Chapter 4

Reduction Reactions of Some Amino Pyrimidines

Abstract: The reactions of hydrated electron ($e_{aq}^-$) with 2-aminopyrimidine (AP), 2-amino 4-hydroxy 6-methylpyrimidine (AHMP), 2-amino 4-methylpyrimidine (AMP), 2-amino 4,6-dimethylpyrimidine (ADMP), and 2-amino 4-methoxy 6-methylpyrimidine (AMMP) were studied using pulse radiolysis in aqueous medium at near neutral pH. The bimolecular rate constant was found to be in the range $0.7\text{-}1.3 \times 10^{10} \text{dm}^3\text{mol}^{-1}\text{s}^{-1}$. Time resolved absorption spectra were characterized with absorption maximum in the range 310-340 nm at 2μs after the pulse. At higher time scale, all the spectra showed a first order decay. The electron adduct was found to react with the oxidant methyl viologen (MV$^2+$) and the yield of methyl viologen radical cation (MV$^{3+}$) was calculated in terms of G(MV$^{3+}$). These values were $2.4 \text{ to } 2.7 \times 10^{-7} \text{ mol J}^{-1}$. It is proposed that a carbon centered radical anion is formed initially which gets protonated ($k = 0.11\text{-}2.8 \times 10^5 \text{ s}^{-1}$) to form a nitrogen protonated carbon centered radical. Both these radicals are reducing in nature with respect to MV$^{3+}$. The carbon protonation observed in the case of uracil and some of its derivatives is fully ruled out in the present case.
4.1 Reaction of Hydrated Electron with Nucleobases

The radiation chemical studies of nucleobases and nucleosides are important in understanding the chemical basis of radiation induced lesions in DNA. The major reactive radicals that are produced during the radiolysis of water are the hydrated electron ($e_{aq}^-$) and hydroxyl radical (·OH). Hydrated electron reacts rapidly with the nucleobases leading to the formation of radical anions ($\kappa_1 \approx 10^{12} \text{ dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$). This radical anion may undergo a fast protonation ($k \approx 10^7 \text{ s}^{-1}$) at the heteroatom leading to the formation of a protonated electron adduct. In the case of uracil and its alkyl derivatives it is reported that protonation occurs both at oxygen and at carbon atoms.\(^2\)\(^4\) Generally protonation and deprotonation at heteroatom are faster than at carbon.\(^5\) At neutral pH, deprotonation at oxygen is facile as protonation, but deprotonation at carbon is much slower.\(^6\) It is identified that the redox properties of the oxygen protonated and the carbon protonated radicals are quite different.\(^4\) However, the conversion of the initially formed heteroatom protonated electron adduct to carbon protonated electron adduct is predominant only in purine nucleosides.\(^7\)\(^11\) These transformation reactions are catalysed by OH\(^-\) and phosphate buffer. It is also reported that these transformations are known to be controlled by both kinetic and thermodynamic factors.\(^7\)\(^11\) It is identified that pyrimidines reacts with hydrated electron in diffusion controlled rates.\(^1\) In the case of pyrimidines the initially formed electron
adduct undergo protonation at different rates. The electron adduct react further by addition of a proton at C-6 to give pyrimidin-5-yl radicals (more preferred).\textsuperscript{12,13} The protonation of electron adduct of cytosine in water is significantly fast.\textsuperscript{11} But in the case of uracil the protonation is comparatively slow. It is also observed that in uracil and its alkylated derivatives the conversion of oxygen protonated to carbon protonated electron adduct can be catalyzed by phosphate buffer.\textsuperscript{3,4} In this study, a detailed investigation of the properties of the electron adduct of some amino substituted pyrimidines in aqueous medium at near neutral pH has been carried out using the pulse radiolysis technique. These compounds are particularly important since they all possess fluorescence properties unlike other pyrimidine derivatives.\textsuperscript{14} They may also form ideal fluorophores for probing the charge transfer process in DNA, though such studies are only in the exploration stage.

