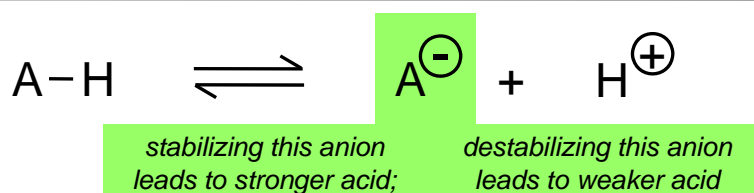
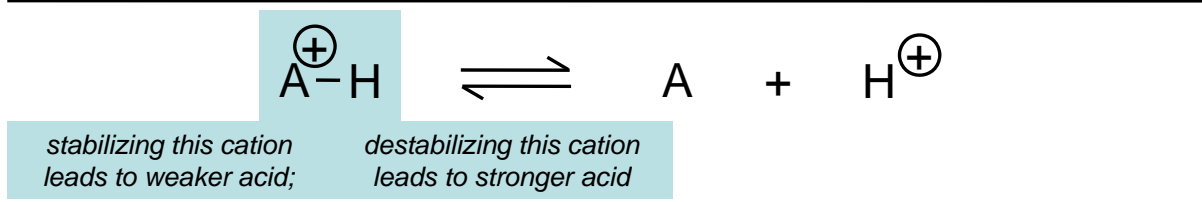


Relative Stabilities of Acids and Conjugate Bases

- 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 ₂ O	⇌	F [⊖]	+	H ₃ O [⊕]	6.8 × 10 ⁻⁴	3.2
	H ₂ O	+	H ₂ O	⇌	HO [⊖]	+	H ₃ O [⊕]	1.8 × 10 ⁻¹⁶	15.7
	NH ₃	+	H ₂ O	⇌	H ₂ N [⊖]	+	H ₃ O [⊕]	1 × 10 ⁻³³	33
	CH ₄	+	H ₂ O	⇌	H ₃ C [⊖]	+	H ₃ O [⊕]	<1 × 10 ⁻⁴⁰	>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_a table.

