N23 – Bonding

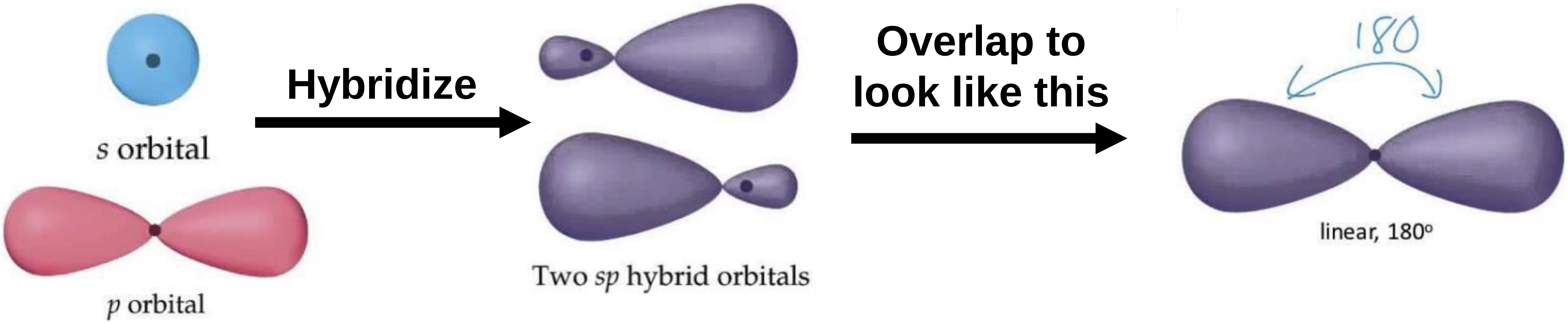
Hybridization

<u>Hybridization</u>- the blending of orbitals

Hybridization is the combining of two or more orbitals of nearby equal energy within the same atom into orbitals of equal energy.

sp Hybridization

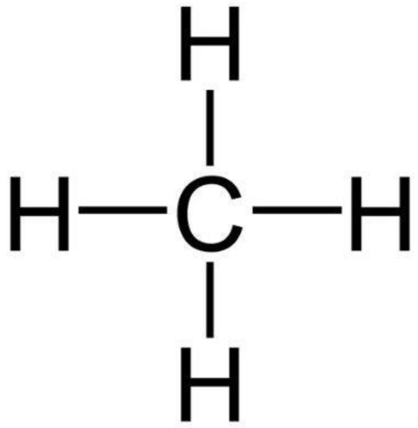
An s orbital and a p orbital turn into two new orbitals with slightly different shapes, the new orbitals have combined s and p character.



What Proof Exists for Hybridization?

Let's think about how covalent bonds share electrons, and about the electron configurations of the atoms involved.

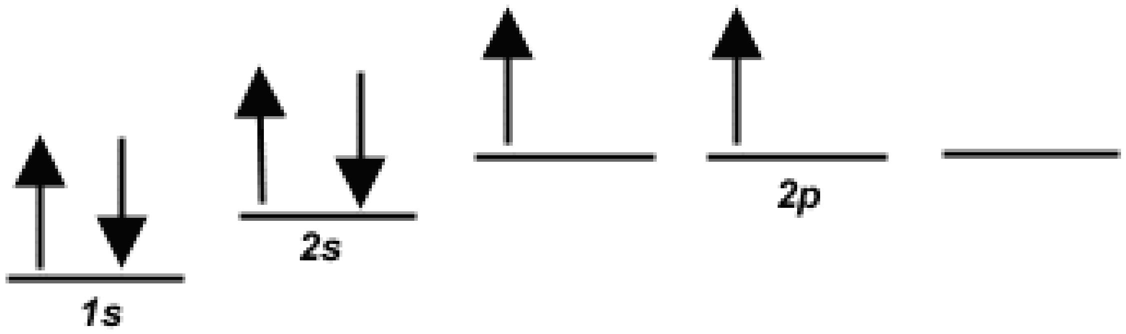
Lets look at a molecule of methane, CH_4.



