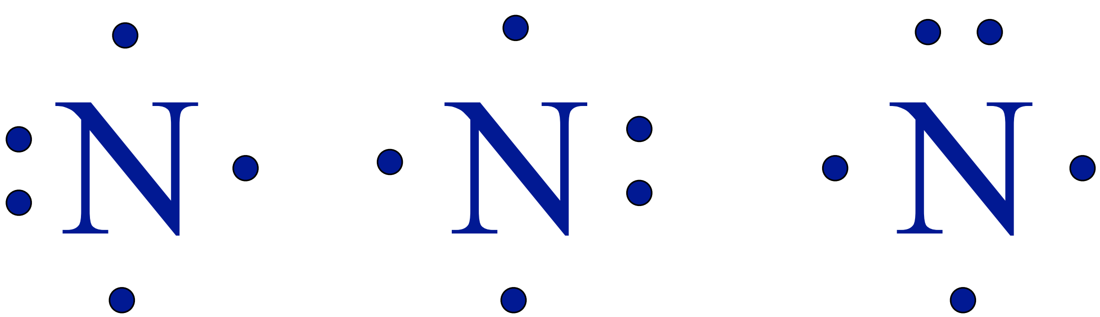


- The electrons involved in bonding are called valence electrons.
- Valence electrons are found in the incomplete, outermost shell of an atom. The valence shell.
- As a pictorial understanding of where the electrons are in an atom, we represent the electrons as dots around the symbol for the element.
- The number of valence electrons available for bonding are indicated by unpaired dots.
- We generally place the electrons on four sides of a square around the element's symbol.



- These symbols are called Lewis symbols or Lewis electron-dot symbols.



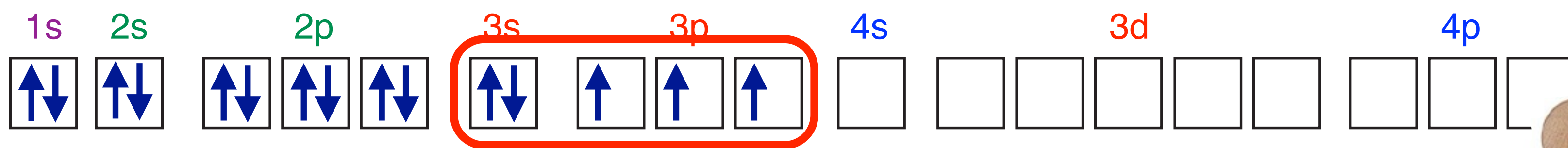


ground state

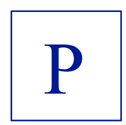
$1s^2 2s^2 2p^3$

7 electrons
5 valence electrons

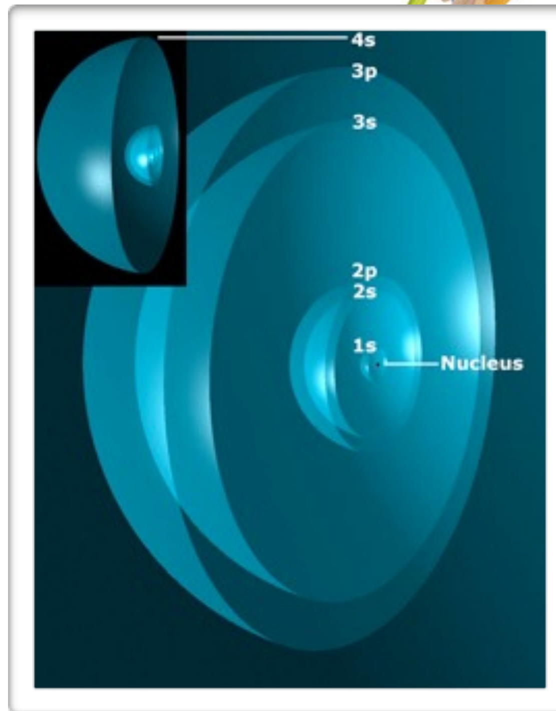
Lewis Symbols

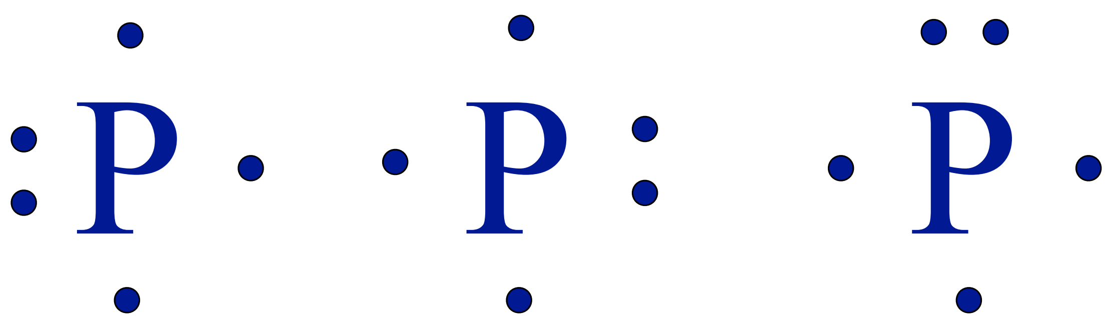


- The electrons involved in bonding are called valence electrons.
- Valence electrons are found in the incomplete, outermost shell of an atom. The valence shell.
- As a pictorial understanding of where the electrons are in an atom, we represent the electrons as dots around the symbol for the element.
- The number of valence electrons available for bonding are indicated by unpaired dots.
- We generally place the electrons on four sides of a square around the element's symbol.



- These symbols are called Lewis symbols or Lewis electron-dot symbols.





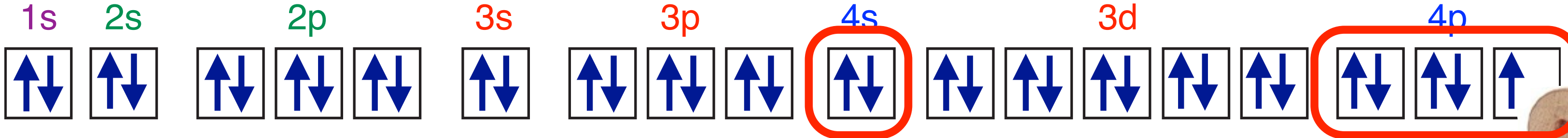
ground state

$1s^2 2s^2 2p^6 2s^2 2p^3$

15 electrons

5 valence electrons

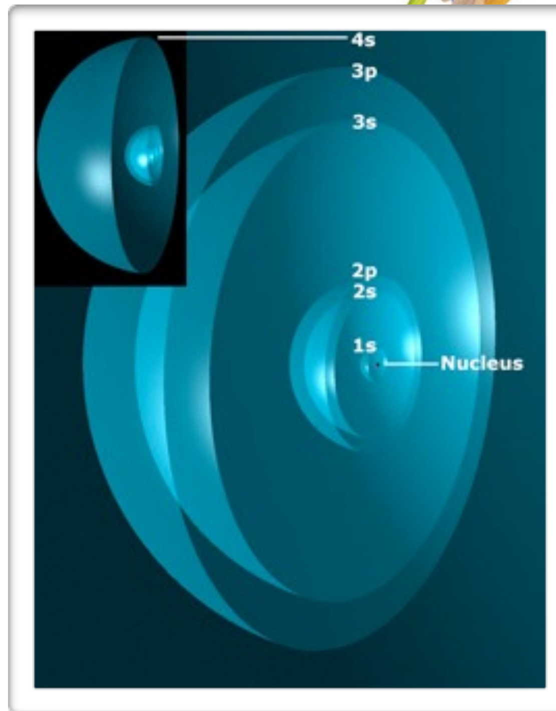
Lewis Symbols

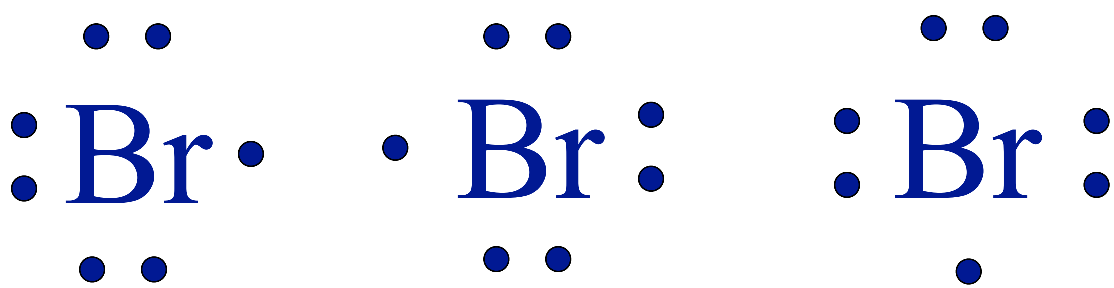


- The electrons involved in bonding are called valence electrons.
- Valence electrons are found in the incomplete, outermost shell of an atom. The valence shell.
- As a pictorial understanding of where the electrons are in an atom, we represent the electrons as dots around the symbol for the element.
- The number of valence electrons available for bonding are indicated by unpaired dots.
- We generally place the electrons on four sides of a square around the element's symbol.

Br

- These symbols are called Lewis symbols or Lewis electron-dot symbols.





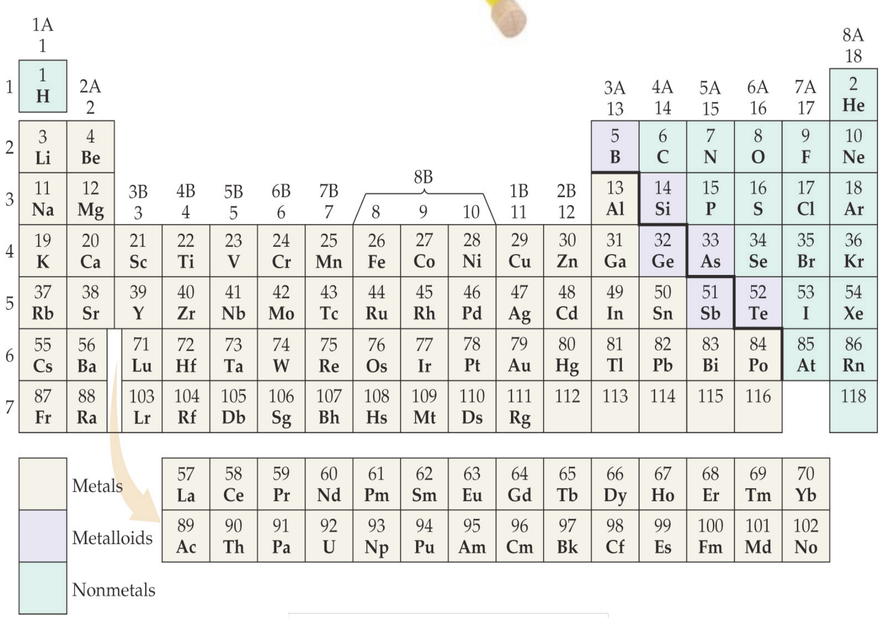
ground state

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$

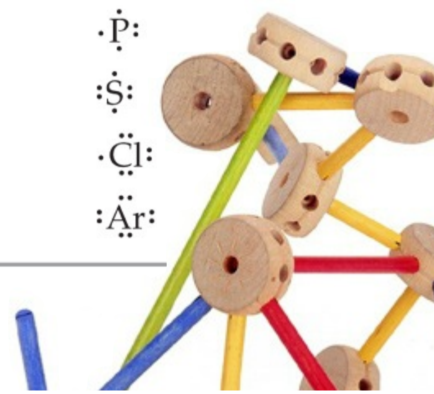
35 electrons

7 valence electrons

Lewis Symbols



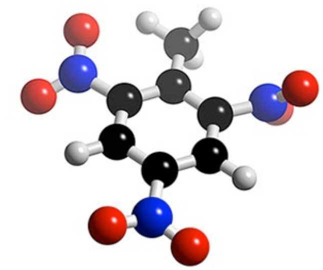
Element	Electron Configuration	Lewis Symbol
Li	$[He]2s^1$	Li·
Be	$[He]2s^2$	·Be·
B	$[He]2s^22p^1$	·Ḃ·
C	$[He]2s^22p^2$	·Ċ̣·
N	$[He]2s^22p^3$	·Ṇ̇:
O	$[He]2s^22p^4$	:Ọ̇:
F	$[He]2s^22p^5$	·F̤̈:
Ne	$[He]2s^22p^6$	:N̤̈e:
Na	$[Ne]3s^1$	Na·
Mg	$[Ne]3s^2$	·Mg·
Al	$[Ne]3s^23p^1$	·Ȧl·
Si	$[Ne]3s^23p^2$	·Ṩi·
P	$[Ne]3s^23p^3$	·Ṗ̣:
S	$[Ne]3s^23p^4$	:Ṩ:
Cl	$[Ne]3s^23p^5$	·C̤̈l:
Ar	$[Ne]3s^23p^6$	:Ä̤r:

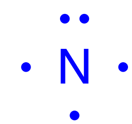


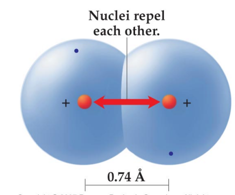
Chemical Bonds

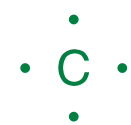
- Atoms forming Molecules
  - Composition, Connectivity & Shape
- Types of Connectivity (Bonding)
  - ionic - stealing electrons
  - covalent - sharing electrons
  - metallic - swimming in electrons
- Lewis Dot Notation
  - Lewis Symbols
    - elemental symbol surrounded by valence electrons
  - The Octet Rule
    - Why it's a reliable predictor.