4.2 Kinetics

The second order rate constants of the reaction of hydrated electron with 2-aminopyrimidine (AP), 2-amino 4-hydroxy 6-methylpyrimidine (AHMP), 2-amino 4-methylpyrimidine (AMP), 2-amino 4,6-dimethylpyrimidine (ADMP) and 2-amino 4-methoxy 6-methylpyrimidine (AMMP) in N\textsubscript{2} saturated aqueous solution containing 0.2 mol dm\textsuperscript{-3} of 2-methyl-2-propanol was determined by monitoring the decay of e\textsubscript{aq} at 700 nm as a function of substrate concentrations at pH 6. In all the cases the pseudo-first order
decay constant ($k_{obs}$) versus concentration plots were straight lines with very good correlation coefficients ($\approx 0.99$). Figure 4.1 is a representative plot obtained in the reaction of AP with $e_{aq}^-$. The inset shows a representative decay trace of the hydrated electron in the presence and in the absence of the substrate.

**Figure 4.1 Kinetics of the Reaction of $e_{aq}^-$ with AP:** Plot of pseudo first order rate constant of the decay of $e_{aq}^-$ at 700 nm ($k_{obs}$) versus concentration of AP at pH 6. **Inset:** Decay trace at 700 nm (i) in the presence and (ii) in the absence of AP.

The bimolecular rate constant was found to be in the range $0.7-1.3 \times 10^{10}$ dm$^3$ mol$^{-1}$ s$^{-1}$. The intercept ($5.2 \times 10^5$ s$^{-1}$) obtained in this plot may be due to the reaction of hydrated electron with some impurities.
present in water and /or by H\(^+\) formed during the pulse radiolysis. The second order rate constant obtained for the selected compounds are listed in table 4.1. It should be noted that these values are in agreement with the rate constants reported with other pyrimidines.\(^1\) In general, pyrimidines have high reactivity with hydrated electron because of the electron deficient pyrimidine ring.

**Table 4.1** Second-order rate constants (k) for the reaction of e\(_{aq}\)\(^-\) with aminopyrimidines at pH 6.

<table>
<thead>
<tr>
<th>Compound</th>
<th>k (dm(^3) mol(^{-1})s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-aminopyrimidine</td>
<td>1.3 \times 10^{10}</td>
</tr>
<tr>
<td>2-amino 4-hydroxy 6-methyl pyrimidine</td>
<td>8.05 \times 10^{9}</td>
</tr>
<tr>
<td>2-amino 4-methylpyrimidine</td>
<td>1.3 \times 10^{10}</td>
</tr>
<tr>
<td>2-amino 4,6-dimethylpyrimidine</td>
<td>7.8 \times 10^{9}</td>
</tr>
<tr>
<td>2-amino 4-methoxy 6-methylpyrimidine</td>
<td>7.01 \times 10^{9}</td>
</tr>
</tbody>
</table>

### 4.3 Properties of the Transient Absorption Spectra of Aminopyrimidines

The transient absorption spectra were recorded in the reaction of hydrated electron with 2-aminopyrimidine (AP) by the pulse radiolysis of N\(_2\) saturated aqueous solution containing 0.2 mol dm\(^{-3}\) of 2-methyl-2-propanol. The spectra were recorded at near neutral pH. The transient absorption spectrum at 2 \(\mu\)s after the pulse at pH 6 is characterized with an absorption maximum at 320 nm (figure 4.2). This spectrum showed a first
order decay at 320 nm \((k = 2.8 \times 10^5 \text{ s}^{-1})\), and the resulting spectrum has similar features but the absorption maximum is shifted to 330 nm.

**Figure 4.2 Reaction of \(e_{aq}^-\) with AP at pH 6:** Transient absorption spectra obtained from the pulse radiolysis of \(N_2\) saturated aqueous solutions of 2-aminopyrimidine (AP) \((1 \times 10^{-3} \text{ mol dm}^{-3})\) containing 2-methyl-2-propanol \((0.2 \text{ mol dm}^{-3})\) at 2 \(\mu\)s (O) and 40 \(\mu\)s (●) after the pulse at pH 6. **Inset:** MV** build up at 605 nm obtained from the reaction of the intermediate with MV^2+ at pH 6.
Methyl viologen (MV') was used as an oxidant to explore the reducing nature of the intermediate radicals. In the reaction of hydrated electron with AP, a strong absorption build of the methyl viologen radical cation (MV') is observed at 605 nm (see inset figure 4.2). The G values were calculated from the absorption trace of this build up of methyl viologen radical cation by taking a typical molar extinction coefficient (ε) of MV' as 12800 dm³ mol⁻¹ cm⁻¹ at 605 nm. The yields, G(MV'), the second order rate constants for the electron transfer reactions and the first order decay rate constants of the transients are compiled in table 4.2. In the reaction of AP, a G-value of 2.4 × 10⁻⁷ mol J⁻¹ is obtained at pH 6 which constitute about 89% of the total reaction. The percentage is calculated by taking a quantitative yield of the electron adduct as 2.7 × 10⁻⁷ mol J⁻¹ at pH 6. Therefore, the observed G value corresponds to the nearly quantitative yield of the electron adduct.
Table 4.2 Protonation rate constant (k) of the electron adduct of aminopyrimidines, the yields (G(MV")) and the second-order rate constant (k') for the reaction of their electron adducts with MV^{2+} at pH 6.

