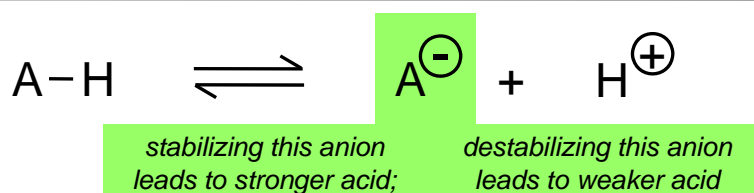
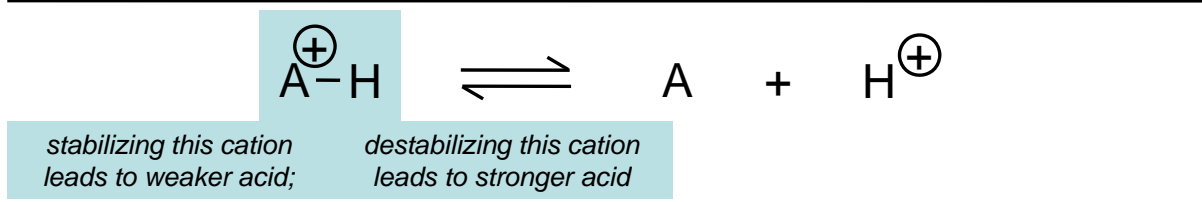


## Relative Stabilities of Acids and Conjugate Bases

- In comparing acids or bases, look at stability of both starting material and product.
- Either acid or conjugate base will be charged; relative acidity often driven by relative stability of charge.



## Relative Acidities

	acids		conjugate bases		$K_a$	$pK_a$			
↑ stronger acids	HF	+	H <sub>2</sub> O	⇌	F <sup>⊖</sup>	+	H <sub>3</sub> O <sup>⊕</sup>	6.8 × 10 <sup>-4</sup>	3.2
	H <sub>2</sub> O	+	H <sub>2</sub> O	⇌	HO <sup>⊖</sup>	+	H <sub>3</sub> O <sup>⊕</sup>	1.8 × 10 <sup>-16</sup>	15.7
	NH <sub>3</sub>	+	H <sub>2</sub> O	⇌	H <sub>2</sub> N <sup>⊖</sup>	+	H <sub>3</sub> O <sup>⊕</sup>	1 × 10 <sup>-33</sup>	33
	CH <sub>4</sub>	+	H <sub>2</sub> O	⇌	H <sub>3</sub> C <sup>⊖</sup>	+	H <sub>3</sub> O <sup>⊕</sup>	<1 × 10 <sup>-40</sup>	>40
					↓ stronger bases				

Stronger acids have lower  $pK_a$  values.

Stronger bases have conjugate acids with higher  $pK_a$  values.

(Weak acids have strong conjugate bases.)