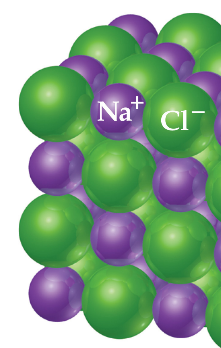
- Ionic Bonding
  - Forming Ions to Bond Atoms
  - Thermodynamics
    - Born-Haber cycle
    - Lattice energy
      - trends: by size & charge
  - Checking the Model
- Covalent Bonding
  - Sharing Electrons to Bond Atoms
  - Thermodynamics
  - Lewis Structures
    - Identifies Lone Pairs
    - Predicts Bond Order
  - Checking the Model

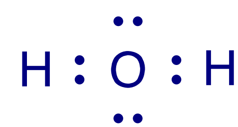


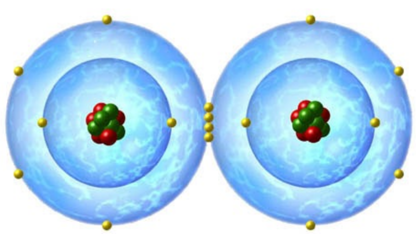


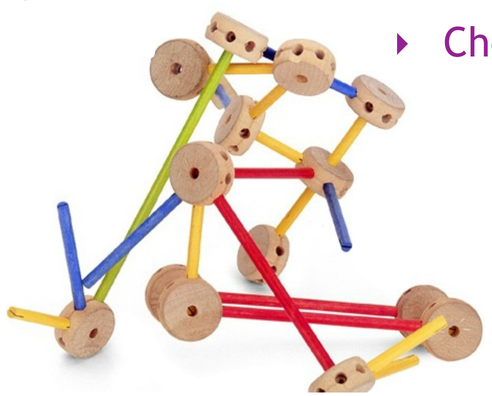


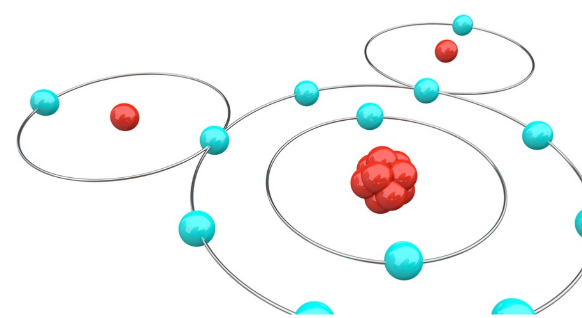




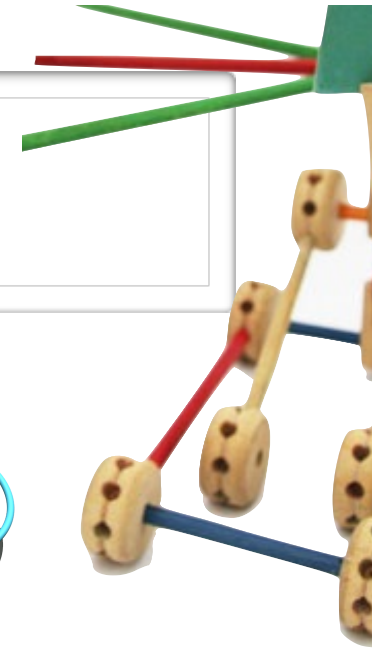


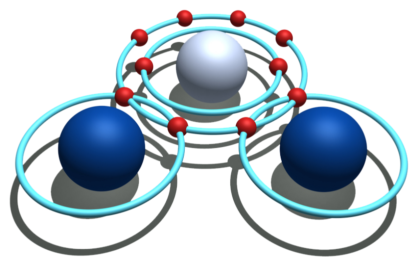




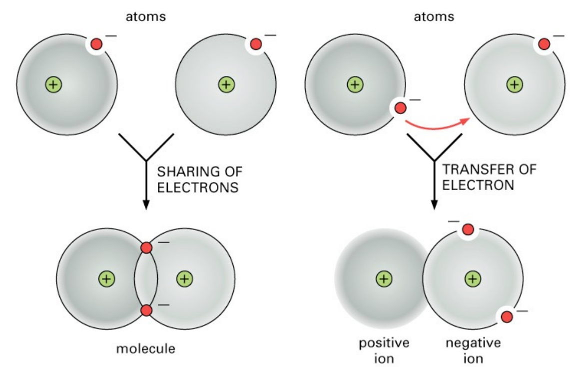


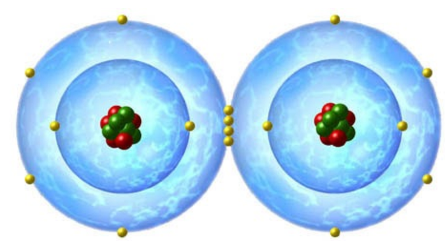
The Octet Rule

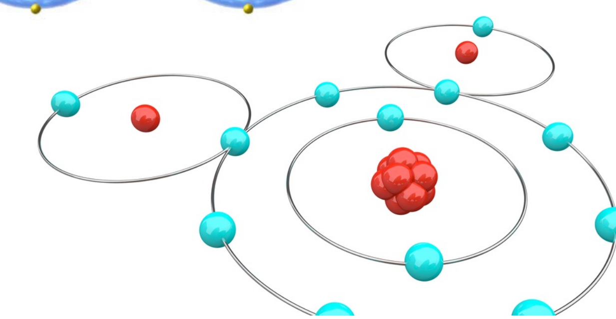




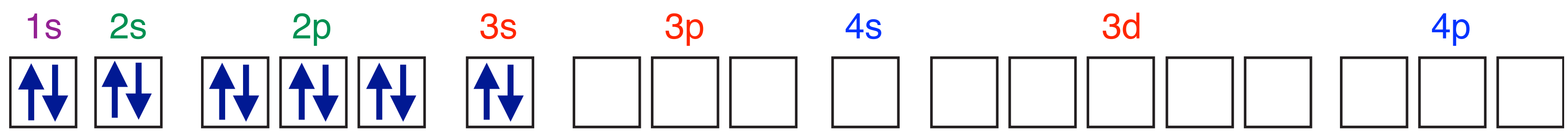
- A full valence shell is a plateau in energy.
  - There's a considerable gain in energy by reaching a full shell.
  - There's little gain in trying to add more electrons.
- The valence shell for all main group atoms (for this class we will say all atoms) have between 1-8 electrons
- The octet rule:
  - Most elements want 8 electrons in their valence shell.
- Lewis structures accurately predict chemical bonding by simply trying to fill the octet of each element by sharing or transferring electrons.
  - It's a very simple model that gives very good predictions.
  - There are exceptions to the octet rule:
    - Some elements prefer less than a full octet: H, He, Al, and B are the most common.
    - A few elements have an expanded octet.
      - This can only happen in the 3rd period and below.
      - We'll talk about this more later in this chapter.
    - If a molecule has an odd number of electrons, someone ends up with 7.
      - 7 is the "second best" to 8, never 5 or 1 or 9 or anything else



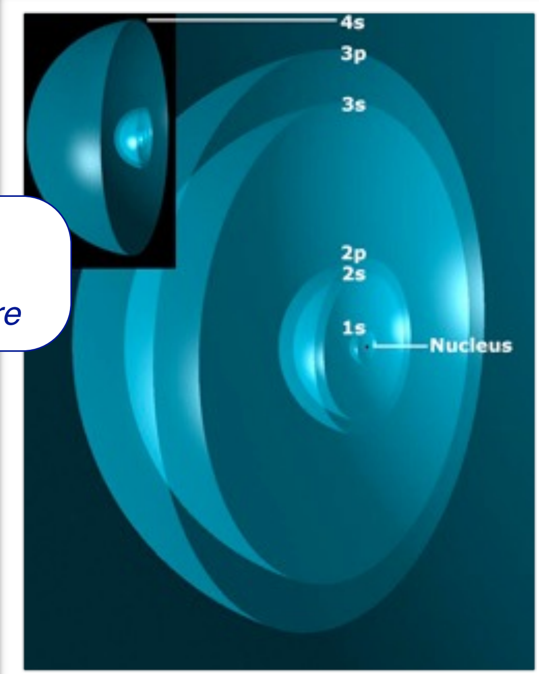




Lewis Symbols - Cations



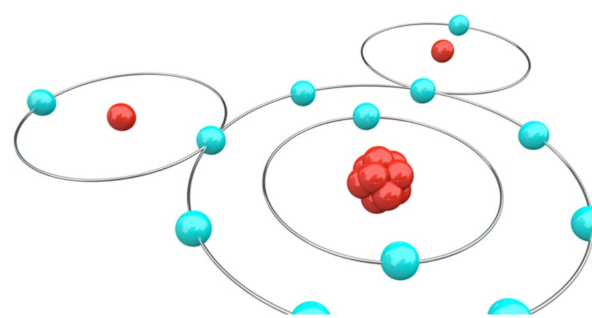
- For cations, start with the lewis dot symbol of the neutral element and remove the appropriate electrons.
- Then put the corresponding charge on the symbol.



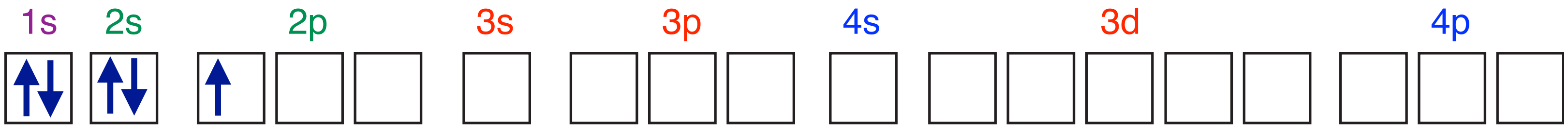
•Mg• → Mg^{2+}

$1s^2 2s^2 2p^6 \underline{3s^2}$ → $1s^2 2s^2 2p^6$

for **<u>most</u>** cations:
8 valence electrons
but no dots in structure



Lewis Symbols - Cations



- For cations, start with the lewis dot symbol of the neutral element and remove the appropriate electrons.
- Then put the corresponding charge on the symbol.

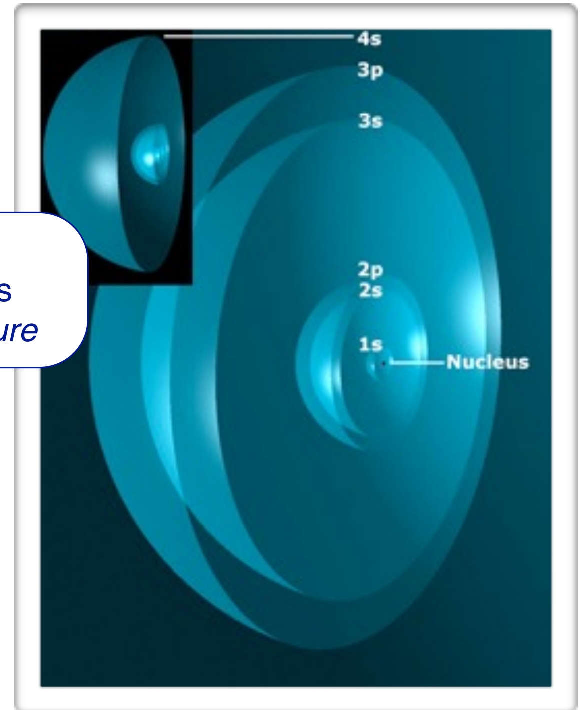
•Mg• → Mg^{2+}

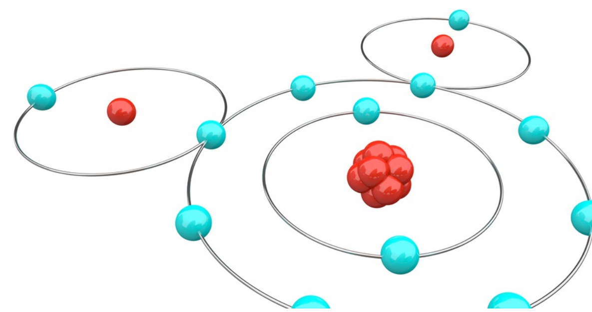
$1s^2 2s^2 2p^6 \underline{3s^2}$ → $1s^2 2s^2 2p^6$

