Nitrogen-Containing Functional Groups

- Nitrogen is in Group V of the periodic table, and in most of its compounds, it has three single bonds and one lone pair:

\[ \text{N} \]

- In this chapter, we will take a look at two functional groups which contain nitrogen atoms connected to carbons: the \textbf{amines} and the \textbf{amides}.

\begin{align*}
\text{Amine} & : & R - \text{N} - R'' \\
\text{Amide} & : & R - \text{C} - \text{N} - R' \\
\end{align*}
Classification and Nomenclature of Amines

Amines

- Amines and amides are abundant in nature. They are a major component of proteins and enzymes, nucleic acids, alkaloid drugs, etc. (Alkaloids are N-containing, weakly basic organic compounds; thousands of these substances are known.)
- Amines are organic derivatives of ammonia, NH₃, in which one or more of the three H’s is replaced by a carbon group.
- Amines are classified as primary (1°), secondary (2°), or tertiary (3°), depending on how many carbon groups are connected to the nitrogen atom.

![Amine Structures]

Ammonia | 1° Amine | 2° Amine | 3° Amine
Examples: Classifying Amines

- Classify the following amines as primary (1°), secondary (2°), or tertiary (3°).

\[
\begin{align*}
\text{NCH}_3\text{CH}_2\text{CH}_2\text{N-H} & , \quad \text{CH}_3\text{N-CH}_3 & , \quad \text{CH}_3\text{CH}_2\text{CHCH}_3\text{N-H} \\
\text{CH}_3\text{CH}_2\text{N-CH}_3 & , \quad \text{N-CH}_2\text{CH}_3
\end{align*}
\]

Nomenclature of Amines

- **Simple 1°, 2°, and 3° amines:** common (trivial) names are obtained by alphabetically arranging the names of the alkyl substituents on the nitrogen and adding the suffix -amine (e.g., ethylmethylamine).

- **Amines in the IUPAC system:** the “e” ending of the alkane name for the longest chain is replaced with –amine. The amine group is located by the position number. Groups that are attached to the nitrogen atom are located using “N” as the position number. More complex primary amines are named with —NH$_2$ as the amino substituent.

- **Aromatic amines:** named as derivatives of the parent compound aniline. Substituents attached to the nitrogen are indicated by using “N-” as the location number.
**Examples: Nomenclature of Amines**

- Provide common names for the following 2° and 3° amines; for 1° amines, provide common and/or IUPAC names where possible.

\[
\text{CH}_3\text{NH}_2 \quad \text{CH}_3\text{NCH}_3
\]

\[
\text{CH}_3\text{NCH}_2\text{CH}_3 \quad \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2
\]

**Examples: Nomenclature of Amines**

- Provide common names for the following 2° and 3° amines; for 1° amines, provide common and/or IUPAC names where possible.

\[
\text{NH}_2 \quad \text{CH}_3
\]

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_3 \quad \text{CH}_3\text{NCH}_3
\]

\[
\text{NH} \quad \text{CH}_3
\]

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_3 \quad \text{NH}_2
\]
**Examples: Nomenclature of Amines**

- Provide common names for the following $2^\circ$ and $3^\circ$ amines; for $1^\circ$ amines, provide common and/or IUPAC names where possible.

![Chemical structures](image)

**Examples: Nomenclature of Amines**

- Provide names for the following aromatic amines.

![Chemical structures](image)
Examples: Nomenclature of Amines

- Provide names for the following aromatic amines.

\[
\begin{align*}
\text{CH}_3 \text{NCH}_3 \\
\text{C}_6\text{H}_5 \text{CH}_3
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3 \text{NCH}_3 \text{CH}_3 \\
\text{C}_6\text{H}_5 \text{CH}_2\text{CH}_3
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3 \text{NH} \\
\text{C}_6\text{H}_5 \text{CH}_2\text{CH}_3
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3 \text{NCH}_3 \text{CH}_2\text{CH}_3 \\
\text{C}_6\text{H}_5 \text{CH}_2\text{CH}_3
\end{align*}
\]

Examples: Nomenclature of Amines

- Draw structural formulas for the following molecules:
  - ethylisopropylamine
  - tert-butylamine
  - 2-pentanamine
Examples: Nomenclature of Amines

