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Molecular Literacy for All

making sense of the “monstrous and boundless thicket” of everyday chemistry

Every breath I take…the molecules in the air we breathe are used to teach a model for atomic bonding.

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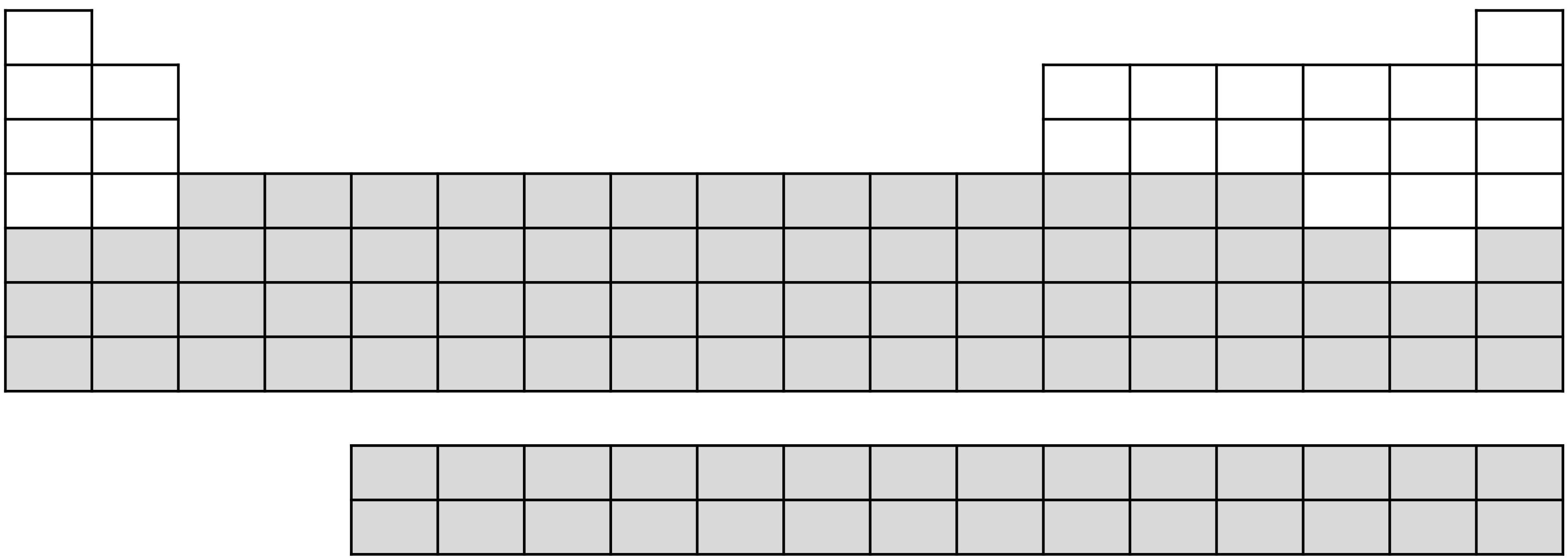
Satisfying an atom's electron count

- The *electron count* is the total number electrons in the valence shell of an atom
- Atoms gain or lose electrons to achieve the valence electron count of its nearest noble gas
- Nearest noble gas for H, He, Li, Be $\Rightarrow$ 2 valence electrons
- Nearest noble gas for B, C, N, O, F, Ne, Na, Mg, Al, Si, P, S, Cl, Ar, Se, $\Rightarrow$ 8 valence electrons
- Indicate the charge on each atom that gives it a filled shell
- Show the valence electrons as dots



Electron Pair Domain	Number of Bonding Pairs	Representation	Total Electron Count
nonbonding domain	0	$\ddot{A}$	2
single bond domain	1	A–A	2
double bond domain	2	A=A	4
triple bond domain	3	A≡A	6

Electron pair domains (EPDs)

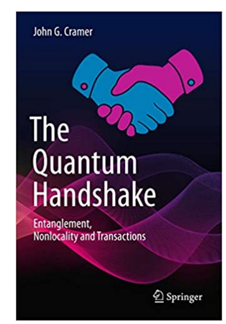
Regions around an atom having a high density of valence-shell electrons are called electron pair domains. An **electron-pair domain** consists of either a nonbonding pair of electrons, a single pair of bonding electrons, two pairs of bonding electrons, or three pairs of bonding electrons. A single pair of bonding electrons is known as a single bond; two or more pairs of bonding electrons are called multiple bonds.

