

Nitrogen Compounds

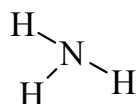
Specification from OCR

Three main points.

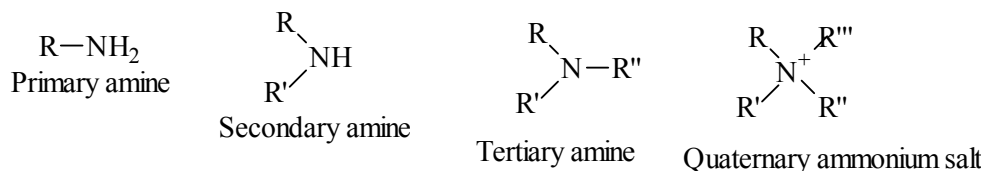
- Properties of primary amines
- Amino acids; peptide formation
- Hydrolysis of proteins

Amines

Amines are essentially molecules of ammonia where one or more of the hydrogen atoms have been replaced with an alkyl group.

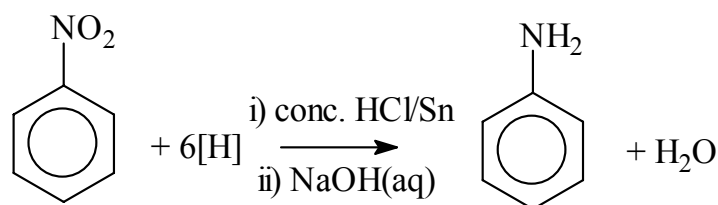


Replace one hydrogen atom with an alkyl group = primary amine, replace 2 = secondary amine etc.



Attaching a benzene ring to NH_2 gives different chemical properties to that expected from non aromatic amines.

Reduction of nitrobenzene to give phenylamine

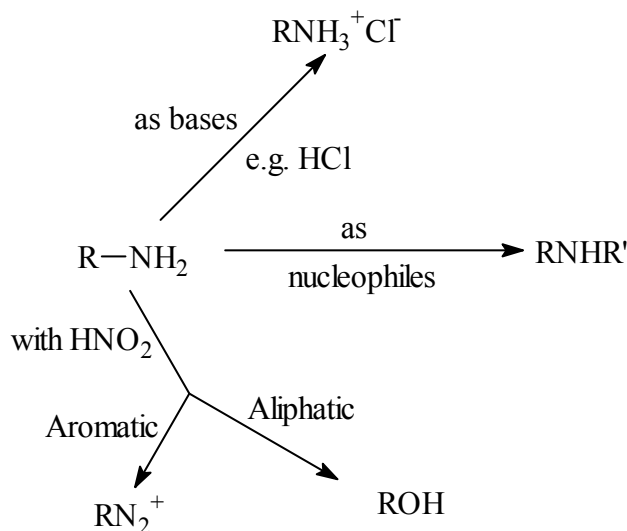


Conditions are reflux, this is important in the production of compounds called azo-dyes. The NaOH is essential to liberate the phenylamine rather than the salt.

Reactions of Amines

There are 3 main reactions that amines undergo:

- As bases
- As nucleophiles
- With nitrous acid



The reactivity of amines depends on:

- The availability of the 'lone pair' of electrons on the nitrogen
- Nitrogen is less electronegative than oxygen
- The lone pair is more available on nitrogen than it is with the alcohols

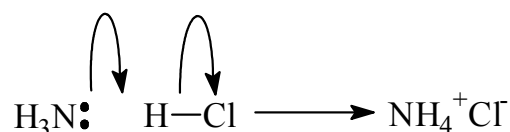
The donation of the lone pair of the electrons results in amines acting as:

- Quite good bases (donating a lone pair to an H^+ atom)
- Excellent ligands (in transition metal chemistry)
- Good nucleophiles – able to attack the positive end of a polarised bond.

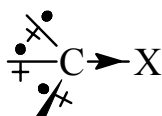
Amines as bases

Bases are proton acceptors. They don't actually accept protons, they donate a lone pair to the hydrogen atom to form a dative bond.

Ammonia and bases can do this with any suitable acid to give a salt.



An alkyl group is slightly electron donating. This is because the electron pairs around the carbon repel the electron pair in the bond between the carbon and the functional group.