<table>
<thead>
<tr>
<th>Compound</th>
<th>k (s(^{-1}))</th>
<th>G(MV&quot;) / 10^7 mol J(^{-1})</th>
<th>k' / (dm^3 mol(^{-1}) s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-amino 4-hydroxy 6-methyl pyrimidine</td>
<td>2.8 x 10^5 (320 nm)*</td>
<td>2.4</td>
<td>1.1 x 10^9</td>
</tr>
<tr>
<td>2-amino 4-methylpyrimidine</td>
<td>2.5 x 10^4 (320 nm)*</td>
<td>2.7</td>
<td>4.6 x 10^9</td>
</tr>
<tr>
<td>2-amino 4, 6-dimethylpyrimidine</td>
<td>8.3 x 10^4 (320 nm)*</td>
<td>2.5</td>
<td>1.2 x 10^9</td>
</tr>
<tr>
<td>2-amino 4-methoxy 6-methylpyrimidine</td>
<td>2.8 x 10^5 (310 nm)*</td>
<td>2.7</td>
<td>1.8 x 10^9</td>
</tr>
<tr>
<td>2-amino 4-hydroxy 6-methyl pyrimidine</td>
<td>1.1 x 10^5 (340 nm)*</td>
<td>2.7</td>
<td>2.9 x 10^9</td>
</tr>
</tbody>
</table>

* wavelengths at which the rate constants were calculated; k' = k(electron adduct + MV^{2+})

The transient absorption spectrum obtained with 2-amino 4-hydroxy 6-methyl pyrimidine (AHMP) at near neutral pH is shown in figure 4.3. The transient absorption spectrum obtained at 2 μs after the pulse at pH 6 is characterized by an absorption maximum at 320 nm. This on fast decay (similar to AP) (k at 320 nm = 2.5 x 10^4 s\(^{-1}\)) transforms to a spectrum with an absorption maximum at 350 nm.

The reducing nature of the intermediate species was studied by the reaction with MV^{2+}. Very strong absorption build of MV^{2+} is observed...
at 605 nm indicating the reducing nature of the intermediate. The G value of this reaction is calculated from this absorption build up and it is found to be $2.7 \times 10^{-7}$ mol J$^{-1}$ at pH 6 and it corresponds nearly quantitative yield of the electron adduct.

**Figure 4.3** Reaction of $e_{aq}^-$ with AHMP at pH 6: Transient absorption spectra obtained from the pulse radiolysis of N$_2$ saturated aqueous solutions of 2-amino 4-hydroxy 6-methylpyrimidine (AHMP) ($1 \times 10^{-3}$ mol dm$^{-3}$) containing 2-methyl-2-propanol (0.2 mol dm$^{-3}$) at 2 µs (O) and 40 µs (●) after the pulse at pH 6. Inset: (i) MV$^{2+}$build up at 605 nm obtained from the reaction of the intermediate with MV$^{2+}$ at pH 6. (ii) Decay trace of the intermediate obtained at 320 nm, at pH 6.
In the case of 2-amino 4-methylpyrimidine, the transient absorption spectra obtained at 2 µs and 40 µs after the pulse at pH 6, are shown in figure 4.4. The build up of the methyl viologen radical cation obtained from the reaction of the intermediate with MV$^{2+}$ is shown in the inset of this figure.