:B• → B^{3+}

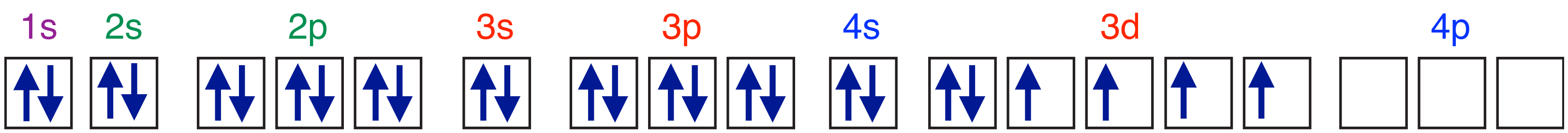
$1s^2 \underline{2s^2 2p^1}$ → $1s^2$

for **most** cations:
8 valence electrons
but no dots in structure

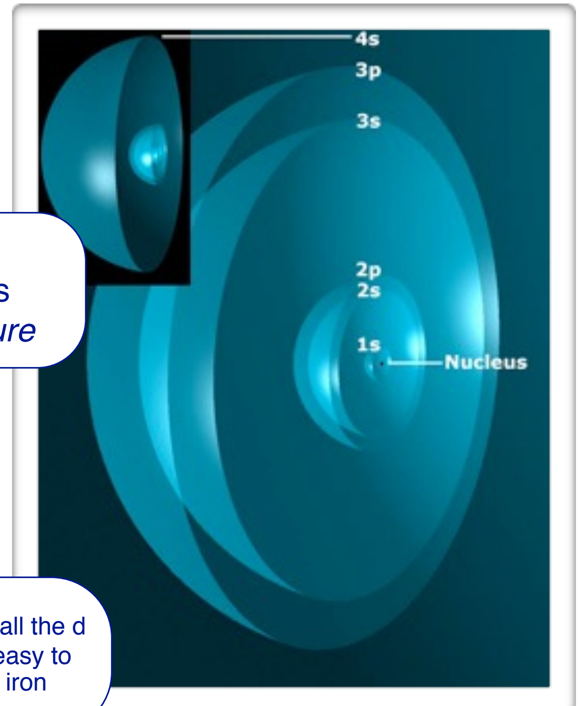




Lewis Symbols - Cations



- For cations, start with the lewis dot symbol of the neutral element and remove the appropriate electrons.
- Then put the corresponding charge on the symbol.



for **most** cations:
8 valence electrons
but no dots in structure

• Mg • → Mg^{2+}

$1s^2 2s^2 2p^6 \underline{3s^2}$ → $1s^2 2s^2 2p^6$

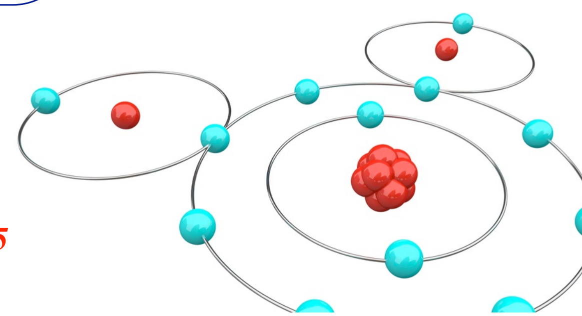
: B • → B^{3+}

$1s^2 \underline{2s^2 2p^1}$ → $1s^2$

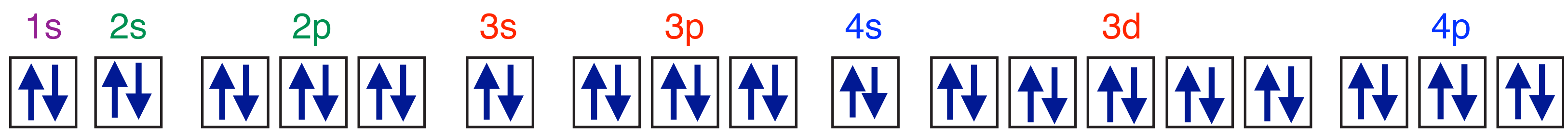
the stabilization from having all the d orbitals half filled makes it easy to pull a third electron off of iron

• Fe • → Fe^{2+} Fe^{3+}

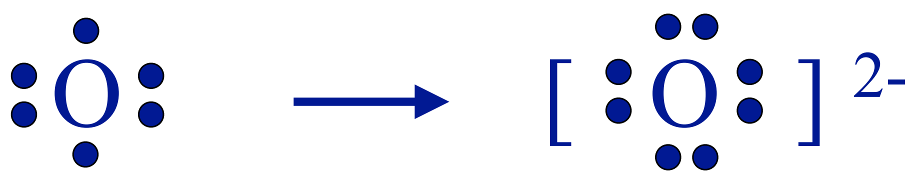
$1s^2 2s^2 2p^6 3s^2 3p^6 \underline{4s^2} 3d^6$ → $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$



Lewis Symbols - Anions

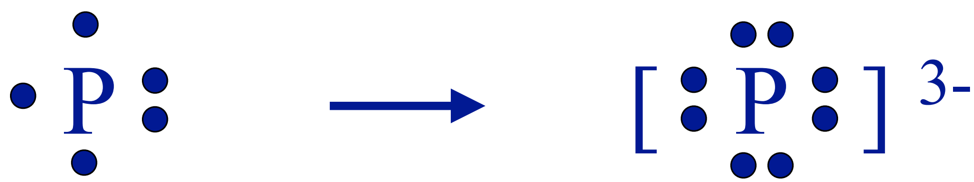


- For anions, start with the lewis dot symbol of the neutral element and add the appropriate electrons.
- Put brackets around the symbol *to be clear those extra electrons belong to it*.
- Then put the corresponding charge on the symbol — outside the bracket.

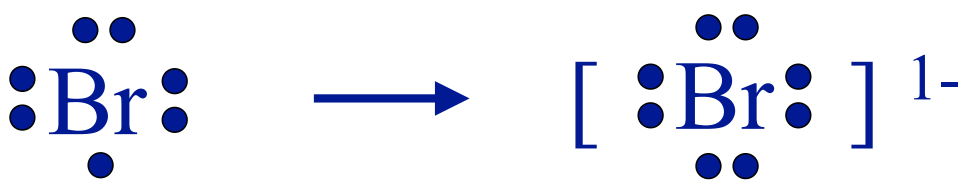


$1s^2 2s^2 2p^4$ → *$1s^2 2s^2 2p^6$*

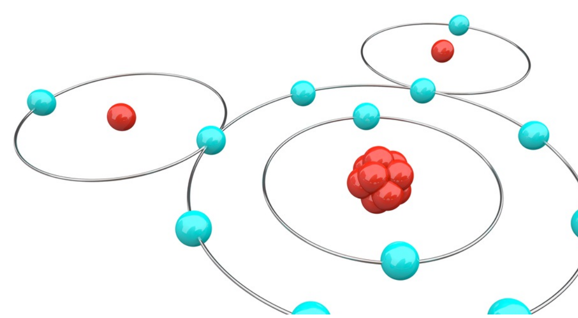
for **most** anions:
8 valence electrons
8 dots in structure
don't forget the brackets!



$1s^2 2s^2 2p^6 3s^2 3p^3$ → *$1s^2 2s^2 2p^6 3s^2 3p^6$*

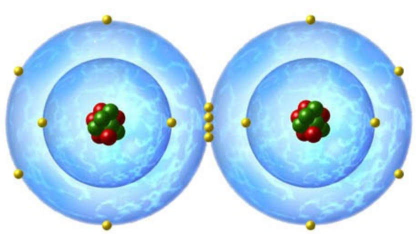


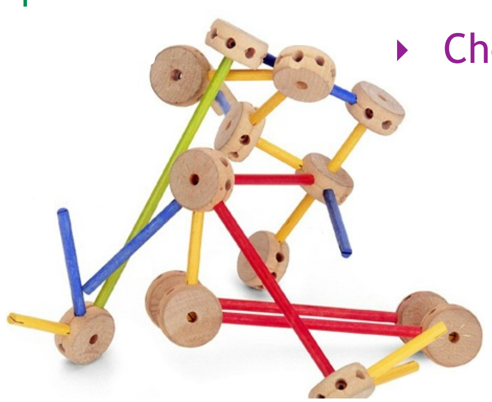
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$ → *$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$*



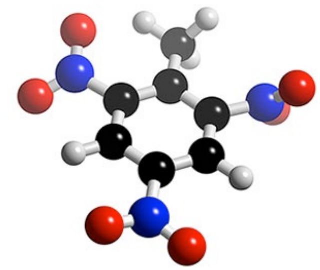
Chemical Bonds

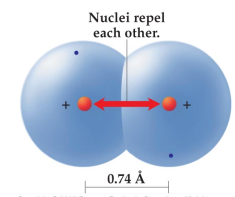
- Atoms forming Molecules
  - Composition, Connectivity & Shape
- Types of Connectivity (Bonding)
  - ionic - stealing electrons
  - covalent - sharing electrons
  - metallic - swimming in electrons
- Lewis Dot Notation
  - Lewis Symbols
    - elemental symbol surrounded by valence electrons
  - The Octet Rule
    - Why it's a reliable predictor.





- Ionic Bonding
  - Forming Ions to Bond Atoms
  - Thermodynamics
    - Born-Haber cycle
    - Lattice energy
      - trends: by size & charge
  - Checking the Model
- Covalent Bonding
  - Sharing Electrons to Bond Atoms
  - Thermodynamics
  - Lewis Structures
    - Identifies Lone Pairs
    - Predicts Bond Order
  - Checking the Model

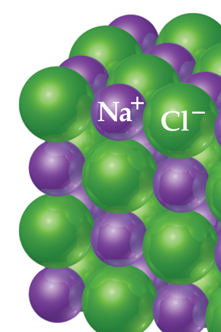


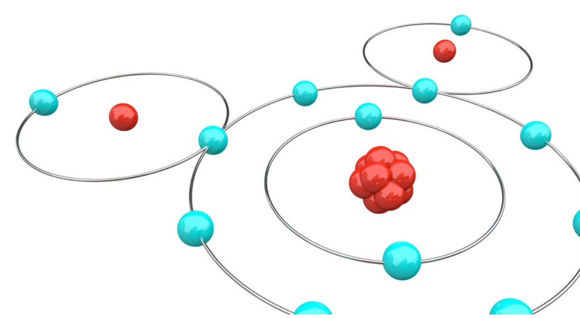


N

C

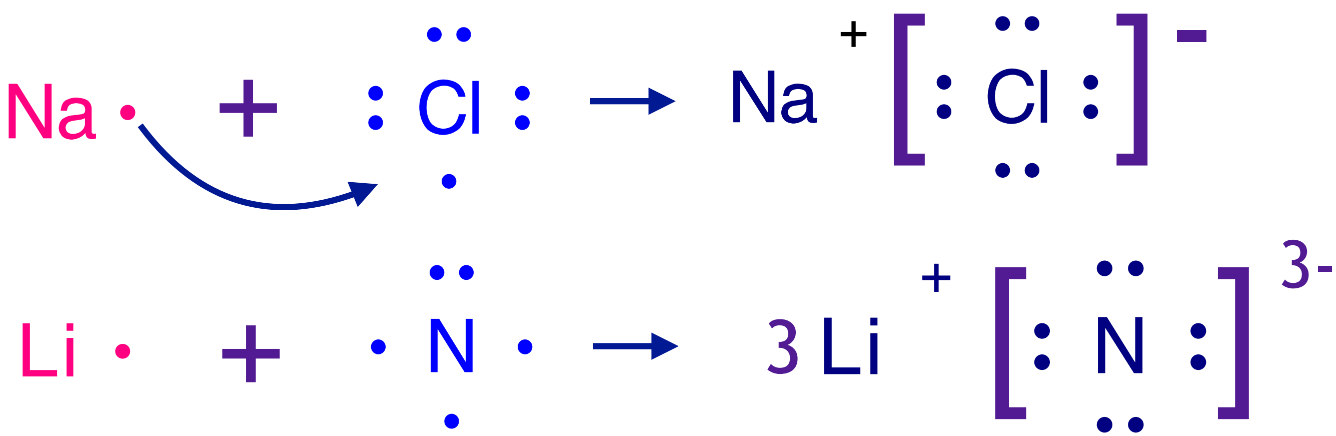
H : O : H





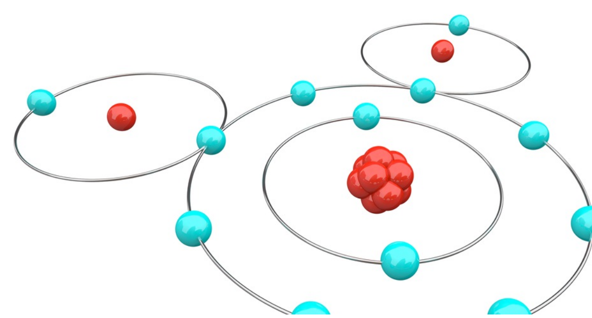
Ionic Bonding

- Lewis symbols can be used to show the structure of ions and ionic compounds.
- Ions & ionic compounds can be predicted by the octet rule.
- Elements with low ionization energy become cations.
- Elements with high electron affinity become anions.
  - Use square brackets when showing the charge of any atom or molecule that has extra electrons.
- Lewis symbols identify the chemical formula of ionic compounds.



NaCl

Li_3N



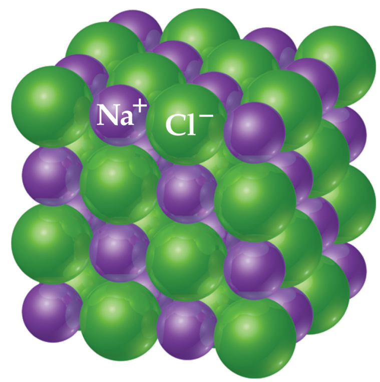
Ionic Bonding

- Ionic Bonding is extremely strong. *4x*
- The strength from ionic bonding comes from:
  - The thermodynamic difference in moving the electron.
  - The electrostatic attraction between ions.
    - Which exists between ions on all sides.
    - This energy is substantial.
    - It's called the lattice energy.

