

TUESDAY, JANUARY 14, 2025 AP CHEMISTRY

REVISED JAN 9, 2026

CH. 9

~~DON'T WORRY, IT'S NOT ON~~

~~YOUR Q2 TEST OR THE MIDTERM!~~

IN 2026 THIS IS ON Q2 TEST AND MIDTERM!

MOLECULAR GEOMETRY OR THE 3D SHAPES OF MOLECULES

WHY DO WE CARE?

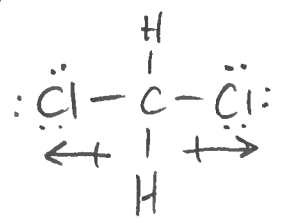
3D SHAPE DETERMINES

- MOLECULAR POLARITY
- SOLUBILITY
- HOW MOLECULES ABSORB & EMIT RADIATION
- MELTING POINT
- BOILING POINT
- CHEMICAL REACTIVITY

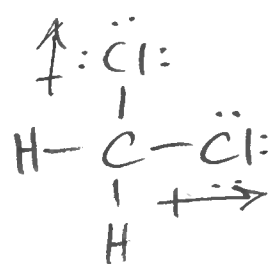
ONE CHALLENGE IS HOW WE DRAW MOLECULES IN 2D TO REPRESENT 3D MOLECULES.

FOR EX. WHICH OF THESE IS THE TRUE STRUCTURE OF  $\text{CH}_2\text{Cl}_2$ ?

[A]



[B]



OVERALL (ADDING UP BOND DIPOLES)

(C-Cl)  $\rightarrow$

SYMMETRY MEANS BOND DIPOLES CANCEL OUT MAKING  $\text{CH}_2\text{Cl}_2$  NON-POLAR

BOND VECTORS ADD UP TO PREDICT THAT  $\text{CH}_2\text{Cl}_2$  IS POLAR

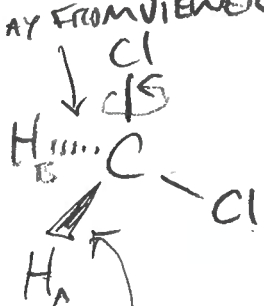
THESE DRAWINGS APPEAR TO BE SQUARE PLANAR AND THIS MAKES [A] LOOK DIFF. FROM [B].

①

THE TRUE 3D SHAPE IS NEITHER **A** NOR **B**!

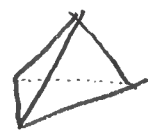
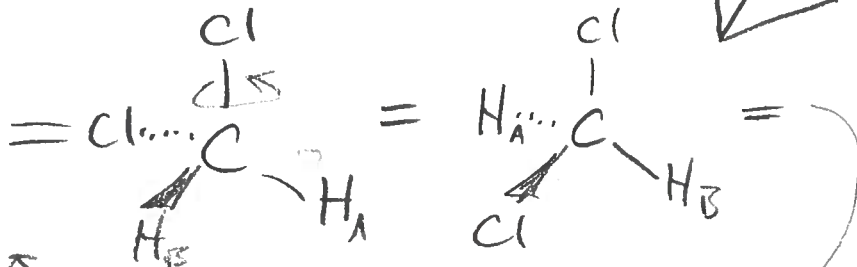
IT'S ACTUALLY TETRAHEDRAL.

POINTED IN  
AWAY FROM VIEWER



POINTED OUT  
TOWARD VIEWER

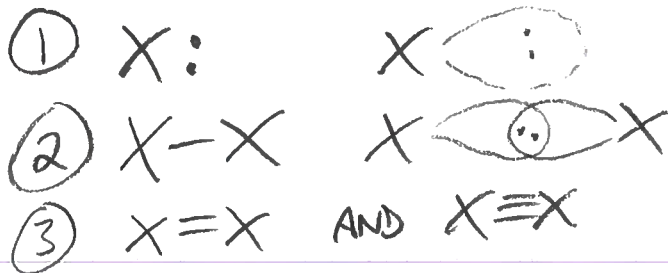
(BOTH Cl ATOMS  
ARE IN THE PLANE  
OF THE PAPER)



## VSEPR (VESPER)


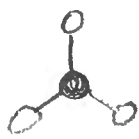
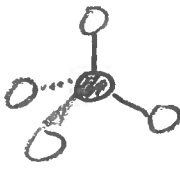
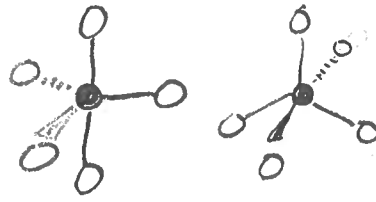

# VALENCE SHELL ELECTRON PAIR REPULSION

- AS YOU KNOW, THE PAULI EXCLUSION PRINCIPLE SAYS THAT ELECTRON PAIRS CANNOT OCCUPY THE SAME VOLUME.
- ELECTRONS EXIST IN PAIRS IN BONDS AND AS NON-BONDING PAIRS. (nbp). "LONE PAIRS"
- IN VSEPR BONDS AND NBP ARE KNOWN AS "ELECTRON DOMAINS"



- IN VSEPR 3D SHAPES OF MOLECULES ARE PREDICTED BASED ON THE IDEA THAT ELECTRON DOMAINS STAY AS FAR APART AS POSSIBLE.