So replacing a hydrogen in ammonia has the following sequence of events:

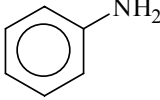
- Causes increased electron donation in the C-N bond
- Becomes polar, and nitrogen becomes slightly negative
- Lone pair on nitrogen slightly repelled
- Can be donated to a proton more easily
- 1° amines are more basic than ammonia

So following the same argument, 2° amines will be more basic still, as the lone pair will be repelled even more.

In phenylamine, the lone pair becomes involved in the aromaticity, so it is less basic. The lone pair as part of the ring's delocalised system, it is less readily donated to a proton.

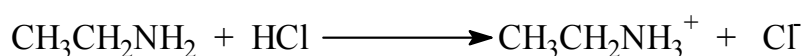
A tertiary amine will be more basic still.

The relative basicity of some amines

Name	Type	Structure	pK_a	pK_b
Ammonia		NH ₃	9.25	4.75
Ethylamine	Primary	C ₂ H ₅ NH ₂	10.75	3.27
Diethylamine	Secondary	(C ₂ H ₅) ₂ NH	10.93	3.07
Triethylamine	Tertiary	(C ₂ H ₅) ₃ N	10.64	3.36
Phenylamine	Aromatic		4.62	9.38

Remember pK_a is a little like pH , the higher the value the more basic a compound is.

Reaction of amines with acids



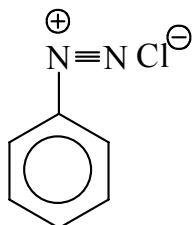
A pretty standard Acid Base reaction.

Questions

- Write the structural formulae for these amines:
 - Ethylamine
 - Diethylamine
 - Diethylpropylamine
 - Phenylamine
- Place the amines in question 1 in order of basicity, starting with the most basic
- Write the reaction of propylamine with the following acids
 - Hydrochloric acid
 - Sulphuric acid
 - Ethanoic acid
 - Nitric Acid
- This is a salt of an amine $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_3^+$.
 - Name the amine that this salt comes from
 - How would this salt react with sodium hydroxide? Write the equation.
Hint, this might give the amine back.
- What would you expect to happen if phenylamine reacted with concentrated sulphuric acid and tin, and then reacted with sodium hydroxide?

Diazonium Salts

Diazonium: there are 2 nitrogen atoms joined together in the positive ion. In French, nitrogen is still called by its old name 'azote' which means unable to support life.



- Notice the triple bond between the nitrogen atoms
- The positive charge is on the nitrogen that is attached to the benzene ring

diazonium chloride

Why are they important? They look pretty weird!

They are essential in the dye industry. A Diazonium salt is produced then reacted with a phenol. If the correct phenol is used, almost any colour can be produced.

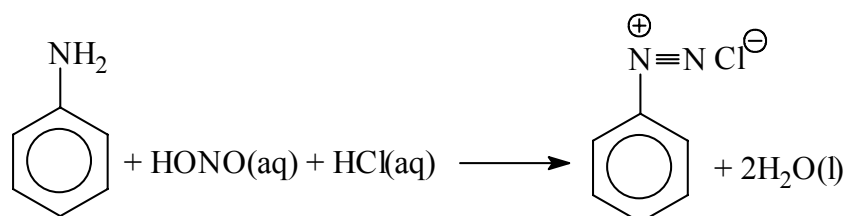
OCR specify this as a reaction you need to know. In the last CRS paper, this was a question worth 6 marks! Very few students got many marks at all.

Formation of the Diazonium salt.

These compounds are formed by reacting phenylamine with sodium nitrite and hydrochloric acid. These reagents form in situ nitrous acid HONO.

- The Diazonium salt is unstable above 10°C, so the reaction is normally carried out in ice.
- An aliphatic Diazonium salt is very unstable, so only aromatics are used.
- The lone pairs present in the salt can participate in the benzene ring, making it more stable. More correctly this is due to overlap of p-orbitals in the diazo group with the π -system in the ring.