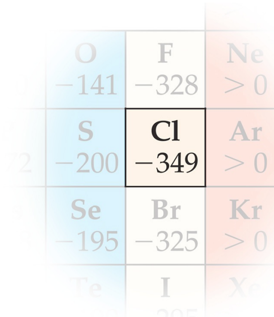
NaCl

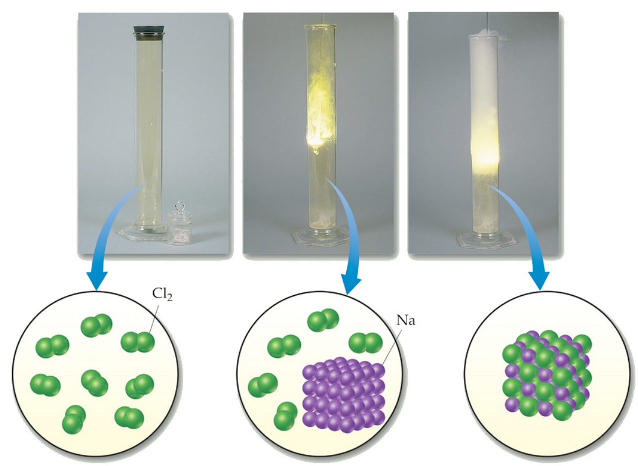
Element	I_1
Na	495
Mg	738

It takes 495 kJ/mol to remove electrons from sodium.



We get 349 kJ/mol back by giving electrons to chlorine.

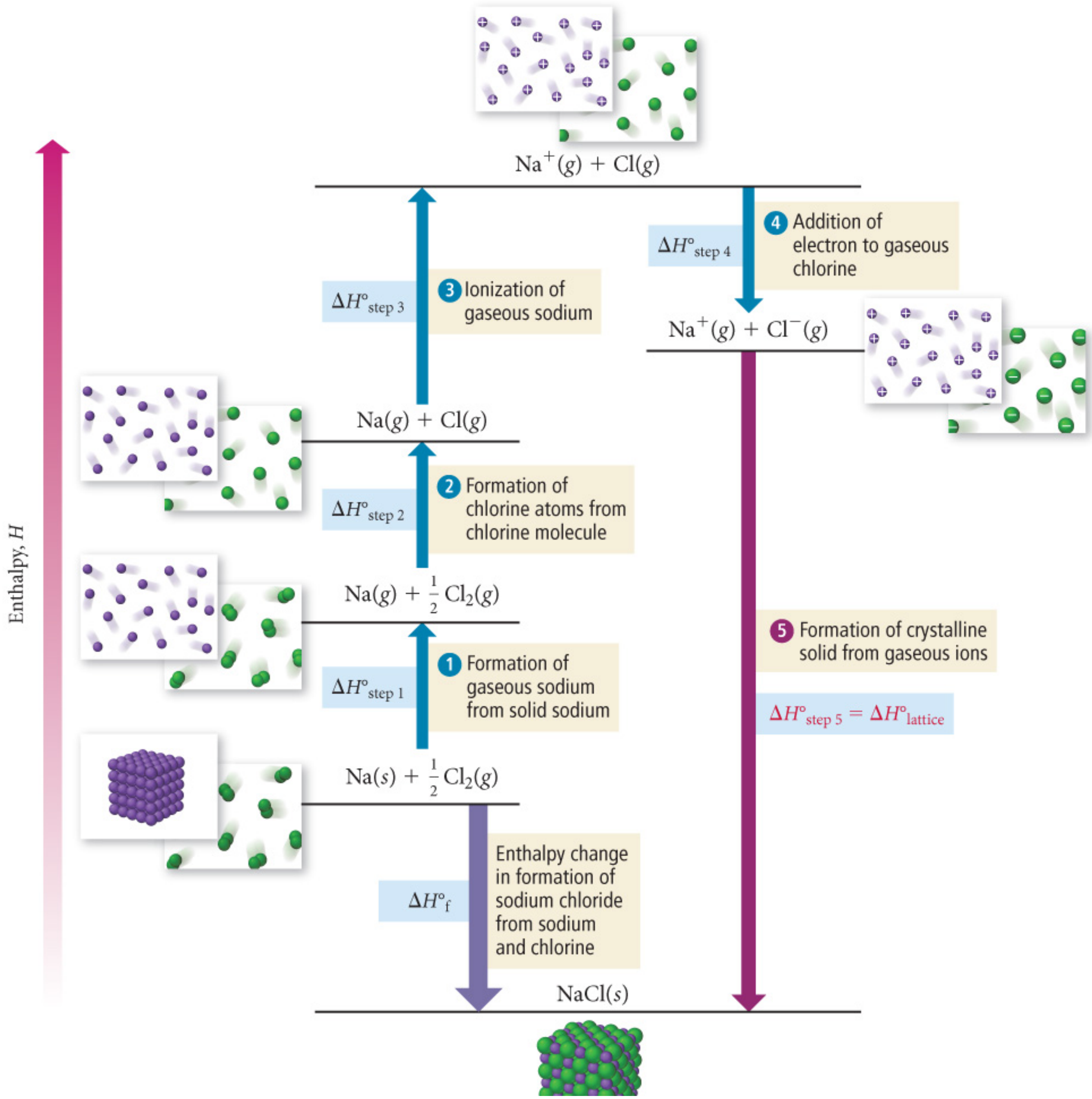




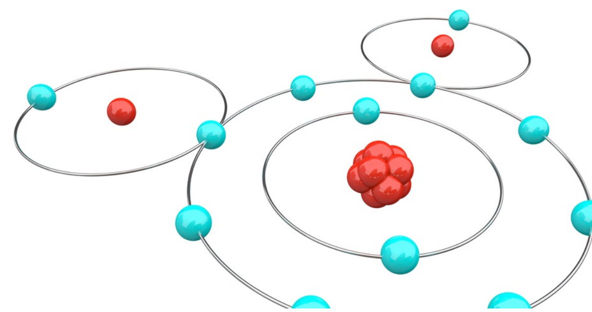
But these numbers don't explain why the reaction of sodium metal and chlorine gas to form sodium chloride is so exothermic!

$\Delta H^\circ_f = -411$ kJ/mol

Born-Haber Cycle

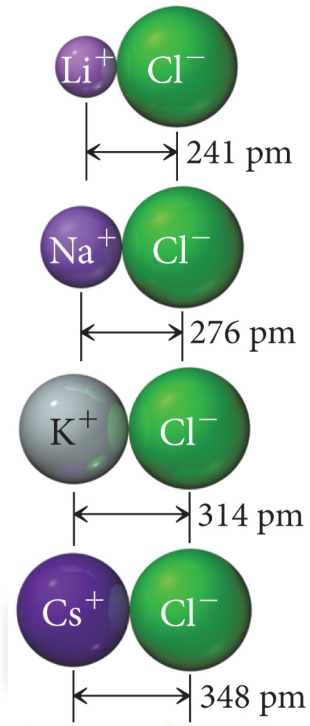


1. $Na_{(s)} \rightarrow Na_{(g)}$ $\Delta H = +108$ kJ
   Energy to Vaporize the Sodium
2. ½ $Cl_{2(g)} \rightarrow Cl_{(g)}$ $\Delta H = +122$ kJ
   Energy from breaking a Bond
3. $Na \rightarrow Na+ + 1e$ $\Delta H = +496$ kJ
   Ionization Energy
4. $Cl_{(g)} + 1e \rightarrow Cl^{1-}_{(g)}$ $\Delta H = -349$ kJ
   Electron Affinity
5. $Na^{+1}_{(g)} + Cl^{-1}_{(g)} \rightarrow NaCl_{(s)}$ $\Delta H = -788$ kJ
   Lattice Energy



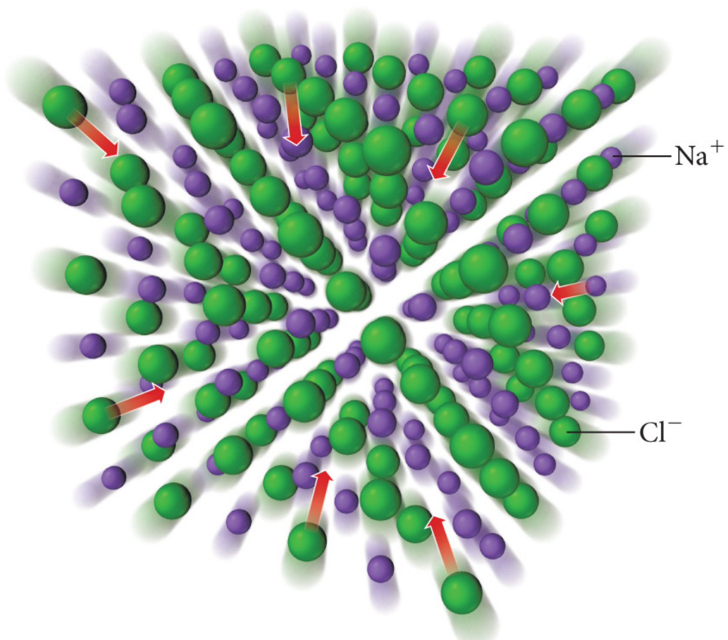
Lattice Energy

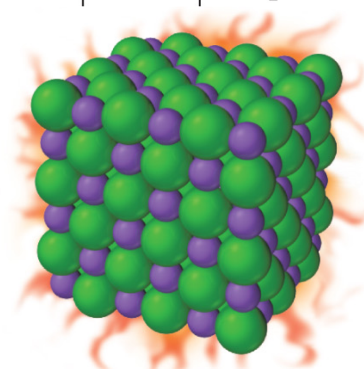
- Ionic Bonding is extremely strong. 4x
- The strength from ionic bonding comes from:
  - The thermodynamic difference in moving the electron.
  - The electrostatic attraction between ions.
    - Which exists between ions on all sides.
    - This energy is substantial.
    - It’s called the lattice energy.
- Lattice Energy
  - Increases as atomic radius decreases
  - Increases with atomic charge



Metal Chloride	Lattice Energy kJ/mol
LiCl	−834
NaCl	−788
KCl	−701
CsCl	−657

Compound	Lattice Energy (kJ/mol)
NaF	−910
CaO	−3414





$Na^+(g) + Cl^-(g) \longrightarrow NaCl(s)$ → ΔH° = lattice energy

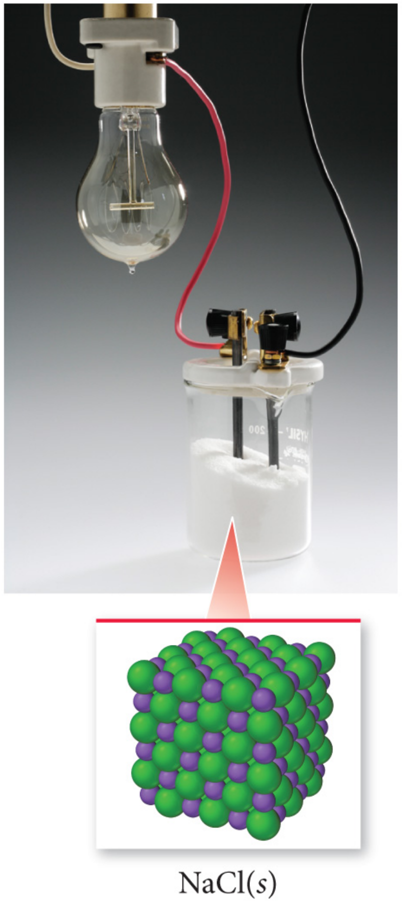
Checking the Model

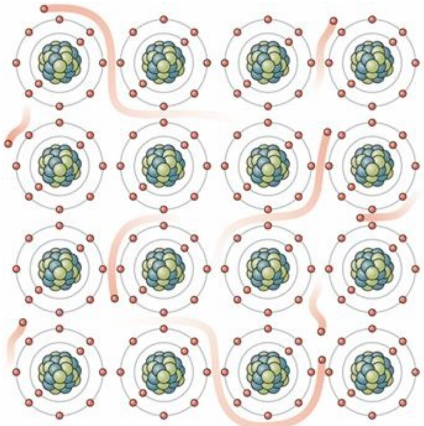
Theory

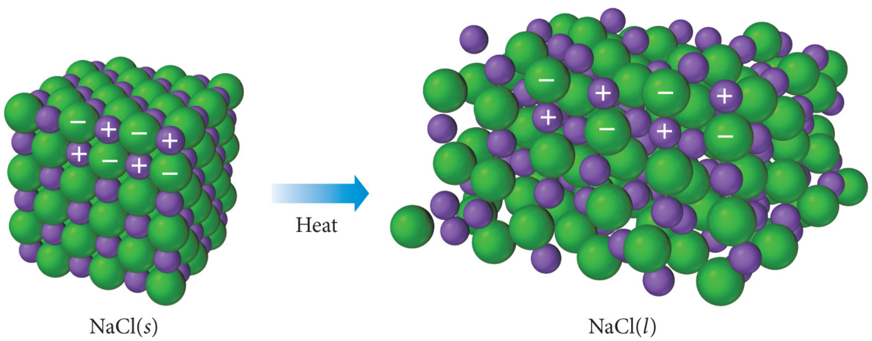
- Ionic solids have separation of charge (like metallic solids)
  - Charges are locked in position within a crystal lattice.
  - Charges that can be liberated by salvation in water.
  - A latticework made of strong nondirectional electrostatic attraction.