- Draw structural formulas for the following molecules:
  - N-methyl-2-propanamine
  - 1,6-diaminohexane
  - 3-amino-1-propanol

Examples: Nomenclature of Amines

- Draw structural formulas for the following molecules:
  - N-methyl-2-chloroaniline
  - N,3-diethylaniline
  - N,N-dimethylaniline
Physical Properties of Amines: $H$-Bonding

- $1^\circ$ and $2^\circ$ amines can hydrogen bond to each other:

- $3^\circ$ amines cannot hydrogen bond to each other:
Physical Properties of Amines: Boiling Points

- Nitrogen is less electronegative than oxygen, so the N—H bond is not quite as polar as the O—H bond.
  - Hydrogen bonds from N—H’s are not as strong as those resulting from O—H’s.
  - Hydrogen bonding between 1° and 2° amines is not as strong as those found in alcohols or carboxylic acids.
- 1° and 2° amines have lower boiling points than alcohols of similar molecular weight.
- 3° amines, since they do not hydrogen bond to each other, have boiling points similar to hydrocarbons of the same molecular weight.

### Physical Properties of Amines: Boiling Points

#### Boiling Point:

- Carboxylic acid
- Alcohols
- 1°/2° Amines
- 3° Amines/Alkanes

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular weight</th>
<th>Boiling point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>60.0 g/mol</td>
<td>118°C</td>
</tr>
<tr>
<td>1-propanol</td>
<td>60.1 g/mol</td>
<td>97°C</td>
</tr>
<tr>
<td>propyl amine</td>
<td>59.1 g/mol</td>
<td>48°C</td>
</tr>
<tr>
<td>ethylmethylamine</td>
<td>59.1 g/mol</td>
<td>36°C</td>
</tr>
<tr>
<td>trimethylamine</td>
<td>59.1 g/mol</td>
<td>2.9°C</td>
</tr>
<tr>
<td>butane</td>
<td>58.1 g/mol</td>
<td>-0.5°C</td>
</tr>
</tbody>
</table>
**Physical Properties of Amines: Water Solubility**

- $1^\circ$, $2^\circ$, and $3^\circ$ amines can all form hydrogen bonds with water.
- Low-molecular weight amines are generally water-soluble.

![Chemical structures of amines](image)

**Physical Properties of Amines: Odor**

- Low molecular-weight amines tend to have sharp, penetrating odors similar to ammonia.
- Higher molecular-weight amines often smell like rotting fish, and are often found in decaying animal tissues.

![Chemical structures of amines](image)

- **Trimethylamine** (Responsible for the odor of rotting fish)
- **1,4-Diaminobutane (Putrescine)**: A poisonous oil present in rotting flesh; produced during the decomposition of the amino acid arginine; also partially responsible for the odor of urine and bad breath.
- **1,5-Diaminopentane (Cadaverine)**: A poisonous, viscous liquid present in rotting flesh; produced during the decomposition of the amino acid lysine; also partially responsible for the odor of urine and bad breath.
Examples: Predicting Physical Properties

- Arrange the following compounds in order of increasing boiling point. (All of the compounds have about the same molecular weight.)
  - propanoic acid, diethylamine, 1-butanol, ethyldimethylamine

Examples: Predicting Physical Properties

- Which member of each of the following pairs of compounds would you expect to have a higher boiling point?
  - 2-aminopropane or 2-aminohexane
  - triethylamine or 1-aminohexane
  - propanoic acid or diethylamine
  - 1-pentanol or 1-aminopentane
Some Important Alkaloids

**Caffeine**
Found in the seeds of *Coffea arabica*, roasted coffee beans; inhibits the action of phosphodiesterase, an enzyme which inhibits cyclic adenosine monophosphate (AMP), which is responsible for forming glucose in the bloodstream.

**Theobromine**
Found in the seeds of *Theobroma cacao*; the stimulating ingredient in chocolate.

**Nicotene**
Found in tobacco plants; mild stimulant in small doses; addictive, but not especially harmful itself.

**Dextromethorphan**
Ingredient in cough suppressants.

**Quinine**
Antimalarial drug from *cinchona* tree.
Chapter 6 Amines and Amides

**Cocaine**
The form which is “snorted” is the hydrochloride salt; the free-base “crack” form is burned and inhaled, and reaches the brain in 15 seconds.