## Can evaluate acidity and basicity from a pK<sub>a</sub> table.

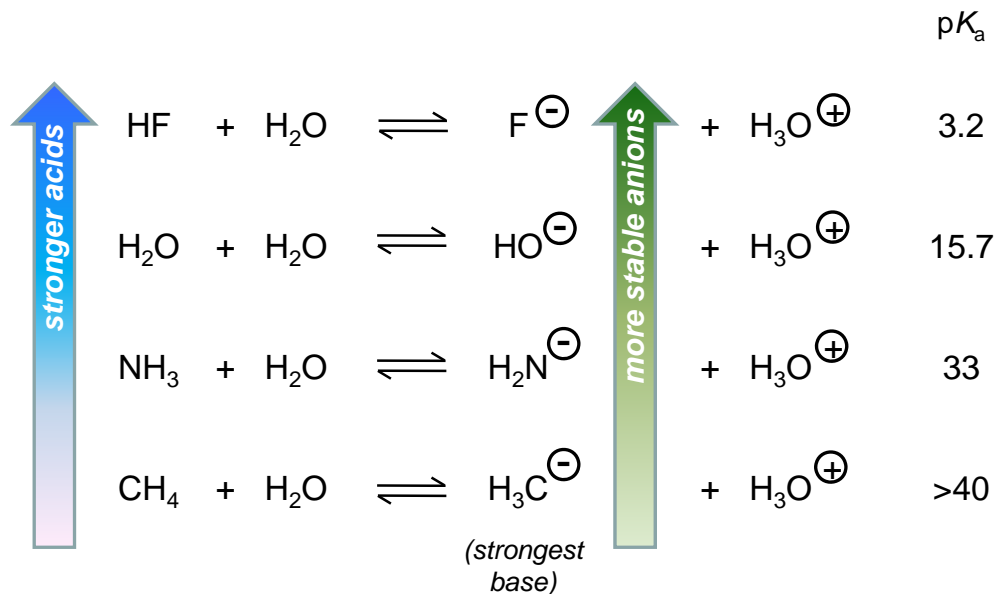
Substrate	pK <sub>a</sub>	H <sub>2</sub> O (DMSO)	Substrate	pK <sub>a</sub>	H <sub>2</sub> O (DMSO)	Substrate	pK <sub>a</sub>	H <sub>2</sub> O (DMSO)	Substrate	pK <sub>a</sub>	H <sub>2</sub> O (DMSO)		
<b>PROTONATED NITROGEN</b>			<b>AMINES</b>			<b>IMIDES</b>			<b>HYDROXAMIC ACID &amp; AMIDINES</b>				
N <sup>+</sup> H <sub>4</sub>	9.2	(10.5)	HN <sub>3</sub>	4.7	(7.9)		8.30	(14.7)		8.88	(13.7)		
EtN <sup>+</sup> H <sub>3</sub>	10.6		NH <sub>3</sub>	38	(41)		(17.9)			R= Me	(17.3)		
<i>i</i> -Pr <sub>2</sub> N <sup>+</sup> H <sub>2</sub>	11.05		<i>i</i> -Pr <sub>2</sub> NH	(36 THF)					R= Ph	(15.0)			
Et <sub>3</sub> N <sup>+</sup> H	10.75	(9.00)	TMS <sub>2</sub> NH	26(THF)	(30)	<b>SULFONAMIDE</b>			<b>HETEROCYCLES</b>				
PhN <sup>+</sup> H <sub>3</sub>	4.6	(3.6)	PhNH <sub>2</sub>	(30.6)		RSO <sub>2</sub> NH <sub>2</sub>	R = Me	(17.5)		(20.95)		(16.4)	
PhN <sup>+</sup> (Me) <sub>2</sub> H	5.20	(2.50)	Ph <sub>2</sub> NH	(25.0)			Ph	(16.1)		(11.9)		(23.0)	
Ph <sub>2</sub> N <sup>+</sup> H <sub>2</sub>	0.78		NCNH <sub>2</sub>	(16.9)		MeSO <sub>2</sub> NHPh	CF <sub>3</sub>	6.3	(9.7)			(23.0)	
2-napthal-N <sup>+</sup> H <sub>3</sub>	4.16			(44)				(12.9)		X = O	(24)		(18.6)
H <sub>2</sub> NN <sup>+</sup> H <sub>3</sub>	8.12			(37)		<b>GUANIDINIUM, HYDRAZONES, -IDES, &amp; -INES</b>				X = S	(13.3)		(13.9)
HON <sup>+</sup> H <sub>3</sub>	5.96			(26.5)			NH <sub>2</sub>	(21.6)		X = O	(14.8)		(13.9)
Quinuclidine	11.0	(9.80)	<b>AMIDES &amp; CARBAMATES</b>				Ph	(18.9)		X = S	(11.8)		(19.8)
Morpholine	N <sup>+</sup> H <sub>2</sub>	8.36	R= H	(23.5)		PhSO <sub>2</sub> NHNH <sub>2</sub>		(17.2)		X = S	(27.0)		(24.0)
N-Me morpholine		7.38	R= CH <sub>3</sub>	15.1	(25.5)	PhNHNHPh		(26.1)		X = S	(27.0)		(24.0)
		-9.3	R= Ph	(23.3)						X = S	(27.0)		(24.0)
		2.97, 8.82 (2.97, 8.93)	R= CF <sub>3</sub>	(17.2)		<b>PROTONATED HETEROCYCLES</b>				X = S	(27.0)		(24.0)
		6.90, 9.95	(urea) NH <sub>2</sub>	(26.9)		DBU		(12) (estimate)		X = S	(27.0)		(24.0)
PhCN <sup>+</sup> H	-10		OEt	(24.8)		DMAP		9.2		X = S	(27.0)		(24.0)
				12	(20.5)			6.95		X = S	(27.0)		(24.0)
				n=1	(24.1)			5.21		X = S	(27.0)		(24.0)
				n=2	(26.4)			4.95		X = S	(27.0)		(24.0)
				(15)				6.75		X = S	(27.0)		(24.0)
				(12.1)				0.72		X = S	(27.0)		(24.0)
							R= H (PPTS)	5.21	(3.4)				
							<i>t</i> -Bu	4.95	(0.90)				
							Me	6.75	(4.46)				
							Cl, H	0.72					