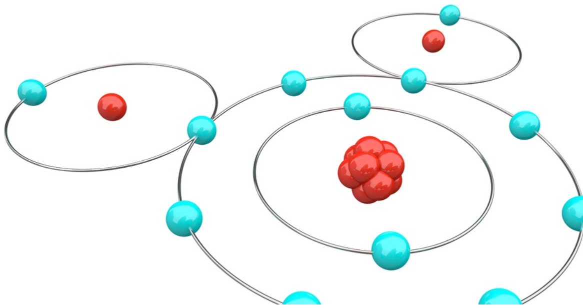
Experiment

- Ionic solids don't conduct electricity.
- Ionic solids dissolved in water conduct electricity.
- Ionic solids have extremely high melting points.
- Melted ionic solids are excellent conductors of electricity.









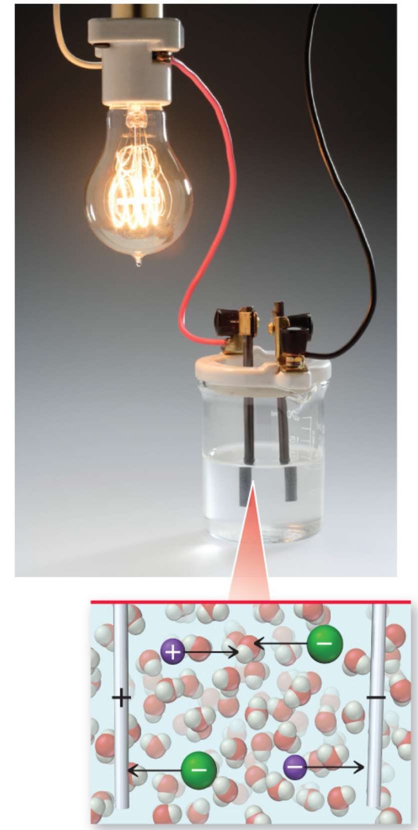
Checking the Model

Theory

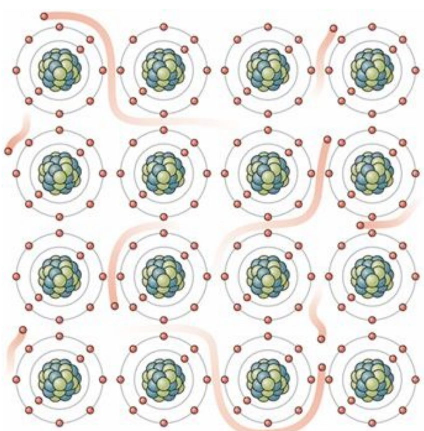
- Ionic solids have separation of charge (like metallic solids)
  - Charges are locked in position within a crystal lattice.
  - Charges that can be liberated by salvation in water.
  - A latticework made of strong nondirectional electrostatic attraction.

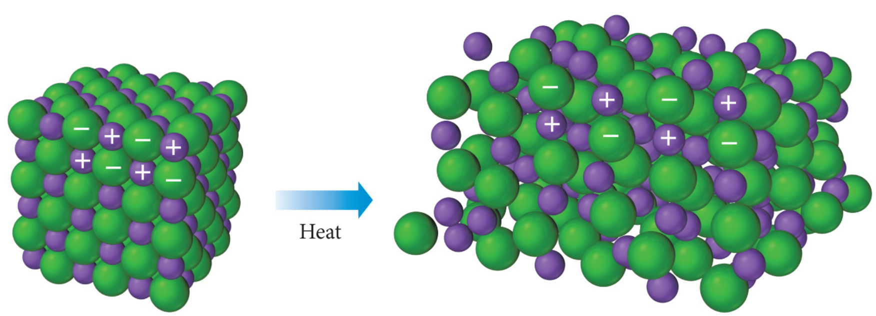
Experiment

- Ionic solids don't conduct electricity.
- Ionic solids dissolved in water conduct electricity.
- Ionic solids have extremely high melting points.
- Melted ionic solids are excellent conductors of electricity.

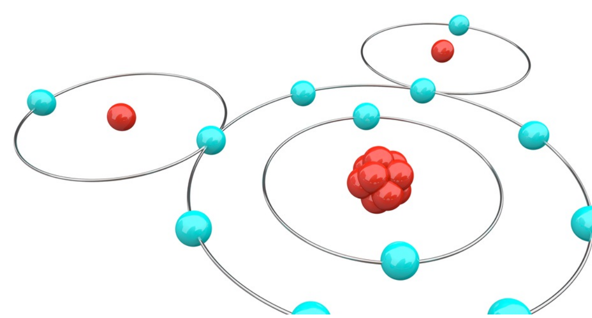


NaCl(aq)





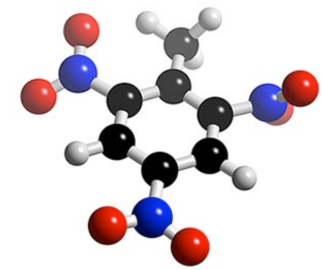
NaCl(s) NaCl(l)

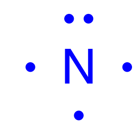


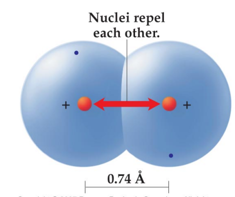
Chemical Bonds

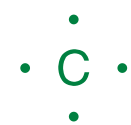
- Atoms forming Molecules
  - Composition, Connectivity & Shape
- Types of Connectivity (Bonding)
  - ionic - stealing electrons
  - covalent - sharing electrons
  - metallic - swimming in electrons
- Lewis Dot Notation
  - Lewis Symbols
    - elemental symbol surrounded by valence electrons
  - The Octet Rule
    - Why it's a reliable predictor.

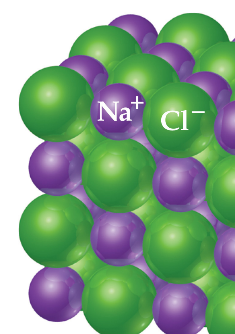
- Ionic Bonding
  - Forming Ions to Bond Atoms
  - Thermodynamics
    - Born-Haber cycle
    - Lattice energy
      - trends: by size & charge
  - Checking the Model
- Covalent Bonding
  - Sharing Electrons to Bond Atoms
  - Thermodynamics
  - Lewis Structures
    - Identifies Lone Pairs
    - Predicts Bond Order
  - Checking the Model

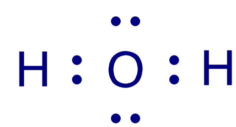


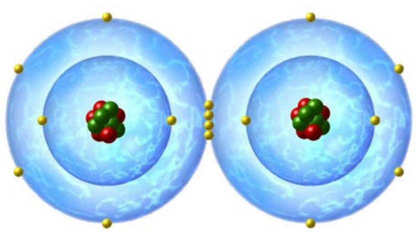


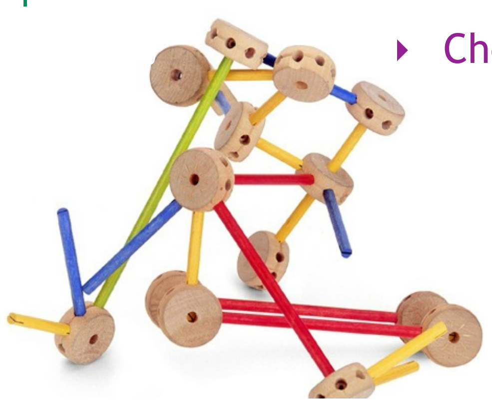


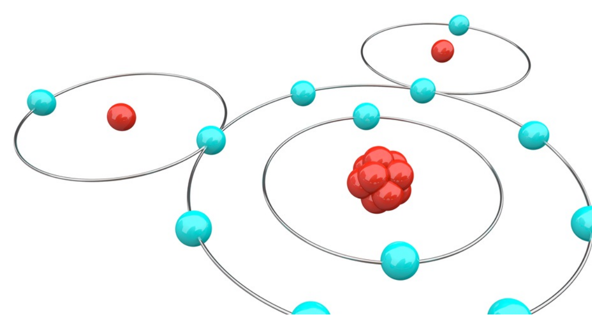






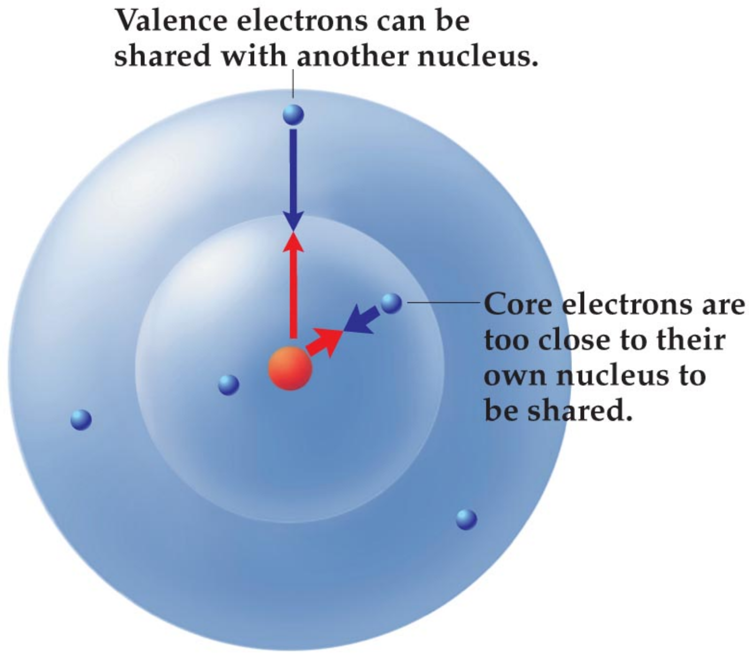




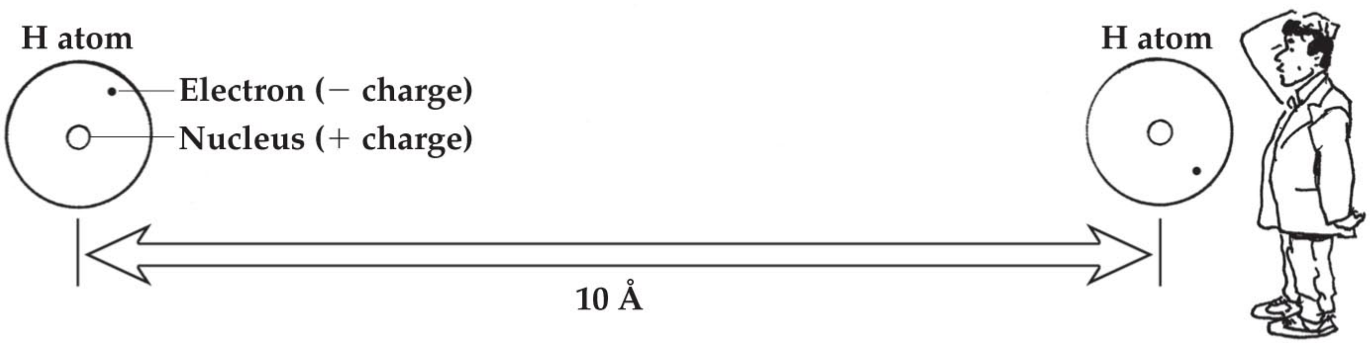


The Covalent Bond

- Thermodynamics drive bond formation.
  - Thermodynamics favors ionic bonds…
    - — when it takes less energy to rip an electron off an atom that you get back by putting it on another.
  - When that's not the case, there is still a way to satisfy atoms with strong electron affinity.
    - By sharing electrons.
- Covalent Bonding occurs between neutral atoms with strong EA.
- When these atoms get within 8 angstroms (0.8 nanometers) they begin to pull on each others valence electrons.
  - Electrons that are shielded from their own nucleus.
- Like a ball falling down hill, the atoms fall into each others e-m field.
- The atoms never meet, because as they get closer the repulsion between nucleus increases, until that energy repulsion matches the attractive energy.
- That's the bottom of the well.
- At that point the atoms lock into a fixed distance from each other, usually about an angstrom (0.1 nanometer).
- Separating those atoms, breaking that bond, requires energy.

