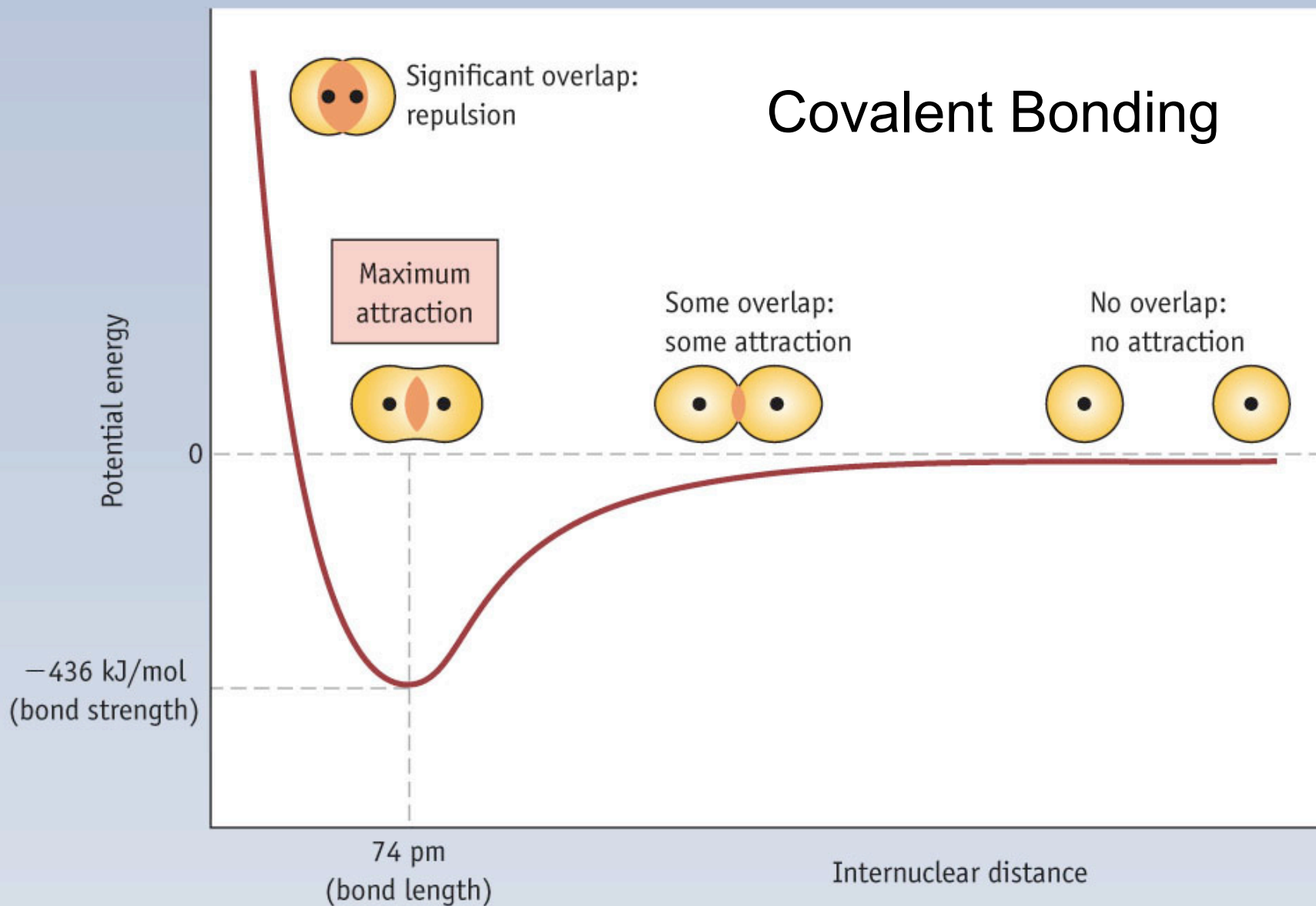
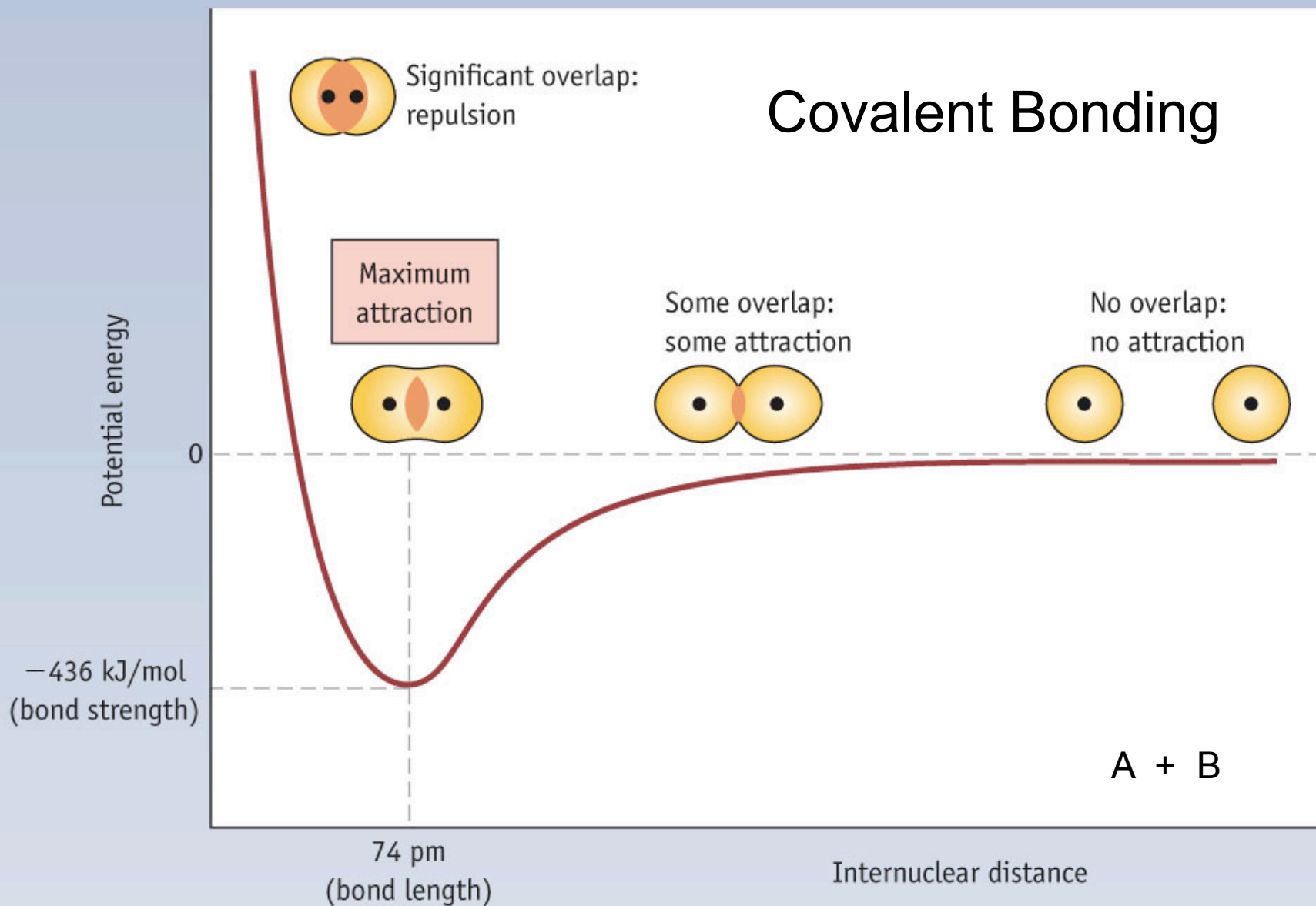