\*Values <0 for H<sub>2</sub>O and DMSO, and values >14 for water and >35 for DMSO were extrapolated using various methods.

page 2 of 5; [http://daecr1.harvard.edu/pdf/evans\\_pKa\\_table.pdf](http://daecr1.harvard.edu/pdf/evans_pKa_table.pdf) (or Google "pKa table")

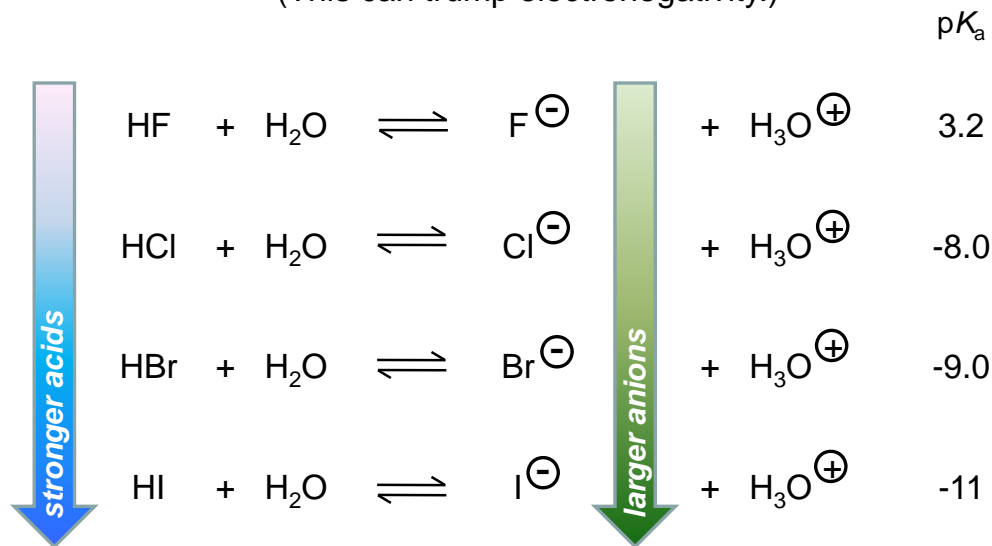
## Stability Trends in Organic Acids: Electronegativity

Electronegativity affects stability of >charge in acids/conjugate bases.



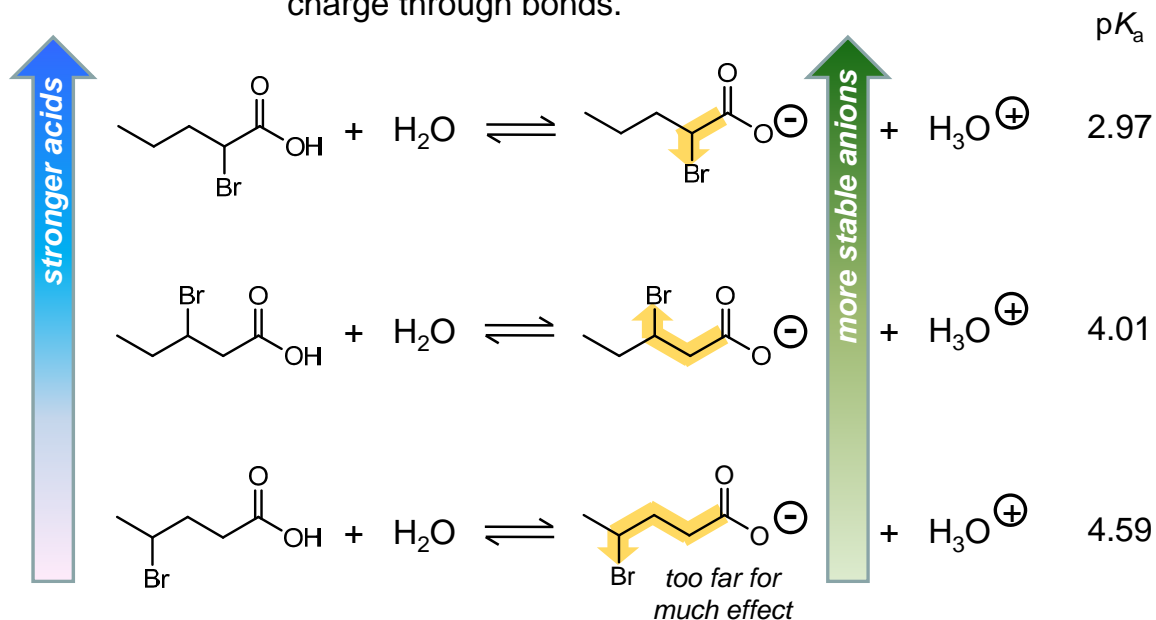
## Stability Trends in Organic Acids: Size