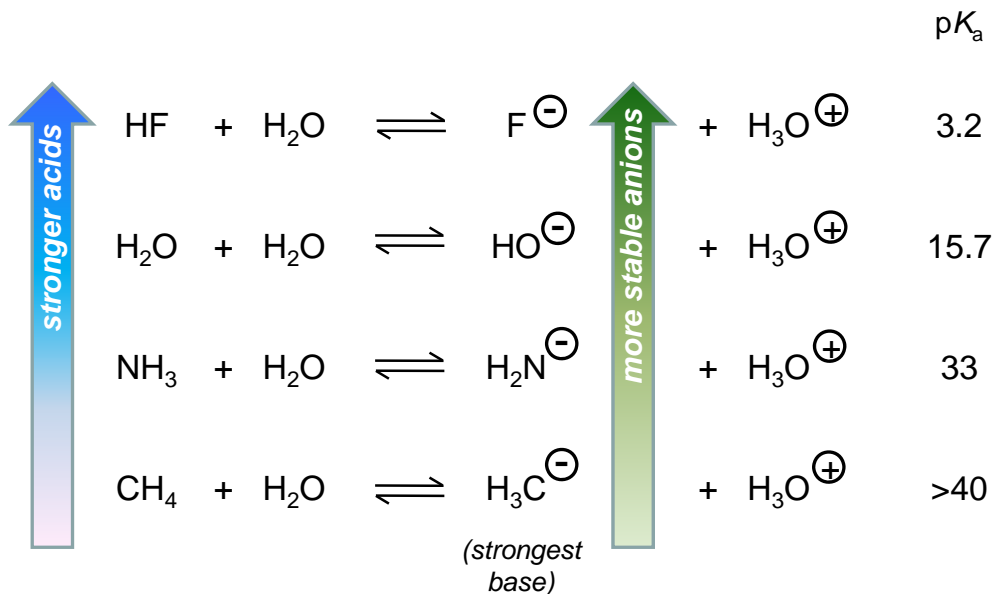
Substrate	pK _a	H ₂ O (DMSO)	Substrate	pK _a	H ₂ O (DMSO)	Substrate	pK _a	H ₂ O (DMSO)	Substrate	pK _a	H ₂ O (DMSO)
PROTONATED NITROGEN			AMINES			IMIDES			HYDROXAMIC ACID & AMIDINES		
N ⁺ H ₄	9.2	(10.5)	HN ₃	4.7	(7.9)		8.30	(14.7)		8.88	(13.7)
EtN ⁺ H ₃	10.6		NH ₃	38	(41)						
i-Pr ₂ N ⁺ H ₂	11.05		i-Pr ₂ NH	(36 THF)					R = Me	(17.3)	
Et ₃ N ⁺ H	10.75	(9.00)	TMS ₂ NH	26(THF)	(30)			R = Ph	(15.0)		
PhN ⁺ H ₃	4.6	(3.6)	PhNH ₂	(30.6)		SULFONAMIDE			HETEROCYCLES		
PhN ⁺ (Me) ₂ H	5.20	(2.50)	Ph ₂ NH	(25.0)		RSO ₂ NH ₂	R = Me	(17.5)		(20.95)	
Ph ₂ N ⁺ H ₂	0.78		NCNH ₂	(16.9)		Ph	(16.1)			(11.9)	(16.4)
2-naphthal-N ⁺ H ₃	4.16			(44)		CF ₃	6.3	(9.7)		(23.0)	
H ₂ NN ⁺ H ₃	8.12			(37)		MeSO ₂ NHPh		(12.9)		X = O	(24)
HON ⁺ H ₃	5.96									X = S	(13.3)
Quinuclidine	11.0	(9.80)				GUANIDINIUM, HYDRAZONES, -IDES, & -INES				X = O	(24)
Morpholine	N ⁺ H ₂	8.36	AMIDES & CARBAMATES							X = S	(11.8)
N-Me morpholine		7.38	R = H	(23.5)						X = S	(13.9)
		-9.3	CH ₃	15.1	(25.5)					X = S	(13.3)
		2.97, 8.82 (2.97, 8.93)	Ph	(23.3)						X = S	(11.8)
DABCO		6.90, 9.95	CF ₃	(17.2)						X = O	(14.8)
		-9.0, 12.0 (-, 7.50)	(urea) NH ₂	(26.9)						X = S	(11.8)
PhCN ⁺ H	-10		OEt	(24.8)						X = S	(27.0)
						PROTONATED HETEROCYCLES				X = O	(24.4)
						DBU		(12) (estimate)		X = S	(27.0)
						DMAP		9.2			
								6.95			
								5.21 (3.4)			
								4.95 (0.90)			
								6.75 (4.46)			
								0.72			

* Values <0 for H₂O 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 (or Google "pKa table")

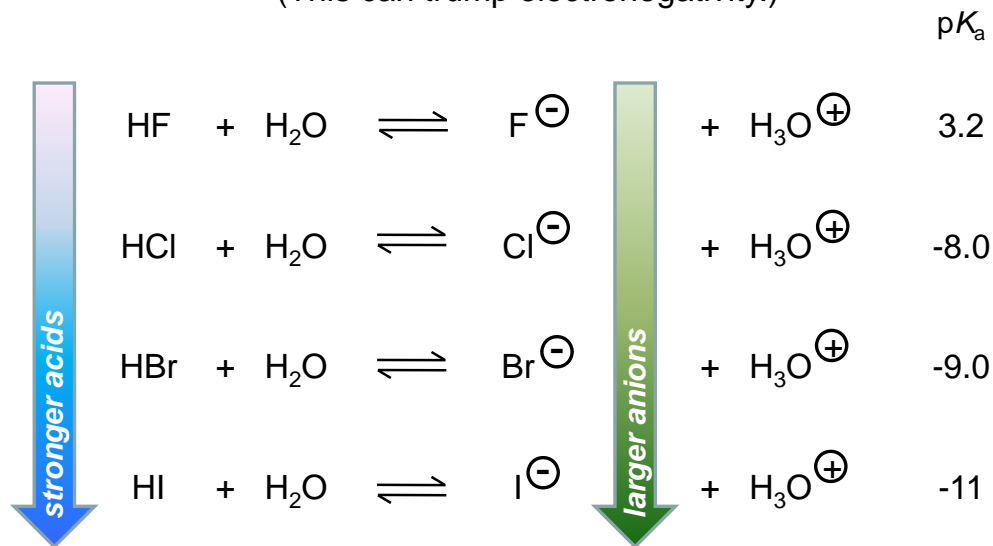
Stability Trends in Organic Acids: Electronegativity