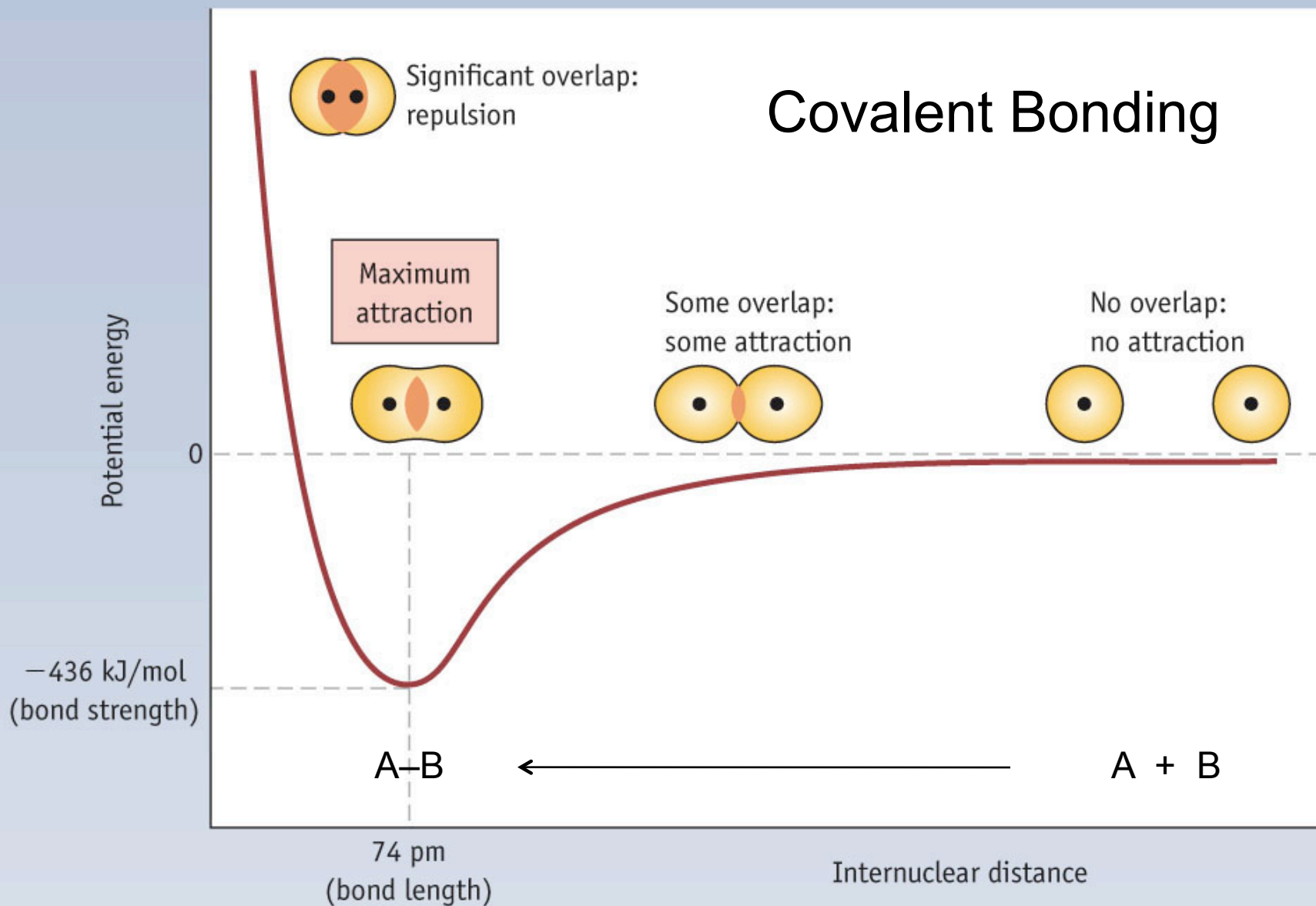
# Covalent Bonding

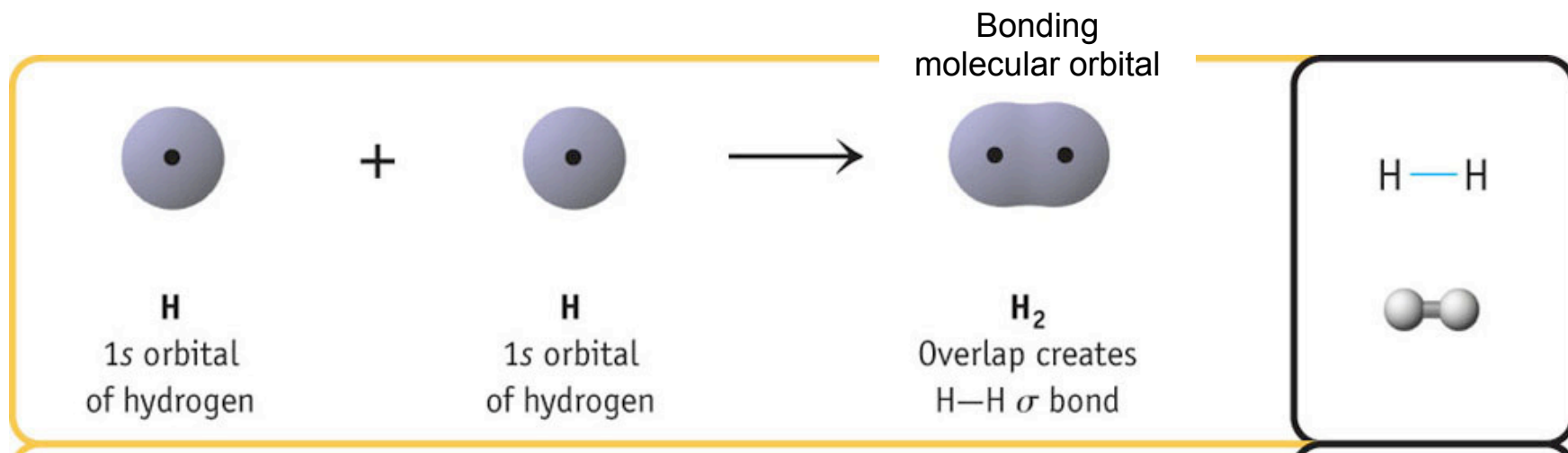


# Covalent Bonding

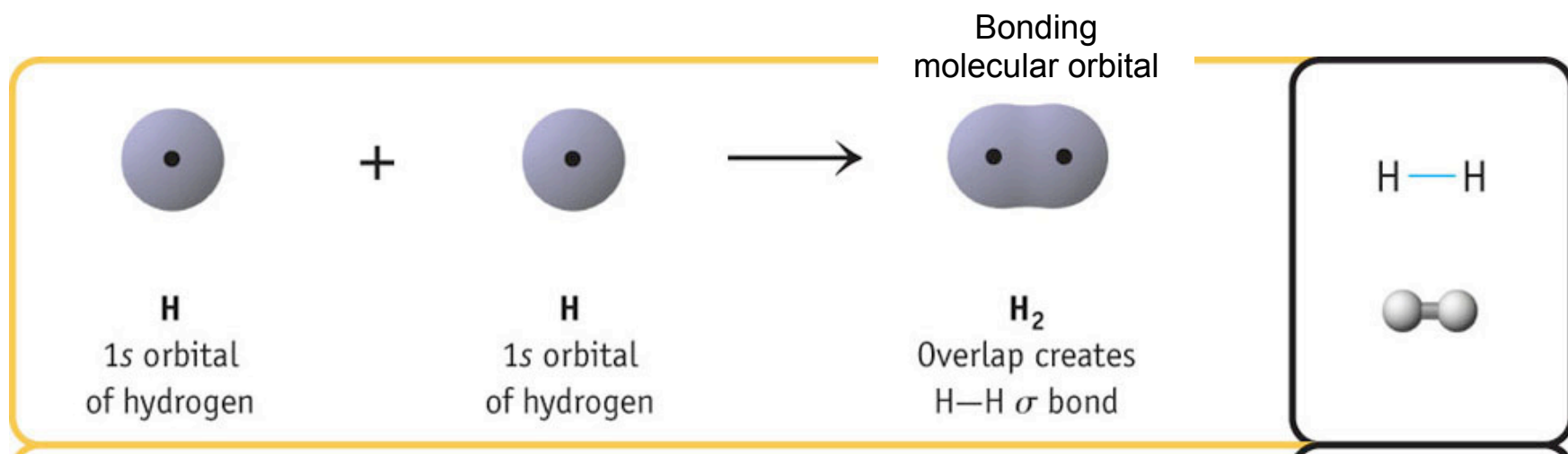


# Covalent Bonding



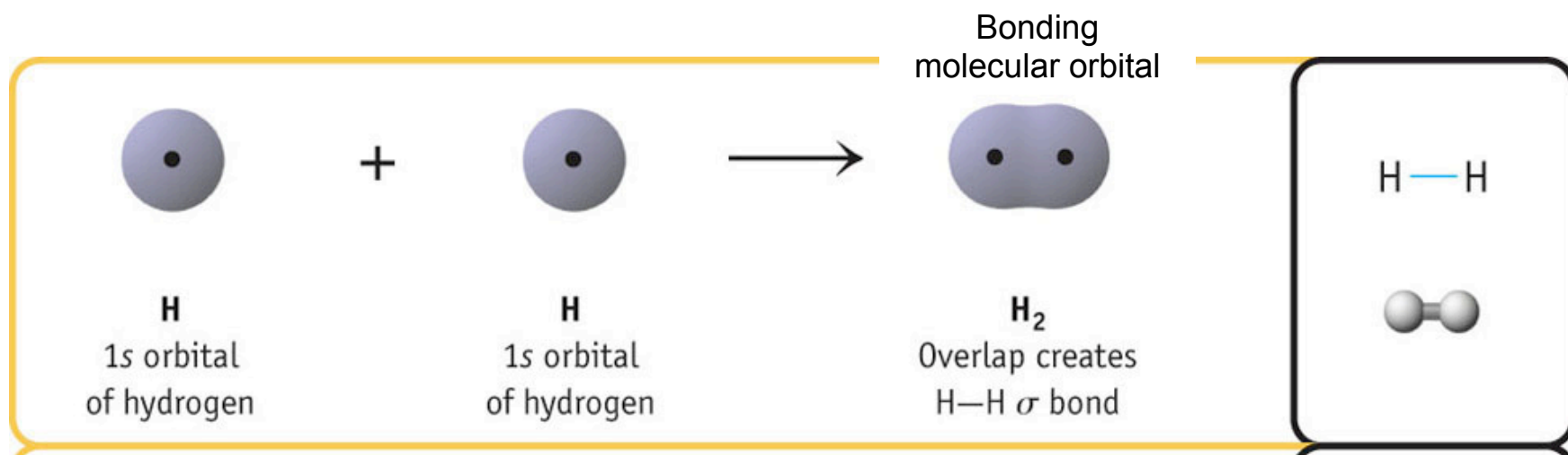


We can combine two **atomic orbitals** to create a new **molecular orbital**



We can combine two **atomic orbitals** to create a new **molecular orbital**

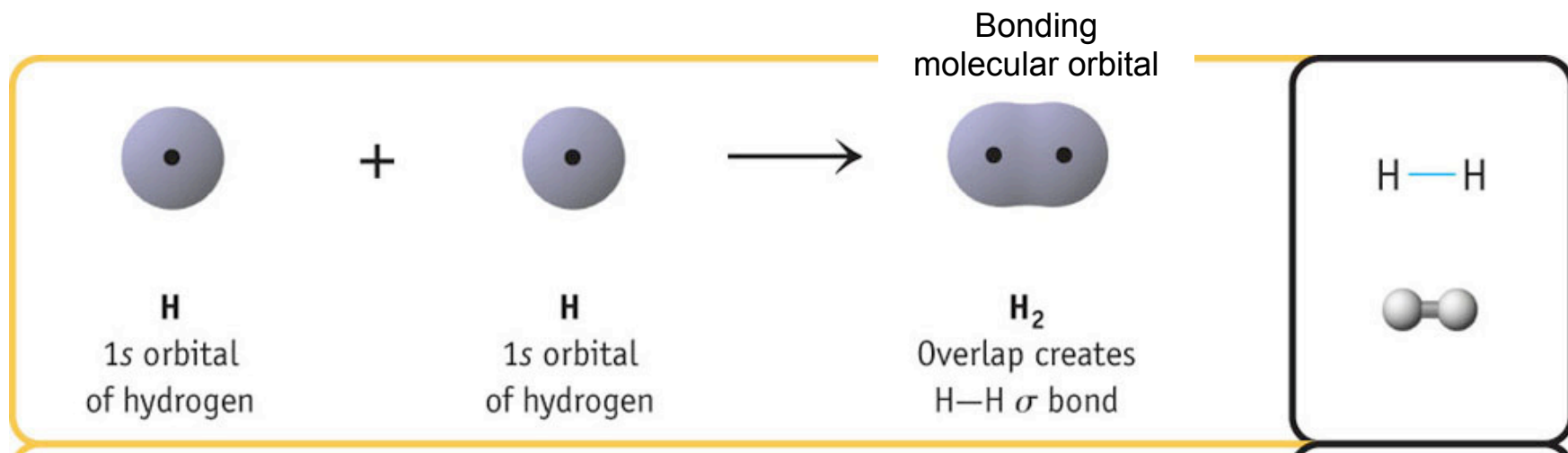
In reality, when we combine **two atomic orbitals**, we get back **two molecular orbitals**