**Figure 4.4 Reaction of e$_{aq}^-$ with AMP at pH 6**: Transient absorption spectra obtained from the pulse radiolysis of N$_2$ saturated aqueous solutions of 2-amino 4-methylpyrimidine (AMP) (1 × 10$^{-5}$ mol dm$^{-3}$) containing 2-methyl-2-propanol (0.2 mol dm$^{-3}$) at 2 µs (○) and 40 µs (●) after the pulse at pH 6. **Inset**: (i) MV$^{+}$ build up at 605 nm obtained from the reaction of the intermediate with MV$^{2+}$ at pH 6. (ii) Trace of the intermediate obtained at 320 nm, at pH 6.
The spectrum recorded at 2 μs after the pulse at near neutral pH is characterized with an absorption maximum at 320 nm similar to the typical electron adduct spectrum of pyrimidines.\cite{3,4,6} At higher time scale it shows a first order decay at 320 nm with a rate constant of about $8.3 \times 10^4$ s$^{-1}$. The spectrum recorded at 40 μs after the pulse is characterized with an absorption maximum at 340 nm. In this case also, the reducing nature of the transient intermediates was investigated by the electron transfer reaction of the electron adduct with methyl viologen and a very strong absorption build up characteristic of the methyl viologen radical cation (MV$^{**}$) was observed at 605 nm. The $G$ value of MV$^{**}$ ($G(\text{MV}^{**})$) was calculated as $2.5 \times 10^{-7}$ mol J$^{-1}$ which constitutes about 93% of the total reaction. By expecting very negligible direct reaction of $e_{aq}^-$ with MV$^{2+}$ under the experimental condition, the observed $G$ value gives a quantitative yield of the transient species. Based on the quantitative formation of the methyl viologen radical cation, it can be understood that the intermediate species formed in the reaction of AMP with hydrated electron is reducing in nature.

The transient absorption spectrum recorded in the reaction of 2-amino 4,6-dimethylpyrimidine (ADMP) with $e_{aq}^-$ at pH 6 is shown in figure 4.5. The spectrum obtained at 2 μs after the pulse is characterized by an absorption maximum at 310 nm with a broad band centered around
350 nm. However, at 40 μs after the pulse the spectrum shows decay at 310 nm \( (k = 2.8 \times 10^5 \text{s}^{-1}) \) and this spectrum is characterized with an adsorption maximum at 350 nm.

**Figure 4.5 Reaction of e_{aq}^- with ADMP at pH 6:** Transient absorption spectra obtained from the pulse radiolysis of \( \text{N}_2 \) saturated aqueous solutions of 2-amino 4,6-dimethylpyrimidine (ADMP) \( (1 \times 10^{-3} \text{ mol dm}^{-3}) \) containing 2-methyl-2-propanol \( (0.2 \text{ mol dm}^{-3}) \) at 2 μs (○) and 40 μs (●) after the pulse at pH 6. **Inset:** (i) MV" build up at 605 nm obtained from the reaction of the intermediate with MV²⁺ at pH 6. (ii) Absorption trace of the intermediate obtained at 310 nm, at pH 6.

The formation of MV" is also monitored at 605 nm and a \( G (G(\text{MV}^\text{"}) \) value of \( 2.7 \times 10^{-7} \text{ mol J}^{-1} \) is obtained. This constitutes nearly quantitative yield of the total reaction at near neutral pH. Therefore, the transient intermediate formed in the reaction of ADMP will be reducing in nature.
The transient absorption spectra obtained in the reaction of 2-amino 4-methoxy 6-methylpyrimidine (AMMP) with hydrated electron by the pulse radiolysis of \( \text{N}_2 \) saturated aqueous solution containing 0.2 mol dm\(^{-3} \) of 2-methyl-2-propanol at pH 6 is shown in figure 4.6.

Figure 4.6 Reaction of \( e_{aq}^- \) with AMMP at pH 6: Transient absorption spectra obtained from the pulse radiolysis of \( \text{N}_2 \) saturated aqueous solutions of 2-amino 4-methoxy 6-methylpyrimidine (AMMP) \( (1 \times 10^{-3} \text{ mol dm}^{-3}) \) containing 2-methyl-2-propanol \( (0.2 \text{ mol dm}^{-3}) \) at 2 \( \mu \text{s} \) (○) and 40 \( \mu \text{s} \) (●) after the pulse at pH 6. Inset: MV\(^{2+}\) build up at 605 nm obtained from the reaction of the intermediate with MV\(^{2+}\) at pH 6.