Larger atoms accommodate charge better.  
(This can trump electronegativity.)



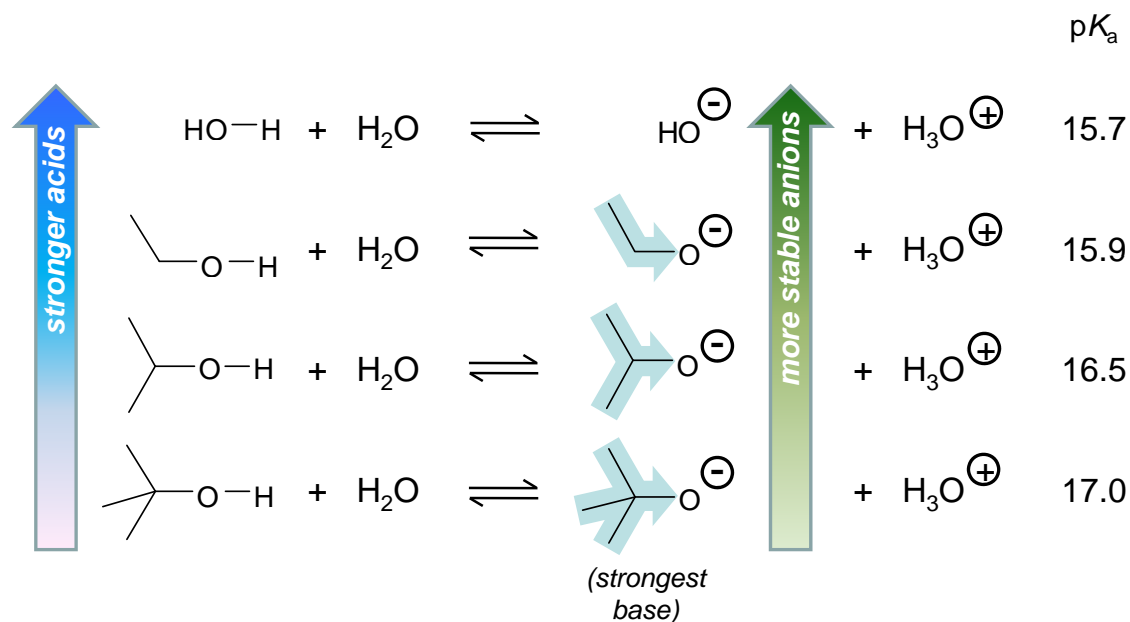
## Stability Trends in Organic Acids: Inductive Effects

Electronegative/positive nuclei can stabilize distant  
charge through bonds.