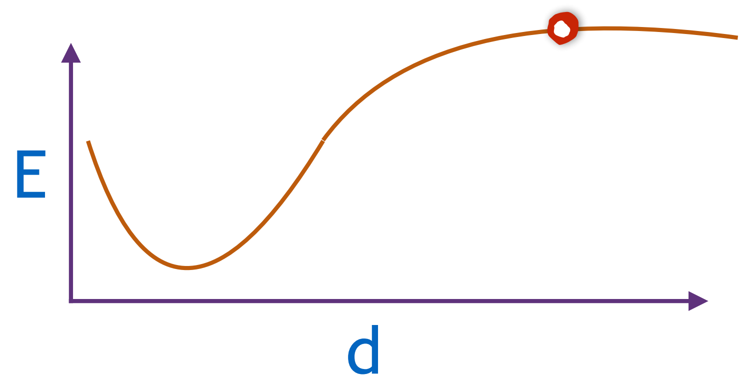


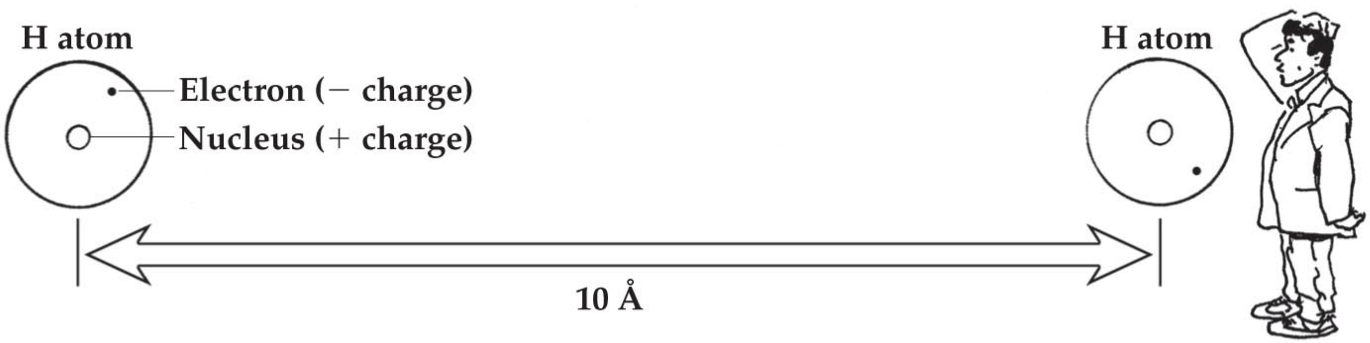
Only valence electrons participate in covalent bonding.



The Covalent Bond

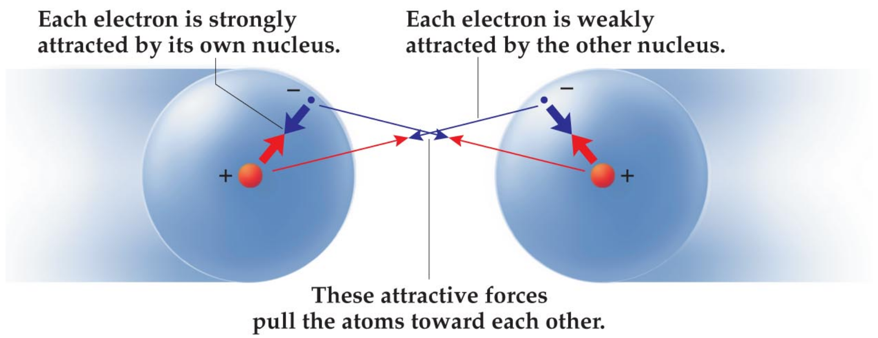
- Thermodynamics drive bond formation.
  - Thermodynamics favors ionic bonds…
    - — when it takes less energy to rip an electron off an atom that you get back by putting it on another.
  - When that's not the case, there is still a way to satisfy atoms with strong electron affinity.
    - By sharing electrons.
- Covalent Bonding occurs between neutral atoms with strong EA.
- When these atoms get within 8 angstroms (0.8 nanometers) they begin to pull on each others valence electrons.
  - Electrons that are shielded from their own nucleus.
- Like a ball falling down hill, the atoms fall into each others e-m field.
- The atoms never meet, because as they get closer the repulsion between nucleus increases, until that energy repulsion matches the attractive energy.
- That's the bottom of the well.
- At that point the atoms lock into a fixed distance from each other, usually about an angstrom (0.1 nanometer).
- Separating those atoms, breaking that bond, requires energy.

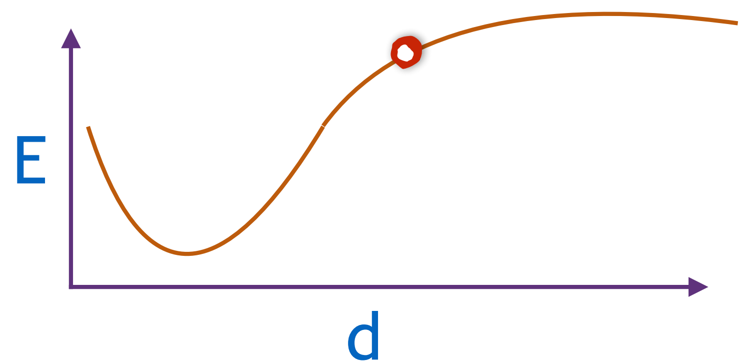


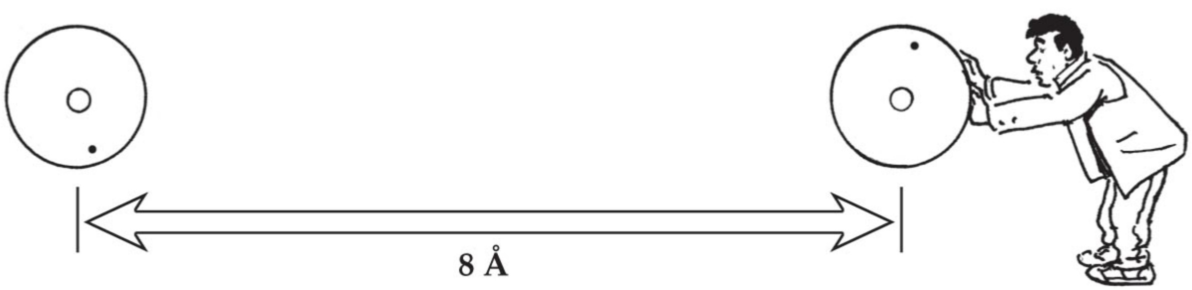


The Covalent Bond

- Thermodynamics drive bond formation.
  - Thermodynamics favors ionic bonds…
    - – when it takes less energy to rip an electron off an atom that you get back by putting it on another.
  - When that's not the case, there is still a way to satisfy atoms with strong electron affinity.
    - By sharing electrons.
- Covalent Bonding occurs between neutral atoms with strong EA.
- When these atoms get within 8 angstroms (0.8 nanometers) they begin to pull on each others valence electrons.
  - Electrons that are shielded from their own nucleus.
- Like a ball falling down hill, the atoms fall into each others e-m field.
- The atoms never meet, because as they get closer the repulsion between nucleus increases, until that energy repulsion matches the attractive energy.
- That's the bottom of the well.
- At that point the atoms lock into a fixed distance from each other, usually about an angstrom (0.1 nanometer).
- Separating those atoms, breaking that bond, requires energy.

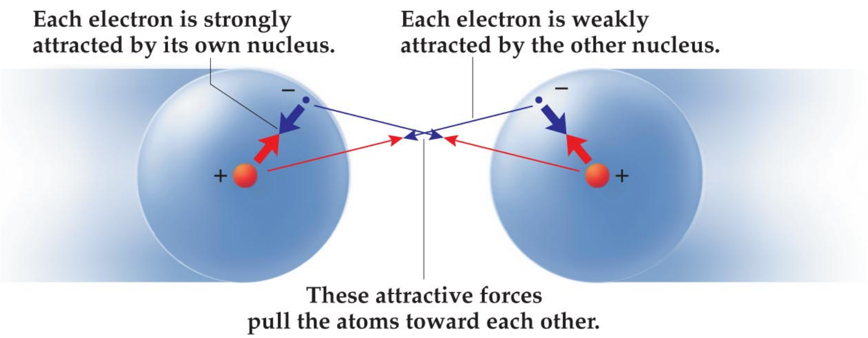


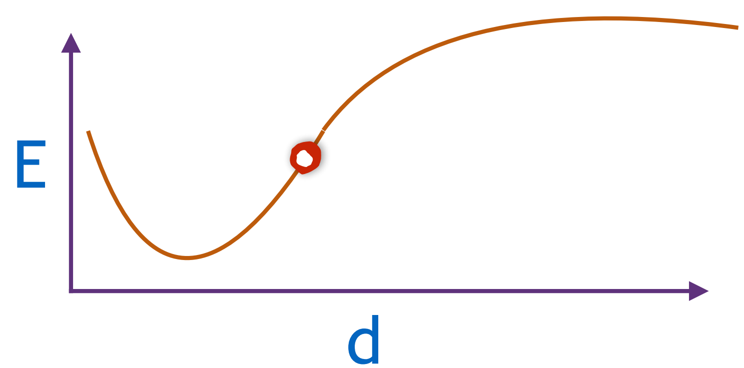


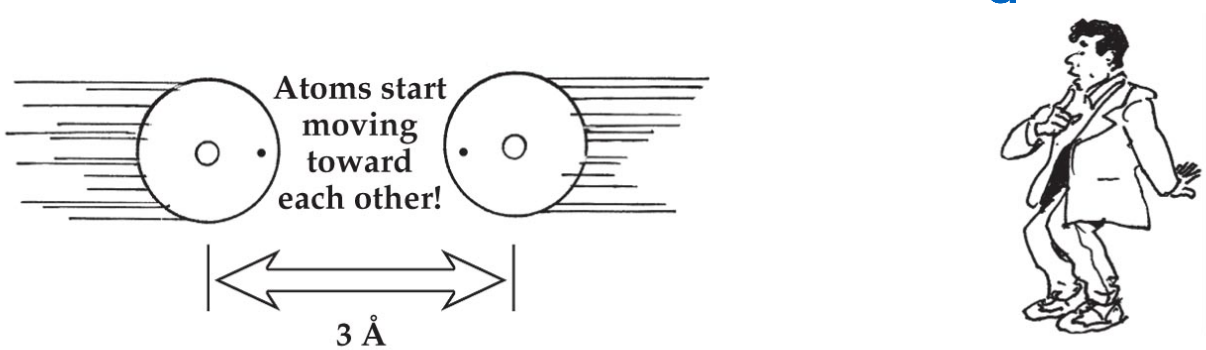


The Covalent Bond

- Thermodynamics drive bond formation.
  - Thermodynamics favors ionic bonds…
    - – when it takes less energy to rip an electron off an atom that you get back by putting it on another.
  - When that's not the case, there is still a way to satisfy atoms with strong electron affinity.
    - By sharing electrons.
- Covalent Bonding occurs between neutral atoms with strong EA.
- When these atoms get within 8 angstroms (0.8 nanometers) they begin to pull on each others valence electrons.
  - Electrons that are shielded from their own nucleus.
- Like a ball falling down hill, the atoms fall into each others e-m field.
- The atoms never meet, because as they get closer the repulsion between nucleus increases, until that energy repulsion matches the attractive energy.
- That's the bottom of the well.
- At that point the atoms lock into a fixed distance from each other, usually about an angstrom (0.1 nanometer).
- Separating those atoms, breaking that bond, requires energy.

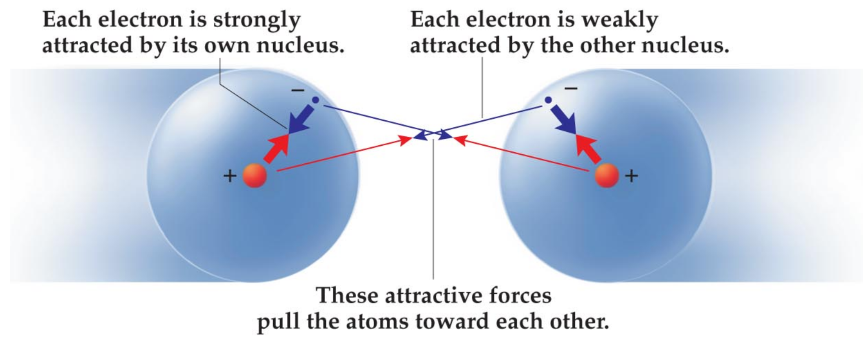


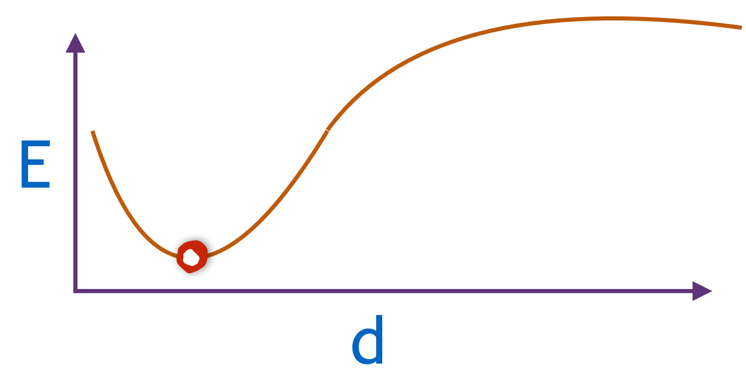


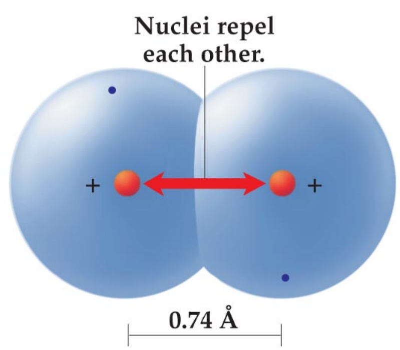


The Covalent Bond

- Thermodynamics drive bond formation.
  - Thermodynamics favors ionic bonds…
    - – when it takes less energy to rip an electron off an atom that you get back by putting it on another.
  - When that's not the case, there is still a way to satisfy atoms with strong electron affinity.
    - By sharing electrons.
- Covalent Bonding occurs between neutral atoms with strong EA.
- When these atoms get within 8 angstroms (0.8 nanometers) they begin to pull on each others valence electrons.
  - Electrons that are shielded from their own nucleus.
- Like a ball falling down hill, the atoms fall into each others e-m field.
- The atoms never meet, because as they get closer the repulsion between nucleus increases, until that energy repulsion matches the attractive energy.
- That's the bottom of the well.
- At that point the atoms lock into a fixed distance from each other, usually about an angstrom (0.1 nanometer).
- Separating those atoms, breaking that bond, requires energy.

