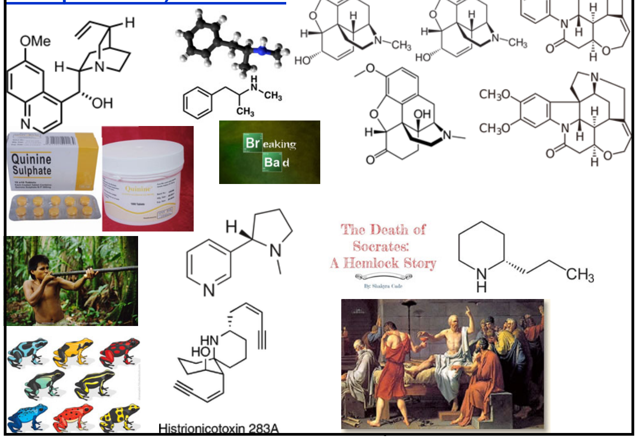
Chapter 10, Amines



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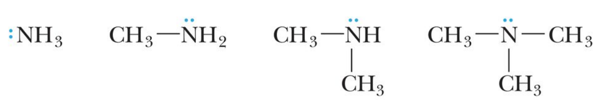
Structure & Classification

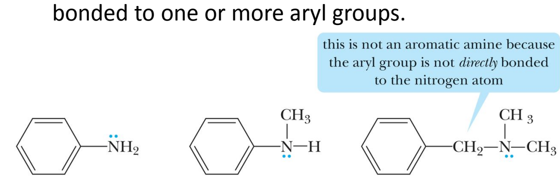
- Classification
  - **1°, 2°, or , 3° amines**: Amines in which 1, 2, or 3 hydrogens of NH_3 are replaced by alkyl or aryl groups.



Ammonia | Methylamine (a 1° amine) | Dimethylamine (a 2° amine) | Trimethylamine (a 3° amine)

Structure & Classification

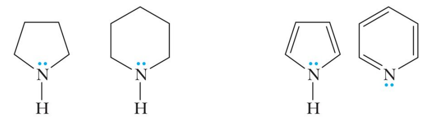
- Amines are further divided into aliphatic, aromatic, and heterocyclic amines.
  - **Aliphatic amine**: An amine in which nitrogen is bonded only to alkyl groups.
  - **Aromatic amine**: An amine in which nitrogen is bonded to one or more aryl groups.



Aniline (a 1° aromatic amine) | *N*-Methylaniline (a 2° aromatic amine) | Benzyldimethylamine (a 3° aliphatic amine)

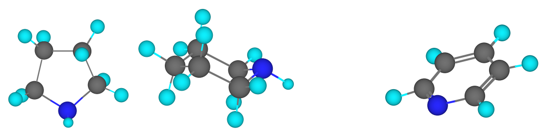
Structure & Classification

– **Heterocyclic amine**: An amine in which nitrogen is one of the atoms of a ring.



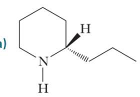
Pyrrolidine Piperidine
(heterocyclic aliphatic amines)

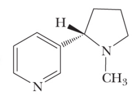
Pyrrole Pyridine
(heterocyclic aromatic amines)

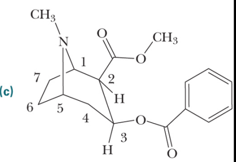


Structure & Classification

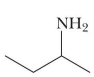
• **Example**: Classify each amino group by type.

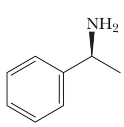
(a)

(*S*)-Coniine

(b)

(*S*)-Nicotine

(c)

Cocaine

Aliphatic Amines: Replace the suffix of the parent alkane by **–amine**.


2-Butanamine


(*S*)-1-Phenylethanamine

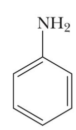
the number modifiers "di, tri, tetra, etc." are inserted based on the number of amino groups

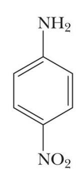
$H_2N(CH_2)_6NH_2$

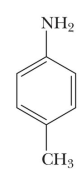
1,6-Hexanediamine

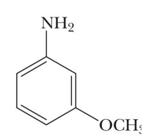
Nomenclature

• The IUPAC system retains the common name aniline.


