The Electronic Structures of Base Components of Nucleic Acids and Their Tautomers Calculated by CNDO Method

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The relative stability of the DNA bases and their tautomers is of interest in connection with the mechanism of mutation in which the conversion of the DNA bases into their tautomers has been supposed to be involved. By means of infrared spectra and X-ray diffraction *etc.*, the amino and the keto forms (usual forms) of the DNA bases have been confirmed to be more stable than the imino and the enol forms (rare forms) in solid state or in solution. Comparison of the energies for the usual and the rare forms obtained by the molecular orbital calculation was made by some investigators,[1,2] and the usual forms were found to be more stable than the rare forms for all bases. In these calculations, however, the electronic repulsion is not explicitly taken into account. In such circumstances, CNDO method[3] was considered to be more reliable in discussing the relative stability of molecules,[4] and it was applied to the four tautomers of purine.[5]

In the present communication, the total energies calculated by means of CNDO/2 method[3] for the usual and the rare forms of the bases of nucleic acids and a base analog, were compared and the relative stability among these compounds was discussed in relation to the mutagenesis. Bond lengths and bond angles for the usual forms of bases and a base analog were obtained from Spencer's data.[6] For the rare tautomeric forms, the geometry of the purine and pyrimidine rings was assumed to be the same as the usual form. Bond lengths for C–N and N–H bonds in the imino form were taken as 1.27 Å and 1.0 Å, respectively, and for C–O and O–H in the enol form, as 1.47 Å and 0.96 Å, respectively. The calculated total energies of the bases and the base analog in the usual and the rare forms are listed in Table 1. Except guanine,

TABLE 1. TOTAL ENERGIES FOR THE USUAL AND THE RARE FORMS OF THE BASES OF NUCLEIC ACIDS AND A BASE ANALOG (IN eV)

Bases	Usual form	Rare form	Difference
A	−2655.09	−2652.97	−2.12
G	−3156.11	−3156.68	+0.57
T	−2726.04	−2725.53	−0.51
C	−2326.68	−2325.53	−1.15
U	−2489.58	−2489.13	−0.45
FU	−3223.42	−3222.99	−0.43

the usual forms are more stable than the rare forms in agreement with the experimental results. For guanine, the rare form is found to be more stable than the usual form. But from X-ray diffraction and infrared spectra, guanine was shown to exist predominantly as the keto form in water and solid state. In connection with this, the following fact should be remarked; from the total energies calculateld by means of CNDO method for the zwitter ion and neutral form of glycine, it was predicted that the latter form was more stable than the former.[7] In fact, glycine is known to exsit as neutral molecule in gaseous state, although it exists as zwitter ion in water and solid state. Bearing this fact in mind, it may not be unreasonable to suppose that the predominant form of guanine in gaseous state is the so-called rare form, *i. e.*, the enol form. The ease of the conversion of the usual tautomeric form into the rare form decreased in the order, guanine>fluorouracil>uracil>thymine >cytosine>adenine, and this order is in accordance with Danilov's result.[2] It is interesting that fluorouracil is found to be more easily converted into the rare form than uracil and thymine in reference to the fact that fluorouracil is known to be mutagenic.

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