**Atropine**
Relaxes muscles and reduces secretion of saliva during surgery; used to dilate pupils for eye examinations.

**Scopolamine**
Used in treatment of motion sickness.

**Coniine**
Poison from hemlock

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Chapter 6 Amines and Amides

Nitrogen Wastes

The disposal of waste nitrogen from the body is a problem which different species of animals have solved in different ways:

Uric acid
Birds, reptiles and insects excrete nitrogen wastes in the form of uric acid. Uric acid can be eliminated directly in the solid form, without being dissolved in water. It is produced in the body from foods and beverages rich in purines, such as claret and port. Lactic acid inhibits the removal of salts of uric acid in the urine; these salts instead deposit in the joints, causing gout. Dalmations have been bred to have black spots with no white hairs in them on their coats; however, the gene which determines the presence of white hairs is linked to the gene which codes the enzyme which breaks down uric acid into allantoin. Dalmations thus excrete uric acid instead of allantoin, and are very susceptible to gout.

Allantoin
Most mammals contain enzymes which metabolize uric acid into allantoin.

Allantoic acid
Marine vertebrates further metabolize allantoin into allantoic acid.

Urea
Urea is the major organic component of urine; about 25 g are excreted every day by humans. Cartilaginous fish and amphibians also excrete urea.
Antihistamines

People who are allergic to pollen produce histamine, which causes blood vessels to dilate and leak, releasing fluid into surrounding tissues, causing watery eyes, sniffles, congestion, and other symptoms of hay fever (allergic rhinitis); also causes the symptoms of the common cold and swelling after insect bites.

Diphenhydramine

\[ \text{Diphenhydramine} \]

an antihistamine; active ingredient in Benadryl; sometimes used in sleeping pills

Ephedrine / Pseudoephedrine

\[ \text{Ephedrine / Pseudoephedrine} \]

found in the Chinese ma-huang plant; a decongestant used in many cold remedies

Antihistamines

Loratadine (Claritin®)

\[ \text{Loratadine (Claritin®)} \]

A non-drowsy antihistamine

Fexofenadine (Allegra®)

\[ \text{Fexofenadine (Allegra®)} \]

A non-drowsy antihistamine; available by prescription only

Cetirizide (Zyrtec®)

\[ \text{Cetirizide (Zyrtec®)} \]

A stronger antihistamine than Allegra or Claritin, but causes drowsiness in some people
Reactions of Amines

Bases

• A base takes a proton ($H^+$) from another species. A base produces hydroxide ions, $OH^-$, when dissolved in water:

$$B + H_2O \rightarrow BH^+ + OH^-$$

• A strong base is one that completely dissociates in water (i.e., every molecule of the acid splits apart).

• A weak base is one in which only a small percentage of the molecules are dissociated at any one time.

• Acidic solution: $pH < 7.00$ ($[H_3O^+] > [OH^-]$)
• Basic solution: $pH > 7.00$ ($[H_3O^+] < [OH^-]$)
• Neutral solution: $pH = 7.00$ ($[H_3O^+] = [OH^-]$)
Chemical Properties of Amines: Basicity

• Amines are weak organic bases. They react with water to produce alkylammonium ions and hydroxide anions:

\[ \text{R-NH}_2 + \text{H}_2\text{O} \rightarrow \text{RNH}_3^+ + \text{OH}^- \]

• and with acids to produce alkylammonium salts:

\[ \text{RNH}_2 + \text{HCl} \rightarrow \text{RNH}_3^+ + \text{Cl}^- \]

Alkylammonium Salts

• Salts of amines are named by changing “amine” to “ammonium” and adding the name of the negative ion to the end of the word:

\[ \text{CH}_3\text{NH}_3\text{Cl} \text{ (methylammonium chloride)} \]

\[ \text{CH}_3\text{N}\text{CH}_2\text{CH}_3\text{C}_2\text{H}_5\text{O}_2^- \text{ (ethylmethylammonium acetate)} \]

\[ \text{CH}_3\text{CH}_2\text{N}\text{CH}_2\text{CH}_3\text{Br}^- \text{ (triethylammonium bromide)} \]
**Alkylammonium Salts**

- Salts of amines are generally white crystalline solids with high melting points.
- The ionic charges make these salts more soluble in water than the neutral amines. Many amine-containing drugs are administered in the form of alkylammonium salts to increase their solubility in bodily fluids.