Similar to the other selected aminopyrimidines, it is observed that the transient absorption spectrum recorded at 2 \( \mu \text{s} \) after the pulse is characterized with an absorption maximum at 340 nm. At higher time
scale it shows a first order decay at 340 nm with a rate constant of about $1.1 \times 10^4 \text{ s}^{-1}$. In the electron transfer reaction with MV$^{2+}$ at near neutral pH, a G value $2.7 \times 10^{-7} \text{ mol J}^{-1}$ is observed and this represents quantitative yield of the electron adduct. From the quantitative formation of the methyl viologen radical cation it can be understood that the electron adduct formed in the reaction of AMMP is reducing in nature.

In general the $e_{aq}^-$ reacts with pyrimidines at diffusion controlled rates which leads to the formation of a radical anion and it subsequently gets protonated by water or H$^+$. It is reported that the cytosine radical anion rapidly reacts with water ($k = 3.5 \times 10^6 \text{ s}^{-1}$) with a half life of 210 ns.$^{11}$ However the electron adducts of uracil and thymine are longer-lived with respect to the protonation by water ($k \leq 2 \times 10^4 \text{ s}^{-1}$) but are protonated by H$^+$ at diffusion controlled rates ($k = 5 \times 10^{10} \text{ dm}^3\text{ mol}^{-1}\text{ s}^{-1}$).$^{16}$ The potential sites of attack in the case of uracil, cytosine and thymine derivatives$^4$ are the most electron affinic oxygen of the keto group. However, in the present case this attack is, likely, at the nitrogen (N(1) and/or N(3)). The observed spectrum measured at 2 µs after the pulse is attributed to the electron adduct of the aminopyrimidines. The spectral nature of these electron adducts are comparable to the electron adducts of other pyrimidine derivatives.$^{3,4,6,17,19}$ This electron adduct, being a strong Bronsted base, may get protonated by water. The fast decay of the initial spectrum could
potentially represent the protonation of the electron adduct. A significant difference in the optical density of the electron adducts and its protonated form has been reported in the case of thymine and uracil derivatives. In the present case too such a difference is observed (figures 4.2 - 4.6). The protonation of the electron adduct by water in the case of uracil and thymine is relatively slow \( (k = 10^4 - 10^5 \text{ s}^{-1}) \) and can be easily measurable in the pulse radiolysis scale. Similar rate constants are obtained in the present case with a lowest magnitude recorded for 2-amino 4-methoxy 6-methylpyrimidine (AMMP, \( k = 1.1 \times 10^4 \text{ s}^{-1} \)) and the highest for 2-aminopyrimidine (AP, \( k = 2.8 \times 10^5 \text{ s}^{-1} \)) and 2-amino 4,6-dimethylpyrimidine (ADMP, \( k = 2.8 \times 10^5 \text{ s}^{-1} \)). The protonation of the electron adduct will eventually lead to a nitrogen protonated (N-protonated) carbon centered radical as shown in scheme 4.1. The observed spectrum measured at 40 \( \mu \text{s} \) after the pulse is attributed to this electron adducts. The interpretation for the formation of the electron adduct (carbon centered radical anion, see scheme 4.1) and observed protonated electron adduct is further supported by the nearly quantitative yield of \( \text{MV}^{2+} \) (see table 4.2).
Scheme 4.1  Proposed mechanism of the reaction of $e_{aq}^-$ with amino substituted pyrimidines. AP: \( R = R' = H \); AHMP: \( R = \text{OH}, R' = \text{CH}_3 \); AMP: \( R = \text{CH}_3, R' = H \); ADMP: \( R = R' = \text{CH}_3 \); AMMP: \( R = \text{OCH}_3, R' = \text{CH}_3 \)

The carbon centered radical anion (electron adduct) can be a good reductant which can transfer one electron to the oxidant, methyl viologen. Such electron transfer reaction between the electron adduct and methyl viologen is a well established reaction in the case of pyrimidines derivatives.