# FIVE BASIC SHAPES OR ELECTRON DOMAIN GEOMETRIES

- ① LINEAR 
- ② TRIGONAL PLANAR 
- ③ TETRAHEDRAL 
- ④ TRIGONAL BIPYRAMIDAL 
- ⑤ OCTAHEDRAL 

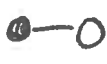
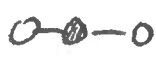
GO TO MOLECULE SHAPES WITH PHET (ADVANCED)

STOPPED HERE GROUP Y TU 2025-01-14 GROUP X TH 2025-01-26

# VSEPR SHAPES AND MODIFICATIONS

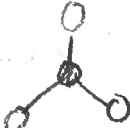
KEY: A = CENTRAL ATOM   
 B = LIGAND ATOM   
 E = LONE PAIR  } ELECTRON DOMAINS (USE MODELS TO DEMONSTRATE EACH SHAPE)


① <sup>ONE OR</sup> TWO ELECTRON DOMAINS: LINEAR ELECTRON DOMAIN GEOMETRY

AB		ANGLE 180° OR NONE	<div style="border: 1px solid black; padding: 2px;">LINEAR</div>	H <sub>2</sub> N <sub>2</sub> O <sub>2</sub> HCl HBr
AB <sub>2</sub>		ANGLE 180°	<div style="border: 1px solid black; padding: 2px;">LINEAR</div>	CO <sub>2</sub> BeF <sub>2</sub>

MOLECULAR GEOMETRY

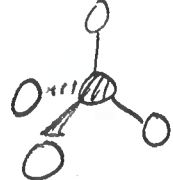
② THREE ELECTRON DOMAINS: TRIGONAL PLANAR


$AB_3$   ANGLE  $120^\circ$  TRIGONAL PLANAR  $BF_3$   $CO_3^{2-}$   
 $NO_3^-$   $H_2CO$


$AB_2E$   ANGLE  $120^\circ$   
OR  $< 120^\circ$  BENT  $SO_2$   $NO_2^-$   $O_3$

NOTE: MOLECULAR GEOMETRY DESCRIBES ATOMS (LIGANDS) ONLY

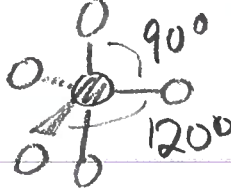
③ FOUR ELECTRON DOMAINS: TETRAHEDRAL


$AB_4$   ANGLE  $109.5^\circ$  TETRAHEDRAL  $CH_4$   $SiCl_4$

$AB_3E$   ANGLE  $109.5^\circ$   
OR  $< 109.5^\circ$  TRIGONAL PYRAMIDAL  $NH_3$   $H_3O^+$

$AB_2E_2$   ANGLE  $109.5^\circ$   
OR  $< 109.5^\circ$  BENT  $H_2O$   $H_2S$

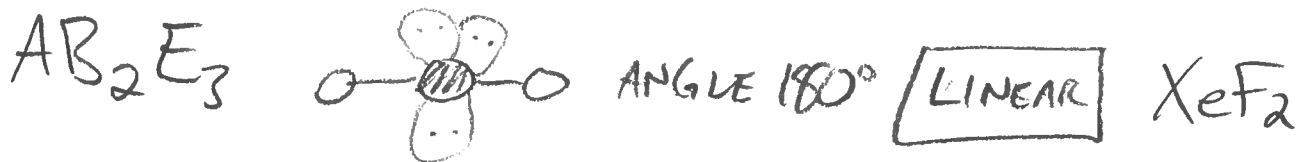
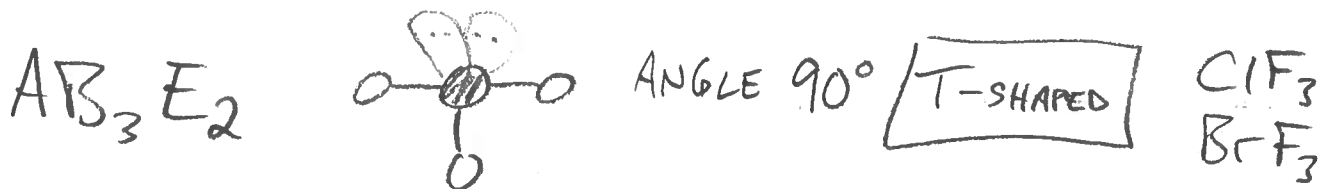
④ FIVE ELECTRON DOMAINS: TRIGONAL BIPYRAMIDAL

