TABLE I

SPLITTING CONSTANTS IN GAUSS OF TRIPLETS DUE TO NUCLEAR SPINS OF NITROGEN (N) AND RING PROTONS (H)[a]

	Position					
Free radical of	1,9 (H)	2,8 (H)	3,7 (H)	4,6 (H)	5	10
Anthracene	2.74	1.57	1.57	2.74	5.56 (H)	5.56 (H)
Phenazine	1.93	1.61	1.61	1.93	5.14 (N)	5.14 (N)
Thianthrene	*b*	1.62	1.62	*b*	0 (S)	0 (S)
Phenothiazine	2.82	0.81	3.80	1.00	0 (S)	7.10 (N)
Lauth's violet	2.77	1.53	*c*	0.93	0 (S)	7.50 (N)
Methylene blue	2.66	1.36	*c*	0.88	0 (S)	7.08 (N)
Methylene violet	2.73	1.46	*c*	0.90	0 (S)	7.29 (N)

[a] For assignments see text. [b] Not observed. [c] Not completely resolved.

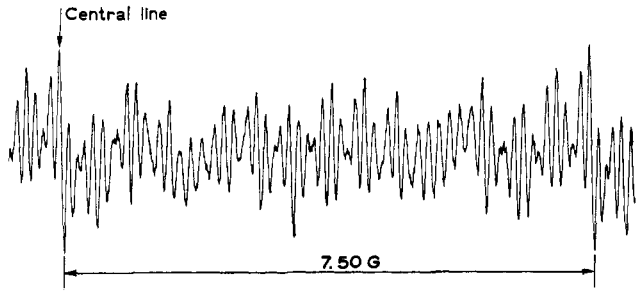
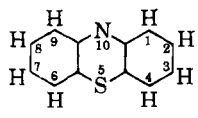


Fig. 1.—Section of the spectrum of Lauth's violet between the central line and one outer component of the central nitrogen triplet.

Recording and analyzing the spectra were hampered by (a) the instability of the free radicals, (b) the many hyperfine structure lines involved, and (c) the pronounced asymmetry of the spectra. This asymmetry, for which theoretical arguments have been given,[3] was most prominent for 7-hydroxyphenoxazine-3,10-dione (resazurin), and will not be discussed further here.

The splittings due to the central nitrogen atom could be determined with higher precision than previously[2]. In addition new splitting constants, due to various protons, were found and are collected in Table I. The inaccuracy in the values is $\leq 5\%$. Data on anthracene in tetrahydrofuran,[4] phenazine in either tetrahydrofuran or dimethoxyethane,[5] and thianthrene in sulfuric acid[6] are included for comparison. Our measurements on these radicals served as a check on the new results. The numbering used in Table I is as follows.



The assignment for the splitting due to the nitrogen atom in position 10 is unique. Comparison of phenothiazine with the phenazine data shows that replacement of nitrogen by sulfur in position 5 notably increases the spin density in position 10. Furthermore appreciable changes are introduced in various proton splittings. For thianthrene in sulfuric acid an incompletely resolved spectrum has been reported,[6] showing five lines at about 1.62 gauss spacing, attributed to the 2,3,7,8 protons. Since the largest proton triplet splitting occurring in phenothiazine is absent in the radicals substituted at the 3,7-positions, one may tentatively assign the largest splitting in phenothiazine to these positions. The other splittings are tentatively assigned by comparison with those of anthracene and phenazine. However, due to the addition of the auxochromic groups, the whole relative spin density pattern in the benzene rings may, of course, have changed, so that the proton splitting assignments are still ambiguous.

The last three substituted radicals of Table I show consistent splittings not only among themselves, but also when compared to a number of other radicals. These were 3-amino-7-dimethylaminophenothiazine (azure A), 3-dimethylamino-7-diethylamino-8-methylphenoxazine (capri blue GN), and 7-hydroxyphenoxazine-3,10-dione (resazurin). These are not included in the analysis, because of less detailed resolution of their spectra.

The splittings shown in Table I by themselves do not fully represent the observed details of the substituted phenazine spectra. To account for all lines observed, one has to assume additional splittings of about 0.5 gauss, which appear to be due to protons of the auxochromic groups. These splittings could not be fully analyzed.

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(4) A. Carrington, F. Dravnieks, and M. C. R. Symons, *J. Chem. Soc.*, 947 (1959).

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Electron Density and Nucleophilic Substitution in the Purine Ring

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Received October 3, 1963

In a recent paper in this journal, Sutcliffe and Robins[1] draw attention to some discrepancies between electron density calculations and experimental observations relative to the nucleophilic substitution in the purine ring. Without questioning the results of these authors concerning the possible occurrence in the course of

(1) E. Y. Sutcliffe and R. K. Robins, *J. Org. Chem.*, **28**, 1662 (1963).

such substitutions of different reacting species, we should like to stress that the appearance of discrepancies may be due, wholly or at least partially, to the misuse of the results of quantum-mechanical calculations by the aforementioned authors.