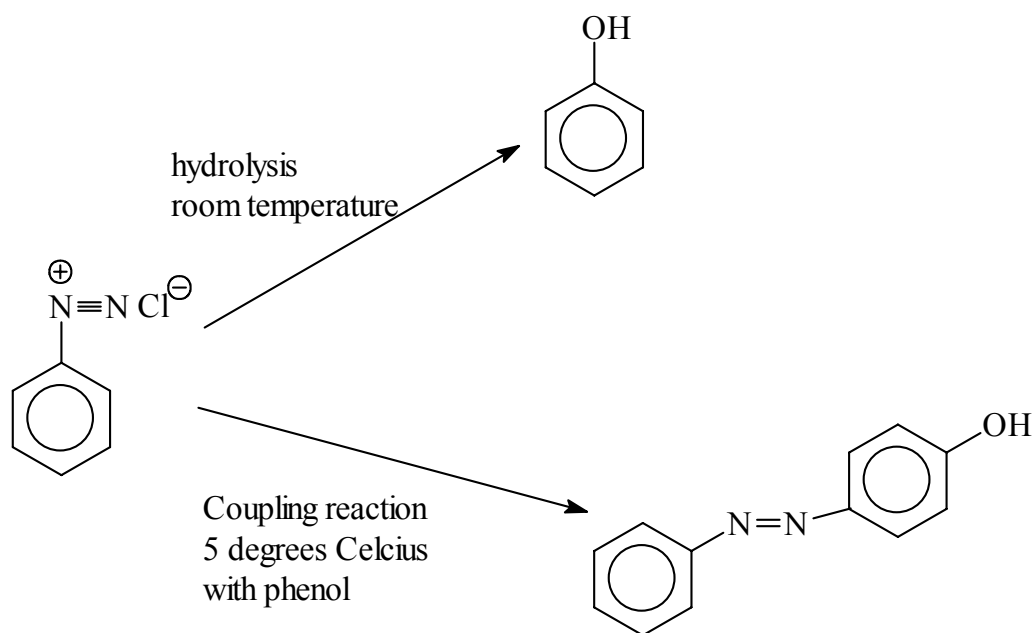
So phenylamine would give benzenediazonium chloride.



The conditions are 5°C and remember the HONO (nitrous acid) is prepared in situ by reacting sodium nitrite with hydrochloric acid.

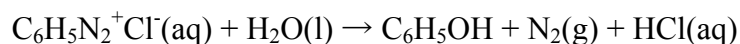
The diazonium salt can then do one of two things depending on the temperature

Reactions of aromatic diazonium salts



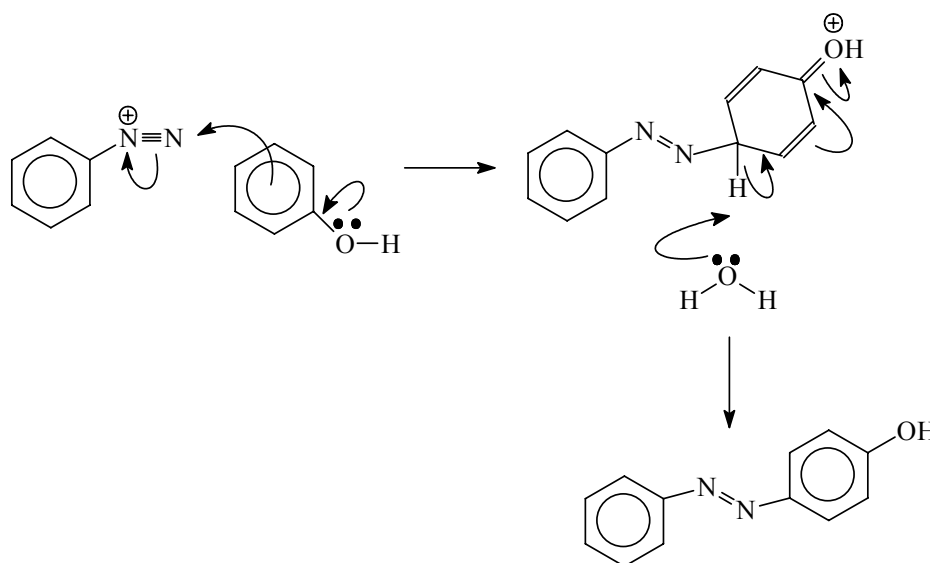
Hydrolysis

The following occurs if a solution of a diazonium salt is warmed up:



Coupling reactions

The mechanism is for interest only, you do not need to know it. Just remember that the diazonium salt is a powerful electrophile, so attacking phenols or other aromatic compounds.