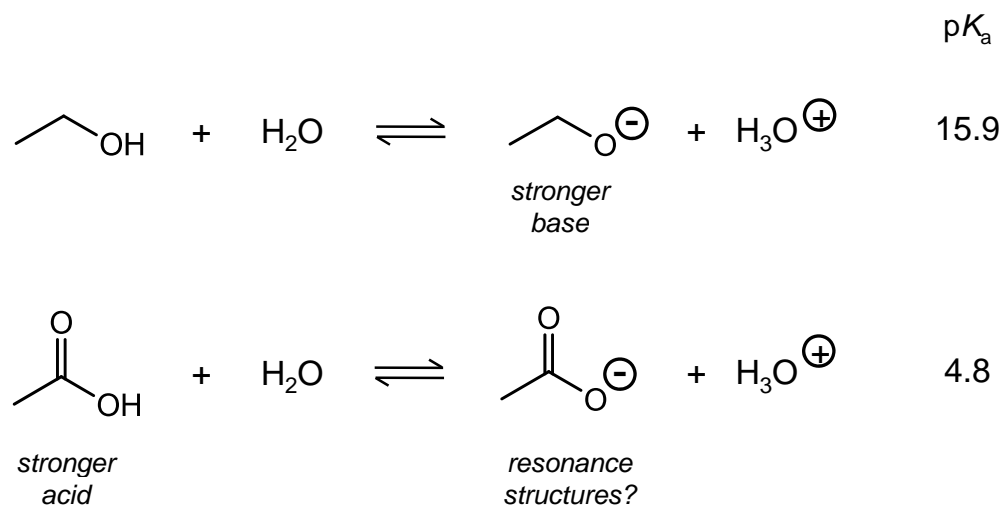
## Stability Trends in Organic Acids: Inductive Effects

Methyl groups are *electropositive*; they push electrons away.



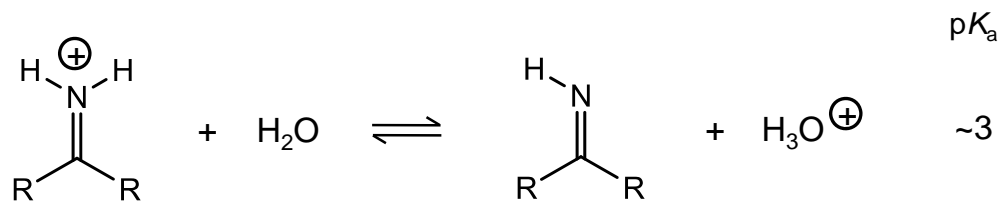
## Stability Trends in Organic Acids: Resonance

Delocalization of charge stabilizes ionic species.

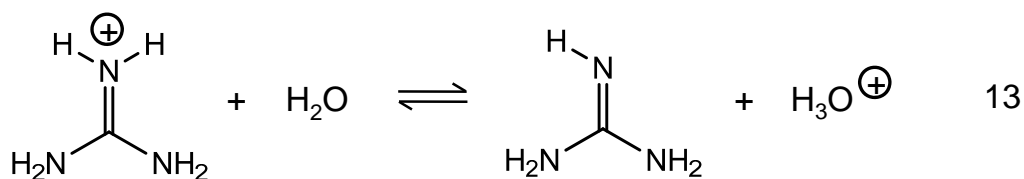


# Stability Trends in Organic Acids: Resonance

Delocalization of charge stabilizes ionic species.



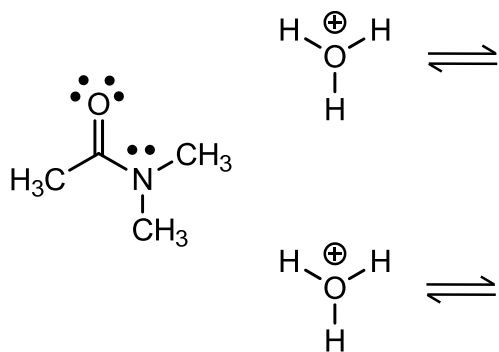
*resonance  
structures?*



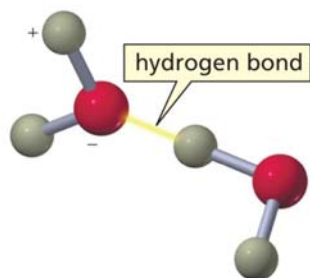
## Resonance in Organic Acids and Bases

Consider resonance when choosing basic electron pairs.

*Which lone pair is protonated?*



# Hydrogen Bonding: Incomplete Electron-Pair Donation



hydrogen bonding in water

Lone pairs can interact with O-H, N-H, and/or halogen-H hydrogens *without* transferring a proton (if H-donor isn't acidic enough).