Methane is a simple natural gas. Its molecule has a carbon atom at the center with four hydrogen atoms covalently bonded around it.

Carbon ground state configuration

What is the expected orbital diagram notation of carbon in its ground state?

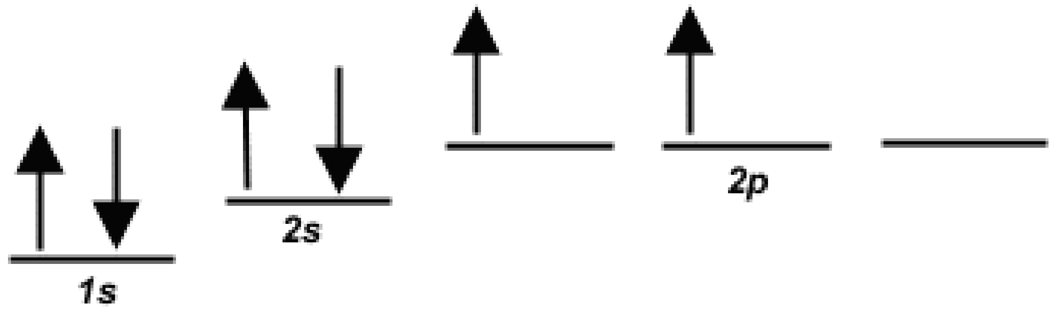


Can you see a problem with this?

Hint: *How many unpaired electrons does this carbon atom have available for bonding?*

<u>Carbon’s bonding problem</u>

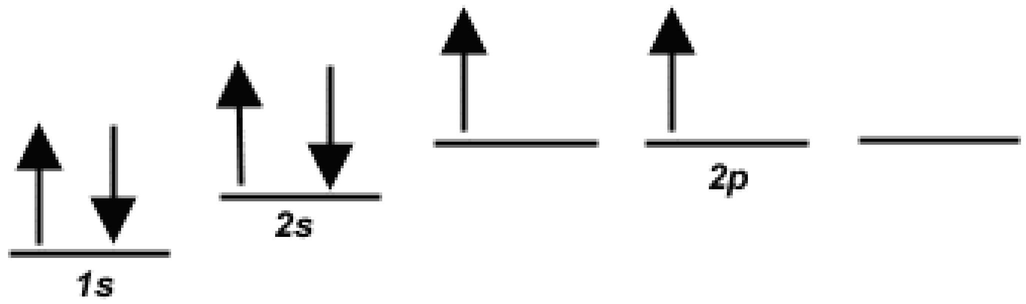
Notice that carbon only has <u>TWO</u> electrons available for bonding. That is not enough!



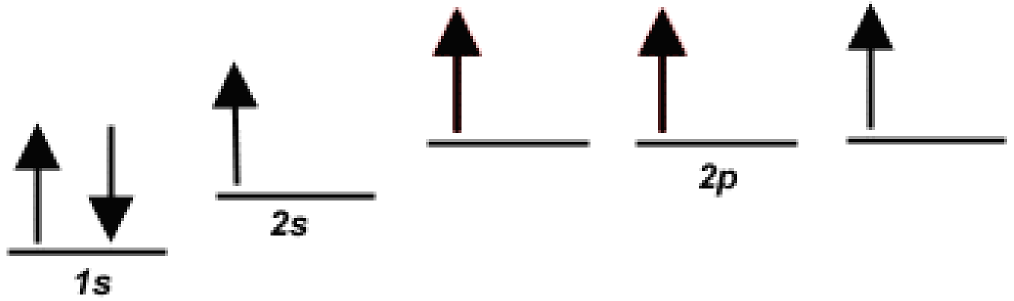
How does carbon overcome this problem so that it may form four bonds????