We can combine two **atomic orbitals** to create a new **molecular orbital**

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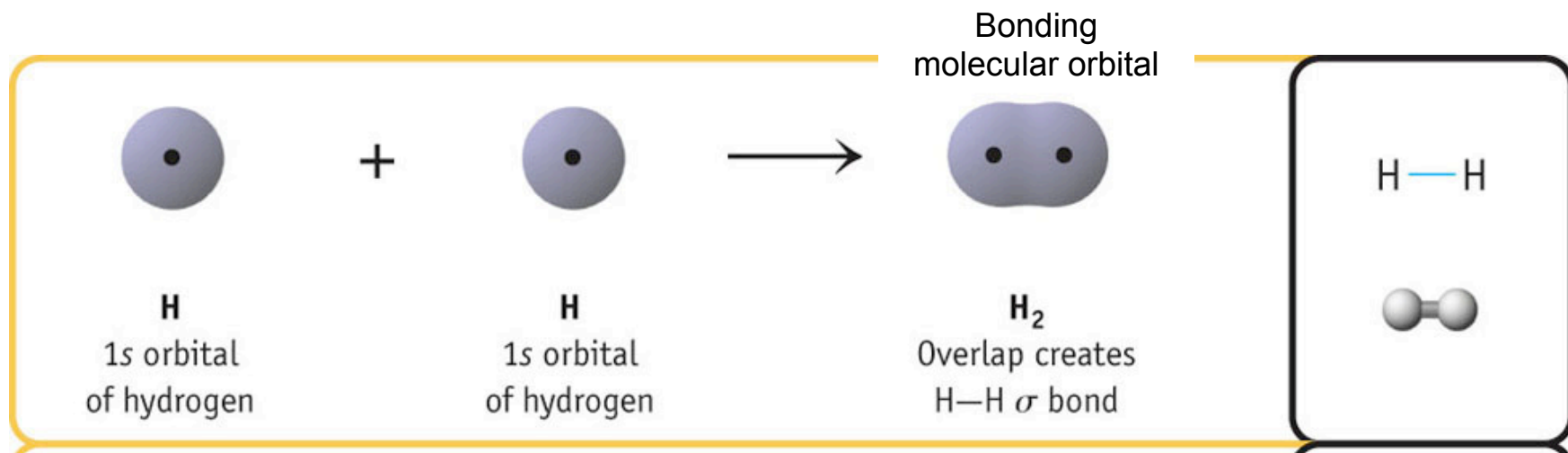
Mixing of the **two atomic orbitals** creates  
one **bonding molecular orbital** (lower in energy)  
one **anti-bonding molecular orbital** (higher in energy)



We can combine two **atomic orbitals** to create a new **molecular orbital**

In reality, when we combine **two atomic orbitals**, we get back **two molecular orbitals**

Mixing of the **two atomic orbitals** creates  
 one **bonding molecular orbital** (lower in energy) 
*both electrons  
go here*  
 ↙
   
 one **anti-bonding molecular orbital** (higher in energy)



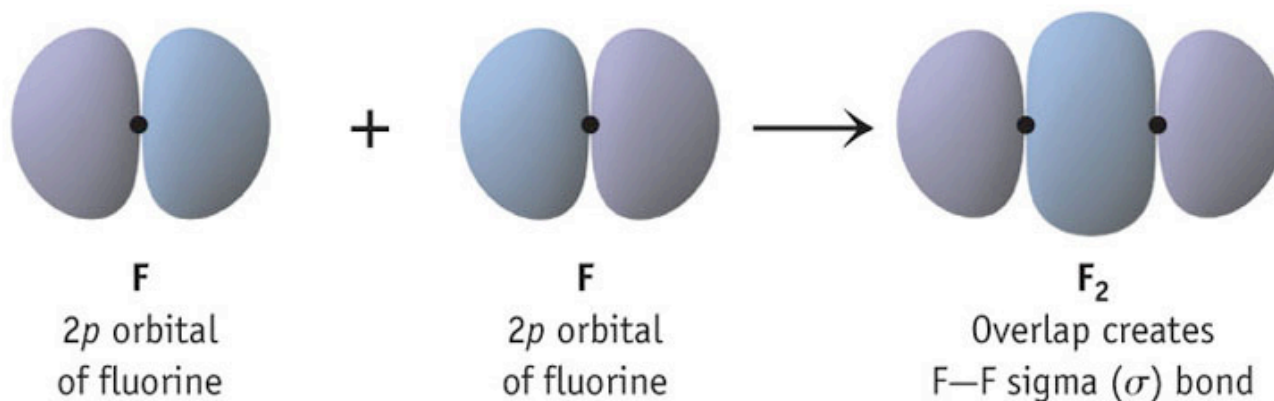
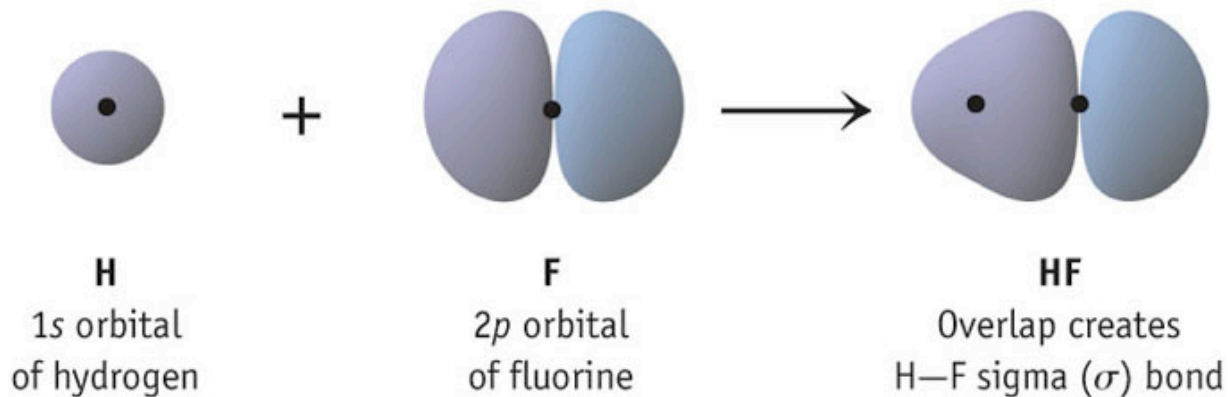
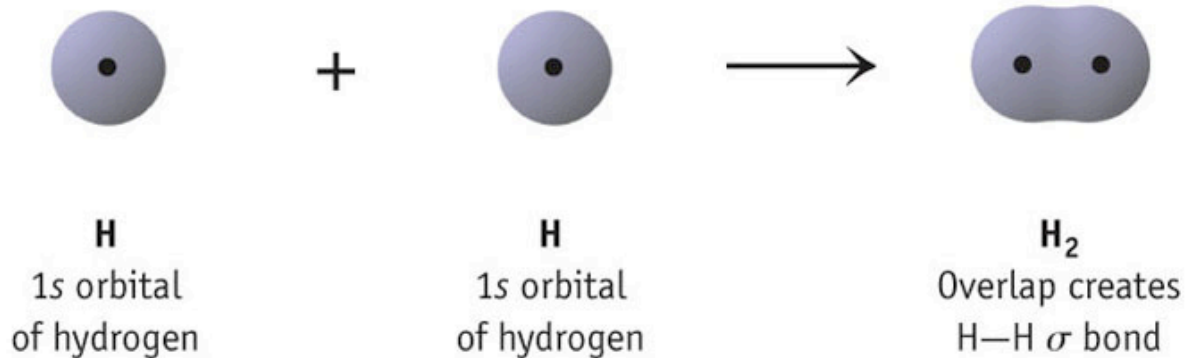
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In reality, when we combine **two atomic orbitals**, we get back **two molecular orbitals**

Mixing of the **two atomic orbitals** creates  
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*both electrons  
go here*  
 ↙
   
 one **anti-bonding molecular orbital** (higher in energy)

Absolute rule: if you “mix” **n atomic orbitals**, you get back **n molecular orbitals**





# Switch our Thinking

Move away from thinking of p and s orbitals

# Switch our Thinking

Move away from thinking of p and s orbitals

We can combine **n atomic orbitals**, to get back **n hybrid atomic orbitals**

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Combine **one** 2s and **one** 2p atomic orbital

# Switch our Thinking

Move away from thinking of p and s orbitals

We can combine **n atomic orbitals**, to get back **n hybrid atomic orbitals**

Combine **one** 2s and **one** 2p atomic orbital

Get back **two sp hybrid** atomic orbitals

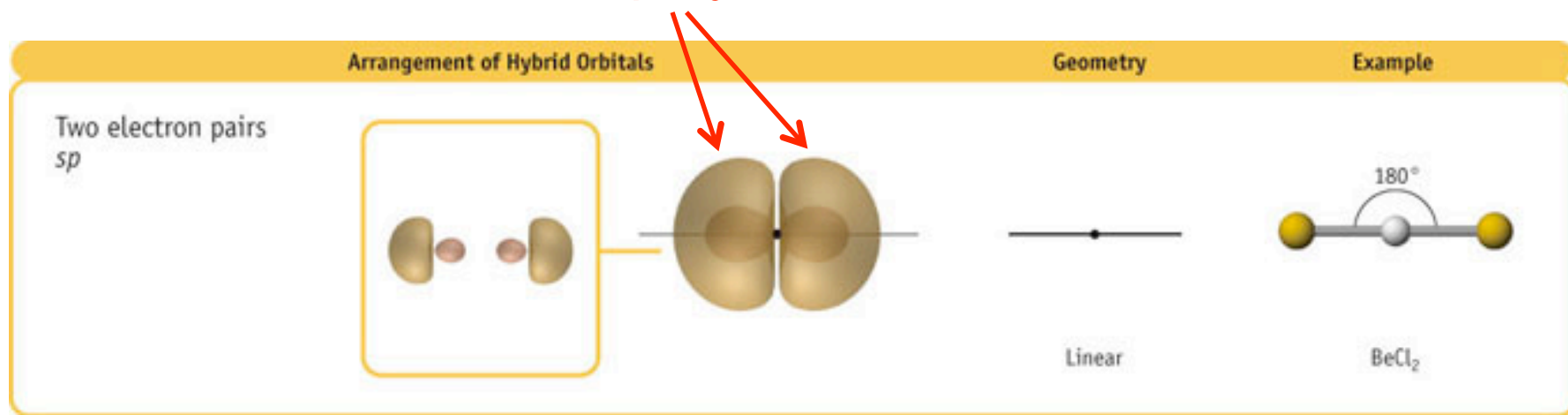
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Combine **one** 2s and **one** 2p atomic orbital

