

Amines, amino acids and condensation polymers in action

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Lesson

Quick answer: Amines are organic bases because the lone pair on nitrogen accepts a proton, and amino acids contain both an amine and an acid group so they form zwitterions. Condensation polymers such as nylon, polyesters and proteins join monomers through amide or ester links while losing small molecules like water.

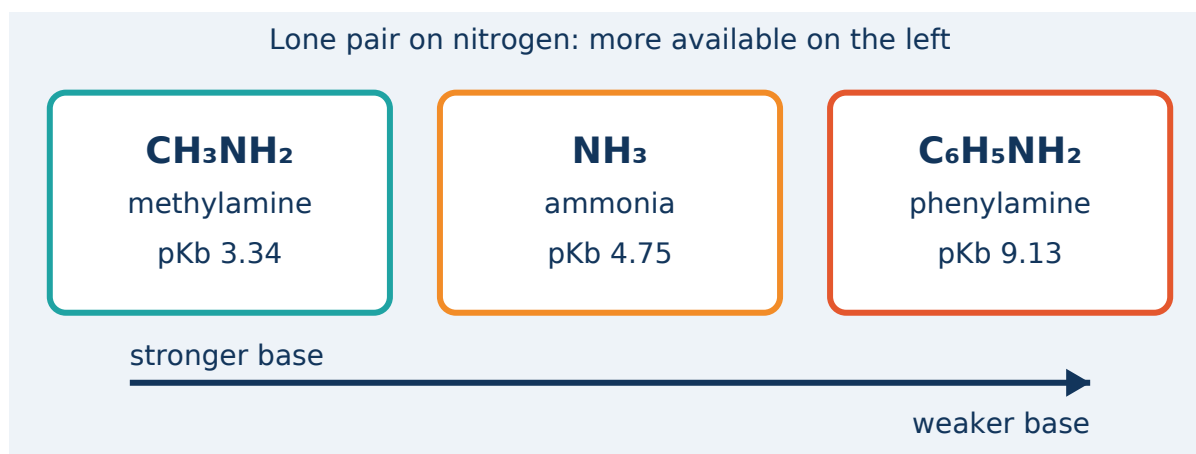
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Why are amines basic?

Definition

An **amine** is an organic compound formed when one or more hydrogen atoms of ammonia are replaced by alkyl or aryl groups. It is *primary* (RNH_2), *secondary* (R_2NH) or *tertiary* (R_3N) according to the number of carbon groups on nitrogen.

The nitrogen atom of an amine carries a lone pair of electrons. It accepts a proton from an acid, so an amine is a Brønsted–Lowry base: $\text{CH}_3\text{NH}_2 + \text{H}^+ \rightarrow \text{CH}_3\text{NH}_3^+$. Alkyl groups push electron density towards nitrogen, which makes the lone pair more available than in ammonia. In phenylamine the lone pair is partly delocalised into the benzene ring, so it is much less available.



Basicity falls from alkylamines through ammonia to phenylamine because the nitrogen lone pair becomes less available.

Compound	pK _b at 25 °C	Reason for its basicity
Dimethylamine	3.27	Two electron-donating methyl groups
Methylamine	3.34	One electron-donating methyl group

Compound	pK _b at 25 °C	Reason for its basicity
Ammonia	4.75	Reference, no donating groups
Phenylamine	9.13	Lone pair delocalised into the ring

Common mistake

Students say that a base with a bigger pK_b is stronger. It is the opposite: a smaller pK_b means a larger K_b and a stronger base.

How are amines made and what do they do?

A haloalkane reacts with an excess of ammonia in ethanol by nucleophilic substitution: $\text{CH}_3\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}$. The excess matters, because the amine formed is itself a nucleophile and would otherwise keep reacting to give secondary and tertiary amines. Nitriles are reduced to primary amines, and nitrobenzene is reduced to phenylamine using tin and concentrated hydrochloric acid. Amines also react with acyl chlorides to give N-substituted amides.

Worked example 1

Calculate the pH of 0.10 mol/dm³ ethylamine, K_b = 4.5×10^{-4} mol/dm³, at 25 °C (K_w = 1.0×10^{-14}).