$AB_5$   ANGLE  $90^\circ$  AND  $120^\circ$  TRIGONAL BIPYRAMIDAL  $PCl_5$   $PF_3Cl_2$

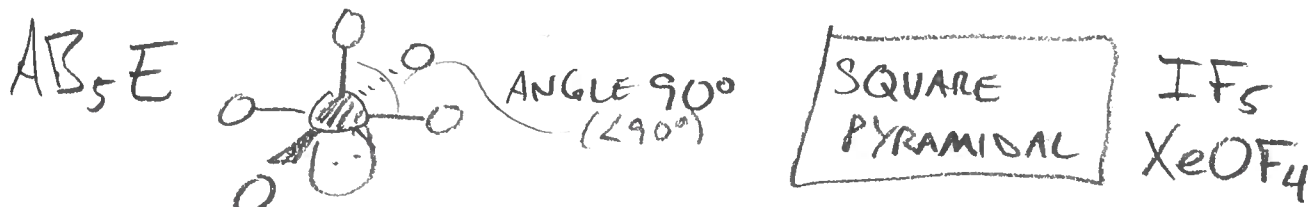
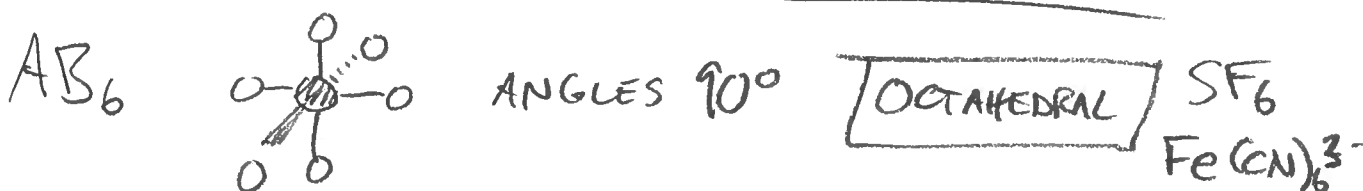
$AB_4E$   ANGLE  $90^\circ$  AND  $120^\circ$   
(OR LESS...) SEE-SAW  $SF_4$   $IO_2F_2^-$   $ClF_4^+$

TRIGONAL BIPYRAMIDAL, CONT

M 2025-01-27 AP CHEM



⑤ SIX ELECTRON DOMAINS: OCTAHEDRAL



TO REINFORCE: PHET MOLECULE SHAPES ACTIVITY

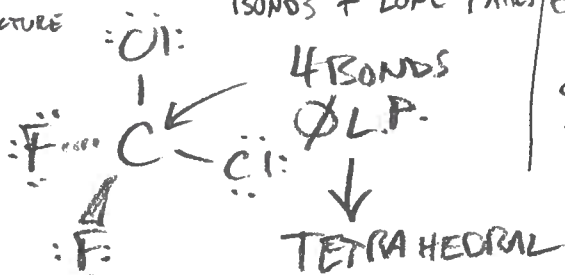
BUILD MODELS WITH KITS

DRAW LEWIS DIAGRAMS AND ID VSEPR SHAPES

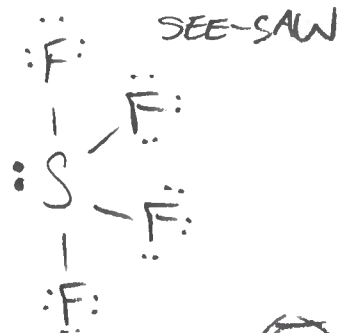
SEE HANDOUT

FOR EXAMPLE, HOW TO ID A SHAPE:

① DRAW A LEWIS STRUCTURE



SHAPE USING BONDS + LONE PAIRS / 6  $4 \times 7 = 34$



STOPPED HERE (GROUP X) M 2025-01-27

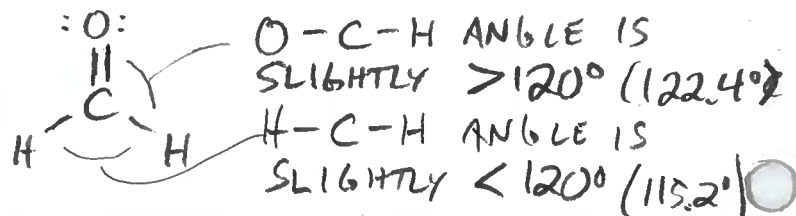
⑤

# REAL BOND ANGLES

BOND ANGLES AS GIVEN IN VSEPR ARE IDEALIZED FROM PURE GEOMETRY. REAL BOND ANGLES MAY MATCH THESE IDEALIZED ANGLES OR THEY MAY NOT. IF LONE PAIRS OR DOUBLE/TRIPLE BONDS ARE INVOLVED ANGLES CHANGE.