Get back **two sp hybrid** atomic orbitals



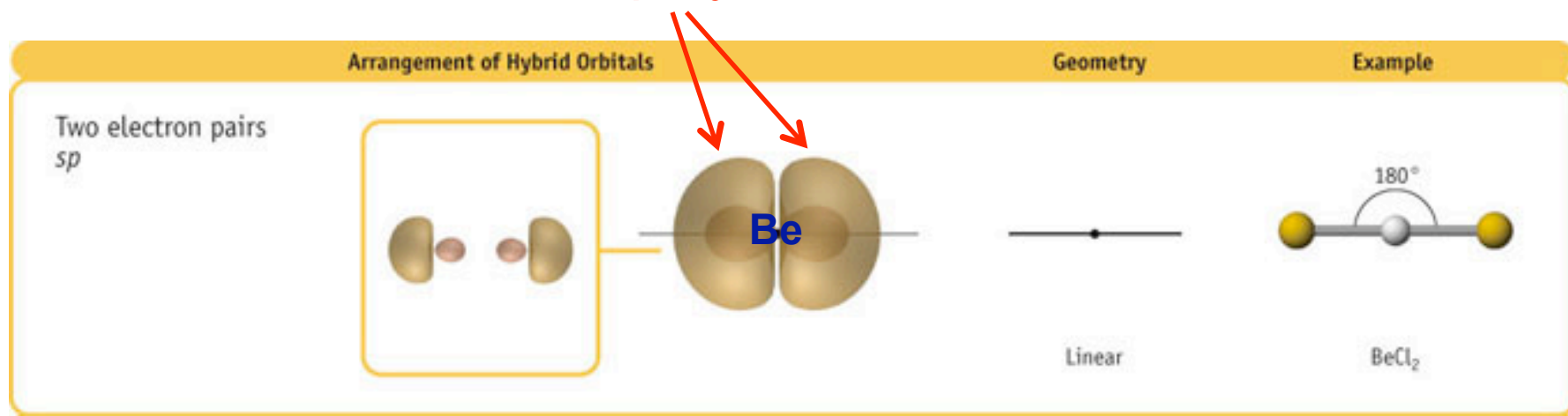
# Switch our Thinking

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We can combine **n atomic orbitals**, to get back **n hybrid atomic orbitals**

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# Switch our Thinking

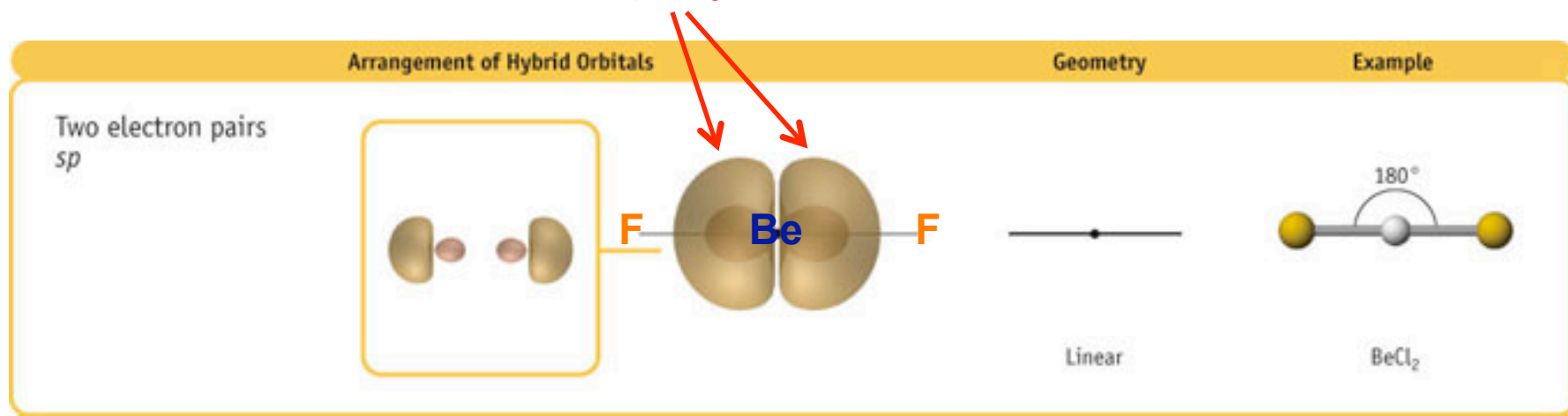
## Hybrid Atomic Orbitals

Move away from thinking of p and s orbitals

We can combine **n atomic orbitals**, to get back **n hybrid atomic orbitals**

Combine **one** 2s and **one** 2p atomic orbital

Get back **two sp hybrid** atomic orbitals





# Switch our Thinking

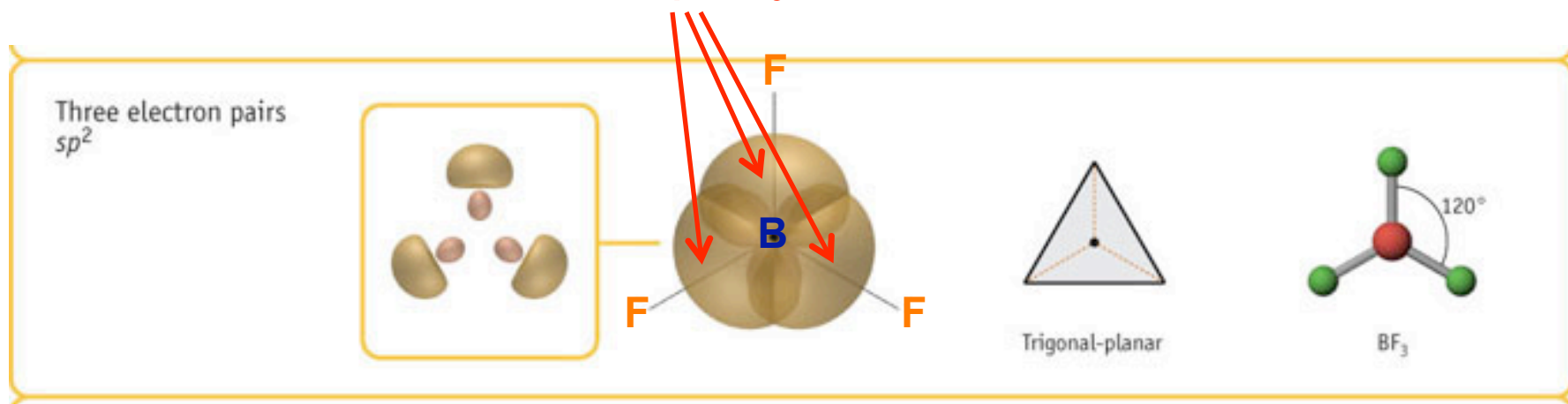
## Hybrid Atomic Orbitals

Move away from thinking of p and s orbitals

We can combine **n atomic orbitals**, to get back **n hybrid atomic orbitals**

Combine **one** 2s and **two** 2p atomic orbitals

Get back **three  $sp^2$  hybrid** atomic orbitals



# Switch our Thinking

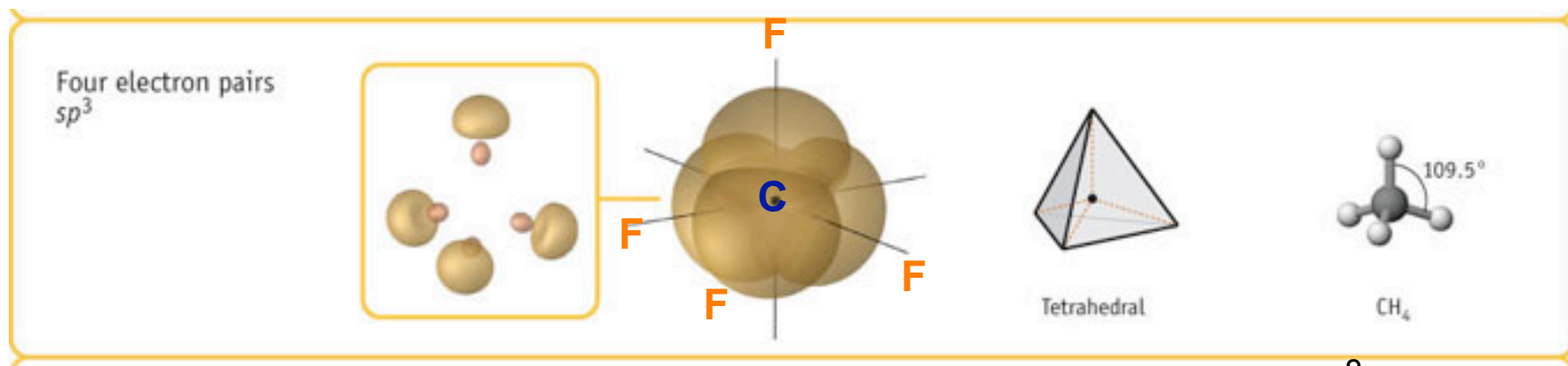
## Hybrid Atomic Orbitals

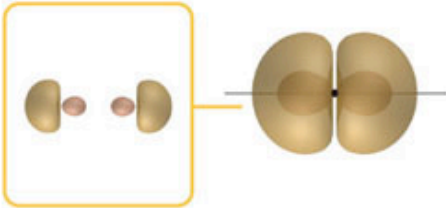


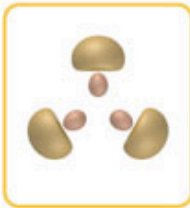
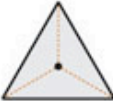
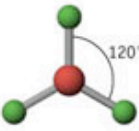


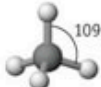

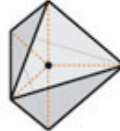
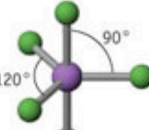
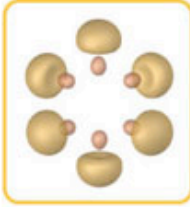

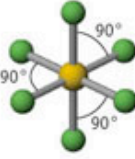
Move away from thinking of p and s orbitals