Carbon ground state configuration

The first thought that chemists had was that carbon promotes one of its *2s* electrons…



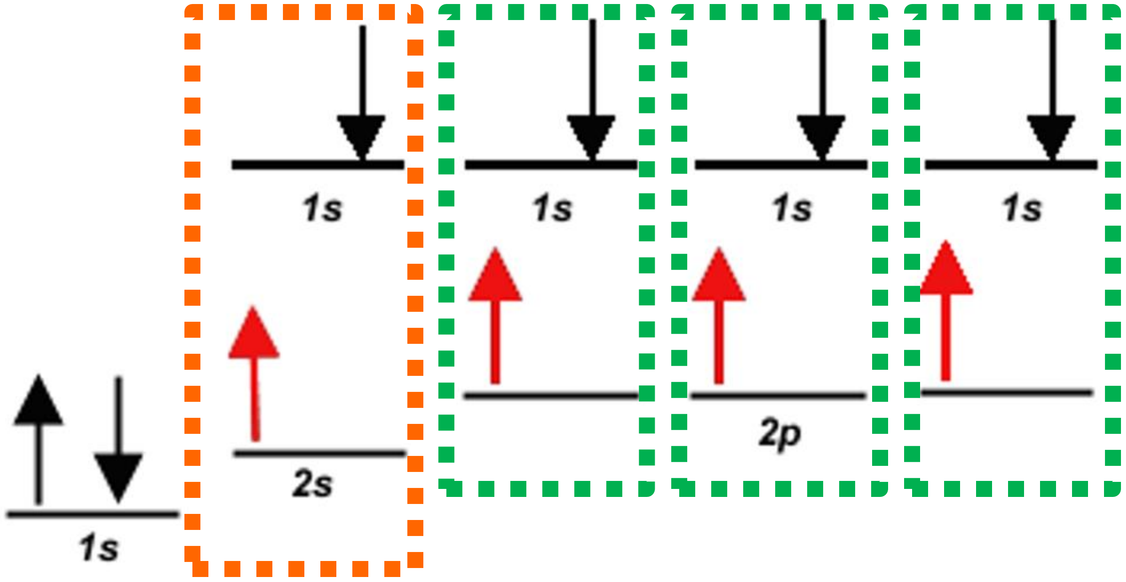
…to the empty *2p* orbital.



But…

They quickly recognized a problem with such an arrangement…

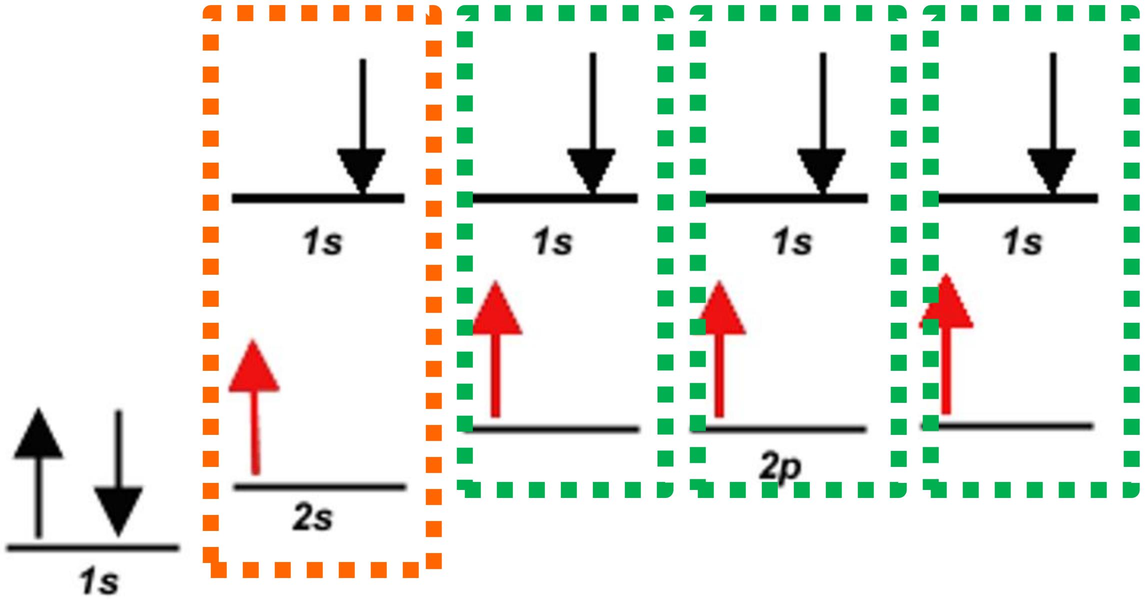
This would result in 3 of the carbon-hydrogen bonds involving an electron pair made up of carbon 2p electron combined with a hydrogen 1s electron.