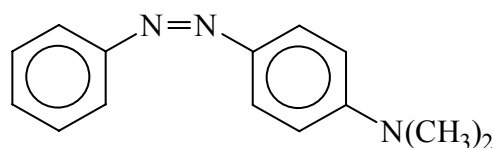


General method for synthesis of azo dyes

- Add a cold aqueous solution of sodium nitrite slowly (with cooling and stirring) to a cold solution of the amine compound in excess hydrochloric acid
- The temperature must not rise above 5°C .
- This solution (still cold) should then be added slowly with stirring to a solution of the coupling compound.
- This should be kept below 5°C the whole time.

Questions

1. Outline the preparation of butteryellow from phenylamine and the tertiary amine $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$. Make sure you mention all reagents and condition for the reaction.



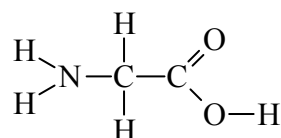
2. Briefly outline the importance of the manufacture of azo dyes from phenylamine. Include the detail of conditions and reagents, as well as a balanced equation for the formation of the diazonium salt of your choice.

Amino Acids

These are bi-functional compounds. They contain 2 functional groups:

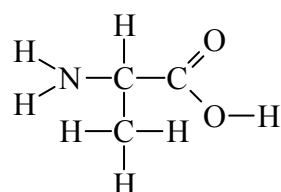
- A primary amine (in most cases) -NH_2
- The carboxylic acid group -COOH
- An amino acid must contain at least both of these functional groups.

The simplest amino acid is glycine:

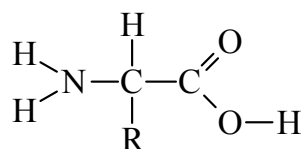


All the amino acids (the twenty vitally important ones biologically) are 2-amino acids. The amine and acid groups are both attached to the same carbon.

All can be named systematically, but in most cases the old names are used. Alanine is also known as 2-aminopropanoic acid, but alanine is the acceptable name to use.

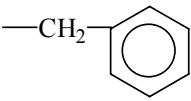
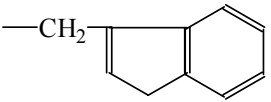
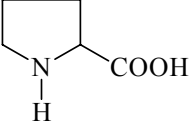


They have a general formula, which OCR insist you know.



They are also known as α -amino acids, because both the functional groups are attached to the alpha carbon.

Some amino acids, they only differ by the R- group.

Name of amino acid	R group	Abbreviation
Glycine	-H	gly
Alanine	-CH ₃	ala
Phenylalanine		phe
Serine	-CH ₂ OH	ser
Cysteine	CH ₃ SH	cys
Aspartic acid	-CH ₂ COOH	asp
Lysine	-CH ₂ CH ₂ CH ₂ CH ₂ NH ₂	Lys
Tryptophan		Try
Proline – a secondary amine		pro

Physical Properties and acid base characteristics of amino acids

Amino acids are:

- White solids
- With relatively high melting points glycine (the simplest) has a melting point of 235°C.
- Normally readily soluble in water
- Almost totally insoluble in non-polar solvents

They are very largely ionic compounds.

- The carboxyl group can lose a proton
- The amine group can gain a proton

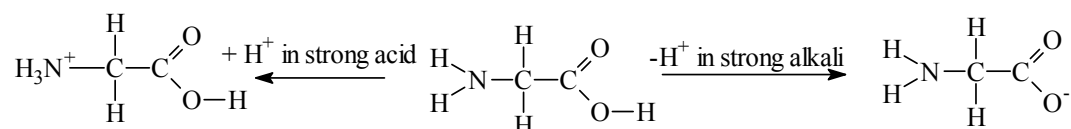
The result is a ZWITTERION. From the German for hermaphrodite, hybrid or mongrel!

Glycine mainly exists as:



- The strong attractions in the crystal cause the high melting point

In aqueous solution depending on the pH, they form either the neutral form, or the carboxylate will lose a proton, or the amino group will gain a proton.



For each amino acid there is a definite pH – the **isoelectric point** at which the acid and basic ionisations are equal.

- The molecule is effectively neutral – it carries equal and opposite charges
- This is rarely near pH 7 because the molecule ionisation tendencies are affected by the other groups in the molecule.