Aniline

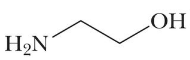

4-Nitroaniline
(*p*-Nitroaniline)


4-Methylaniline
(*p*-Toluidine)

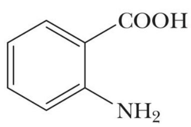

3-Methoxyaniline
(*m*-Anisidine)

Nomenclature

- Among the various functional groups discussed in the text, $-NH_2$ group has one of the lowest priorities.



2-Aminoethanol



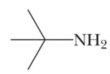
2-Aminobenzoic acid

Nomenclature

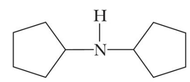
- Common names for most aliphatic amines are derived by listing the alkyl groups bonded to nitrogen in one word ending with the suffix **-amine**.

CH_3NH_2

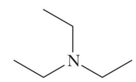
Methylamine



tert-Butylamine



Dicyclopentylamine



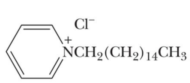
Triethylamine

Nomenclature

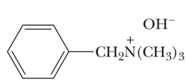
- When four groups are bonded to the nitrogen atom, we name the compound as a salt of the corresponding amine.

$(CH_3)_4N^+Cl^-$

Tetramethylammonium chloride



Hexadecylpyridinium chloride (Cetylpyridinium chloride)



Benzyltrimethylammonium hydroxide

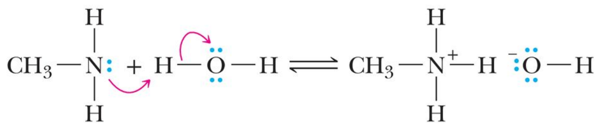
Physical Properties

- Amines are polar compounds, and both 1° and 2° amines form intermolecular hydrogen bonds.
  - N-H- - - N hydrogen bonds are weaker than O-H- - - O hydrogen bonds because the difference in electronegativity between N and H (3.0 - 2.1 = 0.9) is less than that between O and H (3.5 - 2.1 = 1.4).

	CH_3NH_2	CH_3OH
molecular weight (g/mol)	31.1	32.0
boiling point (°C)	–6.3	65.0

Basicity

- All amines are weak bases, and aqueous solutions of amines are basic.



Methylamine   Methylammonium hydroxide

$$K_{eq} = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2][H_2O]}$$

Basicity

- It is also common to discuss the basicity of amines by reference to the ionization constant K_a of its conjugate acid.

$$CH_3NH_3^+ + H_2O \rightleftharpoons CH_3NH_2 + H_3O^+$$

$$K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]} = 2.29 \times 10^{-11} \quad pK_a = 10.64$$

– For any acid-conjugate base pair.

$$pK_a + pK_b = 14.00$$

Basicity

- Using values of pK_a, we can predict the position of equilibrium in acid-base reactions.

$$CH_3NH_2 + CH_3COOH \rightleftharpoons CH_3NH_3^+ + CH_3COO^-$$

$pK_a = 4.76$ $pK_a = 10.64$

Stronger base	Stronger acid	Weaker acid	Weaker base

– Acetic acid is the stronger acid and, therefore, the position of this equilibrium lies to the right.

Basicity

– Aliphatic amines have about the same base strength, pK_b 3.0 – 4.0 and are slightly stronger bases than NH_3.

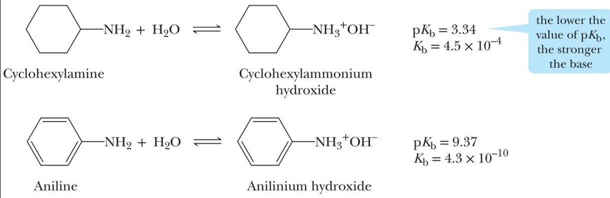
TABLE 10.2 Base Strengths (pK_b) of Selected Amines and Acid Strengths (pK_a) of Their Conjugate Acids*