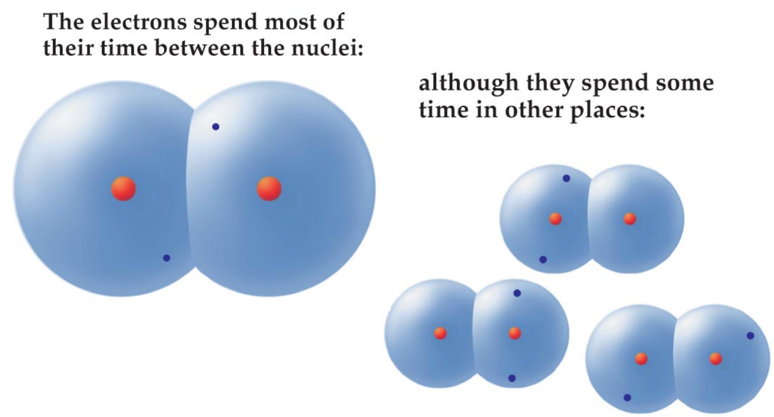


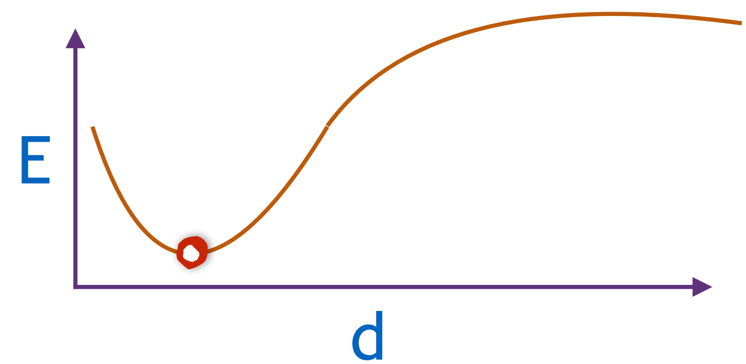


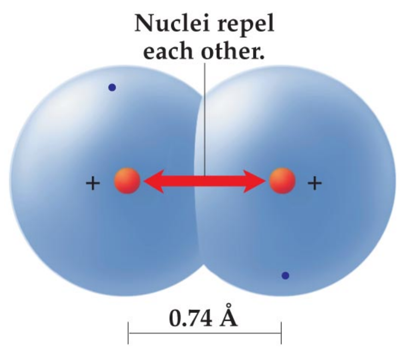


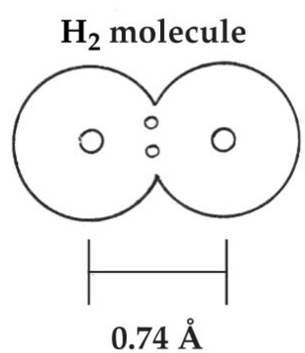
The Covalent Bond

- Thermodynamics drive bond formation.
  - Thermodynamics favors ionic bonds…
    - – when it takes less energy to rip an electron off an atom that you get back by putting it on another.
  - When that's not the case, there is still a way to satisfy atoms with strong electron affinity.
    - By sharing electrons.
- Covalent Bonding occurs between neutral atoms with strong EA.
- When these atoms get within 8 angstroms (0.8 nanometers) they begin to pull on each others valence electrons.
  - Electrons that are shielded from their own nucleus.
- Like a ball falling down hill, the atoms fall into each others e-m field.
- The atoms never meet, because as they get closer the repulsion between nucleus increases, until that energy repulsion matches the attractive energy.
- That's the bottom of the well.
- At that point the atoms lock into a fixed distance from each other, usually about an angstrom (0.1 nanometer).
- Separating those atoms, breaking that bond, requires energy.



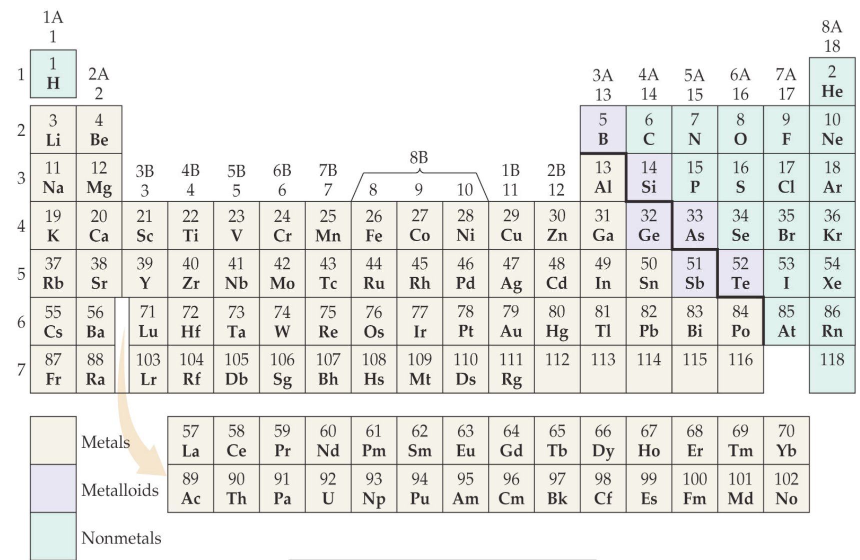


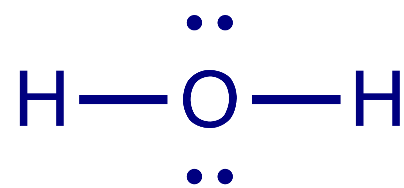


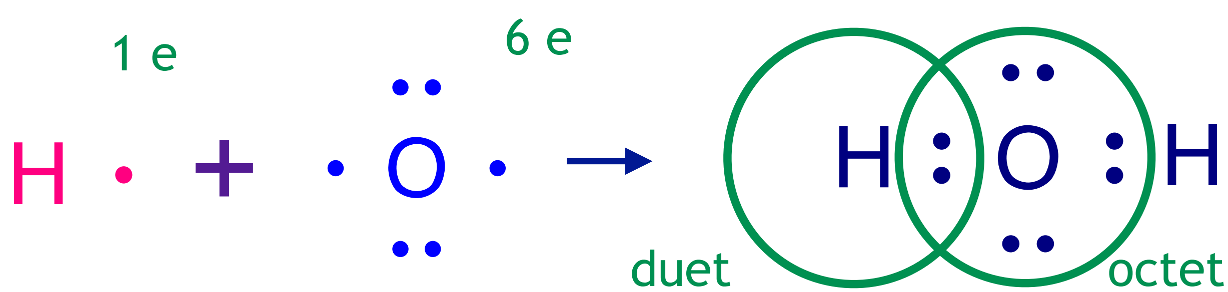


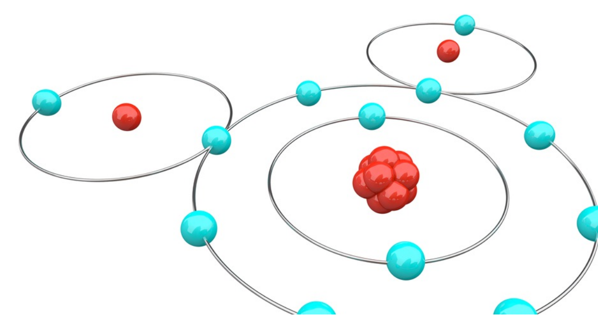
Lewis Molecular Structures

- Lewis symbols provide a simple way of visualizing and predicting covalent bonds.
- Atoms with less than a full valence entangle their orbitals to share electron pairs.
  - Shared electrons are held by both nuclei.
  - Sharing electrons allows each atom to fill it’s valence.
  - The Lewis symbols allow you to predict how many electrons each atom needs and can offer.
  - The octet rule let’s you know when each atom has realized a stable shared configuration.
- Electron pairs not involved in bonding are called lone pairs.
- Electron pairs involved in bonding are called bonding pairs.
  - Bonding pairs may be replaced with a single line.
- Main group elements can form one, two, or three covalent bonds.



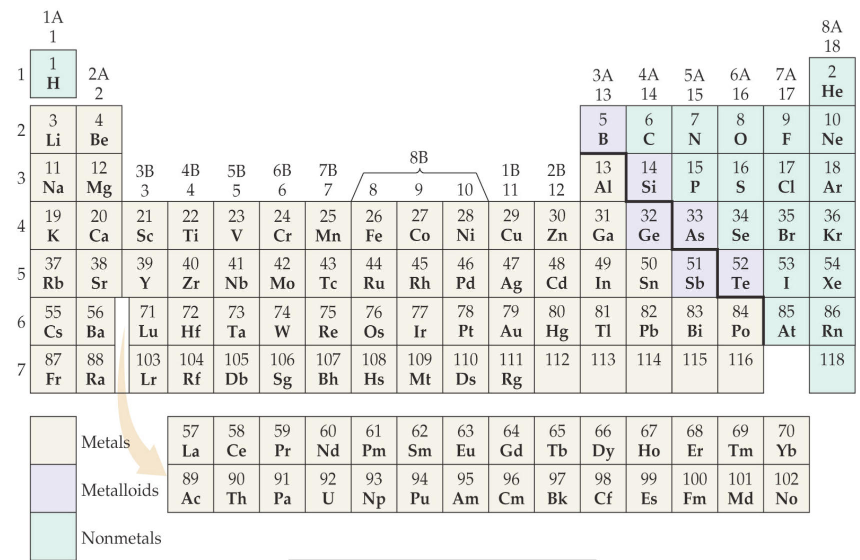


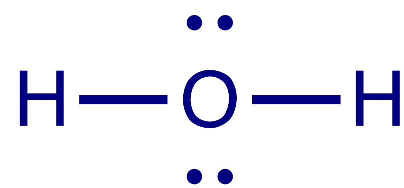


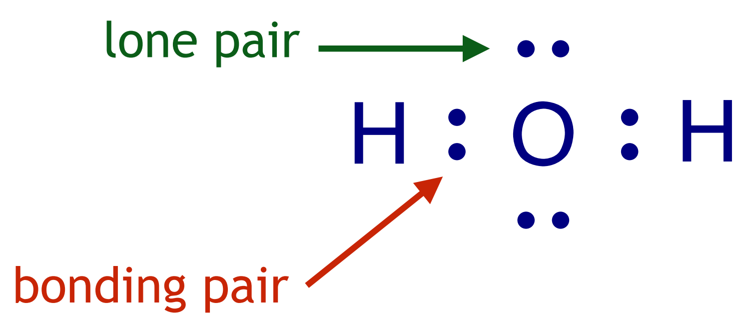


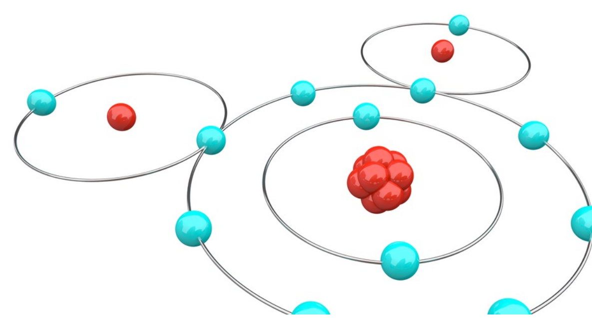
Lewis Molecular Structures

- Lewis symbols provide a simple way of visualizing and predicting covalent bonds.
- Atoms with less than a full valence entangle their orbitals to share electron pairs.
  - Shared electrons are held by both nuclei.
  - Sharing electrons allows each atom to fill it’s valence.
  - The Lewis symbols allow you to predict how many electrons each atom needs and can offer.
  - The octet rule let’s you know when each atom has realized a stable shared configuration.
- Electron pairs not involved in bonding are called lone pairs.
- Electron pairs involved in bonding are called bonding pairs.
  - Bonding pairs may be replaced with a single line.
- Main group elements can form one, two, or three covalent bonds.