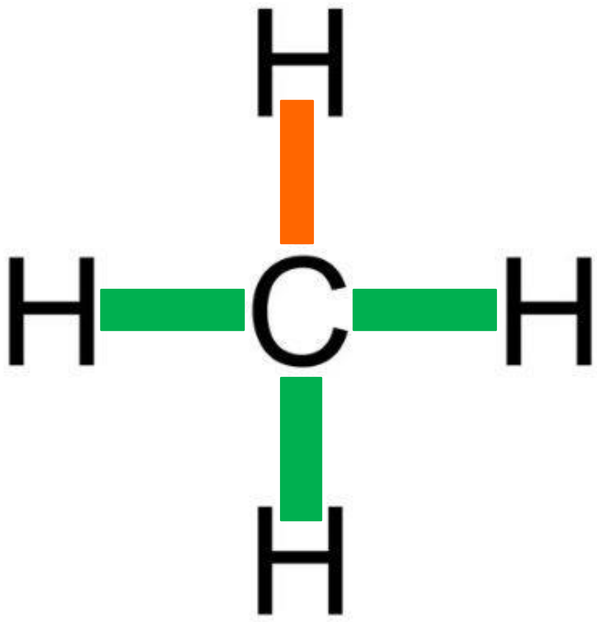


BUT 1 of the carbon-hydrogen bonds would be a carbon 2s electron combined with a hydrogen 1s electron…

This would mean…

This would mean that three of the bonds in a methane molecule would be identical, because they would involve electron pairs of equal energy.