The second order rate constants calculated for the reaction of electron
adduct with methyl viologen are in the range 1.1 - 4.6 x 10^9 dm^3 mol^-1 s^-1, which are comparable to the rate constants observed with other substituted pyrimidines.\textsuperscript{17}

The transformation of the initially formed heteroatom protonated electron adduct to a carbon protonated (C-protonated) electron adduct\textsuperscript{4,17} is also considered in the present case. However, such a transformation is fully ruled out due to the following reasons. The carbon protonated electron adduct is generally non reducing with respect to MV\textsuperscript{2+}.\textsuperscript{4} If we consider such a transformation reaction of the initially formed electron adduct of aminopyrimidines (e.g. 2-aminopyrimidine) the following transformation is expected (scheme 4.2).

\begin{center}
\textbf{Scheme 4.2} Carbon protonation of the electron adduct
\end{center}
As can be seen from scheme 4.2 that the carbon protonated electron adducts will be non reducing with respect to methyl viologen. If this is true, one can expect a competition between the reaction of electron adduct with methyl viologen and the transformation (C-protonated) of the adduct (non reducing). Under this condition reaction 4.5, 4.6 and equation 4.1 can be considered.

\[
\text{Electron adduct} + \text{MV}^{2+} \xrightarrow{k_2} \text{MV}^{**} \quad (4.5)
\]

\[
\text{Electron adduct} \xrightarrow{k_t} \text{C-protonated electron adduct} \quad (4.6)
\]

Where \(k_2\) is the second order rate constant and \(k_t\) is the rate of carbon protonation (assuming that the rate of decay of the initial spectrum is equal to the rate of carbon protonation). Under this condition, the actual G value of \(\text{MV}^{**}\) can be calculated from the following equation.

\[
G = 2.7 \times \frac{k_2 [\text{MV}^{2+}]}{k_2 [\text{MV}^{2+}] + k_t} \quad \text{(equation 4.1)}
\]

where 2.7 is the total yield of the electron adduct. According to this calculation the expected \(G(\text{MV}^{**})\) is 0.4. However, the observed \(G(\text{MV}^{**})\) is 2.4. This clearly rules out the formation of a non reducing carbon protonated electron adduct. This leads to the conclusion that a radical of reducing nature, similar to the electron adduct has been formed at 40 \(\mu\)s.
after the pulse. Therefore, the interpretation of the formation of a reducing electron adduct and subsequent protonation which leads to the formation of a reducing protonated electron adduct can be justified.

It can be assumed from the very similar spectral nature as well as its decay pattern that the reaction of $e_{aq}^-$ with the selected aminopyrimidine proceeds in a similar way. The rate of protonation is however marginally different depending on the nature of the substituents. For example the highest rate is observed in the case of 2-aminopyrimidine (AP, $k = 2.8 \times 10^5$ s$^{-1}$) and 2-amino 4,6-dimethylpyrimidine (ADMP, $k = 2.8 \times 10^5$ s$^{-1}$). However, the rate is considerably lower in the case of 2-amino 4-methoxy 6-methylpyrimidine (AMMP, $k = 1.1 \times 10^4$ s$^{-1}$) and 2-amino 4-hydroxy 6-methyl pyrimidine (AHMP, $k = 2.5 \times 10^4$ s$^{-1}$). This is understandable due to the presence of electron donating methoxy and hydroxyl groups (-I effect), which causes reduced proton affinity of the electron adducts of these compounds.

4.4 Conclusion

In conclusion, the results from the reaction of hydrated electron with some amino substituted pyrimidines in aqueous medium at near neutral pH are presented. The second order rate constants of the reaction were found to be in the range $0.7-1.3 \times 10^{10}$ dm$^3$ mol$^{-1}$ s$^{-1}$ and it is in the diffusion controlled range. The rates are therefore of the same order as
other pyrimidines. It is observed that spectral nature obtained with all these compounds are similar to that of other pyrimidines.\textsuperscript{1,4} The first order spectral decay with all these compounds is similar to that of uracil and thymine. The rate of protonation ($0.11 - 2.8 \times 10^5 \text{s}^{-1}$) of the electron adducts is also of the same order as uracil and thymine ($10^6 \text{s}^{-1}$). The rates, however, differ depending on the nature of the substituents. The rate of reaction of the electron adduct with methyl viologen is also of the same order as that from uracil and thymine. By and large, the properties of the electron adducts of the selected aminopyrimidines are largely similar to the properties of the electron adducts of uracil and thymine at near neutral pH.
References