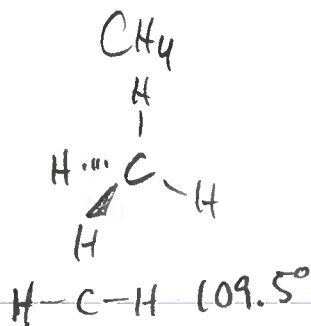
- ① DOUBLE & TRIPLE BONDS OCCUPY MORE VOL. THAN SINGLE BONDS. THEY PUSH NEARBY ATOMS AWAY.

FORMALDEHYDE:  $\text{CH}_2\text{O}$

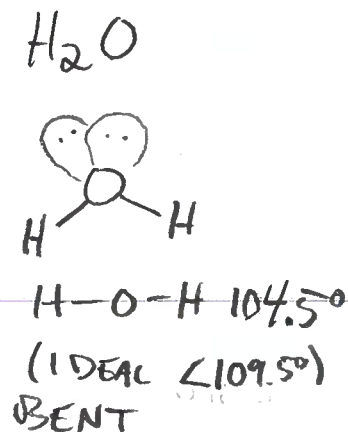
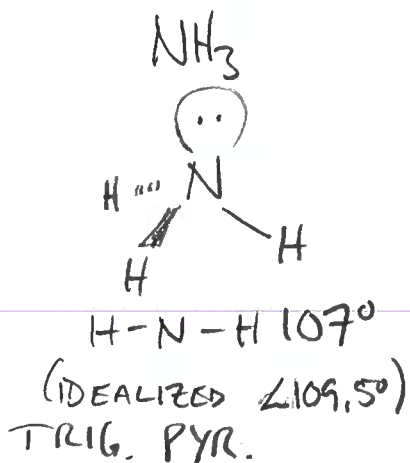


IDEAL ANGLES:  $120^\circ$   
(TRIGONAL PLANAR)

- ② LONE OR NON-BONDING PAIRS OCCUPY A MUCH LARGER VOLUME THAN A BONDING PAIR. THEY PUSH NEARBY ATOMS AWAY.



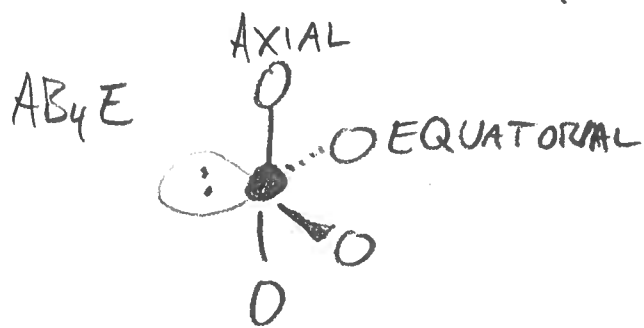
TETRAHEDRAL



SPECIAL CASES:  $AB_4E$  SEE-SAW

$AB_4E_2$  SQUARE PLANAR

C

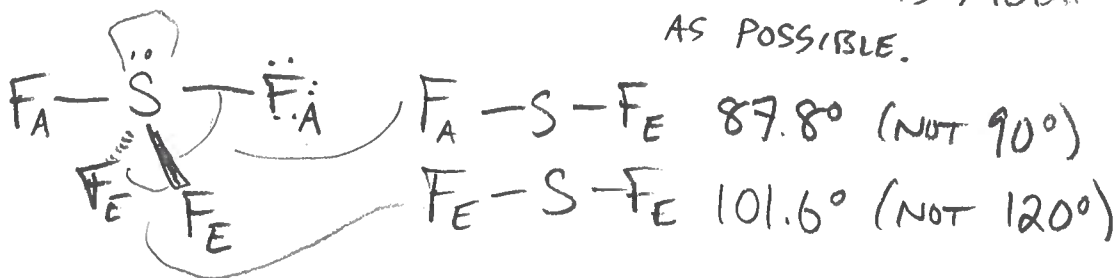


THE LONE PAIR IS ALWAYS IN THE EQUATORIAL POSITION B/C OF THE  $120^\circ$  ANGLE.

IN AN AXIAL POSITION ALL ITS ANGLES WOULD BE  $90^\circ$ .

IT NEEDS AS MUCH SPACE AS POSSIBLE.