We can combine **n atomic orbitals**, to get back **n hybrid atomic orbitals**

Combine **one** 2s and **three** 2p atomic orbitals

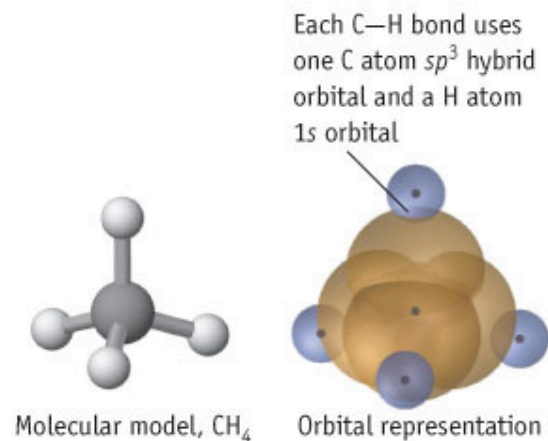
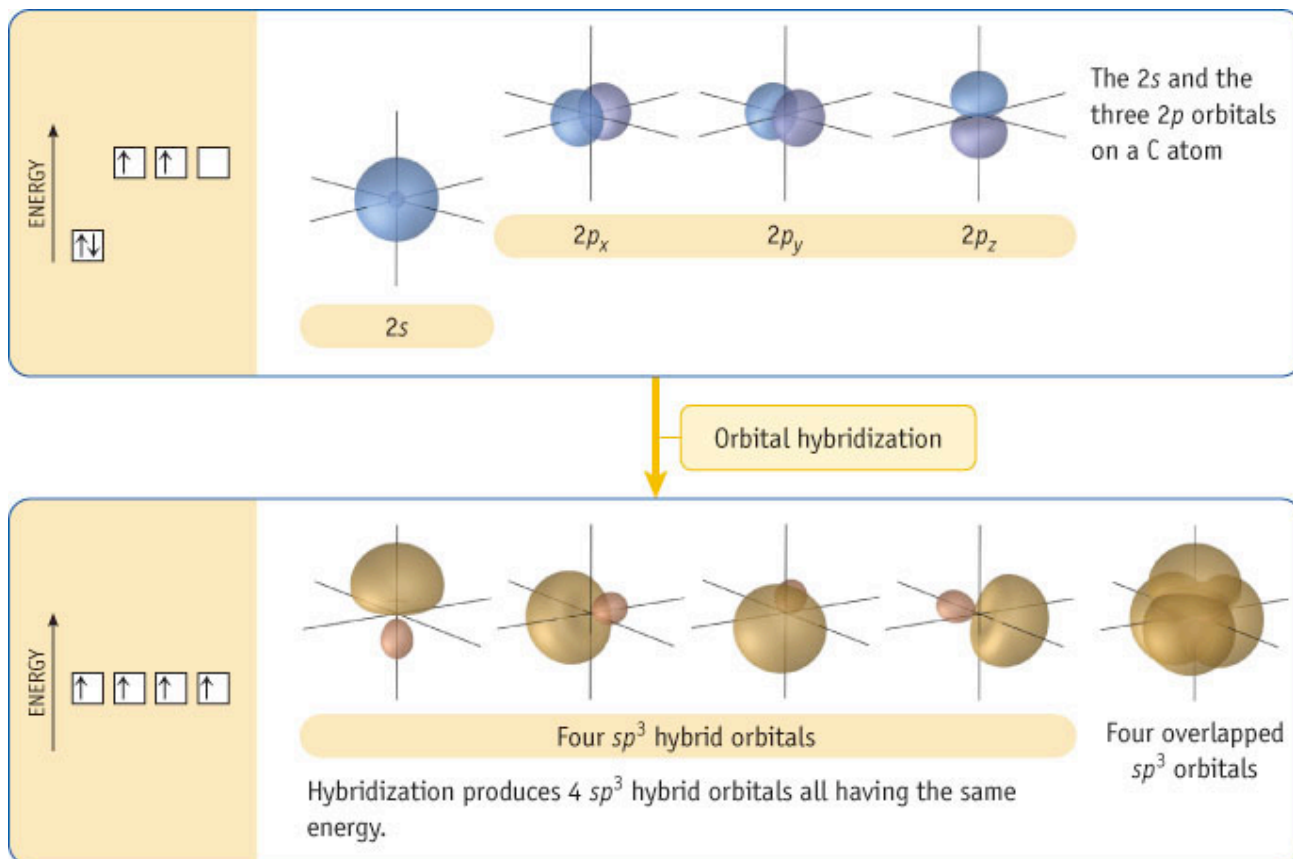
Get back **four  $sp^3$  hybrid** atomic orbitals



		Arrangement of Hybrid Orbitals	Geometry	Example
$s + p$	Two electron pairs $sp$		 Linear	 $\text{BeCl}_2$
$s + p + p$	Three electron pairs $sp^2$		 Trigonal-planar	 $\text{BF}_3$
$s + p + p + p$	Four electron pairs $sp^3$		 Tetrahedral	 $\text{CH}_4$
$s + p + p + p + d$	Five electron pairs $sp^3d$		 Trigonal-bipyramidal	 $\text{PF}_5$
$s + p + p + p + d + d$	Six electron pairs $sp^3d^2$		 Octahedral	 $\text{SF}_6$

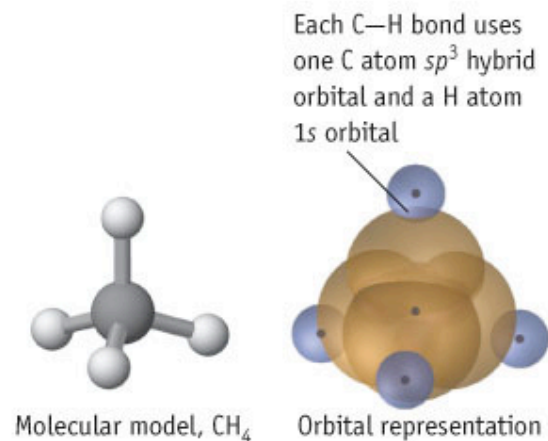
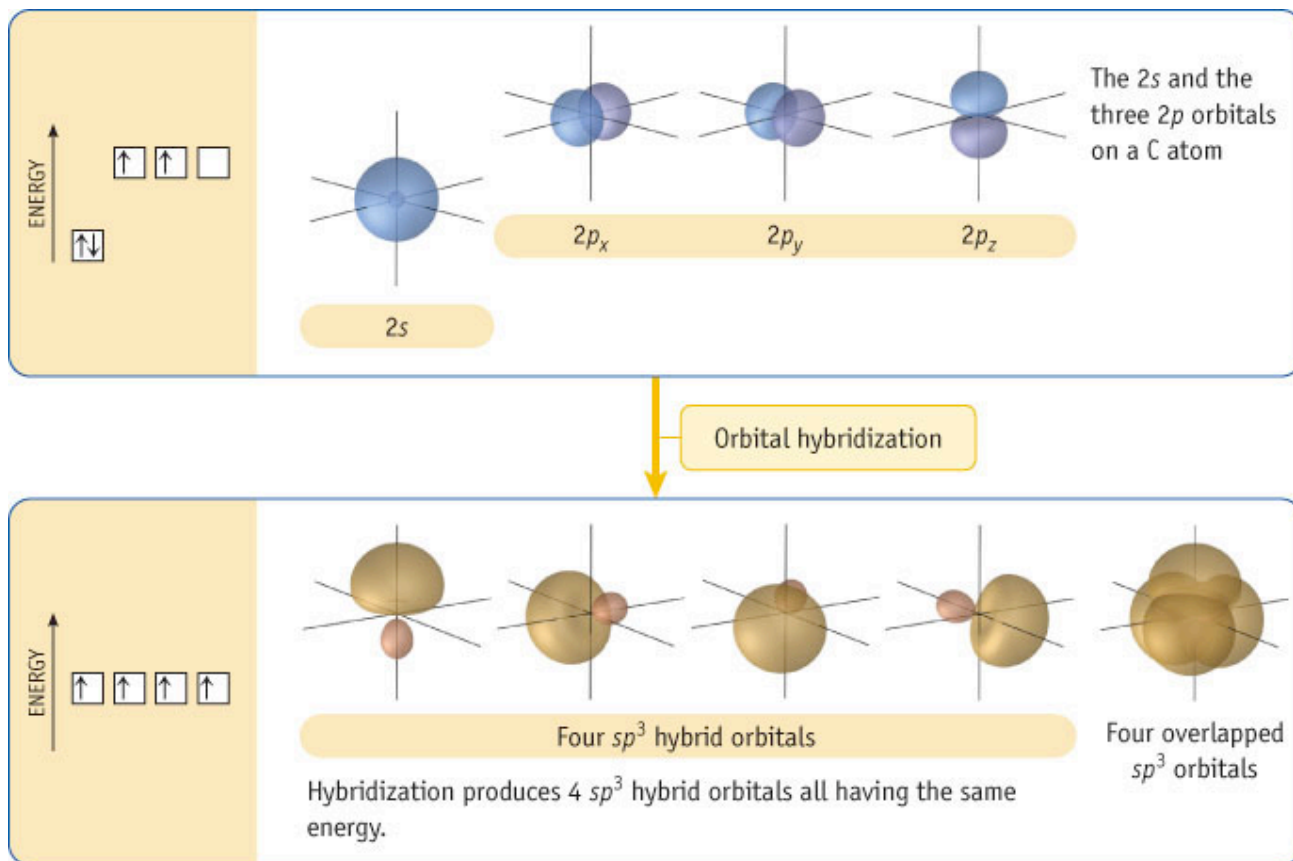
# Conservation of energy

The sum of the energies of the starting orbitals must equal the sum of the energies of the resulting orbitals



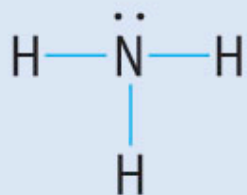
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The sum of the energies of the starting orbitals must equal the sum of the energies of the resulting orbitals

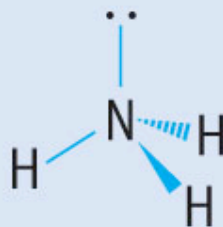


Take home: don't mix more atomic orbitals than you need to

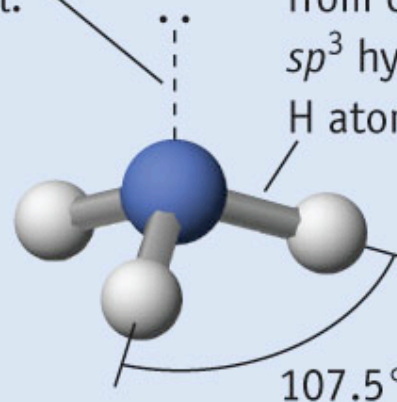
# $sp^3$ hybridization



Lewis structure



Electron-pair geometry

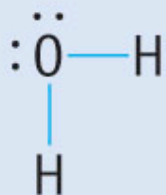


Molecular model

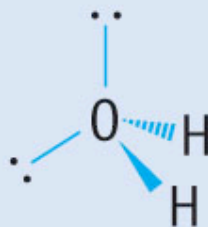
N atom lone pair uses  $sp^3$  hybrid orbital.

N—H bond is formed from overlap of N atom  $sp^3$  hybrid orbital and H atom 1s orbital.