Molecular dihydrogen: the most common molecule in the universe

Covalency: The prefix *co-* means *jointly, associated in action, partnered to a lesser degree,* etc.; thus a "co-valent bond", in essence, means that the atoms share "valence"

Truth table

Subshell	No. e⁻	Filled
1s		
1s		

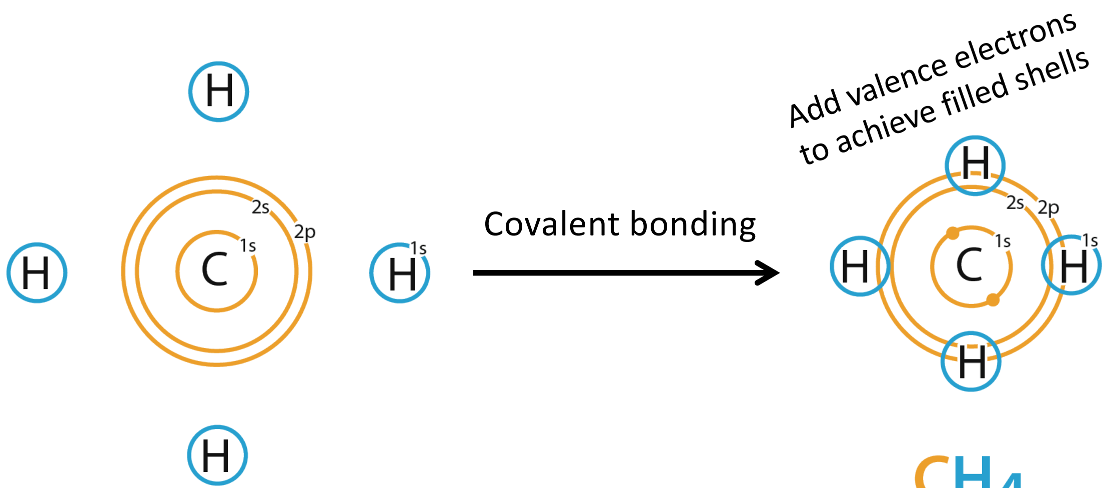


The dihydrogen molecule, H_2

By sharing, or pooling, their valence electrons, each nuclei counts a filled shell of electrons.
The electrons pair together to make a covalent bond.
The electrons in an electron pair have a special relationship. They engage in *The Quantum Handshake.*

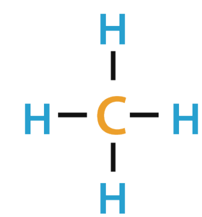
Methane teaches how heavier atoms acquire filled shells through covalent bonding

An electron count of eight fills the valence shell for B, C, N, O, F, and Ne (these are atoms of elements that reside in the second row of the periodic table).



CH_4

Subshell	No. e^-	Filled
1s		
2s		
2p		



The methane molecule

By pooling valence electrons, then dividing the pool into pairs, then properly distributing them between the valence subshells, four hydrogen atoms and one carbon atom combine to make one CH_4 (i.e., a methane molecule).

Hydrogen is a truncator atom

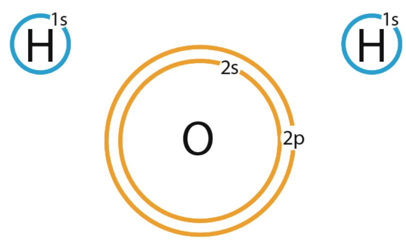
- A single covalent bond involves two electrons i.e., it's one electron pair.
- Hydrogen completes its valence shell with just two electrons.
- Therefore, hydrogen is bonded to, at most, one-and-only-one other atom.
- Because hydrogen is bonded to just one atom, it serves as a truncator to block the sites on carbon that could otherwise go on and bond to other carbon atoms.
- This will become important when we talk about implicit hydrogen atoms; i.e., it is implied that the "unsubstituted sites" in molecular drawings are capped by hydrogen atoms, even if they are not explicitly shown.

For example, see: cholesterol

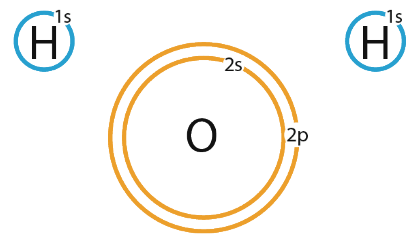
Water (H_2O)

(did you ever wonder why water is H_2O and not something else, like H_6O?)