![Chemical Structures](image)

**Chemical Properties of Amines: Basicity**

- Ammonium salts may be converted back into neutral amines by a strong base:

\[
R—\text{NH}_3^+ \text{Cl}^- + \text{NaOH} \rightarrow R—\text{NH}_2 + \text{H}_2\text{O} + \text{NaCl}
\]

- Thus, by adjusting the pH of the solution, it is possible to influence whether an amine is present in the neutral form or as its ammonium cation form:

![Chemical Reactions](image)
**Quaternary Ammonium Salts**

- In addition to salts of 1°, 2°, and 3° amines, it is possible to have amine cations which contain four alkyl groups attached to a nitrogen atom, which will always carry a positive charge, regardless of the pH of the surrounding solution. These are known as *quaternary ammonium salts*.

\[
\text{R}''''\text{N}^+\text{R}''\text{X}^- \quad \text{CH}_2\text{CH}_3
\]

- These salts are present in many antiseptics and antibacterial agents.

---

**Examples: Basicity of Amines**

- Complete the following reactions:

\[
\text{CH}_3\text{NH}_2 + \text{HCl} \rightarrow
\]

\[
\text{C}_6\text{H}_5\text{NHCH}_3 + \text{HCl} \rightarrow
\]

\[
\text{CH}_3\text{N}^+\text{H}^+\text{Cl}^- + \text{NaOH} \rightarrow
\]
Amides

- Amides contain a nitrogen which is directly attached to a carbon in a carbonyl group:

\[
\begin{align*}
\text{Amide linkage (peptide bond)} & \quad \text{Amide} \\
R - C - N - R' & \quad R - C - N - \text{CH}_3 \\
R'' & \quad \text{CH}_3
\end{align*}
\]

N,N-unsubstituted amide  N-substituted amide  N,N-disubstituted amide
Nomenclature of Amides

- Amides are named by changing the -oic acid ending of the corresponding carboxylic acid to -amide. If alkyl groups are attached to the nitrogen, they are named as N-alkyl substituents.

\[
\begin{align*}
\text{methanoic acid} & \quad \text{methanamide} \\
\text{ethanoic acid} & \quad \text{ethanamide} \\
\text{benzamide} &
\end{align*}
\]

Examples: Nomenclature of Amides

- Name the following compounds:

\[
\begin{align*}
\text{CH}_3\text{C\_N\_CH}_3 & \quad \text{CH}_3\text{N\_C\_CH}_3 \\
\text{H} & \quad \text{CH}_3
\end{align*}
\]
Examples: Nomenclature of Amides

• Name the following compounds:

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHCH}_2\text{CN}\text{H}_2\text{CH}_3
\]

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_2\text{C}\underset{\text{NH}_2}{\text{N}}\text{H}_3
\]

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CCH}_3\text{CNCH}_3\text{OC}_\text{H}_2\text{CHCH}_3\text{CH}_3\text{CH}_2\text{CH}_3
\]
Examples: Nomenclature of Amides

- Name the following compounds:

\[
\begin{align*}
&\text{CH}_3\text{C} = \text{N}\text{H} \quad \text{(phenyl amide)} \\
&\text{C} = \text{NCH}_3 \quad \text{(phenyl amide)} \\
&\text{CH}_3\text{C} = \text{NCH}_3 \quad \text{(phenyl amide)} \\
&\text{CH}_3\text{C} = \text{NCH}_3 \quad \text{(phenyl amide)}
\end{align*}
\]
Examples: Nomenclature of Amides

- Draw structural formulas for the following molecules:
  - 2-methylpropanamide
  - N,2,4-trimethylpentanamide
  - N-ethyl-N-methylacetamide
  - N,N,4,4-tetramethylbutanamide (what’s wrong with this name?)
Physical Properties of Amides

- N,N-unsubstituted amides can form a complex network of hydrogen bonds. They tend to have high melting points and also high boiling points.
**Physical Properties of Amides**

- N-substituted amides often have lower melting points and boiling points than N,N-unsubstituted amides because fewer hydrogen bonds can form.
- N,N-disubstituted amides cannot form hydrogen bonds, and have even lower melting points and boiling points.
- All amides can hydrogen bond with water, so low-molecular weight amides are water-soluble.