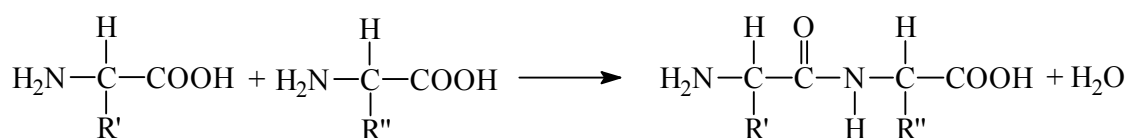
Aspartic acid – which has 2 –COOH groups – is acid in aqueous solution, while lysine with more amino than carboxyl groups is alkaline.

Due to this dual functionality, they are able to act as buffer solutions (able to maintain a reasonably constant pH with small additions of acid or alkali), and we will see later that the majority have optical activity.

How amino acids join together

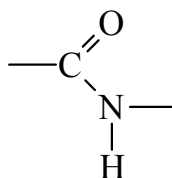
Amino acids join together in specific ways to form specific proteins.

One amino acid can join to another to form a substituted amide.

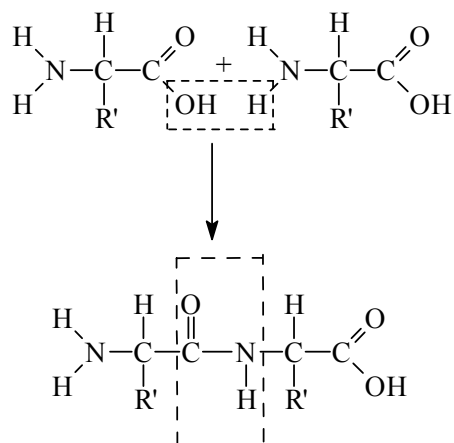


A dipeptide

This kind of bond between 2 amino acids is called a peptide bond or a peptide link.



The peptide link.



Two joined amino acids = dipeptide

- Three = tripeptide
- Many = polypeptide

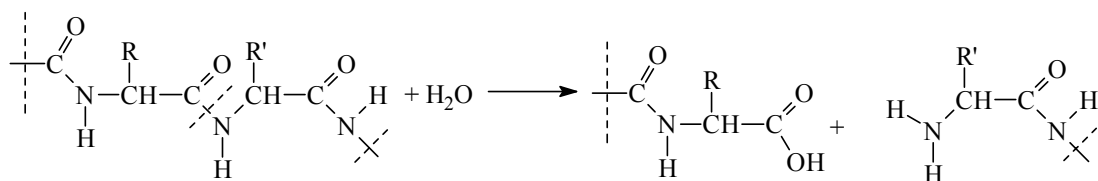
At some point a polypeptide becomes a protein. This can be put at 40 amino acids.

It is difficult to form a specific protein even though a polypeptide will have a free $-\text{COOH}$ and a free $-\text{NH}_2$.

Acid Hydrolysis of proteins

Proteins and peptides can be hydrolysed with hot concentrated (6 mol dm^{-3}). The protein is refluxed for about 24 hours.

This hydrolysis is the exact reverse of the formation of the peptide bond. A molecule of water is in effect added across the linkage to regenerate the original amino acid and carboxyl groups.



Questions

1. Alanine is one of the simplest amino acids.
 - a) Explain why the amino acid is said to be bifunctional
 - b) What is the systematic name of alanine
 - c) What is the product formed when alanine reacts with sodium hydroxide solution?
 - d) Write the formula of the structure formed when alanine reacts with hydrochloric acid.
 - e) Alanine combines with another amino acid to form a dipeptide. Write the displayed formula of the two possible dipeptides that can be formed from alanine and glycine.

2.
 - a) Write the full displayed formulae of phenylalanine $\text{H}_2\text{NCH}(\text{C}_6\text{H}_5)\text{COOH}$; cysteine, $\text{H}_2\text{NCH}(\text{CH}_2\text{SH})\text{COOH}$; and aspartic acid, $\text{H}_2\text{NCH}(\text{CH}_2\text{COOH})\text{COOH}$.
 - b) Which part of the aspartic acid molecule behaves as a base?
 - c) Which part of the phenylalanine molecule acts as an acid?
 - d) These three amino acids join together to form a number of tripeptides. Write the displayed formula of one of the possible tripeptide molecules containing all three amino acids.
 - e) How many different tripeptides (containing all three amino acids) are possible with these three amino acids?