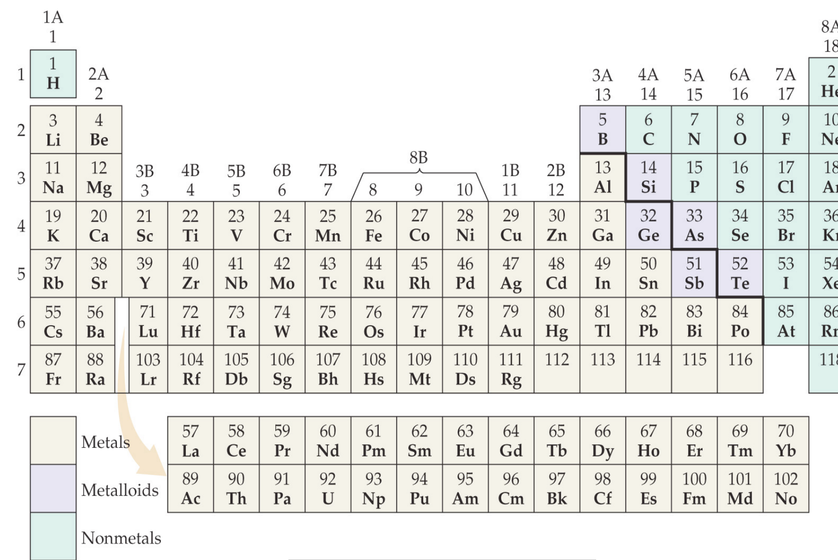


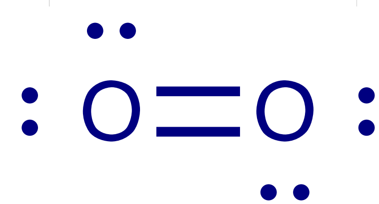


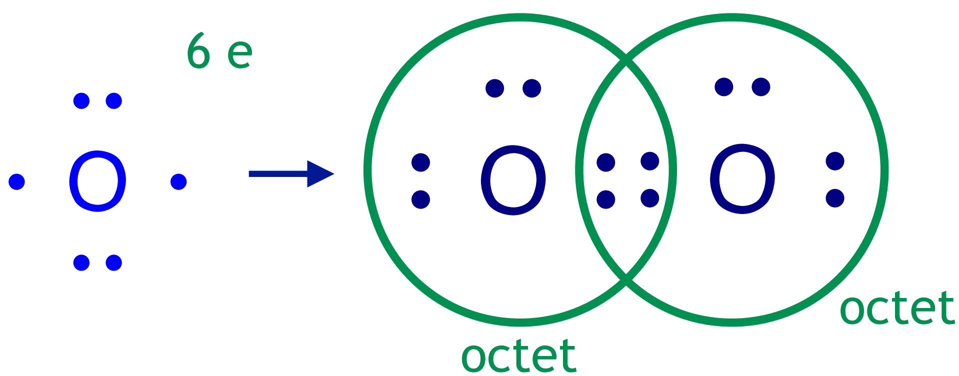


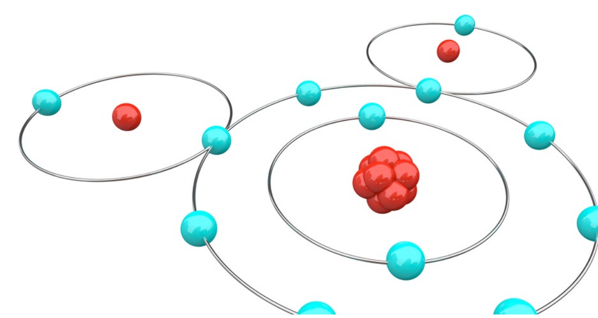
Lewis Molecular Structures

- Lewis symbols provide a simple way of visualizing and predicting covalent bonds.
- Atoms with less than a full valence entangle their orbitals to share electron pairs.
  - Shared electrons are held by both nuclei.
  - Sharing electrons allows each atom to fill it's valence.
  - The Lewis symbols allow you to predict how many electrons each atom needs and can offer.
  - The octet rule let's you know when each atom has realized a stable shared configuration.
- Electron pairs not involved in bonding are called lone pairs.
- Electron pairs involved in bonding are called bonding pairs.
  - Bonding pairs may be replaced with a single line.
- Main group elements can form one, two, or three covalent bonds.



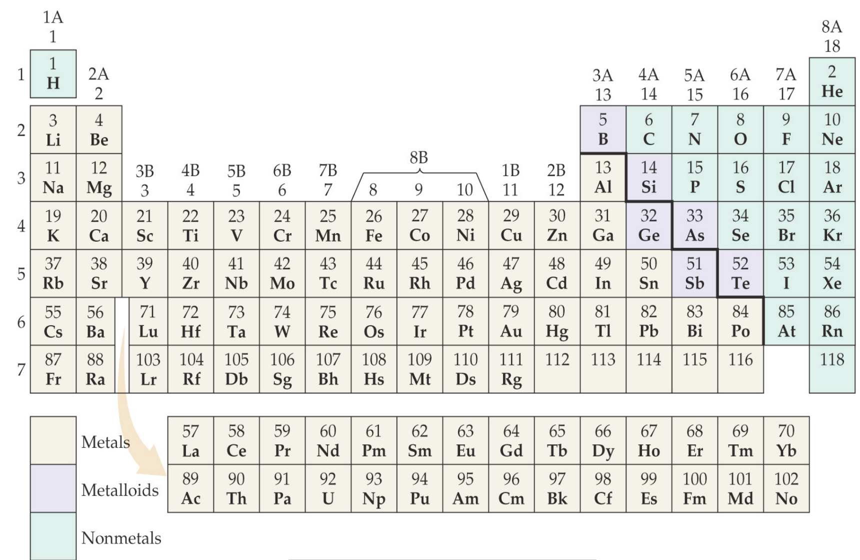


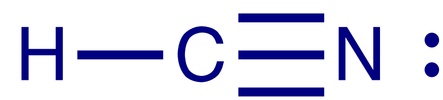


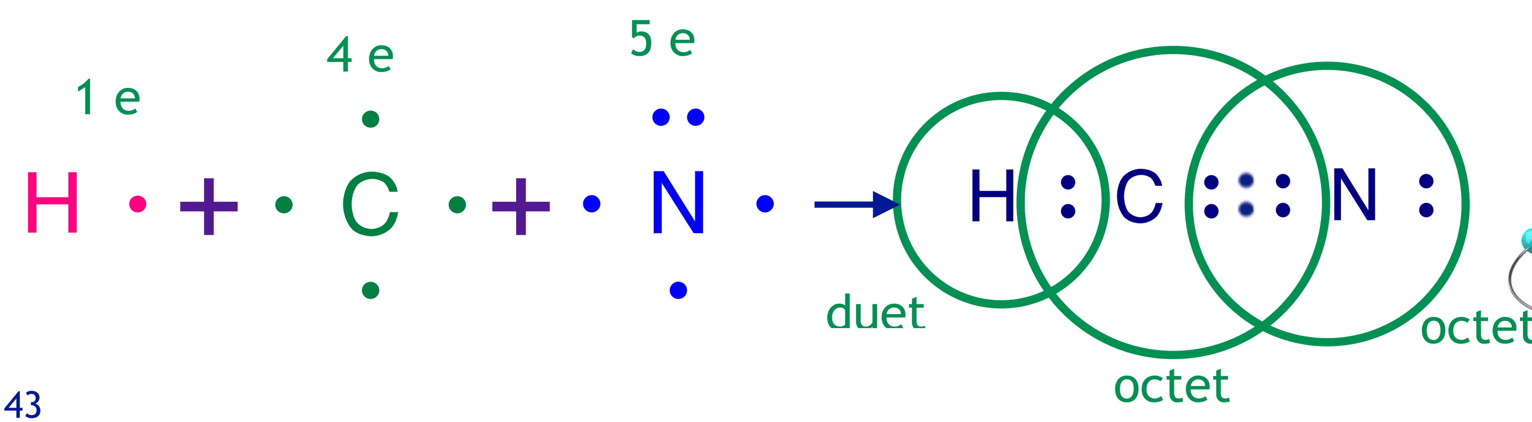


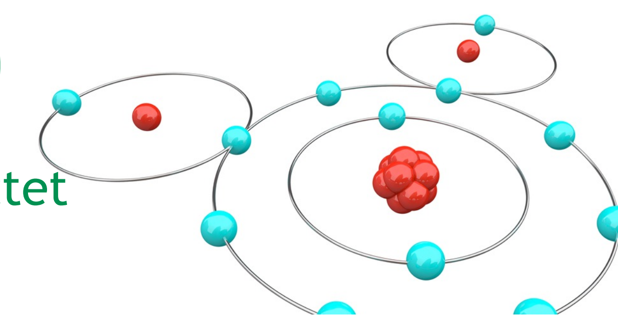
Lewis Molecular Structures

- Lewis symbols provide a simple way of visualizing and predicting covalent bonds.
- Atoms with less than a full valence entangle their orbitals to share electron pairs.
  - Shared electrons are held by both nuclei.
  - Sharing electrons allows each atom to fill it’s valence.
  - The Lewis symbols allow you to predict how many electrons each atom needs and can offer.
  - The octet rule let’s you know when each atom has realized a stable shared configuration.
- Electron pairs not involved in bonding are called lone pairs.
- Electron pairs involved in bonding are called bonding pairs.
  - Bonding pairs may be replaced with a single line.
- Main group elements can form one, two, or three covalent bonds.





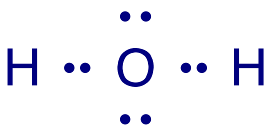




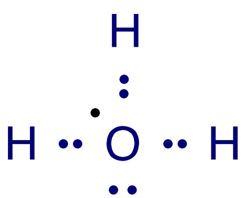
Checking the Model

Theory

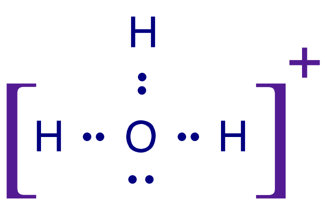
Experiment



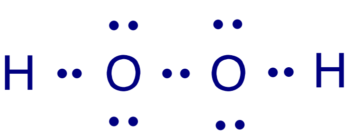
- Octet Satisfied
- H_2O is quite common.



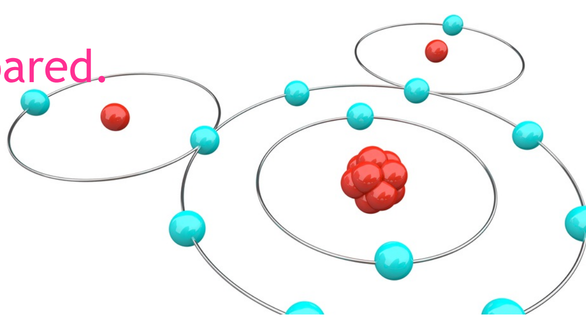
- 9 e in Oxygen Valence
- H_3O has never been seen.



- Octet Satisfied
- H_3O^+ can be prepared in solution.

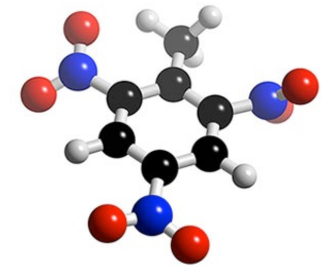


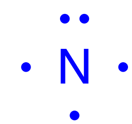
- Octet Satisfied
- H_2O_2 can be prepared.

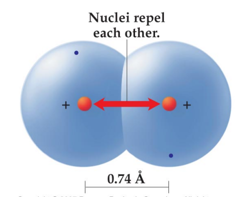


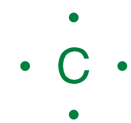
Chemical Bonds

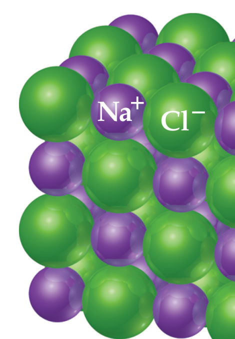
- Atoms forming Molecules
  - Composition,
    Connectivity & Shape
- Types of Connectivity (Bonding)
  - ionic - stealing electrons
  - covalent - sharing electrons
  - metallic - swimming in electrons
- Lewis Dot Notation
  - Lewis Symbols
    - elemental symbol surrounded by valence electrons
  - The Octet Rule
    - Why it's a reliable predictor.
- Ionic Bonding
  - Forming Ions to Bond Atoms
  - Thermodynamics
    - Born-Haber cycle
    - Lattice energy
      - trends: by size & charge
  - Checking the Model
- Covalent Bonding
  - Sharing Electrons to Bond Atoms
  - Thermodynamics
  - Lewis Structures
    - Identifies Lone Pairs
    - Predicts Bond Order
  - Checking the Model

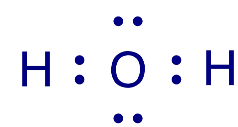


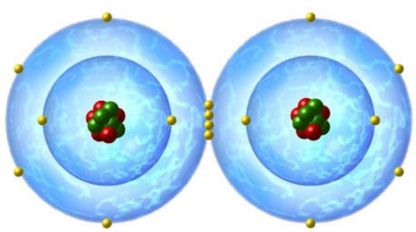


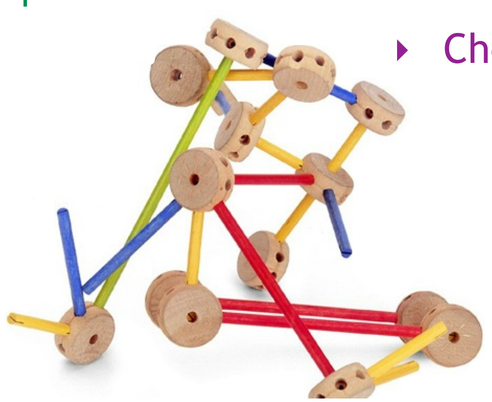


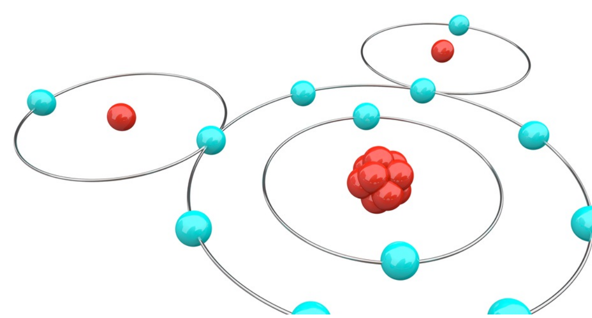












Questions?