**Boiling Point:**
- N,N-unsubstituted amides
- N-substituted amides
- N,N-disubstituted amides

---

**Examples: Predicting Physical Properties**

- Arrange the following compounds in order of increasing boiling point. (All of the compounds have about the same molecular weight.)

  N-ethylethanamide
  
  butanamide
  
  N,N-dimethylethanamide
Important Amides

Diazepam (Valium)
A benzodiazepene tranquilizer; acts by enhancing the inhibitory neurotransmitter GABA; since it binds to the same protein as ethanol, combinations of valium and ethanol can be deadly

N,N-Diethyl-m-toluamide
Active ingredient in OFF

Thalidomide
Until 1956, a very popular, safe sedative; the largest market was for pregnant women who were experiencing morning sickness. However, it caused massive birth defects in women who used it in the early states of pregnancy, and was banned in Europe; it was never authorized for sale in the U.S.
**Hot Stuff**

- **Capsaicin**
  - Found in red and green chili peppers; active component of paprika

- **Allyl isocyanate**
  - Used in horseradish flavor, mustard oil, pickles, salad dressings and sauces; mustard plasters, medications and fumigants

- **Piperine**
  - Component of white and black pepper

- **Zingerone**
  - The pungent, hot component of ginger

---

**Barbiturates**

- **Barbituric acid**
  - First synthesized by Adolf von Baeyer in 1864; barbiturates are soporifics, and are used as tranquilizers and anesthetics; many are also addictive, and overdoses can be fatal. (Other barbiturates include Seconal, Veronal, Phenobarbital, Thiopental, Amobarbital, etc.)

- **Thiopental (Pentothal)**
  - An intravenous anesthetic

- **Amobarbital (Amytal)**
  - Used in the treatment of insomnia

- **Phenobarbital**
  - Anti-convulsion medication, sedative
**Sulfa Drugs**

Sulfanilamide, the first antibiotic, was discovered by Gerhard Domagk (Nobel Prize, 1939), who observed the antibacterial action of the red dye Prontosil; further research showed that it was the metabolic byproduct, sulfanilamide, which was the active form. It prevents bacteria from synthesizing folic acid, which they need in order to grow. Bacterial enzymes synthesize folic acid using para-aminobenzoic acid (PABA); sulfanilamide fits into the enzyme more tightly, blocking it from taking up PABA, and thus blocking folic acid synthesis. The bacterium cannot grow, and eventually dies. Humans obtain folic acid from their diet (an essential vitamin), so sulfa drugs do not harm people in this way (although they can cause allergic reactions).

**Penicillin**

Penicillin is an antibiotic compound produced by the molds Penicillium notatum and Penicillium chrysogenum; it was discovered by Alexander Fleming in 1928 in a culture of bread mold. There are several varieties: Penicillin G and Methicillin are administered by injection; Penicillin V is an oral form which is not broken down in the stomach; Ampicillin is a broad spectrum penicillin which can be administered by injection or orally.
**Molecules To Dye For**

- **Dyes** are compounds that can be used to color other materials, such as clothing, paper, hair, etc.

- Many organic dyes contain a long series of double bonds that are close together. If the chain of double bonds is long enough, these molecules can absorb low-energy light in the visible region of the electromagnetic spectrum, resulting in colors that are visible to the human eye.

  ![Indigo](image1)
  **Indigo**
  A naturally occurring blue dye which has been used for thousands of years. It is obtained from an Indian plant (*Indigofera tinctoria*) and the European woad (*Isatis tinctoria*). Today, indigo can be made synthetically, and is used in dyeing denim to make blue jeans.

  ![Tyrian purple](image2)
  **Tyrian purple**
  6,6'-dibromoindigo
  Tyrian purple, or “royal purple,” is a purple dye originally obtained from a species of mollusk (*Murex*) found near the cities of Tyre and Sidon in ancient Phoenicia. It took about 9,000 mollusk shells to obtain one gram of the dye, making it very expensive. This dye was used by royalty (hence the name “royal purple”) and the Roman aristocracy.