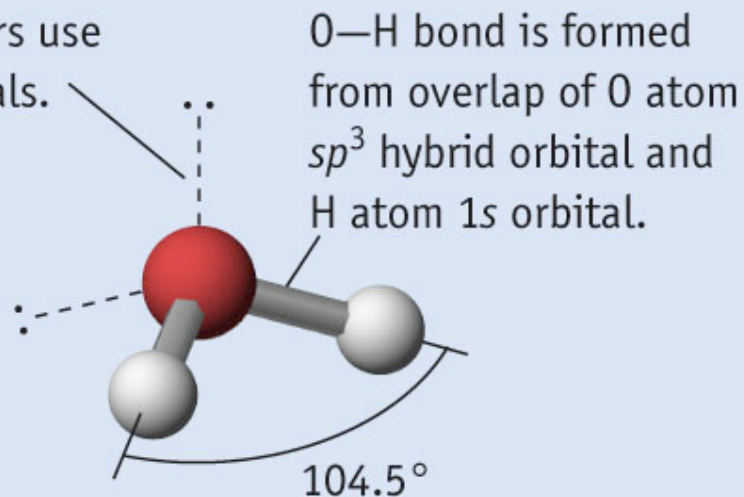
# $sp^3$ hybridization



Lewis structure



Electron-pair geometry



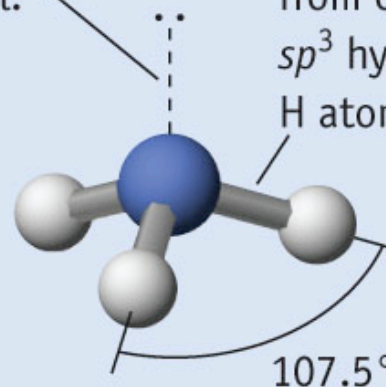
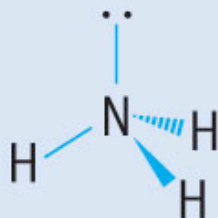
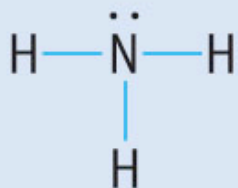
Molecular model



# $sp^3$ hybridization

N atom lone pair uses  $sp^3$  hybrid orbital.

N—H bond is formed from overlap of N atom  $sp^3$  hybrid orbital and H atom 1s orbital.



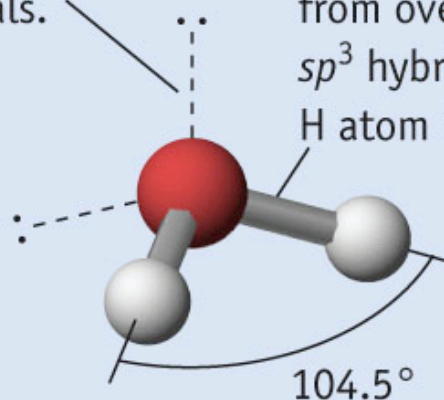
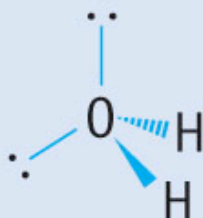
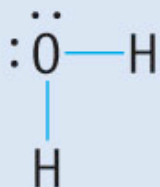
Lewis structure

Electron-pair geometry

Molecular model

O atom lone pairs use  $sp^3$  hybrid orbitals.

O—H bond is formed from overlap of O atom  $sp^3$  hybrid orbital and H atom 1s orbital.

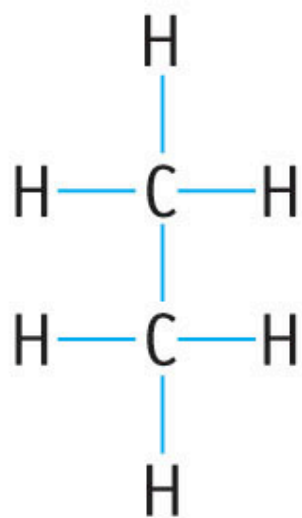


Lewis structure

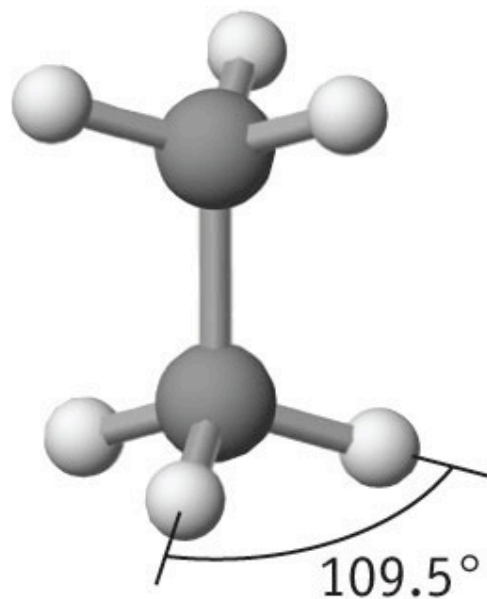
Electron-pair geometry

Molecular model



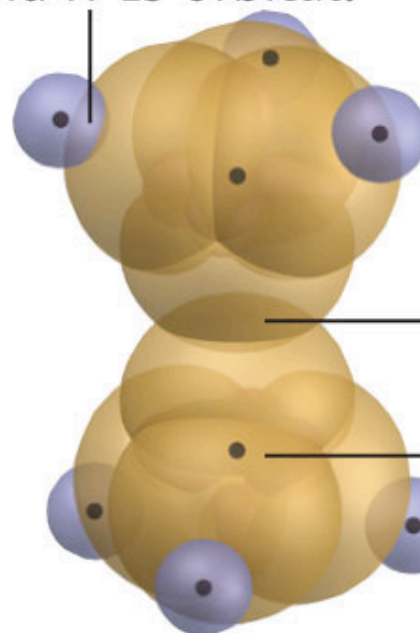


Lewis structure



Molecular  
model

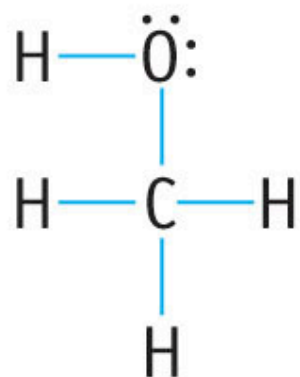
C—H bond is formed from overlap of C atom  $sp^3$  hybrid orbital and H 1s orbital.



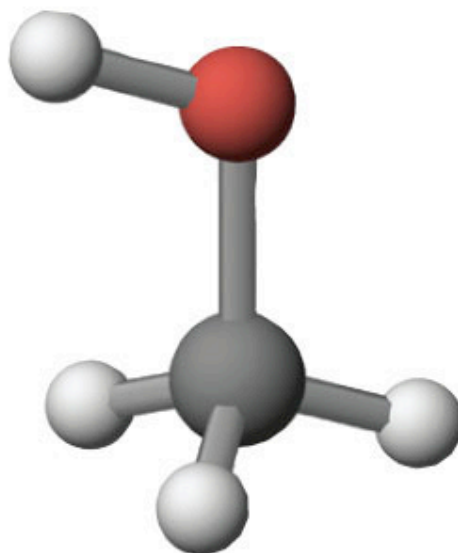
C—C bond is formed from overlap of C atom  $sp^3$  hybrid orbitals.

$sp^3$  hybridized carbon atom.

Orbital  
representation



Lewis structure



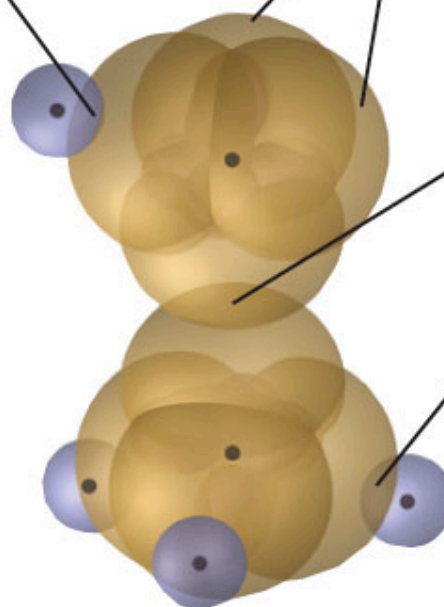
Molecular model

O—H bond formed from O atom  $sp^3$  hybrid orbital and H 1s orbital.

Lone pairs use  $sp^3$  hybrid orbitals on O atom.

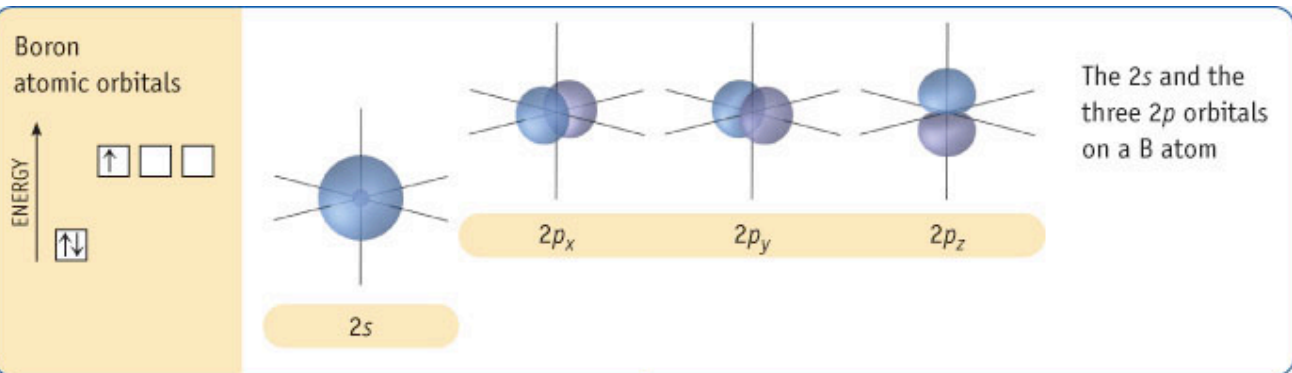
C—O bond formed from O and C  $sp^3$  hybrid orbitals.

C—H bond formed from C atom  $sp^3$  hybrid orbital and H 1s orbital.

