Lewis Dot Structures

Reading: Gray: (2-1), (2-7), (2-11) to (2-13)
OGN: (3.2) to (3.5)

Periodic Chemical Reactivity

- Reactions with hydrogen to form hydrides:
  - LiH vs. HF (notice electronegativity difference)
- Reactions with fluorine:
  - HF vs. F_2

ionic covalent

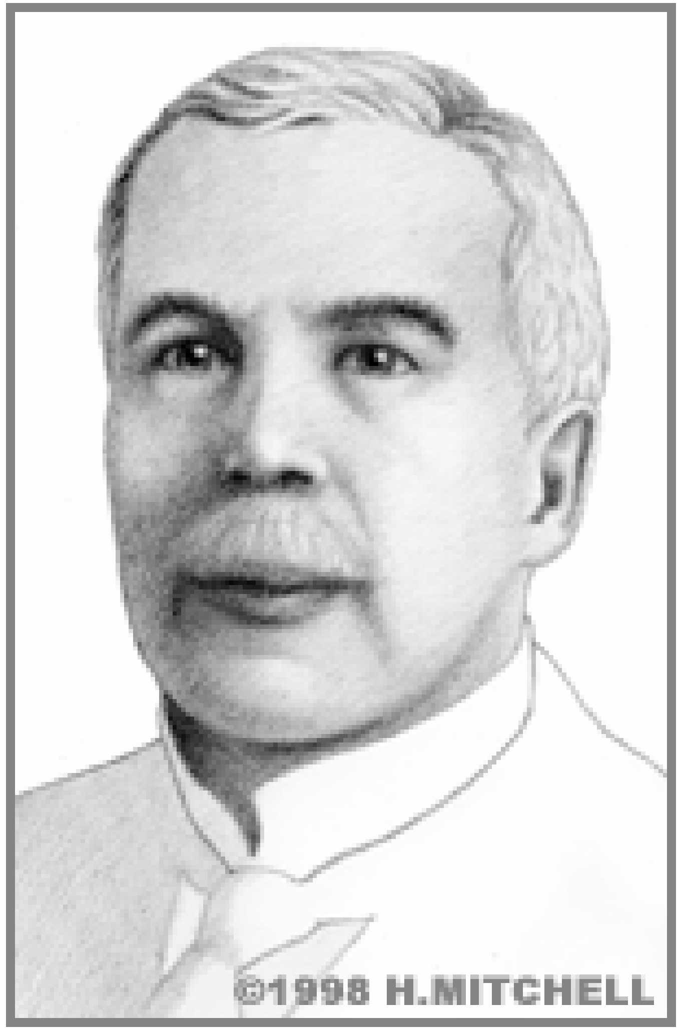
- Reactions with oxygen:
  - Li_2O vs. CO_2 vs. F_2O

Can we predict these structures?

Can we understand their properties?

Yes, we can! We use Lewis dot structures based on valence electrons.

Person of the Day



G.N. Lewis

GILBERT NEWTON LEWIS (1875-1946)

"Heavy Water"

Gilbert Newton Lewis, one of the most influential and admired scientists of the twentieth century, was a pioneer in both chemistry and physics. Born in Weymouth Landing, Massachusetts in 1875, Lewis was reading by the age of 3. He entered college at age 15, then transferred to Harvard University, where he earned a B.S. (1896) and Ph.D. (1899). His research concentrated on thermodynamics and valence theory (on the behavior of electrons when atoms combine). From this early work on valence, Lewis developed the concept of the covalent bond, and invented the **"Lewis symbols"**which are still used to describe ways in which atoms bond.

Lewis taught at Harvard and MIT before becoming a Professor and Dean at the University of California at Berkeley, whose then languishing College of Chemistry he single-handedly transformed into one of the nation's best. Lewis became the mentor to 290 Ph.D. recipients and **20 Nobel Prize winners**.

For example, he directed the experiments that resulted in the discovery of elements 93-106.

In his own work, Lewis combined strict discipline in collecting and organizing data with innovative interpretation of the results. In the early 1930s, he became the first scientist to produce "heavy water," with double-weight hydrogen atoms, which was essential to early experiments in atomic energy. He also worked with Ernest Lawrence in the invention of the cyclotron and in early atom-smashing experiments.

From the late 1930s to his death in 1946, Lewis focused on photochemistry. In fact, it was he who coined the term "photon."

Gilbert Newton Lewis won numerous honors for his work, including the Society of Arts and Sciences Medal as "the outstanding chemist in America" (1930). He was nominated for the **Nobel Prize** in chemistry over 30 times, and still today, many scientists believe he well deserved it.