Electronegativity affects stability of charge in acids/conjugate bases.



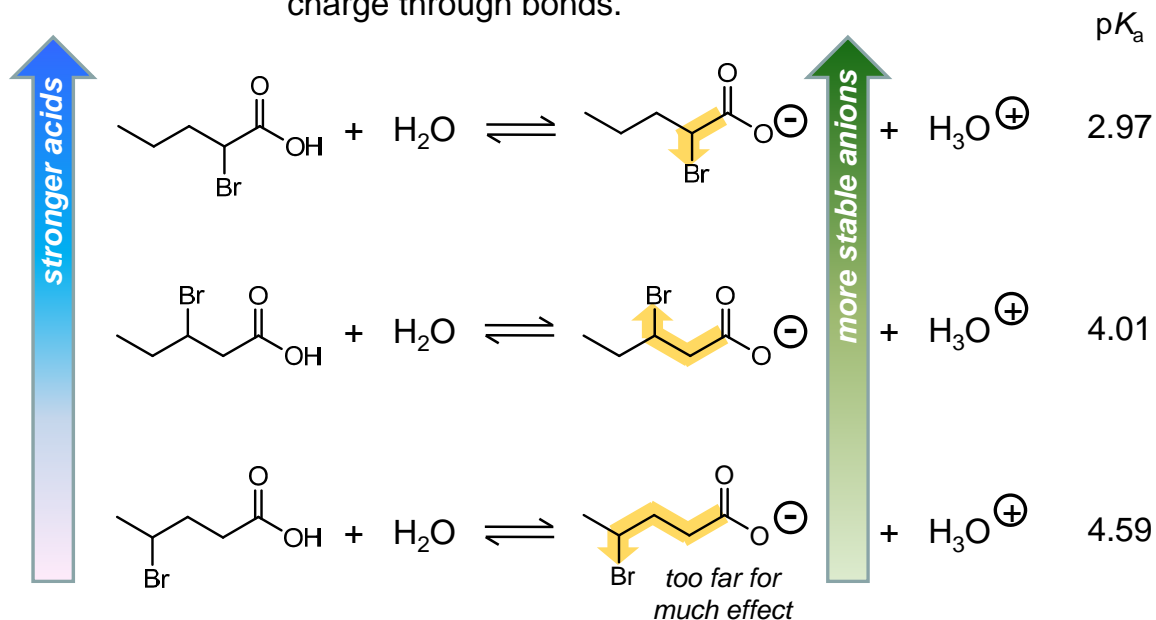
Stability Trends in Organic Acids: Size

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



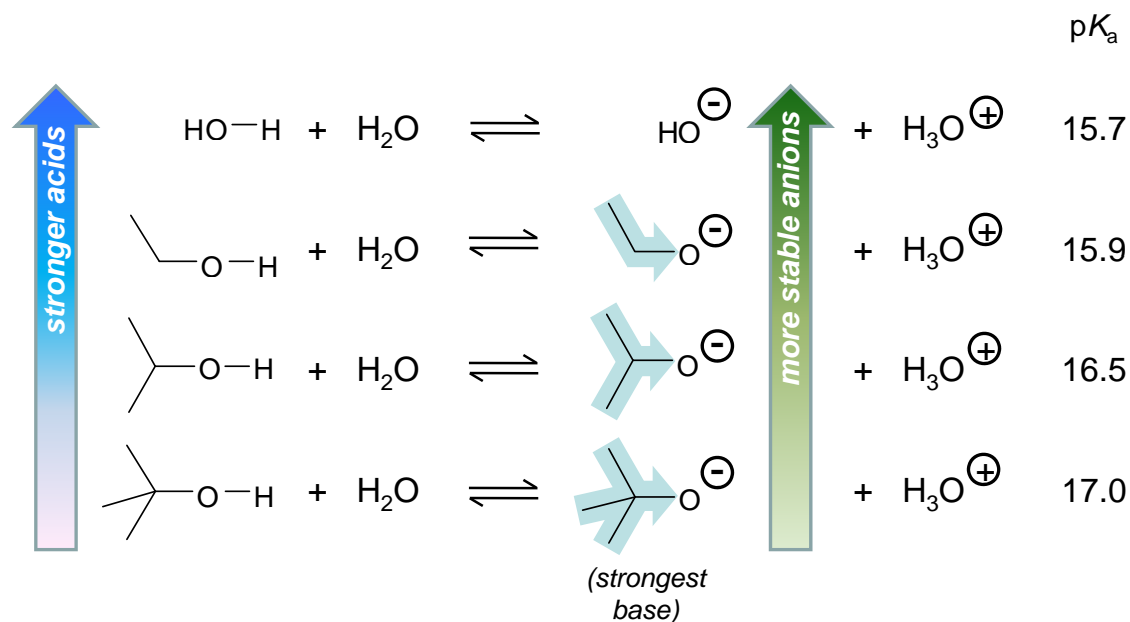
Stability Trends in Organic Acids: Inductive Effects

Electronegative/positive nuclei can stabilize distant