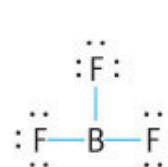
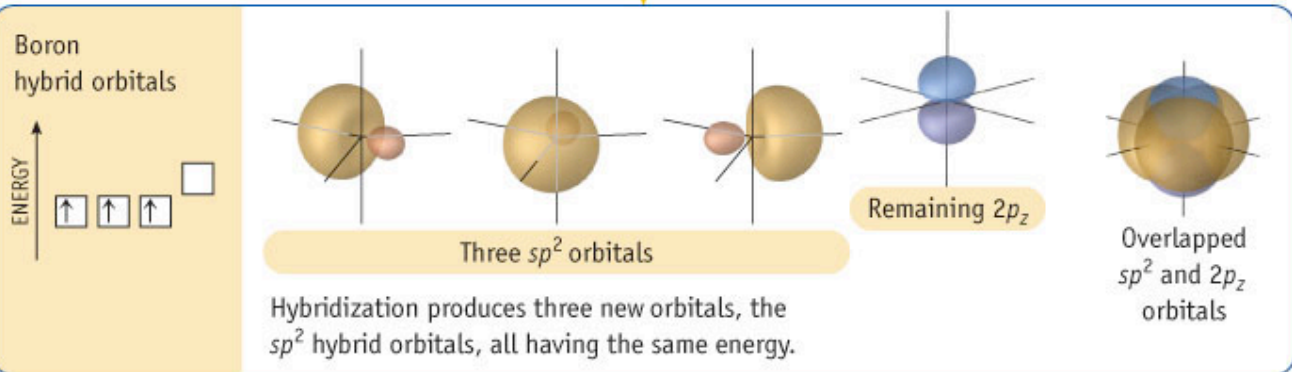


Orbital representation

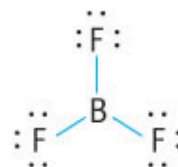
# sp<sup>2</sup> hybridization



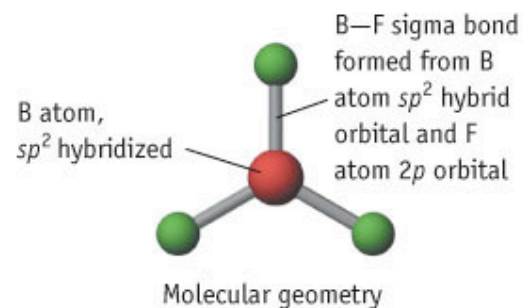
Orbital hybridization



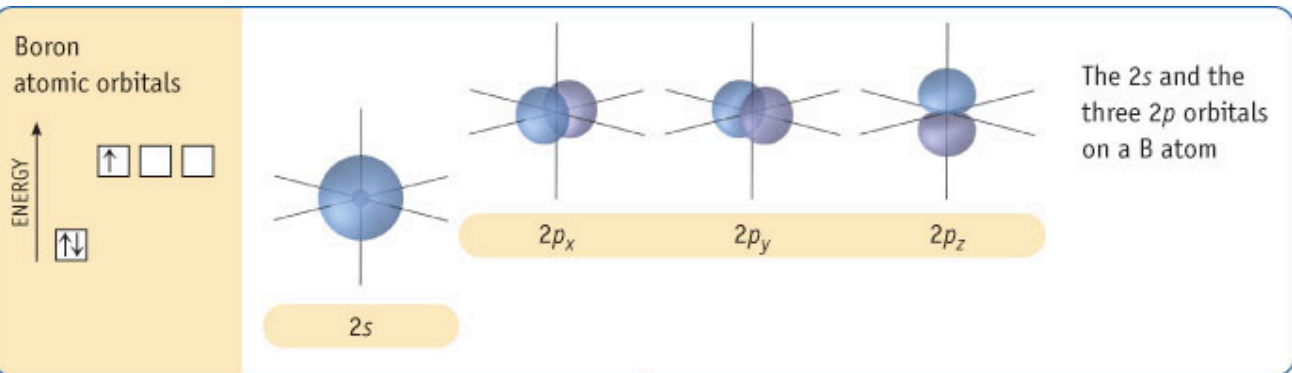
Lewis structure



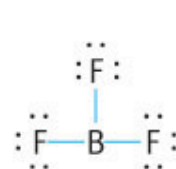
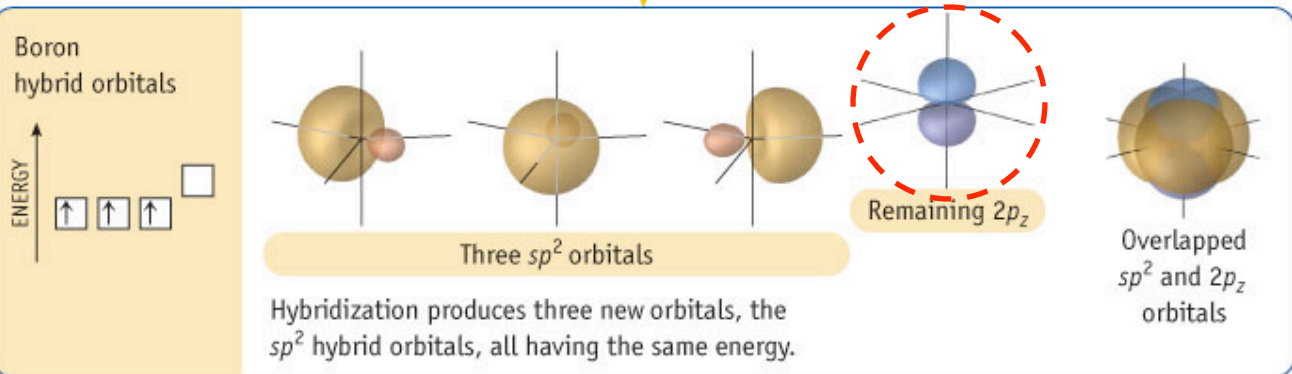
Electron-pair geometry



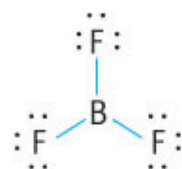
# sp<sup>2</sup> hybridization



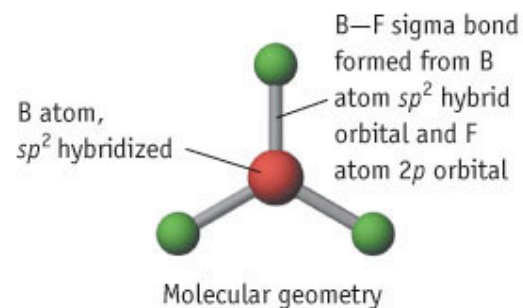
Orbital hybridization



Lewis structure

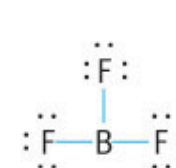
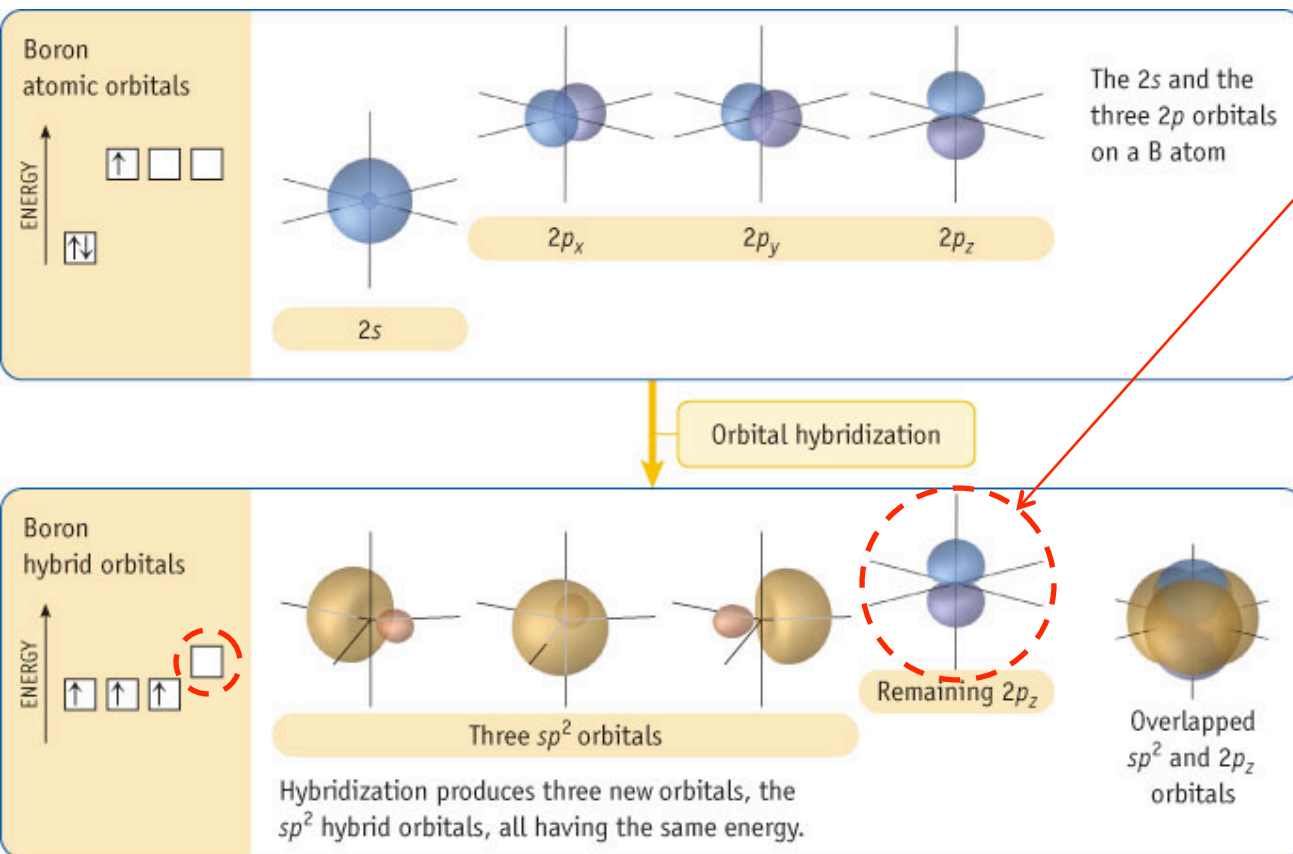