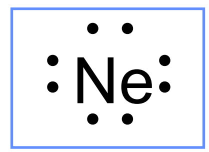
Lewis Dot Structures

How to: 1) Write down configuration
2) Draw the structure (each valence e^- gets a dot)

Neon: $(1s)^2\ (2s)^2\ (2p)^6$ valence level "n" is 2

$2 + 6 =$ **8** electrons on the valence level

So Ne gets **8** dots:

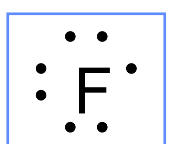


Fluorine: $(1s)^2\ (2s)^2\ (2p)^5$

$n = 2$

$2 + 5 =$ **7** valence electrons for F

So F gets **7** dots:



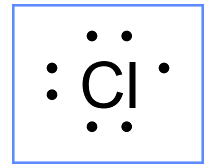
What if we put 2 fluorines together?

Look! They both have 8 electrons: so we predict F_2 is a stable molecule

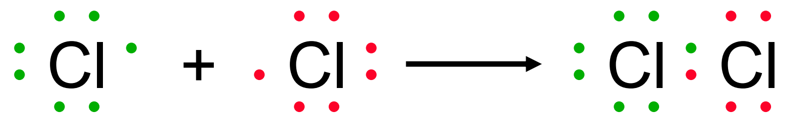
Each Atom Wants 8 Valence Electrons

Chlorine is similar to fluorine: $(1s)^2\ (2s)^2\ (2p)^6\ (3s)^2\ (3p)^5$

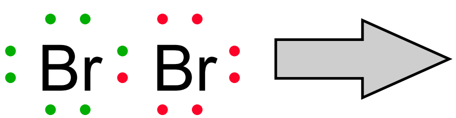
Valence level is now 3, but number of valence electrons is still 7. So, the structure is:



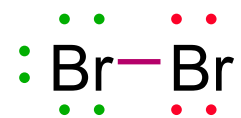
We can also make Cl_2:



Same thing with Br_2, I_2, and the other column VII elements:



which can be rewritten as:

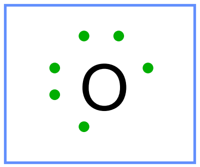


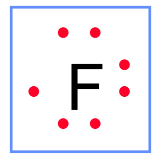
The purple line is a single bond, and it stands for 2 electrons

If each atom has eight dots, then the molecule is stable

Multi-Element Molecules

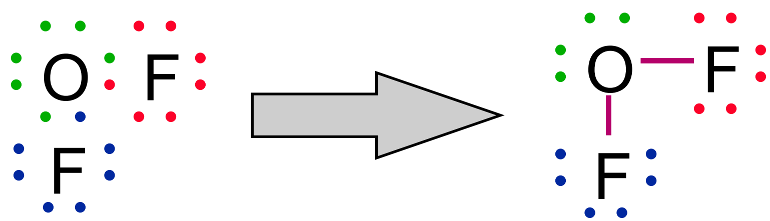
Oxygen: $(1s)^2\ (2s)^2\ (2p)^4 \ \rightarrow$ n = 2; 6 valence electrons:



Fluorine we already know: 

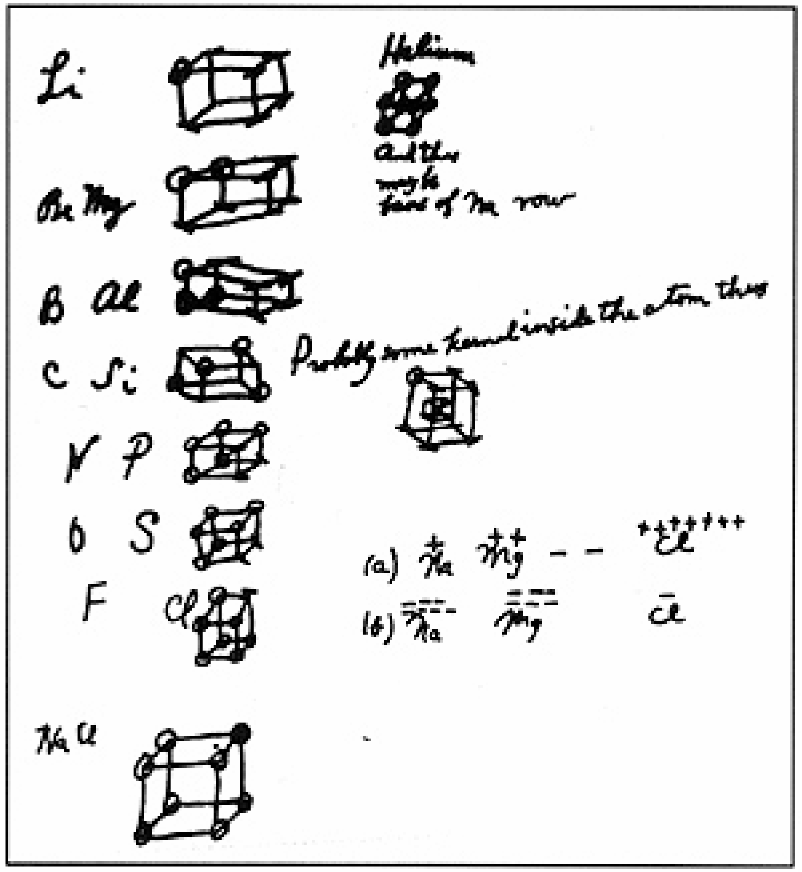
(n = 2; 7 valence e^-)