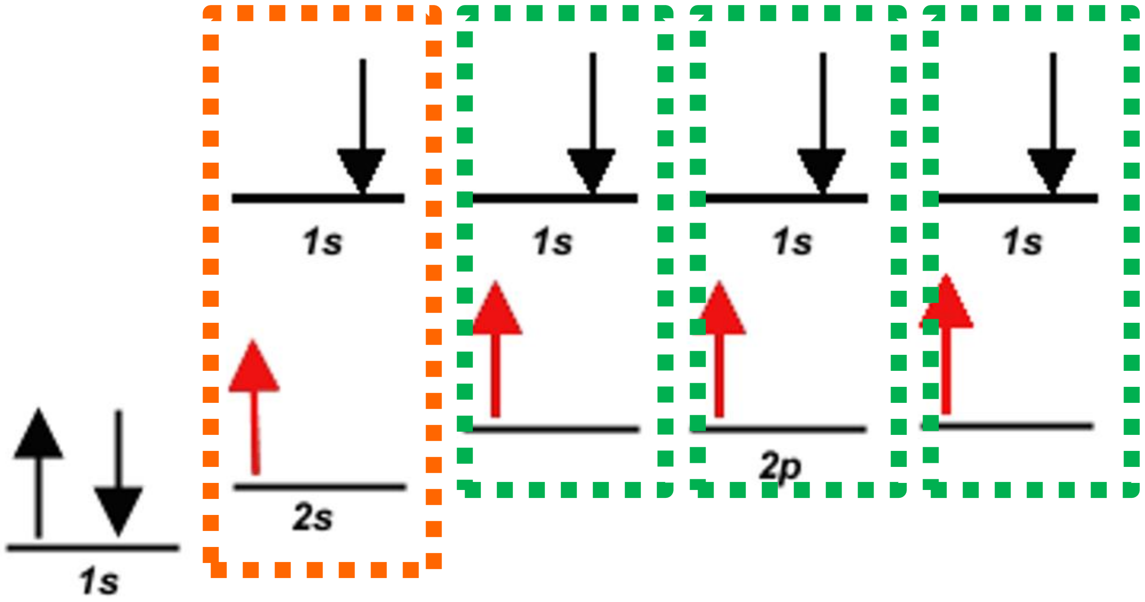


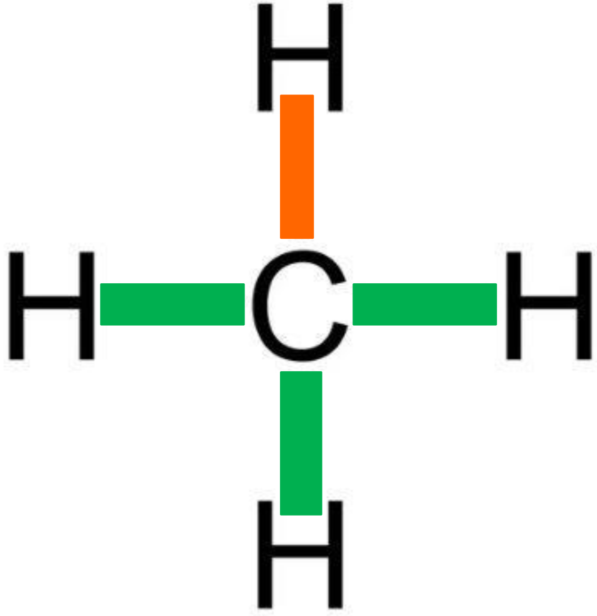


But what about the fourth bond…?

This would mean…

That one of the bonds, the carbon 2s and hydrogen 1s bond would have slightly less energy and different bond length than the other three bonds.

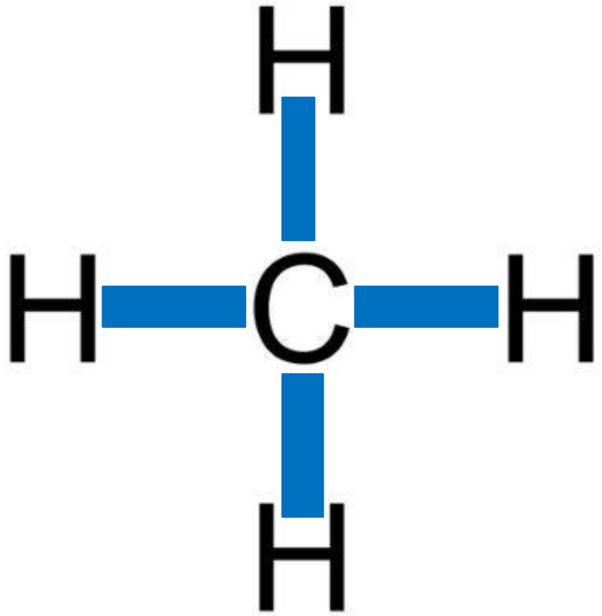




BUT WE DON'T SEE THAT!

All the bonds are equal!

Measurements show that all four bonds in methane are equal. So the "promotion" idea doesn't work.



We need a new theory!

Chemists have proposed an explanation – they call it **Hybridization.**

Hybridization is the combining of two or more orbitals of nearly equal energy within the same atom into orbitals of equal energy.