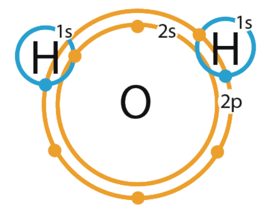
From here on, only valence electrons are shown



Add valence electrons

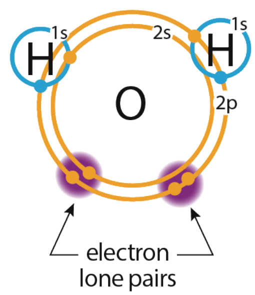


Covalent bonding



Do the quantum handshake

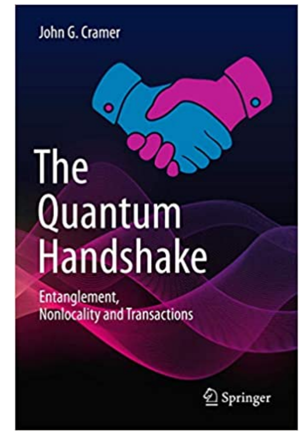
Subshell	No. e⁻	Filled
1s		
2s		
2p		



H_2O

The water molecule

Consider a generic atom, denoted by the symbol “A”



Electrons are usually paired

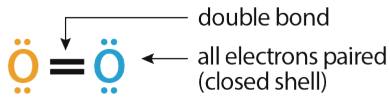
Valence-shell electron pairs come in two types: nonbonding and bonding. Nonbonding electrons, also called lone pairs or unshared pairs, are valence-shell electron pairs that are localized on only one atom. Bonding electrons are pairs of valence-shell electrons that are shared between two atoms.

A Model of Covalent Bonding
double-count electrons at intersections

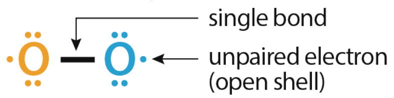
For each atom in a molecule:	H	C	N	O	F
capacity of the valence shell					
– number valence electrons					
number of electrons involved in covalent bonding					

Molecular di fluorine

Molecular dioxygen teaches us about open shells, closed shells, and double bonds



singlet oxygen (highly reactive)



triplet oxygen (most prevalent form)

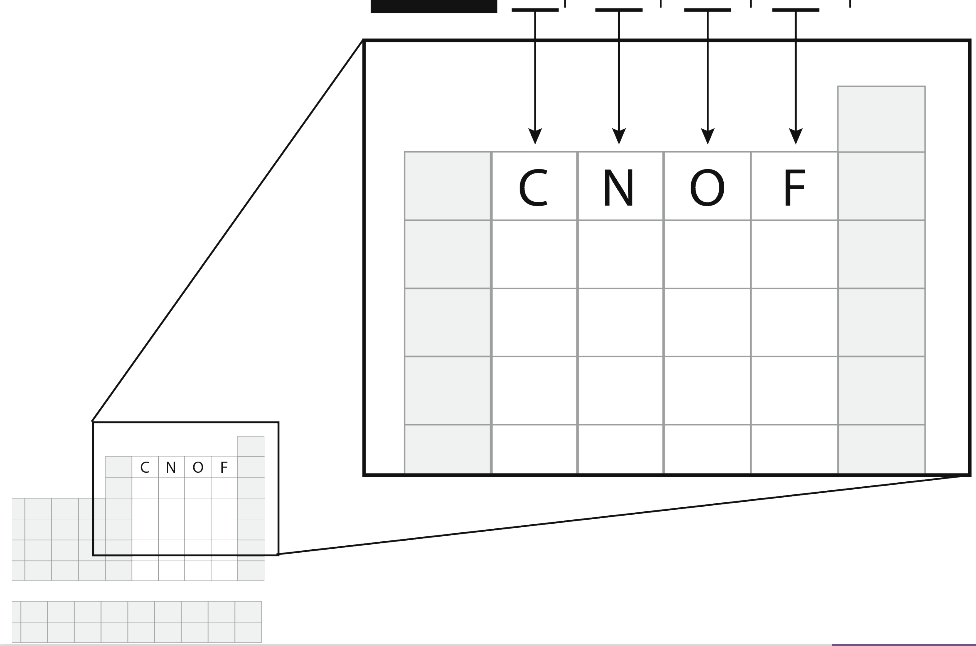
Dinitrogen and the triple bond

The dinitrogen molecule

Pattern seekers

Given our results, deduce the patterns for bonding across the periodic table. Use this observation to write a hypothesis about dicarbon. Write your hypothesis as a factual statement. Name your hypothesis. Now test your hypothesis.

bond type	?	triple bond	double bond	single bond
no. lone pairs per atom	?	1	2	3
molecular structure	?	:N≡N:	Ö=Ö	:F–F:
diatomic molecule	C_2	N_2	O_2	F_2



Diatomic carbon breaks the pattern

(quadruple bonding is not possible with 2nd row elements)

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Charge of the whole molecule

Molecules are neutral, cationic, or anionic according to their overall state of charge. Here's a look at how molecular charge is calculated for ammonia.