To put 8 electrons on each atom, we need two fluorines and one oxygen:



Note: The dot diagram tells us nothing about structure

Lewis’s Dot Structures



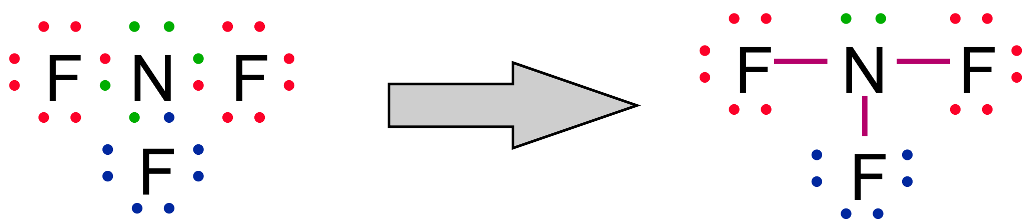
Gilbert Newton Lewis's memorandum of 1902 showing his speculations about the role of electrons in atomic structure.

From *Valence and the Structure of Atoms and Molecules* (1923), p. 29.

More Multi-Element Molecules

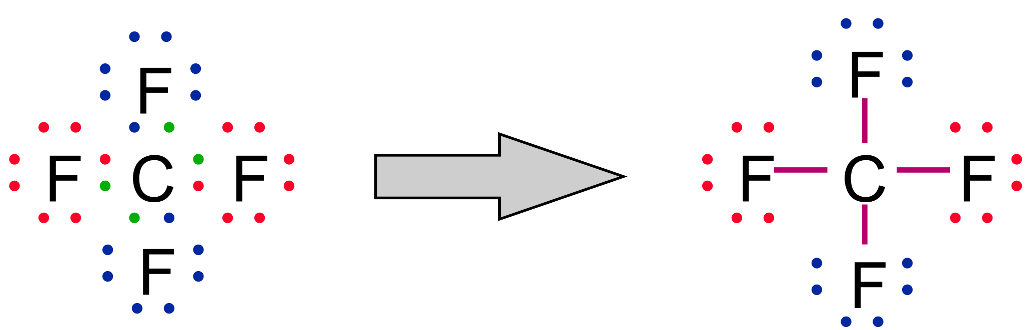
Nitrogen: $(1s)^2\ (2s)^2\ (2p)^3 \rightarrow$ 5 valence electrons

- Nitrogen needs 3 fluorines to get octets on each atom



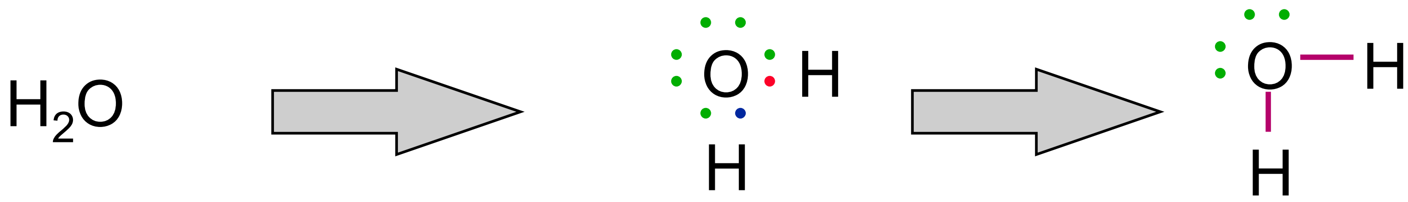
Carbon: $(1s)^2\ (2s)^2\ (2p)^2 \rightarrow$ 4 valence electrons

