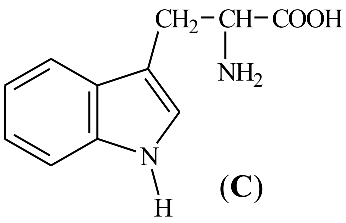
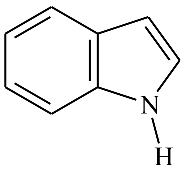
	Marks
• The side-chain of the amino acid tryptophan (**C**) is a substituted derivative of the heterocycle indole (**D**). Explain with the aid of diagrams whether you would expect indole to have aromatic stability or not. Would you expect the nitrogen atom of indole to be basic? Give reasons for your answer.	**3**



(**C**)



(**D**)

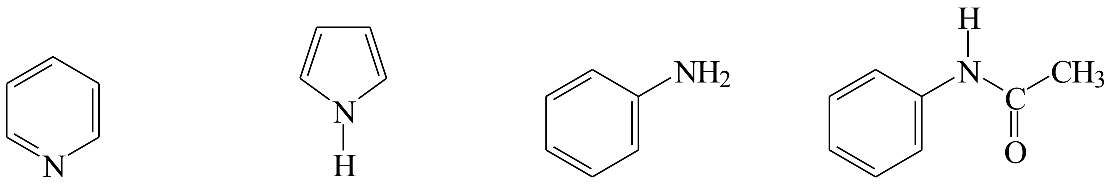
Indole is aromatic:

- **It is a fused ring system with all rings co-planar**
- **All atoms in the rings are *sp*^{2} hybridised with p-orbitals perpendicular to the ring**
- **It has 10 π electrons, which obeys the (4*n* + 2) rule with *n* = 2 required for aromaticity. These 10 electrons comes from 4 C=C (2 e$^-$ each) plus the lone pair from the nitrogen.**

Indole is not basic as the "lone pair" on the nitrogen is is part of the aromatic π system and thus not free to react.

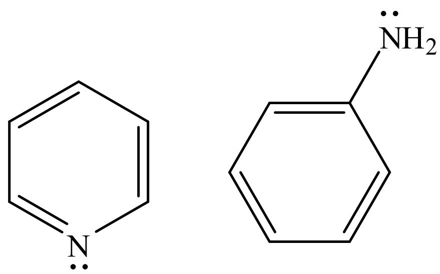
Marks
4

- Two of the following compounds are bases and two are not. Identify the two bases and explain, with the aid of diagrams, why they react with acids and why the other two compounds do not.



pyridine pyrrole aniline acetanilide

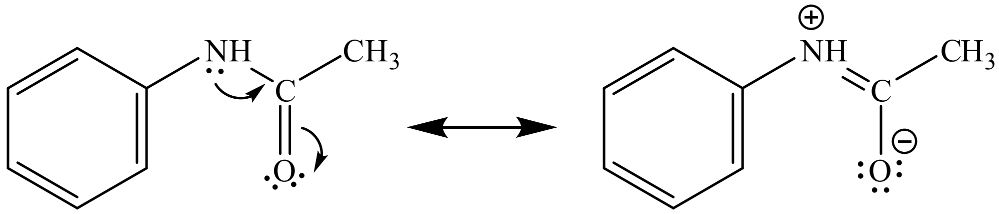
Pyridine and aniline are bases. Both compounds have lone pair of electrons on the N atom that can form bond to H^+ ion:



The nitrogen atom in pyridine is *sp*^{2} hybridized and the ring is aromatic with 6 π electrons coming from two C=C and one C=N bond. The nitrogen uses 3 of its 5 valence electrons to make two C-N σ bonds and one C-N π bond. Its remaining 2 e$^-$ are in a *sp*^{2} hybrid directed away from the ring and are not involved in the π bonding. They are thus available to bond to a proton.

In pyrole, there are two C=C bonds contributing 4 π electrons. The nitrogen is involved in three σ bonds (two C-N and one N-H), leaving it with 2 more electrons. These are in a p-orbital and form part of the π ring. There are therefore 6 π electrons making pyrole aromatic. There is no lone pair on nitrogen and it is therefore not basic.

In the amide acetanilide, the 'lone pair' on nitrogen is actually delocalized over the neighbouring C-N and C=O bonds. This strengthens the C-N bond, making it between a single and a double bond, and, as the 'lone pair' is actually involved in bonding, making it non-basic. This resonance stabilization is important in making the amide C-N bond strong in proteins.

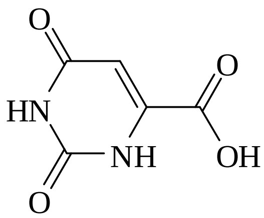


Marks
4

- Lithium salts, especially lithium carbonate, are commonly used in the treatment of bipolar disorder. Write the net ionic equation for the reaction which occurs between lithium carbonate and hydrochloric acid in the stomach.

$Li_2CO_3(s) + 2H^+(aq) \rightarrow 2Li^+(aq) + H_2O(l) + CO_2(g)$

Lithium orotate (as a monohydrate salt, $LiC_5H_3N_2O_4{\cdot}H_2O$) is a controversial alternative formulation sold in some health food stores. The orotate ion is the conjugate base of orotic acid, whose structure is shown below.



orotic acid

Like the carbonate, lithium orotate is taken orally. Using an equation, comment on any differences between the form in which lithium is bioavailable from these two lithium salts.

When lithium orotate, $LiC_5H_3N_2O_4$, dissolves in water, it forms $Li^+(aq)$ ions and orotate ions:

$LiC_5H_3N_2O_4(s) \rightarrow Li^+(aq) + C_5H_3N_2O_4^-(aq)$

Both lithium carbonate and lithium orotate thus give rise to the same form of lithium, $Li^{2+}(aq)$, when taken orally.

Like three of the bases found in DNA and RNA, orotic acid is a derivative of pyrimidine. Also like those bases, orotic acid and its salts have tautomers. Draw the structural formula of a tautomer of lithium orotate.

lithium orotate	tautomer of lithium orotate