charge through bonds.



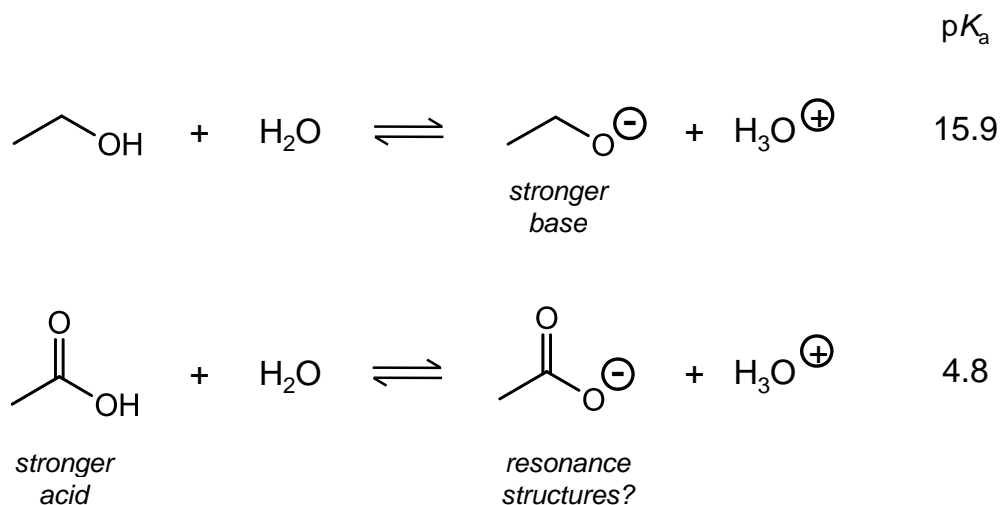
Stability Trends in Organic Acids: Inductive Effects

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



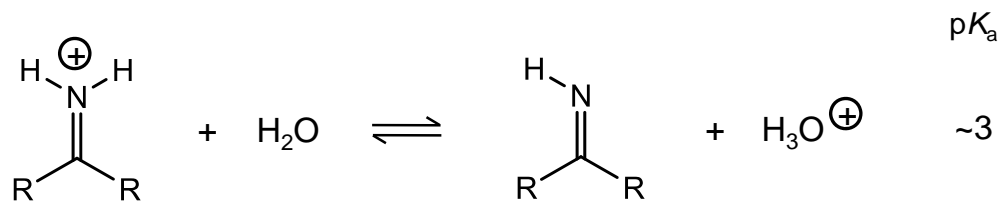
Stability Trends in Organic Acids: Resonance

Delocalization of charge stabilizes ionic species.