  ![Mauve](image3)
  **Mauve**
  This is the first of the synthetic dyes. It was discovered by the 18-year-old English chemist William Henry Perkin in his home laboratory, while attempting to synthesize quinine (the only known treatment for malaria at that time). While cleaning up the sludge from one of his failed attempts, he noticed that the sludge was turning the water in his sink violet, and that cloth would pick up this purple color. Perkin patented his serendipitous discovery, and went into business making dyes, becoming so successful that he was able to retire at the age of 36 to focus his attention on chemical research.
**FD&C Dyes**

These color additives are approved by the Food and Drug Administration (FDA) under the Federal Food, Drug, and Cosmetic Act (FD&C, 1938, amended 1997) for use in foods.

*FD&C Red No. 40*
Allura Red AC

*FD&C Yellow No. 5*
Tartrazine

*FD&C Yellow No. 6*
Sunset Yellow FCF

*Orange B*
Used in sausage and frankfurter casings

*Citrus Red No. 2*
Used to color orange skins
Chapter 6 Amines and Amides

**Molecules To Dye For**

Methyl orange

![Methyl orange structure](image1)

Para red

![Para red structure](image2)

Butter yellow

![Butter yellow structure](image3)

Methyl red

![Methyl red structure](image4)

Chicago blue

![Chicago blue structure](image5)

Resazurin

![Resazurin structure](image6)

Methylene Blue

![Methylene Blue structure](image7)

Methyl violet 10B (crystal violet)

![Methyl violet 10B (crystal violet) structure](image8)

Congo red

![Congo red structure](image9)
Reactions of Amides

**Amide Formation**

• Amides are formed when acid chlorides react with 1° or 2° amines; 3° amines cannot form amides:

```
R-C-Cl + R'-N-H → R-C-N-R' + HCl
```

```
R-C-Cl + R''-N-H → R-C-N-R'' + HCl
```

```
R-C-Cl + R'-N-R'''' → no reaction
```
**Amide Formation**

- Amides are also formed when acid anhydrides react with $1^\circ$ or $2^\circ$ amines.

\[
\begin{align*}
\text{R-C-O-C-R} + \text{R'-N-H} & \rightarrow \text{R-C-N-R'} + \text{HO-C-R} \\
\text{R-C-O-C-R} + \text{R''} & \rightarrow \text{R-C-N-R'} + \text{HO-C-R} \\
\text{R-C-O-C-R} + \text{R'-N-R''} & \rightarrow \text{no reaction}
\end{align*}
\]

**Examples: Formation of Amides**

- Complete the following reactions:

\[
\begin{align*}
\text{C-Cl} + \text{CH}_3\text{-N-H} & \rightarrow
\end{align*}
\]
Examples: Formation of Amides

- Complete the following reactions:

\[
\text{CH}_3\text{C} \begin{array}{c}\text{O} \\ \text{C} \end{array} \text{C} \begin{array}{c}\text{CH}_3 \\ \text{O} \end{array} + \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 \rightarrow
\]

- Complete the following reactions:

\[
\text{CH}_3\text{C} \begin{array}{c}\text{Cl} \\ \text{C} \end{array} + \text{CH}_3\text{N} \begin{array}{c}\text{CH}_3 \\ \text{N} \end{array} \rightarrow
\]
**Chemical Properties of Amides**

- Unlike amines, amides are not basic.
- Amide hydrolysis can take place under acidic or basic conditions:

\[
\begin{align*}
\text{RC} \quad \text{O} \quad \text{NR} & \quad \text{RC} \quad \text{O} \quad \text{OH} \quad \text{N}^+ \quad \text{R}' \quad \text{Cl}^- \\
\text{R} \quad \text{C} \quad \text{N} \quad \text{R}' \quad + \quad \text{H}_2\text{O} \quad + \quad \text{HCl} & \quad \rightarrow \quad \text{RC} \quad \text{OH} \quad + \quad \text{H} \quad \text{N}^+ \quad \text{R}' \quad \text{Cl}^- \\
\text{R} \quad \text{C} \quad \text{N} \quad \text{R}' \quad + \quad \text{NaOH} & \quad \rightarrow \quad \text{RC} \quad \text{O}^- \quad \text{Na}^+ \quad + \quad \text{H} \quad \text{N} \quad \text{R}'
\end{align*}
\]