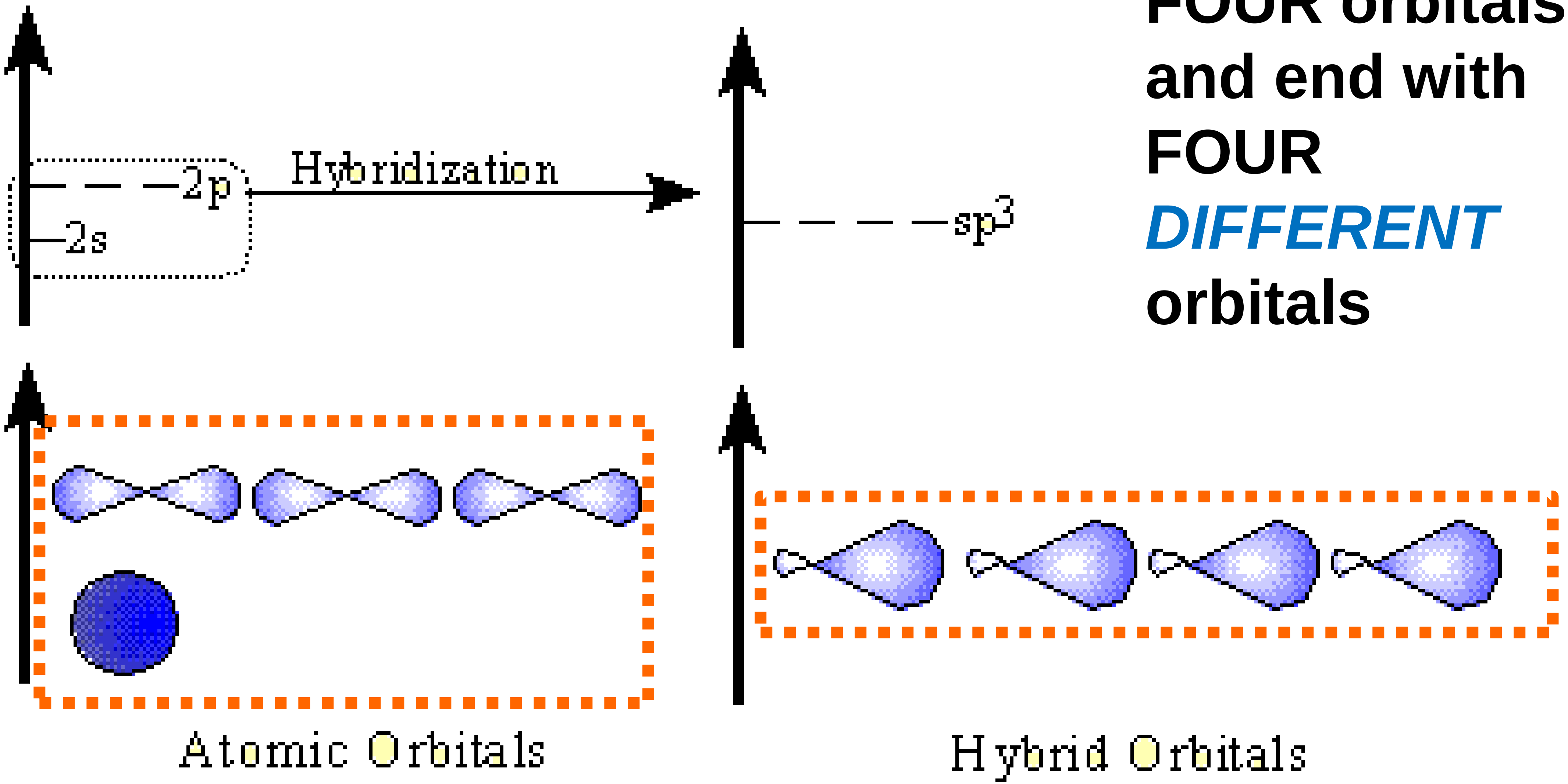
Hybrid Orbitals

In the case of methane, they call the hybridization *sp^3*, meaning that an *s* orbital is combined with three *p* orbitals to create four equal hybrid orbitals.

These new orbitals have slightly MORE energy than the *2s* orbital…

… and slightly LESS energy than the *2p* orbitals.