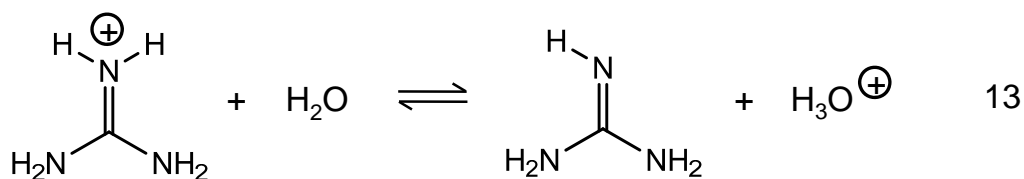


Stability Trends in Organic Acids: Resonance

Delocalization of charge stabilizes ionic species.



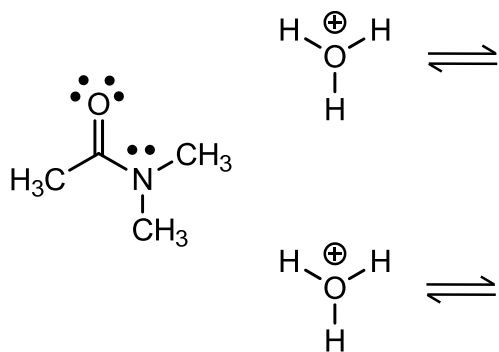
*resonance
structures?*



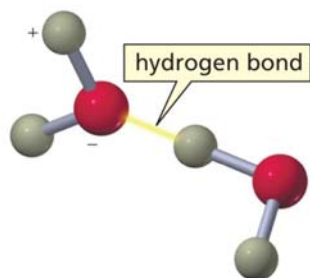
Resonance in Organic Acids and Bases

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	$R-\overset{\cdot\cdot}{X}$ (X = F, Cl, Br, I)	$CH_3-\overset{\cdot\cdot}{Br}$	-X halo group
Alcohol	$R-\overset{\cdot\cdot}{O}H$	$CH_3-\overset{\cdot\cdot}{O}H$	-OH hydroxy group
Ether	$R-\overset{\cdot\cdot}{O}-R$	$CH_3-\overset{\cdot\cdot}{O}-CH_3$	-OR alkoxy group
Amine	$R-\overset{\cdot\cdot}{N}H_2$ or $R_2\overset{\cdot\cdot}{N}H$ or $R_3\overset{\cdot\cdot}{N}$	$CH_3-\overset{\cdot\cdot}{N}H_2$	-NH ₂ amino group
Thiol	$R-\overset{\cdot\cdot}{S}H$	$CH_3-\overset{\cdot\cdot}{S}H$	-SH mercapto group
Sulfide	$R-\overset{\cdot\cdot}{S}-R$	$CH_3-\overset{\cdot\cdot}{S}-CH_3$	-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 ₂ , -CONHR, or -CONR ₂
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)

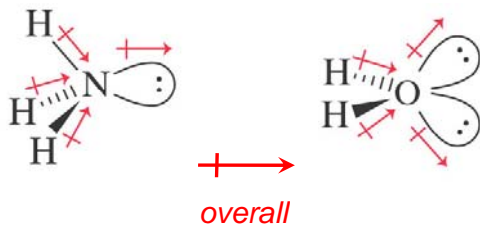
TABLE 2-1 Bond Dipole Moments (Debye) for Some Common Covalent Bonds

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

polar enough to consider

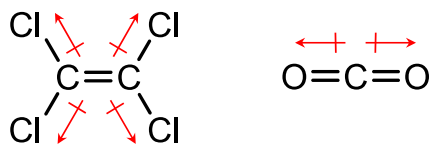
Sum of Bond Polarities, Lone Pairs Determines Polarity of Molecules

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.