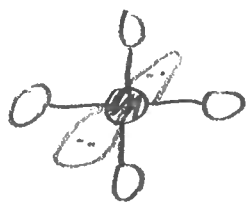
FOR EX.  $SF_4$



$AB_4E_2$  SQUARE PLANAR — TWO LONE PAIRS AND FOUR BONDS IN AN OCTAHEDRAL ELECTRON DOMAIN GEOMETRY

THE LONE PAIRS ARE ON OPPOSITE SIDES OF THE PLANE

C



ANGLES ARE NOT DISTORTED FROM  $90^\circ$

## 9.3 MOLECULE SHAPE AND POLARITY

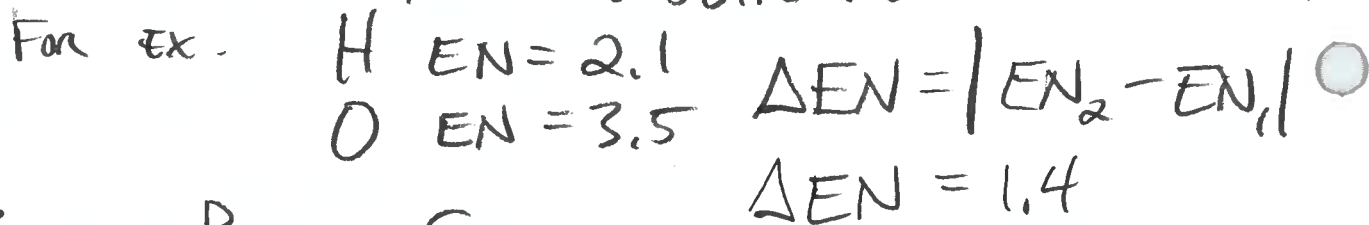
### BOND POLARITY

ATOMS OF THE SAME ELEMENT SHARE ELECTRONS COMPLETELY EQUALLY:  $H-H$   $O=O$   $N\equiv N$

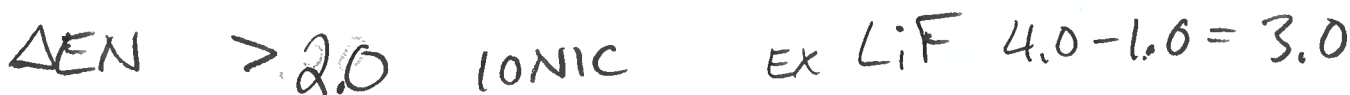
ATOMS OF DIFF. ELEMENTS DO NOT SHARE ELECTRONS EQUALLY DUE TO DIFFERENCES IN EFFECTIVE NUCLEAR CHARGE. ATOMS WITH HIGHER  $Z_{eff}$  DRAW  $e^-$  DENSITY TOWARD THEIR END OF THE BOND.

WE QUANTIFY DIFFERENCES IN  $Z_{eff}$  USING ELECTRONEGATIVITY.

WE USE THE DIFFERENCE IN ELECTRONEGATIVITY (EN) VALUE (FROM A TABLE) TO CALCULATE RELATIVE POLARITY.



### RELATIVE POLARITY SCALE



$\Delta EN$  ACTUALLY FALLS ON A SPECTRUM OF POSSIBLE POLARITIES IN SHADES OF GRAY.

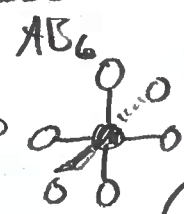
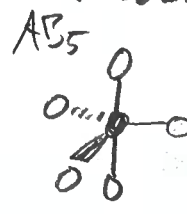
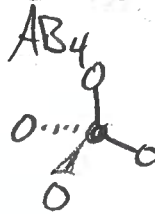
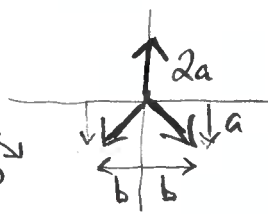
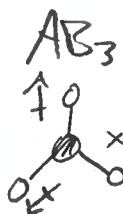
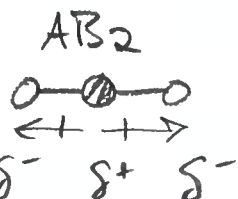
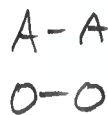
[EN VALUES ARE ON PG 310 FIG 8.7] I'LL GIVE YOU VALUES IF YOU NEED THEM. JUST KNOW THE OVERALL TREND.

### MOLECULAR POLARITY

TO DECIDE WHETHER A MOLECULE IS POLAR YOU NEED TO LOOK AT

1. BOND POLARITY
2. MOLECULAR GEOMETRY
3. MOLECULAR SYMMETRY

REGARDLESS OF BOND POLARITY IF THERE ARE NO NON-BONDING PAIRS AND ALL LIGANDS ARE THE SAME THE MOLECULE IS NON-POLAR.



(8)