- Carbon needs 4 fluorines to get octets on each atom



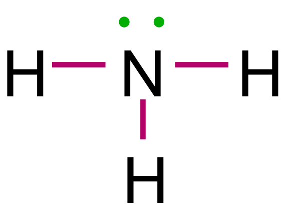
The Duet Rule

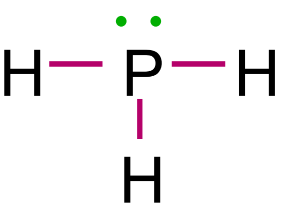
- H, He, Li, and Be only need 2 valence electrons



- They are trying to “be like He”, the nearest inert gas

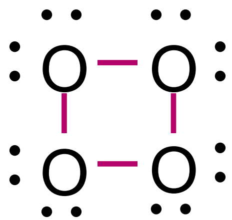
So, we predict NH_3 and PH_3 to be stable compounds



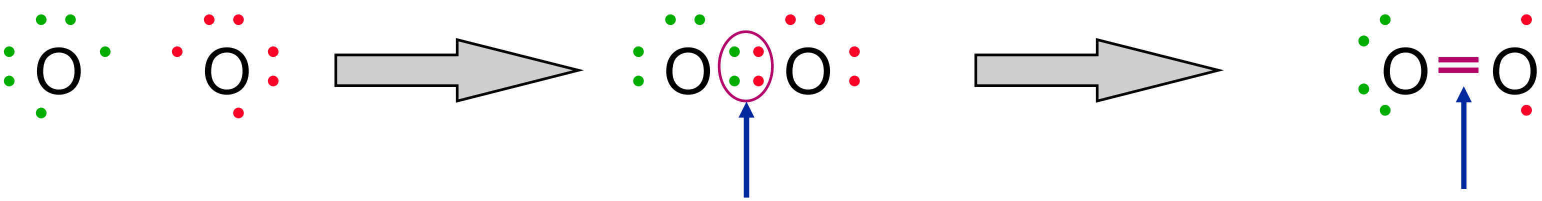


Reasonable Structures, Double Bonds

So far, we have only used the single bond (—), which stands for two electrons. However, sometimes this bond will not work.

- Consider "O_4":  Is this O.K.? Well, yes and no.

But instead of "O_4", we can draw O_2 with a double bond:



double bond

4 e^- total, 2 e^- per line

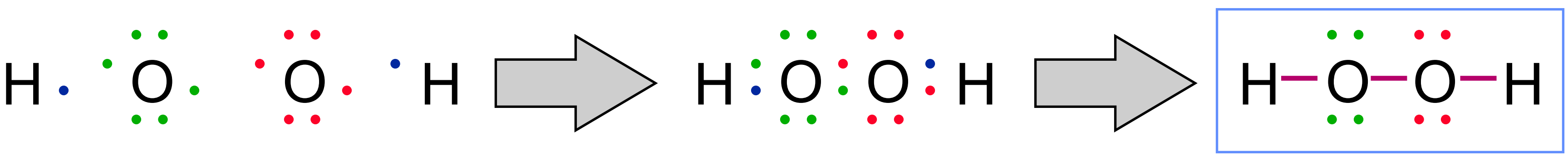
- Note that each oxygen has 8 electrons, so O_2 is stable

Each (—) still stands for 2 e^- $\rightarrow$ 2 lines means <u>4</u> e^- in bond

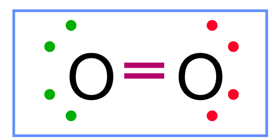
Double Bonds vs. Single Bonds

We can compare the single O–O bond in H_2O_2 with the double O=O bond in O_2.