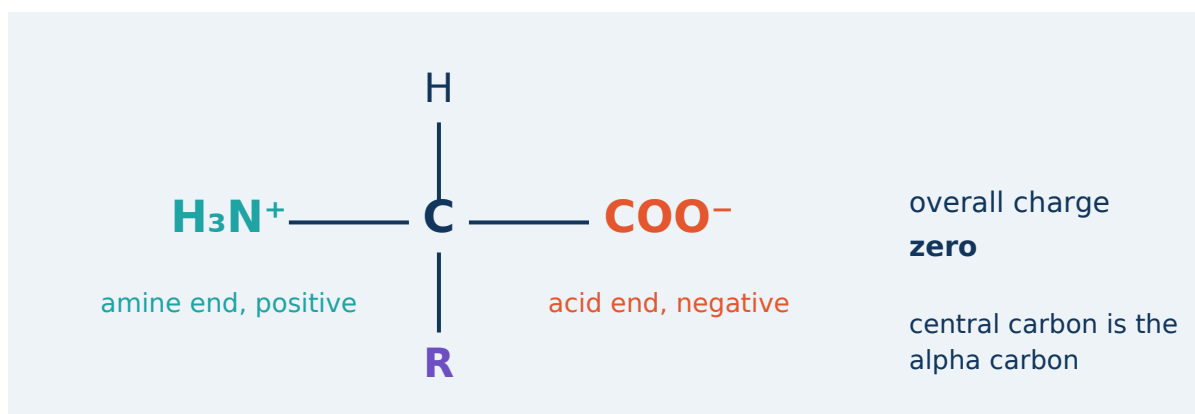
$[\text{OH}^-] = \sqrt{K_b \times c} = \sqrt{(4.5 \times 10^{-4} \times 0.10)} = 6.7 \times 10^{-3}$ mol/dm³. pOH = $-\log(6.7 \times 10^{-3})$ = 2.17, so pH = 14.00 – 2.17 = **11.83**.

What are amino acids and how do they behave?

Definition

An **α-amino acid** has an amino group (–NH₂) and a carboxylic acid group (–COOH) on the same carbon, written RCH(NH₂)COOH. Apart from glycine (R = H), the alpha carbon is a chiral centre.

Because the molecule has both a basic and an acidic group, it is amphoteric. In water and in the solid state the acid group gives H⁺ to the amine group, forming a zwitterion with zero overall charge. This ionic character explains why amino acids are crystalline solids with high melting points and are soluble in water.



An amino acid in the solid state or near neutral pH exists as a zwitterion with both charges on the same molecule.

Solution	Species of an amino acid	Overall charge
Strongly acidic	$\text{RCH}(\text{NH}_3^+)\text{COOH}$	+1
Near the isoelectric point	$\text{RCH}(\text{NH}_3^+)\text{COO}^-$	0
Strongly alkaline	$\text{RCH}(\text{NH}_2)\text{COO}^-$	-1

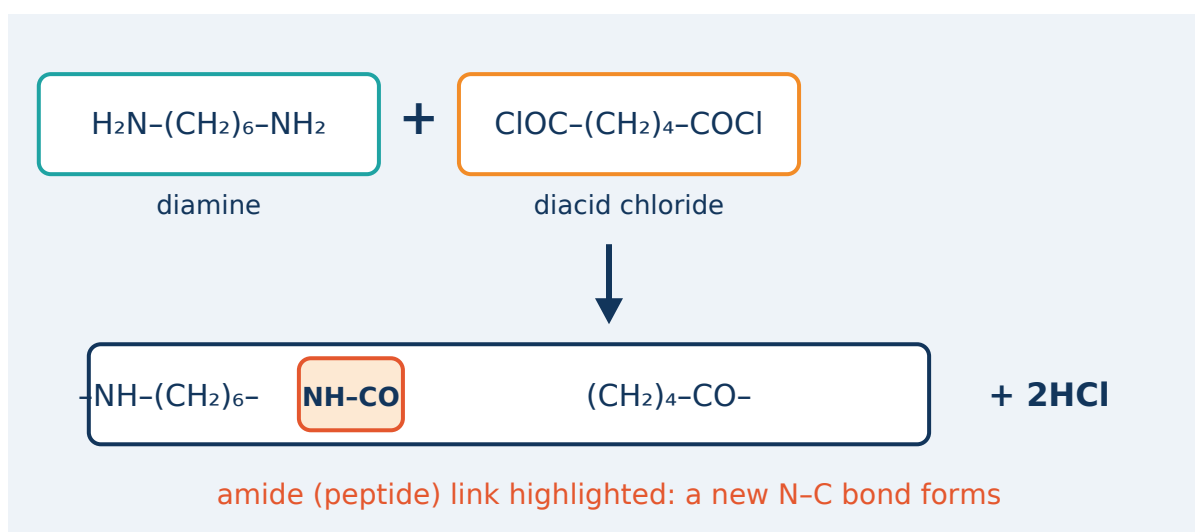
The pH at which the zwitterion dominates is the isoelectric point. A mixture of amino acids can be separated by electrophoresis or chromatography, and spots are revealed with ninhydrin.

How do condensation polymers form?

Definition

In **condensation polymerisation**, monomers with two functional groups join in repeated reactions, and each join releases a small molecule such as H_2O or HCl .

A **polyamide** forms from a diamine and a dicarboxylic acid or diacid chloride, and a **polyester** from a diol and a dicarboxylic acid. Proteins are natural polyamides: amino acids join through peptide links ($-\text{CO}-\text{NH}-$). Both amide and ester links are broken by hydrolysis, which is why these polymers can be broken down by acids or alkalis, unlike polyalkenes with a carbon-carbon chain.



Each time a diamine meets a diacid chloride, an amide link forms and one hydrogen chloride molecule is lost.