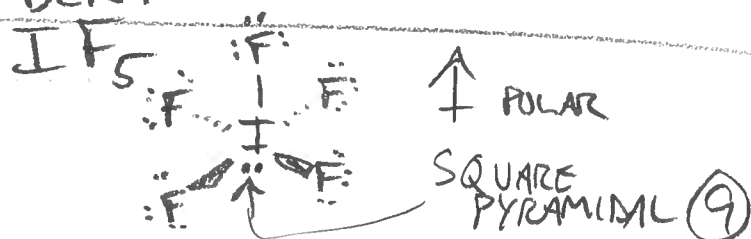
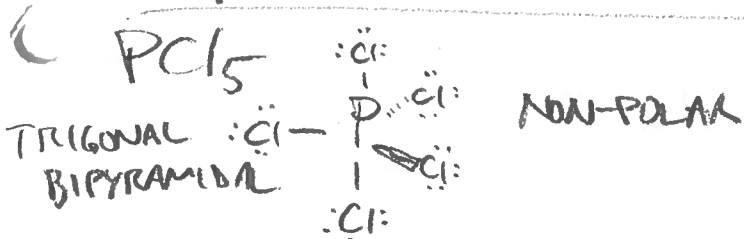
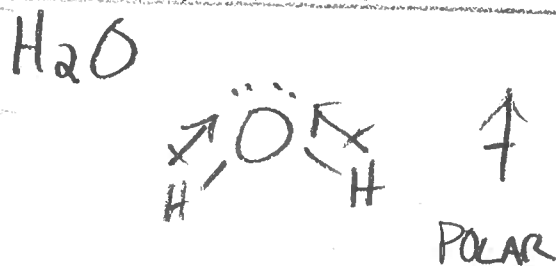
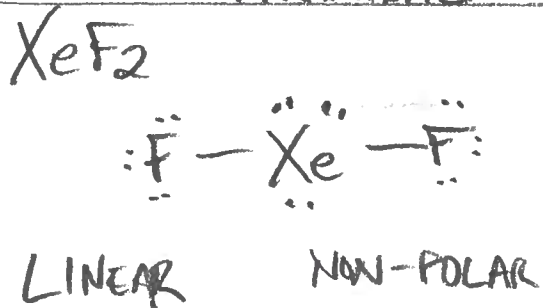
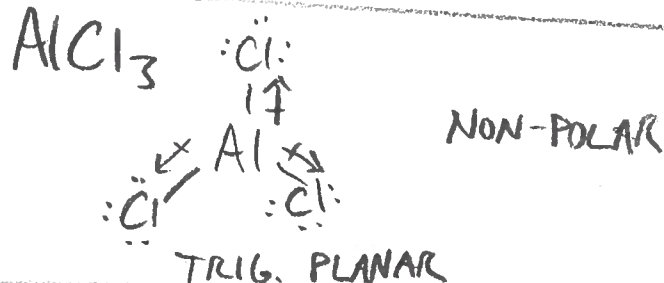
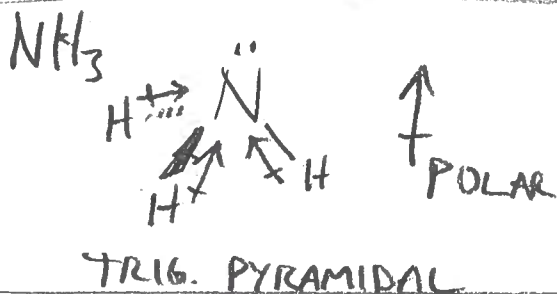
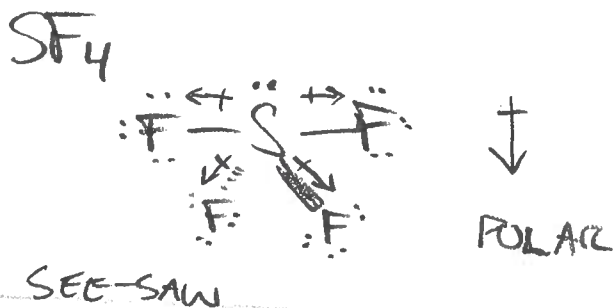
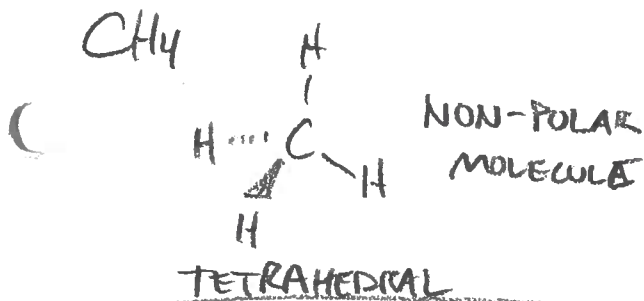
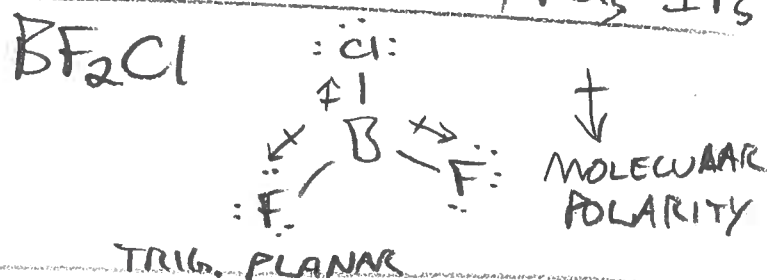
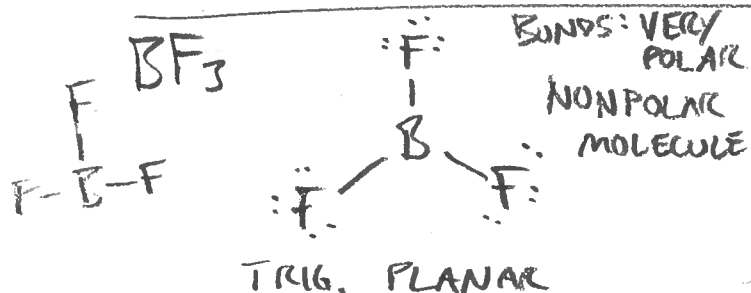
IF A MOLECULE HAS 2 OR MORE KINDS OF LIGAND AND/OR INCL. NON-BONDING PAIRS ON THE CENTRAL ATOM THEN IT IS POLAR.