Amine	Structure	pK_b	pK_a
Ammonia	NH_3	4.74	9.26
Primary Amines			
methylamine	CH_3NH_2	3.36	10.64
ethylamine	$CH_3CH_2NH_2$	3.19	10.81
cyclohexylamine	$C_6H_{11}NH_2$	3.34	10.66
Secondary Amines			
dimethylamine	$(CH_3)_2NH$	3.27	10.73
diethylamine	$(CH_3CH_2)_2NH$	3.02	10.98
Tertiary Amines			
trimethylamine	$(CH_3)_3N$	4.19	9.81
triethylamine	$(CH_3CH_2)_3N$	3.25	10.75
Aromatic Amines			
aniline	NH_2	9.37	4.63
4-methylaniline (*p*-toluidine)	CH_3 NH_2	8.92	5.08
4-chloroaniline	Cl NH_2	9.85	4.15
4-nitroaniline	O_2N NH_2	13.0	1.0
Heterocyclic Aromatic Amines			
pyridine	N	8.75	5.25
imidazole	N N H	7.05	6.95

*For each amine, $pK_a + pK_b = 14.00$.

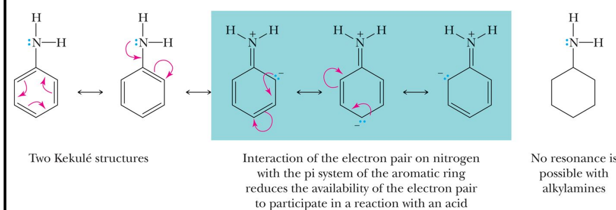
Basicity

– Aromatic amines are considerably weaker bases than aliphatic amines.



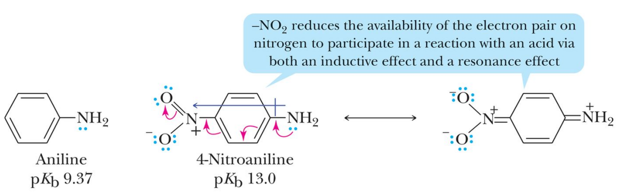
Basicity

Aromatic amines are weaker bases than aliphatic amines because the resonance stabilization of the free base is lost on protonation.



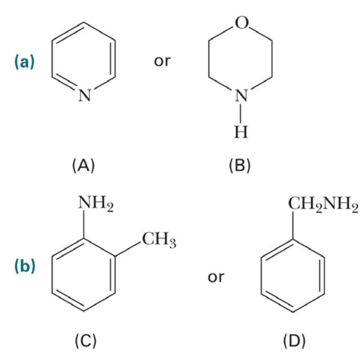
Basicity

- Electron-withdrawing groups, such as halogen, nitro, and carbonyl, decrease the basicity of aromatic amines by decreasing the availability of the electron pair on nitrogen.



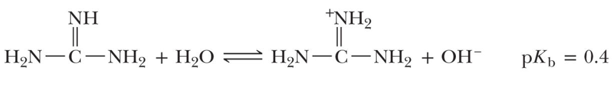
Basicity

- **Example**: Select the stronger base in each pair of amines.



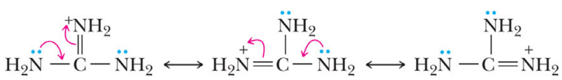
Guanidine

- Guanidine (pK_b 0.4) is the strongest base among neutral organic compounds.



Guanidine   Guanidinium ion

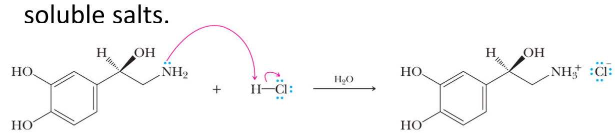
  - Its basicity is due to the resonance delocalization of the positive charge over the three nitrogen atoms.



Three equivalent contributing structures

Reaction with Acids

- All amines, whether soluble or insoluble in water, react quantitatively with strong acids to form water-soluble salts.



(*R*)-Norepinephrine (only slightly soluble in water)   (*R*)-Norepinephrine hydrochloride (a water-soluble salt)

Amines as Nucleophiles

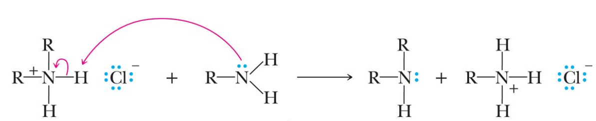
- Reaction of an amine with an alkyl halide can be used to form a new covalent bond.

Step 1: Reaction of a nucleophile with an electrophile to form a new covalent bond.

(a nucleophile) (an electrophile)

Amines as Nucleophiles

- **Step 2: Take a proton away.** Converts the amine salt to a free amine.



unreacted starting material