- First, we find the structure of H_2O_2:



- We know the structure of O_2:



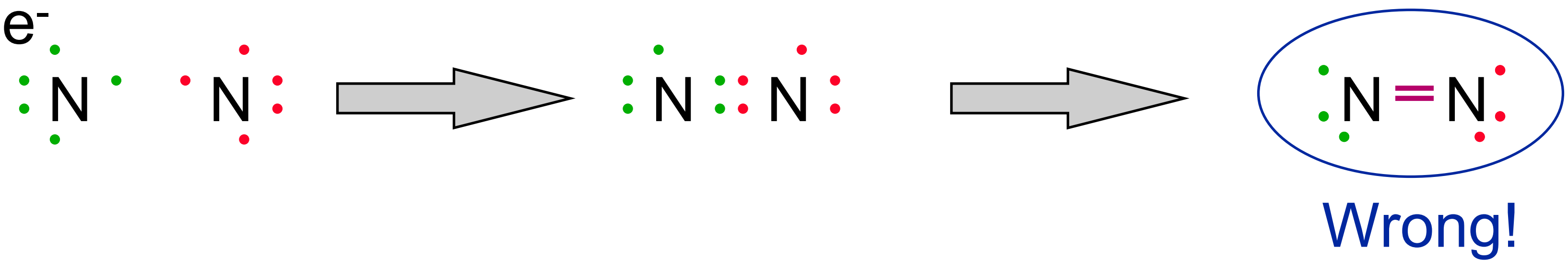
Experiment shows that the single O–O bond in hydrogen peroxide is both <u>longer</u> and <u>weaker</u> than the double bond between the same two oxygens in O_2.

Single bonds are longer and weaker than double bonds

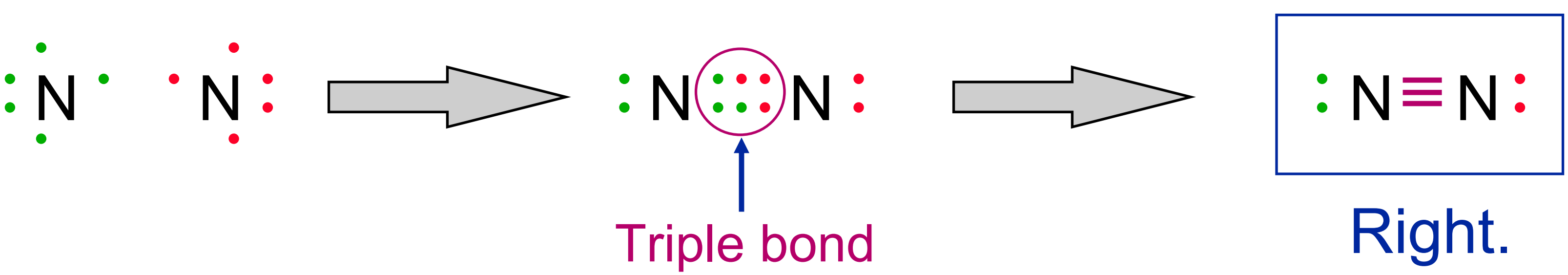
Triple Bonds

Is N_2 stable? It had better be, because it makes up 78% of the atmosphere. First we try to draw it with a double bond:

Nitrogen: $(1s)^2\ (2s)^2\ (2p)^3 \rightarrow$ n = 2, 5 valence e^-

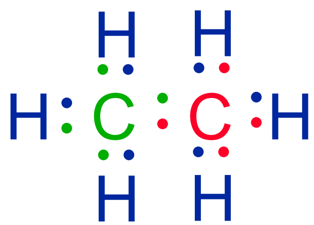
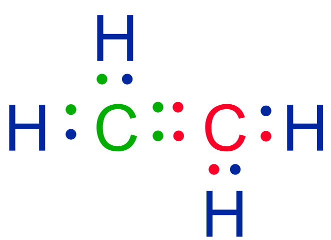
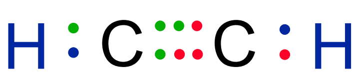


Each N has only 7 electrons! How can we fix this problem? We use a triple bond:

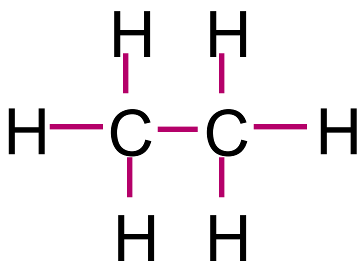
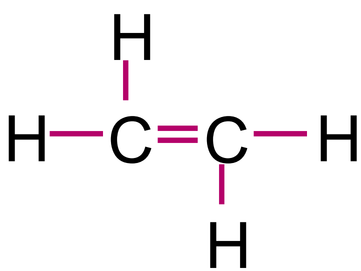


Triple bonds are shorter and stronger than double bonds

Single, Double, and Triple Bonds

	molecule, formula	**C-C bond length(Å)**
	ethane, C_2H_6	1.536
	ethylene, C_2H_4	1.339
	acetylene, C_2H_2	1.208