In the first place, electronic charges calculated for the isolated, unreacting molecules should not be used without care for the interpretation of their chemical reactivity. This reactivity depends on the properties of the molecule in the activated complex. Information about these properties, although rarely complete, may be reached, *e.g.*, through calculations of localization energies. While, in some cases, predictions based on the results of charge distribution in the ground state correlate with those obtained from the localization energies, this is in no way a general rule. We have already discussed the significance of this situation for the particular case of purine.[2,3] It also may be useful to add that the same observation concerns properties other than chemical reactivity, in particular the basicity which Jones and Robins[4] have also proposed to correlate recently in the case of purines with the electron density on the nitrogen atoms. Fundamental studies of this problem[5,6] show that the basicity of the nitrogens, in particular in a polyazaheterocyclic compound like purine, depend on a more complex set of factors than the electronic charges of the nitrogen atoms.

In the second place, the calculations to which Sutcliffe and Robins refer are those concerning the purine molecule, while the experimental results with which they are correlated refer to 2,6,8-trichloropurine. Now, it cannot, of course, be assumed without proof or at least without caution that the distribution of the indices responsible for nucleophilic reactivity in a 2,6,8-trisubstituted purine parallels exactly the distribution of the same indices in purine itself. No calculations are available, unfortunately, for 2,6,8-trichloropurine, but an illustration of the fact that this may not be the case is offered by the calculations available for 2,6,8-trihydroxypurine (the enol form of uric acid).[7] The calculations of localization energies predict that the most reactive center towards nucleophilic substitution in this molecule should be carbon 6, while in purine itself equal reactivity was found from that point of view for carbons 6 and 8.

In conclusion, while it is, of course, true that a careful examination of the actual species undergoing the reaction is a most important factor to be considered, it is not less important that the correlation with quantum-mechanical calculations refer to the proper or at least very closely related structure and that the theoretical indices (taken into account) be appropriate for the phenomenon investigated.

Acknowledgment.—This work was sponsored by Grant CY-3073 of the U. S. Public Health Service (National Cancer Institute).

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The Effect of an α-Bromine on the Dienone–Phenol Rearrangement

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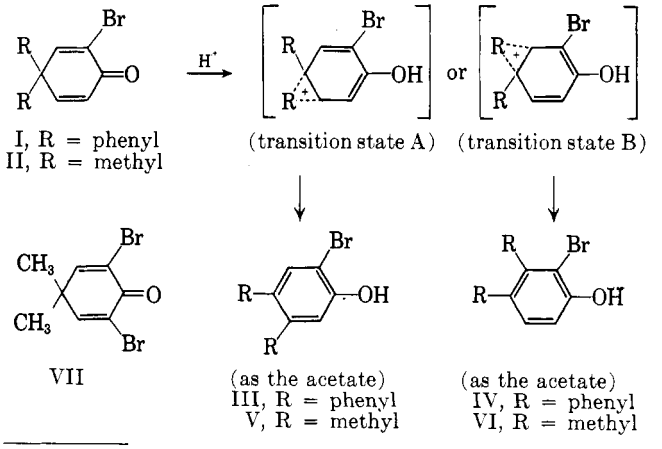
Received August 26, 1963

Kirk and Petrow have reported that substitution of a chlorine in the 2- and/or 4-position of $\Delta^{1,4}$-dien- and $\Delta^{1,4,6}$-trien-3-keto steroids results in a marked decrease in the facility with which they undergo the dienone–phenol rearrangement.[2] Likewise, Inhoffen and coworkers found that the rearrangement of the methyl ester of 2,4-dibromo-3-keto-12α-acetoxy-$\Delta^{1,4,6}$-cholatrienic acid was sluggish as compared to the unbrominated substance.[3] The availability of 2-bromo-4,4-diphenylcyclohexa-2,5-dienone (I) and 2-bromo-4,4-dimethylcyclohexa-2,5-dienone (II)[4] offered an opportunity to study the influence of an α-bromine atom on the dienone–phenol rearrangement unencumbered by subsequent reactions which often complicate such rearrangements in steroids.[5]

Acid-catalyzed rearrangements of either I or II in acetic anhydride led to two isomeric products. In both instances the major product was the 2-bromo-4,5-disubstituted phenyl acetate, the minor component being the 2-bromo-3,4-disubstituted phenyl acetate. The preference was about 2 to 1 in the dimethyl series but only about 1.2 to 1 in the diphenyl series.

The major product formed in a dienone–phenol rearrangement can generally be accounted for by considering the relative stabilities of the transition states for the possible modes of rearrangement. Of the two possible transition states A and B, A will be favored in that the positive charge is further removed from the electrophilic carbon atom bearing the bromine than is true for B. Steric factors also favor transition state A, but this effect cannot be a deciding factor, since a larger amount of the more sterically crowded product is



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