TO DETERMINE POLARITY

- ① DETERMINE LEWIS STRUCTURE & 3D SHAPE
- ② DETERMINE BOND POLARITIES
- ③ CONSIDER SYMMETRY

TRY THESE

BF <sub>3</sub>	BF <sub>2</sub> Cl
CH <sub>4</sub>	SF <sub>4</sub>
NH <sub>3</sub>	AlCl <sub>3</sub>
XeF <sub>2</sub>	H <sub>2</sub> O
PCl <sub>5</sub>	IF <sub>5</sub>



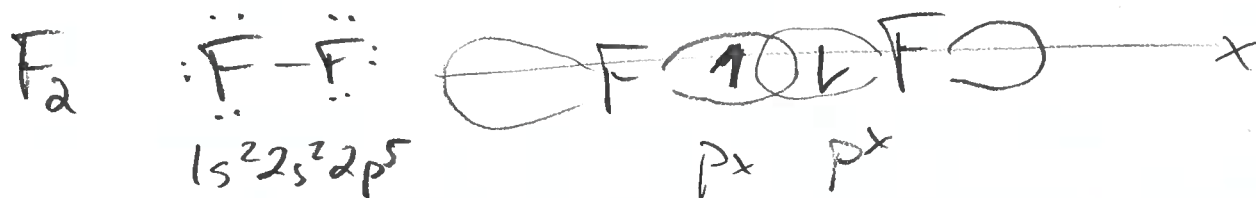
# 9.4 COVALENT BONDING AND ORBITAL OVERLAP

## 9.5 HYBRID ORBITALS

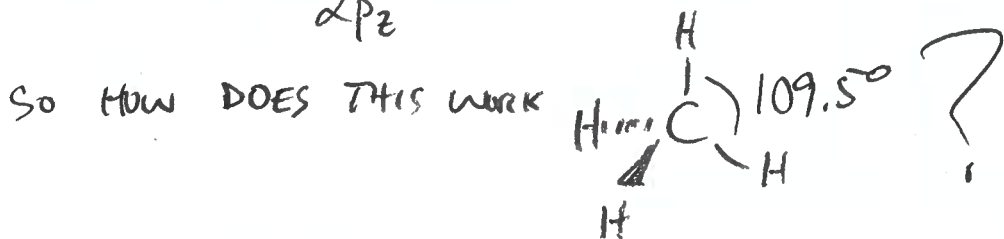
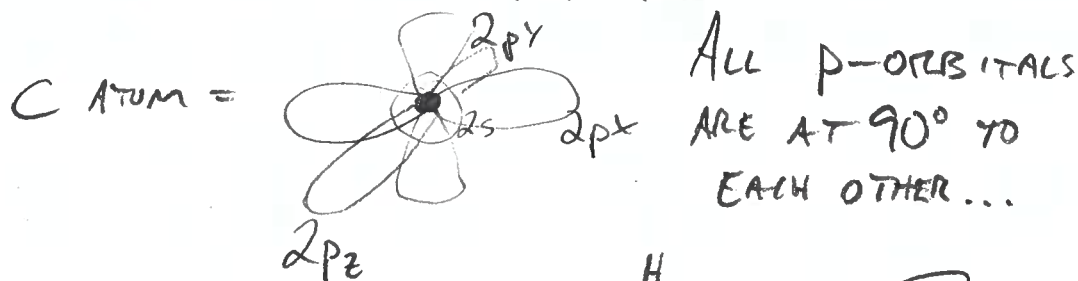
## 9.6 MULTIPLE BONDS

WE IMAGINE A BOND CONSISTING OF THE ELECTRON DENSITY BTWN TWO ATOMS DUE TO THE OVERLAP OF ATOMIC ORBITALS.