Polymer	Monomers	Link	Small molecule lost
Nylon-6,6	Hexane-1,6-diamine and hexanedioyl dichloride	Amide	HCl
PET	Benzene-1,4-dicarboxylic acid and ethane-1,2-diol	Ester	H ₂ O
Protein	Amino acids	Peptide	H ₂ O

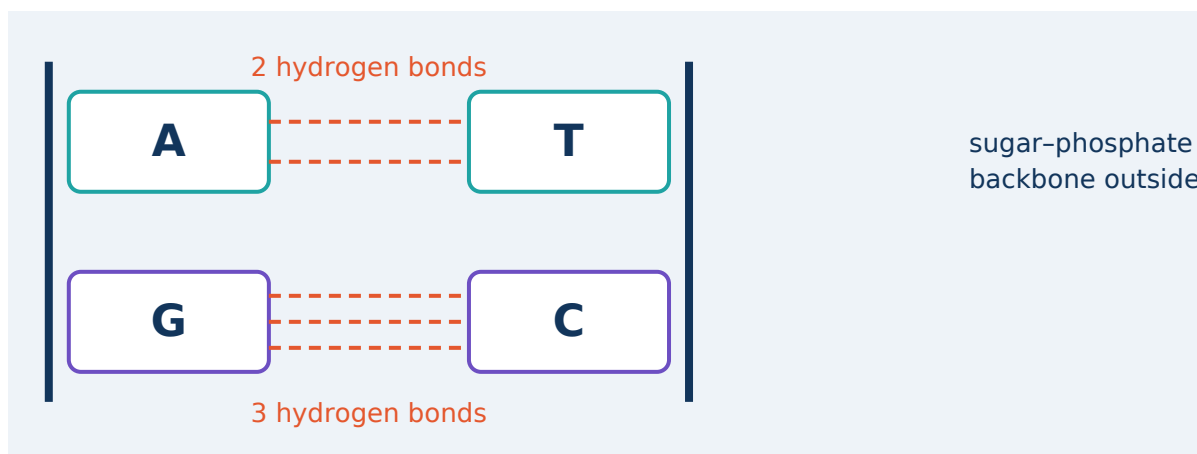
Worked example 2

Calculate the mass of nylon-6,6 formed from 5.80 g of hexane-1,6-diamine ($M_r = 116$) and excess hexanedioic acid, with 100 % yield. The repeat unit $C_{12}H_{22}N_2O_2$ has $M_r = 226$.

$n(\text{diamine}) = 5.80 \div 116 = 0.0500 \text{ mol}$. One repeat unit forms per diamine, so $n(\text{repeat units}) = 0.0500 \text{ mol}$ and $m = 0.0500 \times 226 = \mathbf{11.3 \text{ g}}$. Water lost = $0.100 \text{ mol} \times 18 = 1.80 \text{ g}$.

What is DNA made of?

DNA is a polymer of nucleotides. Each nucleotide joins a phosphate group, the sugar deoxyribose and one of four bases: adenine (A), thymine (T), guanine (G) or cytosine (C). Phosphate and sugar alternate in the backbone of each strand. Two strands twist into a double helix, held by hydrogen bonds between complementary bases: A pairs with T and G pairs with C. The anticancer drug cisplatin works by binding to guanine bases in DNA and stopping cell division.



Complementary base pairing holds the two strands of DNA together; G-C pairs are held more strongly than A-T pairs.

Lina's tip

For any condensation polymer, find the link first (amide or ester), cut it, and add back the small molecule you lost. The two monomers appear at once.

Key points to remember

- Amine basicity: alkylamines are stronger than ammonia, which is stronger than phenylamine; smaller pK_b means a stronger base.
- Amino acid: $RCH(NH_2)COOH$, exists as a zwitterion near its isoelectric point.
- Amide and ester links form with loss of H_2O or HCl and are broken by hydrolysis.
- DNA base pairs: A-T (2 hydrogen bonds) and G-C (3 hydrogen bonds).

Amines, amino acids and condensation polymers in action: frequently asked questions

Why is phenylamine a weaker base than ethylamine?

In phenylamine the nitrogen lone pair overlaps with the delocalised ring electrons, so it is less available to accept H^+ . In ethylamine the alkyl group pushes electron density onto nitrogen, making the lone pair more available.

What is a zwitterion?

A zwitterion is a molecule carrying a positive and a negative charge on different atoms with zero overall charge. An amino acid forms one when its $-COOH$ group transfers a proton to its $-NH_2$ group.

How does a condensation polymer differ from an addition polymer?

A condensation polymer forms from monomers with two functional groups and releases a small molecule such as water or HCl at each link. An addition polymer forms from alkenes and loses nothing.

Why can polyesters and polyamides be hydrolysed?

Ester and amide links contain polar $C=O$ bonds that water can attack, especially with acid or alkali. The carbon-carbon backbone of poly(ethene) has no such site, so it resists breakdown.

Which bases pair in DNA?

Adenine pairs with thymine through two hydrogen bonds, and guanine pairs with cytosine through three. This fixed pairing lets one strand act as a template for the other.