Electron-pair geometry

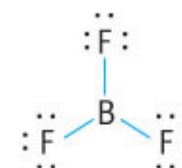


# sp<sup>2</sup> hybridization

Left over (unused)  
atomic orbital



Lewis structure



Electron-pair geometry

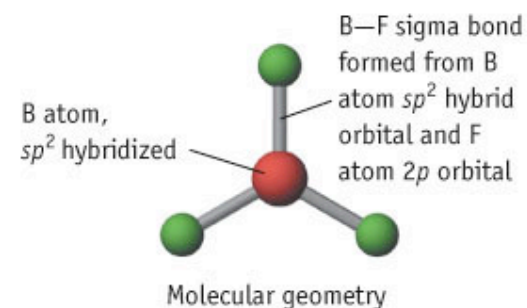
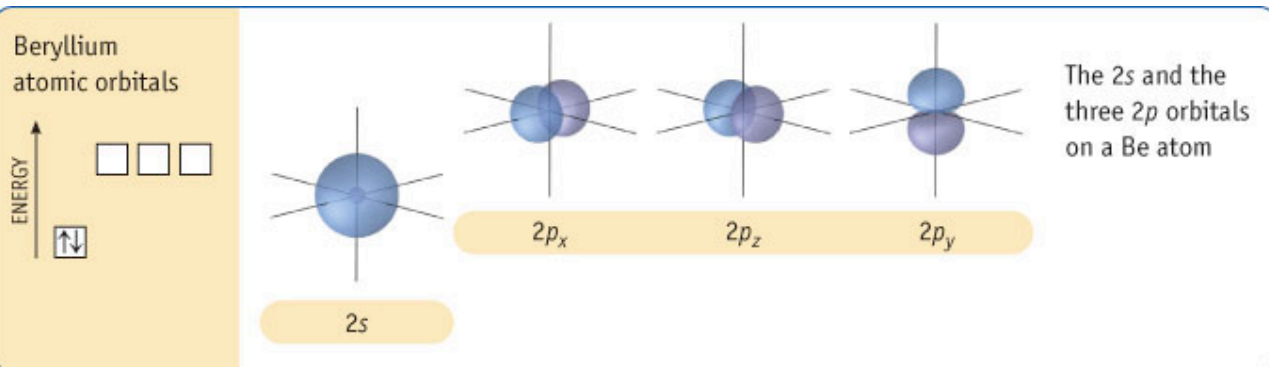
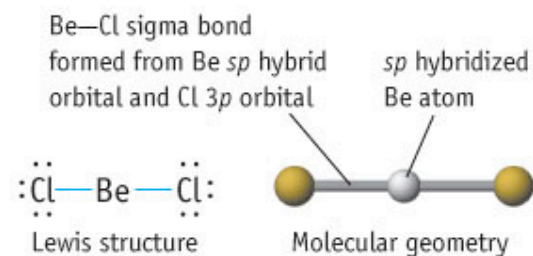
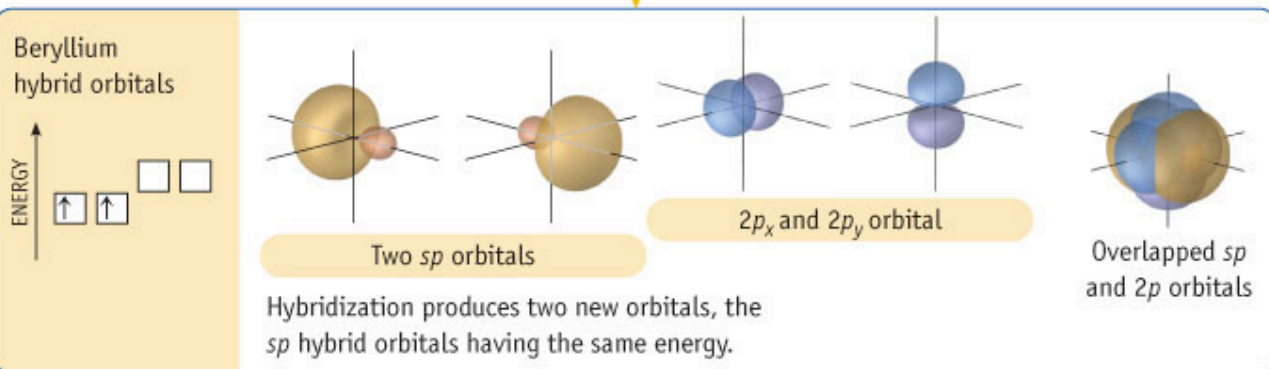


Fig. 9-8, p. 414

# sp hybridization

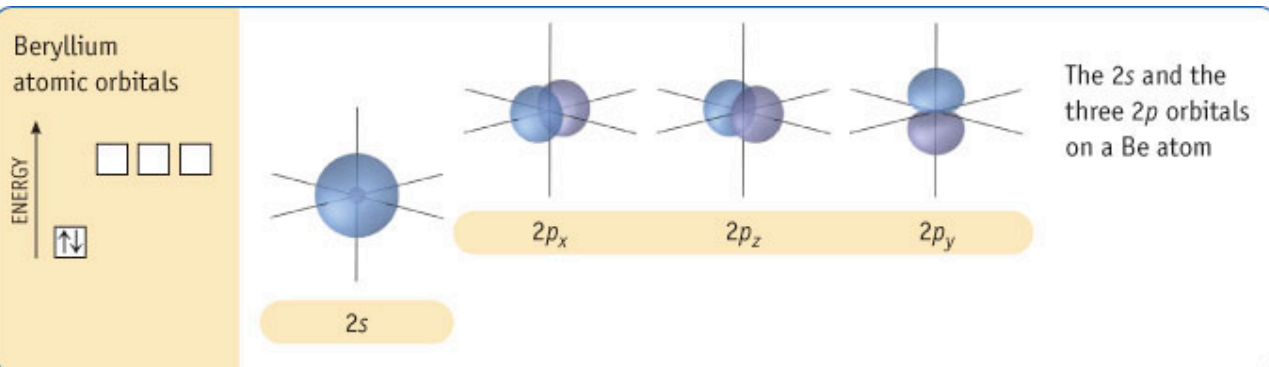


Orbital hybridization

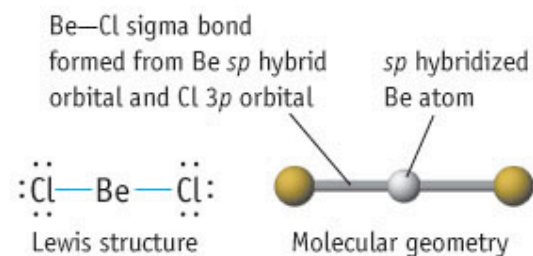
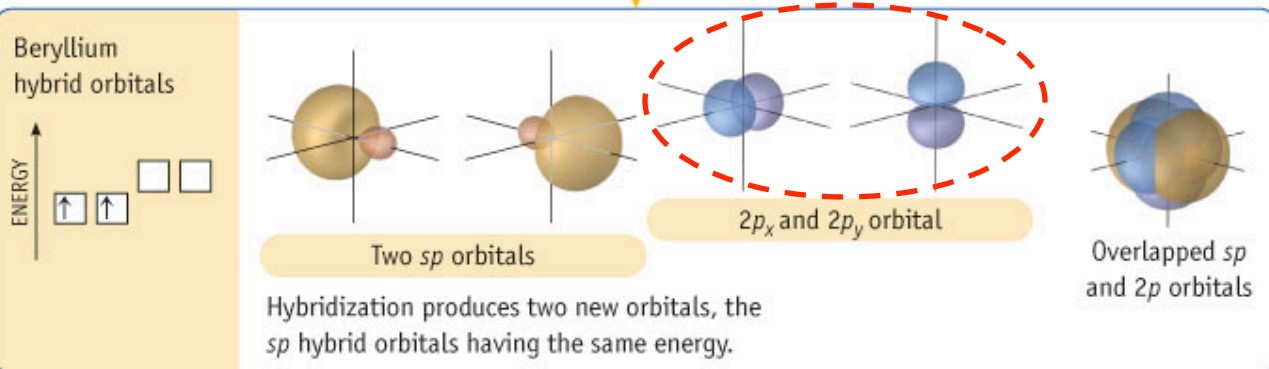




# sp hybridization

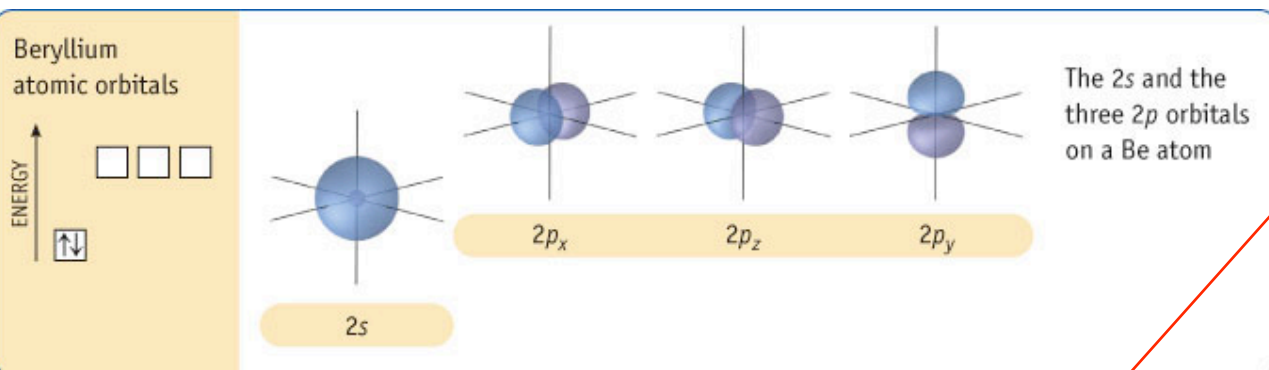


Orbital hybridization

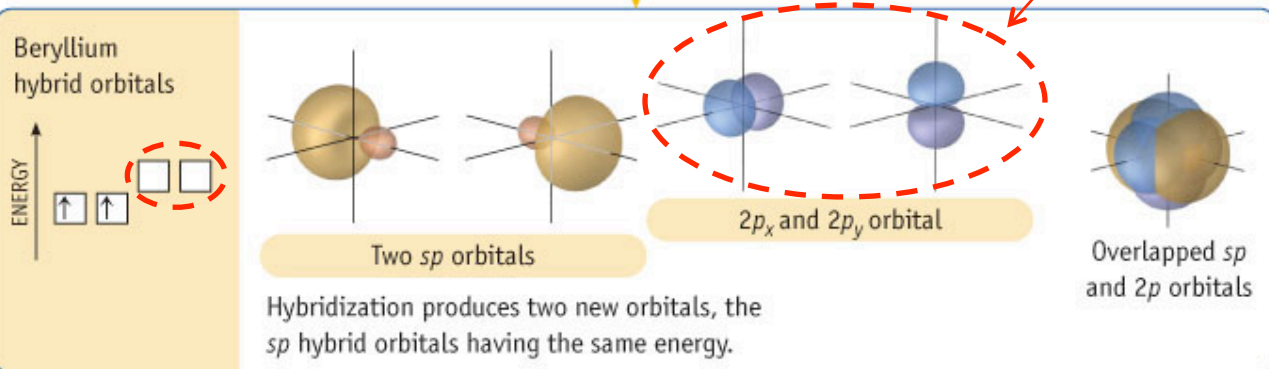


# sp hybridization

Left over (unused)  
atomic orbitals



Orbital hybridization



Be—Cl sigma bond  
formed from Be  $sp$  hybrid  
orbital and Cl 3p orbital