FOR SOME BONDS THIS IS SIMPLE:

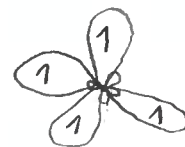
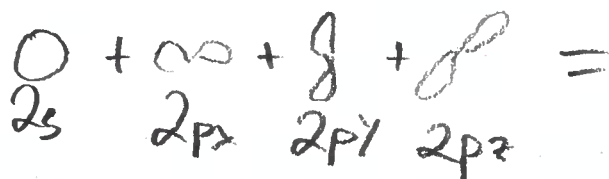


FOR SOME BONDS THIS DOES NOT WORK OUT:



TO DEAL WITH THIS WE IMAGINE A MATHEMATICAL ADDITION OF ATOMIC ORBITALS TO MAKE BONDING HYBRID ORBITALS:

FOR C IN  $CH_4$



4  $sp^3$ -HYBRID ORBITALS (10)

# WHAT YOU NEED TO KNOW:

- HOW TO IDENTIFY MOLECULAR GEOMETRY WITH SPECIFIC HYBRID CODES

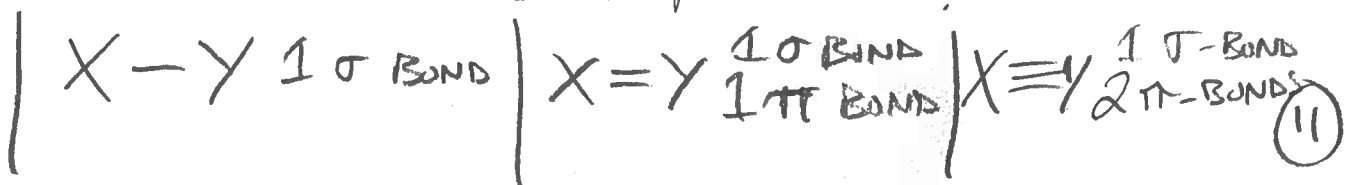
- HOW HYBRIDIZED AND UNHYBRIDIZED ORBITALS CONTRIBUTE TO MOLECULAR GEOMETRY

No. of $e^-$ DOMAINS	ORIGINAL ATOMIC ORBITALS (WHICH WE COMBINE)	RESULTING HYBRID ORBITALS	$e^-$ DOMAIN GEOMETRY	No. of $\pi$ -BONDS POSSIBLE
2	S + P	2 $sp_x$	LINEAR	2 1 $p_y$ 1 $p_z$
3	S + P + P	3 $sp^2_{p_x + p_y}$	TRIGONAL PLANAR	1 $p_z$
4	S + P + P + P	4 $sp^3$	TETRAHEDRAL	$\emptyset$
5	S + 3P + d	5 $dsp^3$	TRIGONAL BIPYRAMIDAL	$\emptyset$
6	S + 3P + 2d	6 $d^2sp^3$	OCTAHEDRAL	$\emptyset$

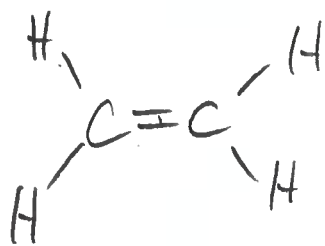
## ABOUT MULTIPLE BONDS:

A SIGMA ( $\sigma$ ) BOND IS A DIRECT ORBITAL OVERLAP.

A PI ( $\pi$ ) BOND IS A SIDE-WAYS OVERLAP OF UNHYBRIDIZED P-ORBITALS.



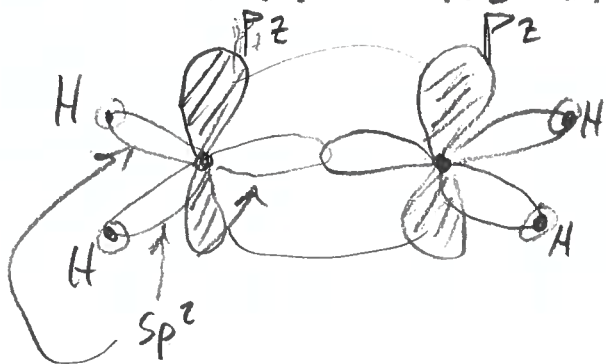
LET'S LOOK AT  $C_2H_4$  TO UNDERSTAND HYBRID ORBITAL AND  $\pi$ -BONDING.



BOTH ATOMS OF C ARE  $sp^2$ -HYBRIDIZED AND SO HAVE 3  $\sigma$ -BONDS IN THE SAME PLANE ( $120^\circ$  APART).

THE  $sp^2$ -HYBRIDIZATION LEAVES ONE p-ORBITAL UNHYBRIDIZED ON EACH C ATOM. LET'S SAY  $p_z$  WHERE  $p_x$  AND  $p_y$  CONTRIBUTE TO THE  $\sigma$ -BONDS.

THE  $p_z$  ORBITAL IS AT  $90^\circ$  TO THE  $p_x$  AND  $p_y$  ORBITALS. THEY MAKE THE  $\pi$ -BOND BY LINING UP WITH EACH OTHER FROM ONE CARBON ATOM TO THE OTHER.



AS A CONSEQUENCE OF THE ALIGNMENT REQUIREMENT ALL 4 HYDROGEN ATOMS ARE IN THE SAME PLANE.