## Organic Functional Groups

Type of compound	General structure	Example	Functional group
Alkyl halide	$R-\ddot{X}:$ (X = F, Cl, Br, I)	$CH_3-\ddot{Br}:$	-X halo group
Alcohol	$R-\ddot{O}H$	$CH_3-\ddot{O}H$	-OH hydroxy group
Ether	$R-\ddot{O}-R$	$CH_3-\ddot{O}-CH_3$	-OR alkoxy group
Amine	$R-\ddot{N}H_2$ or $R_2\ddot{N}H$ or $R_3\ddot{N}$	$CH_3-\ddot{N}H_2$	-NH <sub>2</sub> amino group
Thiol	$R-\ddot{S}H$	$CH_3-\ddot{S}H$	-SH mercapto group
Sulfide	$R-\ddot{S}-R$	$CH_3-\ddot{S}-CH_3$	-SR alkylthio group

# Organic Functional Groups

Type of compound	General structure	Example	Functional group
Aldehyde	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{CH}_3-\text{C}-\text{H} \end{array}$	C=O carbonyl group
Ketone	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{R}-\text{C}-\text{R} \end{array}$	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{CH}_3-\text{C}-\text{CH}_3 \end{array}$	C=O carbonyl group
Carboxylic acid	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{R}-\text{C}-\ddot{\text{O}}\text{H} \end{array}$	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{CH}_3-\text{C}-\ddot{\text{O}}\text{H} \end{array}$	-COOH carboxy group
Ester	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{R}-\text{C}-\ddot{\text{O}}\text{R} \end{array}$	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{CH}_3-\text{C}-\ddot{\text{O}}\text{CH}_3 \end{array}$	-COOR
Amide	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{R}-\text{C}-\ddot{\text{N}}\text{H (or R)} \\ \text{H (or R)} \end{array}$	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{CH}_3-\text{C}-\ddot{\text{N}}\text{H}_2 \end{array}$	-CONH <sub>2</sub> , -CONHR, or -CONR <sub>2</sub>
Acid chloride	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{R}-\text{C}-\ddot{\text{C}}\text{:} \\ \text{:} \end{array}$	$\begin{array}{c} \text{:O:} \\ \parallel \\ \text{CH}_3-\text{C}-\ddot{\text{C}}\text{:} \\ \text{:} \end{array}$	-COCl

## Bond Polarities Can Add Up to Make Polar Molecules (Or Not)

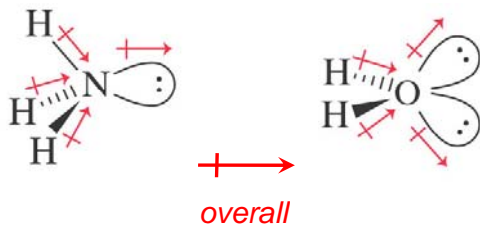
**TABLE 2-1** Bond Dipole Moments (Debye) for Some Common Covalent Bonds

Bond	Dipole Moment, $\mu$	Bond	Dipole Moment, $\mu$
$\overset{\text{+}}{\text{C}}-\overset{\text{-}}{\text{N}}$	0.22 D	$\overset{\text{-}}{\text{H}}-\overset{\text{+}}{\text{C}}$	0.3 D
$\overset{\text{+}}{\text{C}}-\overset{\text{-}}{\text{O}}$	0.86 D	$\overset{\text{-}}{\text{H}}-\overset{\text{+}}{\text{N}}$	1.31 D
$\overset{\text{+}}{\text{C}}-\overset{\text{-}}{\text{F}}$	1.51 D	$\overset{\text{-}}{\text{H}}-\overset{\text{+}}{\text{O}}$	1.53 D
$\overset{\text{+}}{\text{C}}-\overset{\text{-}}{\text{Cl}}$	1.56 D	$\overset{\text{-}}{\text{C}}=\overset{\text{+}}{\text{O}}$	2.4 D
$\overset{\text{+}}{\text{C}}-\overset{\text{-}}{\text{Br}}$	1.48 D	$\overset{\text{-}}{\text{C}}\equiv\overset{\text{+}}{\text{N}}$	3.6 D
$\overset{\text{+}}{\text{C}}-\overset{\text{-}}{\text{I}}$	1.29 D		

polar enough to consider

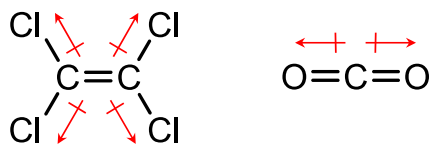
# Sum of Bond Polarities, Lone Pairs Determines Polarity of Molecules

**Polar molecules:**



Lone pairs also contribute to overall dipole; create charge separation from nucleus.

**Nonpolar molecules:**



When individual bond dipoles sum to zero, molecule is nonpolar.