**Examples: Reactions of Amines and Amides**

- Complete the following reactions:

\[
\begin{align*}
\text{CH}_3 \quad \text{C} \quad \text{N} \quad \text{CH}_3 & \quad + \quad \text{H}_2\text{O} \quad + \quad \text{HCl} \\
\text{CH}_3 \quad \text{C} \quad \text{N} \quad \text{CH}_3 & \quad + \quad \text{NaOH}
\end{align*}
\]
Condensation Polymers: Polyamides

1,6-diaminohexane + sebacoyl chloride

\[ \text{H}_2\text{N}-(\text{CH}_2)_6\text{NH}_2 + \text{C}_5\text{H}_4\text{C}=\text{OCl} \rightarrow \text{H}_2\text{N}-(\text{CH}_2)_6\text{NH}_2\text{C}_5\text{H}_4\text{C}=\text{O} \]

etc.
Chapter 6 Amines and Amides

**Condensation Polymers: Polyamides**

Nylon-6,12

a polyamide

Discovered by Wallace Carrothers at DuPont in 1934; polymers average about 10,000 g/mol; 3 billion pound of Nylon made per year; 60% used for nylon fiber in home furnishings (carpet); also used in textile fibers, tire cord, rope, parachutes, paint brushes, Velcro, electrical parts, medical applications (sutures, etc.)

---

**Polyamides**

Kevlar

used in bullet-proof vests and tire cords

(an aramid, "aromatic polyamide")
Chapter 6 Amines and Amides

**Polyamides**

![Chemical structure of Nomex](image)

Nomex
- Insulates ceramic tiles on the space shuttle; used in firefighting equipment, race car driver suits, flight suits, the airbags on the Mars Pathfinder, Spirit, and Opportunity rovers (less strong than Kevlar, but has excellent thermal, chemical, and radiation resistance)

**Polyurethanes**

![Chemical structure of polyurethane](image)

Isocyanate + alcohol → A Urethane
- Toluene diisocyanate + Glycerol → A Polyurethane

![Polyurethane structure](image)
Neurotransmitters

- **Neurotransmitters** are small molecules that carry nerve impulses from one neuron to the next.
- Neurons consist of the main cell body (the **soma**), long stemlike projections (the **axons**), and short fibers connected to the soma (the **dendrites**).
- Neurons are not connected directly to each other, but are separated by a small gap called a **synapse**.
- When an electrical current originating in a neuron reaches the **synaptic terminals** at the end of the axon, the terminals release neurotransmitter molecules into the synapse; these molecules diffuse across the synapse and bind to receptors on the dendrites of the next neuron, stimulating an electrical current, which travels along that neuron until it reaches the next synapse, and so on until the nerve impulse reaches the brain.
Figure 6.5 A nerve cell and the transmission of a nerve signal.

Dopa
Synthesized from the amino acid tyrosine; used as a treatment for Parkinson's disease, which is caused by a breakdown of dopamine-based neurons that control the brain's motor system (dopamine cannot be administered directly because it does not cross the blood-brain barrier; however, the L-form of dopa does)

Dopamine
Synthesized from dopa; used as a treatment for low blood pressure

Norepinephrine (NE)
Synthesized from dopamine; an excess of NE in the brain is related to feelings of elation or manic states; low NE levels are linked to depression; the stimulant action of epinephrine and NE in some cells can be reduced by beta blockers, which are used to treat cardiac arrhythmias, angina, and hypertension

Serotonin
Synthesized from the amino acid tryptophan; influences sleeping, body temperature, and sensory perception; drugs that mimic serotonin are used to treat depression, anxiety, and obsessive-compulsive disorder; serotonin blockers are used to treat migraine headaches and nausea resulting from chemotherapy
Chapter 6 Amines and Amides

Epinephrine (Adrenalin)
More important as a hormone than a neurotransmitter; synthesized in the adrenal gland; release of adrenalin into the bloodstream in response to pain, anger, or fear increases blood glucose levels, and provides a sudden burst of energy (fight-or-flight response); increases force of heart contractions (raising blood pressure); also a vasoconstrictor; used in local anesthetics to keep the anesthetic from being washed away