Single, Double, and Triple Bonds

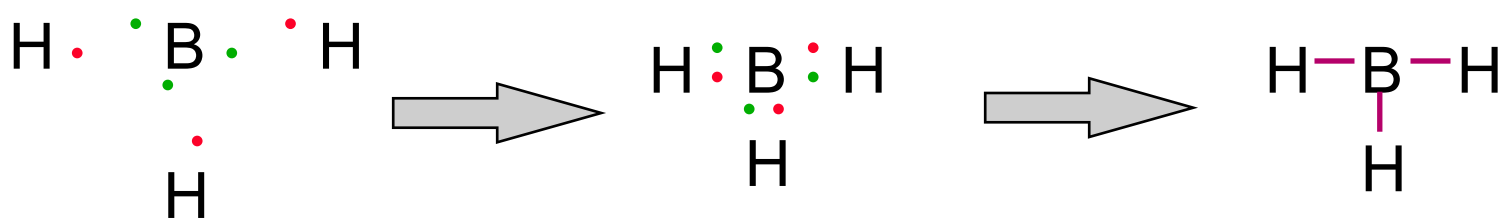
	molecule, formula	C-C bond length(Å)
	ethane, C_2H_6	1.536
	ethylene, C_2H_4	1.339
	acetylene, C_2H_2	1.208

How Does Boron Bond?

- Sometimes, a molecule is stable even if one of its atoms <u>doesn't</u> have 8 or 2 valence electrons. For example:

Given BH_3 exists; What is its Lewis dot structure?

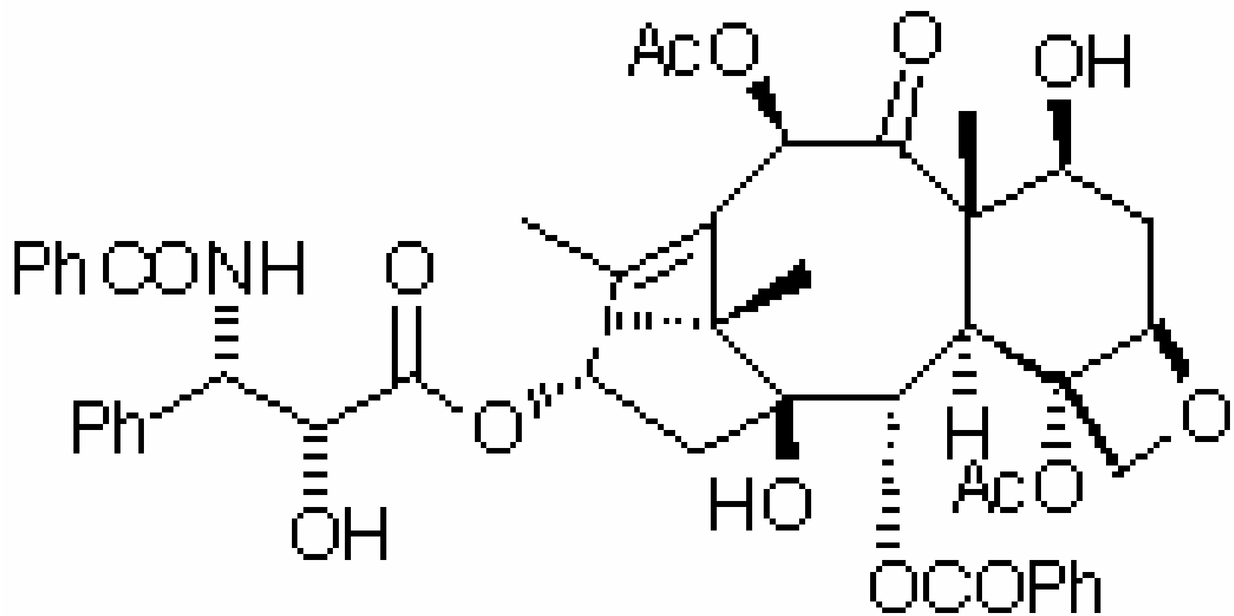
Boron: $(1s)^2\ (2s)^2\ (2p)^1$; $n = 2$, 3 valence e^-



- Notice B has only 6 electrons, not 8 like you would expect; but that's the best we can do.

Lewis dots don't only <u>predict</u> structures—they also <u>explain</u> them

Bonding in Complex Molecules



Taxol

Lewis dot structures work for first two columns and p-orbital elements, but not transition elements:

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

END

Lewis Dot Structures

Reading: Gray: (2-1), (2-7), (2-11) to (2-13)
OGN: (3.2) to (3.5)