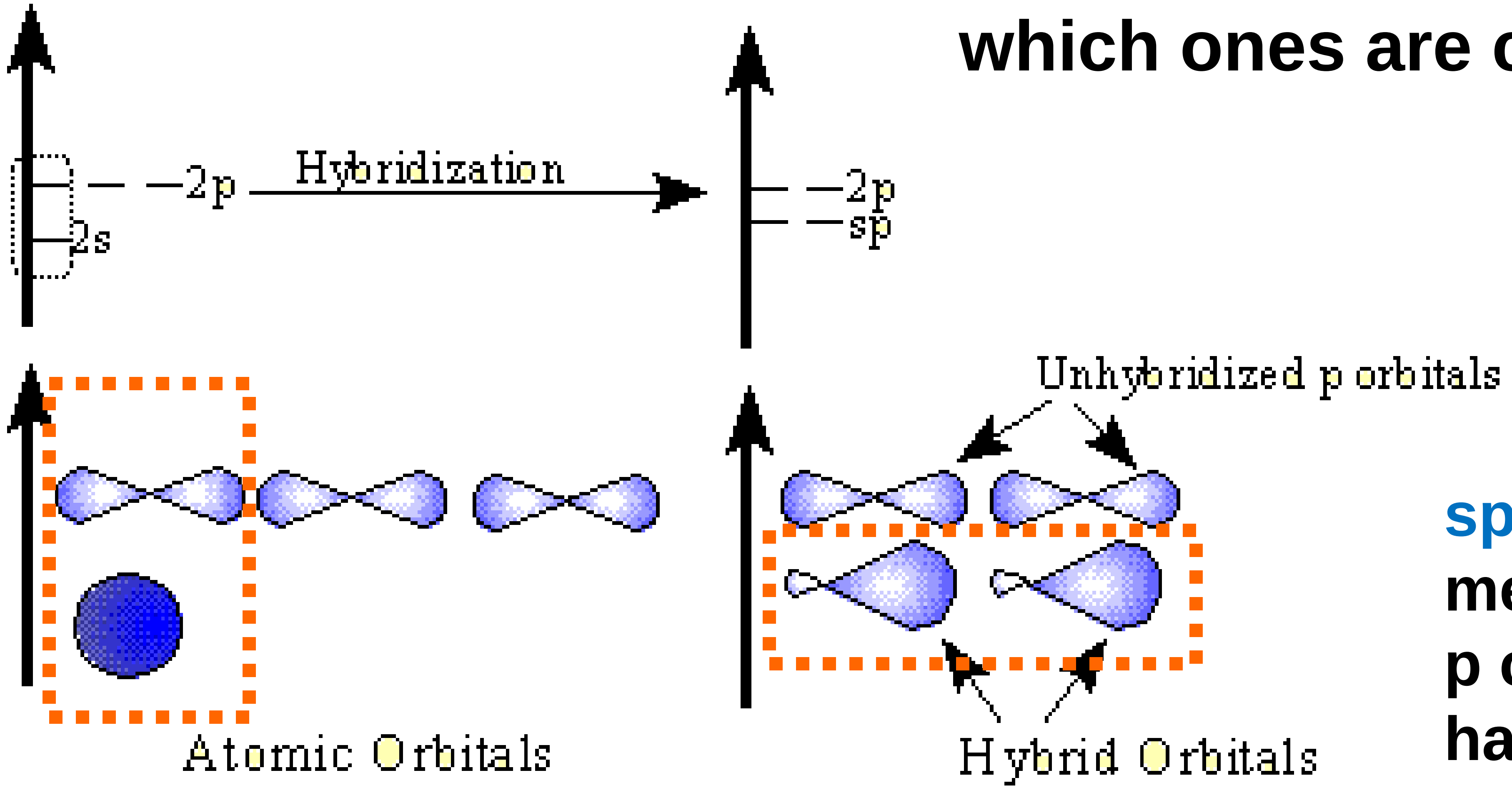
sp³ Hybrid Orbitals



You start with FOUR orbitals and end with FOUR *DIFFERENT* orbitals

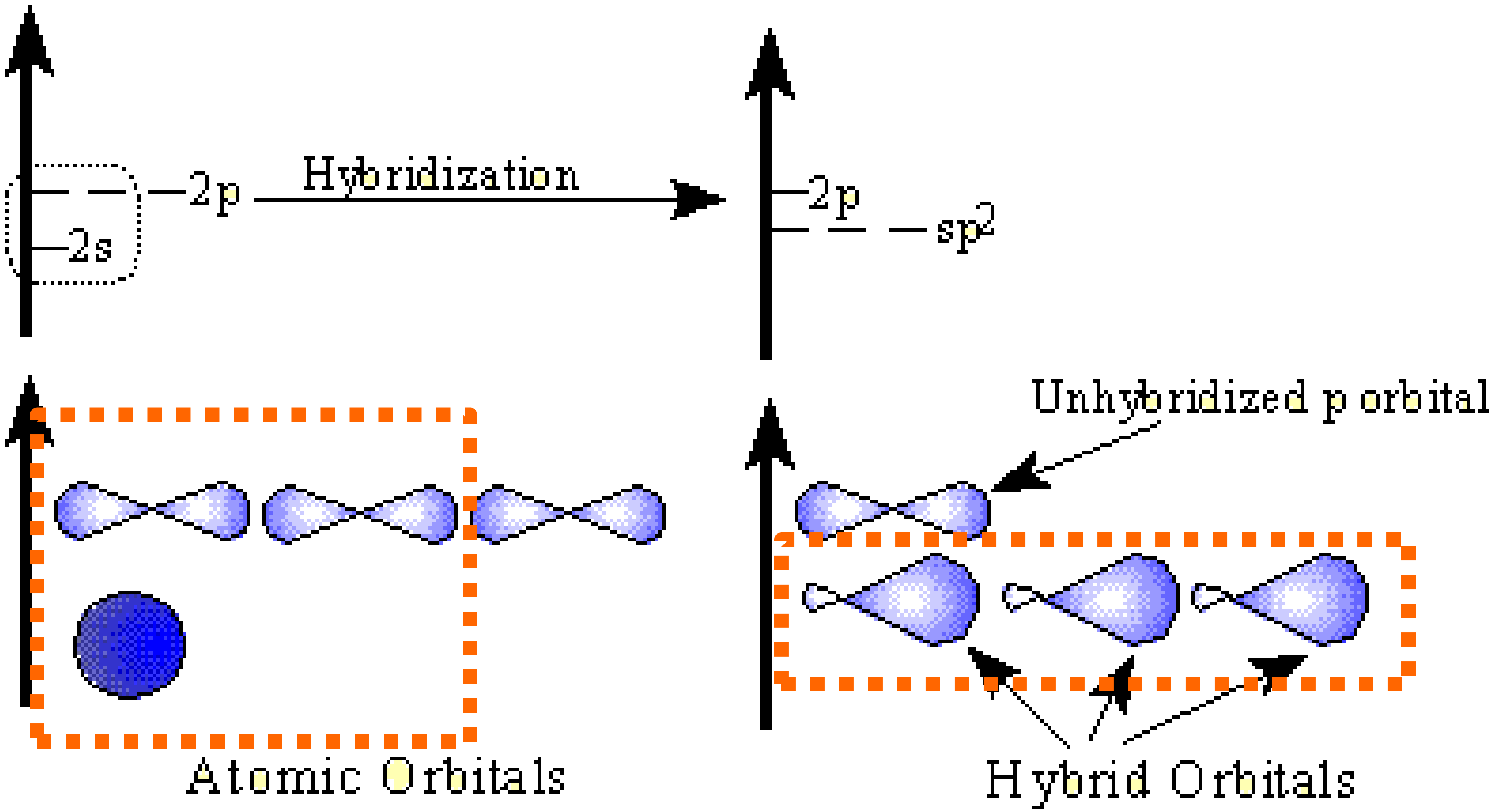
sp Hybrid Orbitals

There are other types of hybrid orbitals. Depends on which ones are combining!



sp hybrid means an s and p combine. You have 2 leftover p orbitals

sp^2 Hybrid Orbitals



sp^2 hybrid means an s and 2 p orbitals combine. You have 1 leftover p orbital

Hybridization and Molecular Geometry

Forms	Overall Structure (electronic geometry)	Hybridization of "A"
AX_2	Linear	*sp*
AX_3, AX_2E	Trigonal Planar	sp^2
AX_4, AX_3E, AX_2E_2	Tetrahedral	sp^3
AX_5, AX_4E, AX_3E_2, AX_2E_3	Trigonal bipyramidal	??
AX_6, AX_5E, AX_4E_2	Octahedral	??

A = central atom

X = atoms bonded to A

E = nonbonding electron pairs on A

Do d-orbitals Hybridize?

- **They used to think so, but don’t think so anymore.**
- **Your chart has d-hybridization listed. AP will avoid asking any questions that would involve it just to be safe. In class we might ask.**
- **So what theory do they think happens instead???? “Molecular Orbital Theory”**
- **Its complicated. And hard. College level stuff. We barely dip our toe into it.**