Acetylcholine
Gamma-aminobutanoic acid (GABA)
A inhibitory neurotransmitter

Pheynlephrines and Amphetamines

Amphetamine (Benzedrine)
a powerful nervous stimulant; raises blood glucose levels, increases heart rate and blood pressure

N-Methyamphetamine (Methedrine, "speed")
Also a powerful nervous stimulant

Ephedrine / Pseudoephehrine
found in the Chinese ma-huang plant; a decongestant used in many cold remedies

Phenylephrine
Common decongestant

Mescaline
Hallucinogen from peyote cactus

3,4-Methylenedioxyemethamphetamine (MDMA), "Ectasy"
Amino Acids and Proteins

*Amino Acids*

- Glycine (Gly)
- Alanine (Ala)
- Valine (Val)
- Leucine (Leu)
- Isoleucine (Ile)
- Phenylalanine (Phe)
- Proline (Pro)
- Methionine (Met)
Chapter 6 Amines and Amides

Aspartate (Asp)

Tryptophan (Try)

Glycine (Gly)

Alanine (Ala)

Ketone (Asp)

Tertiary structure

Primary structure

Secondary structure

Three levels of structure in a telephone cord

Gly—Ala—Asp—Try

a protein
(a polyamide)
Instructions for making proteins are encoded in DNA.
R-group interactions leading to a protein tertiary structure

Segment of a protein showing α-helix, β-pleated sheet, and random coil structures
Some Hideously Complex Molecules
**Chapter 6 Amines and Amides**

**Bufotoxin**
Isolated from the toad *Bufo marinus*; increases the contractive power of weak heart muscles; also causes terrifying hallucinations.

**Taxol**
Potential anti-cancer drug isolated from the Pacific yew tree.

**Vitamin B12**
(Cobalamin)
Found in meat, fish, eggs, and milk; a coenzyme involved in amino acid metabolism; needed for the production of red blood cells (a deficiency in vitamin B12 results in anemia).
Chapter 6 Amines and Amides

**Functional Groups**

- **Alkane** (-ane)
- **Alkene** (-ene)
- **Alkyne** (-yne)
- **Aromatic Ring** (phenyl, -benzene)
- **Phenol** (phenol)

- **Primary (1°) Alcohol** (-ol)
- **Secondary (2°) Alcohol** (-ol)
- **Tertiary (3°) Alcohol** (-ol)

- **Ether** (alkoxy, -ether)
- **Thiol**

- **Aldehyde** (-al)
- **Ketone** (-one)
- **Hemiacetal**
- **Acetal**
- **Hemiketal**
- **Ketal**

- **Carboxylic Acid** (-oic acid)
- **Carboxylate Salt** (metal + -oate)
- **Ester** (alkyl + -oate)
- **Acid Chloride**
- **Acid Anhydride**

- **Primary (1°) Amine** (amino, -amine)
- **Secondary (2°) Amine** (-amine)
- **Tertiary (3°) Amine** (-amine)
- **Quaternary Ammonium Salt** (alkyl ammonium + anion)

- **Amide** (N-alkyl + -amide)
- **Phosphate Ester**
Reactions of Amines and Amides

1. Reaction of an amine with water to produce an alkylammonium ion.

\[
\text{amine} + \text{H}_2\text{O} \rightarrow \text{alkylammonium ion}
\]

2. Reaction of an amine with acid to produce an alkylammonium salt.

\[
\text{amine} + \text{HCl} \rightarrow \text{alkylammonium chloride}
\]

3. Conversion of an alkylammonium salt back to an amine.

\[
\text{R—NH}_3^+ \text{Cl}^- + \text{NaOH} \rightarrow \text{R—NH}_2 + \text{H}_2\text{O} + \text{NaCl}
\]

4. Formation of an amide. (NR with tertiary amines.)

\[
\text{acid chloride} + \text{amine} \rightarrow \text{amide}
\]

5. Hydrolysis of amides under acidic and basic conditions.

\[
\text{amide} + \text{H}_2\text{O} + \text{HCl} \rightarrow \text{carboxylic acid + alkylammonium salt}
\]

\[
\text{amide} + \text{NaOH} \rightarrow \text{carboxylate salt + amine}
\]