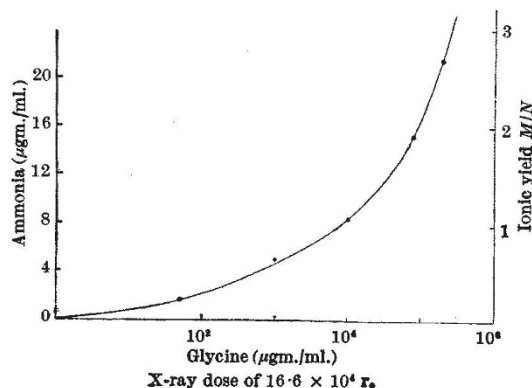


that one OH radical can affect more than one amino-acid molecule, which is unlikely, or that one ion pair can give rise to more than one OH radical, or that some of the radiation energy can form radicals by excitation rather than by ionization. In general, therefore, one would always expect an ionic yield exceeding unity in relatively concentrated solutions, independent of the nature of the solute, with perhaps the exception of very big molecules. A further possibility, but remote in the case of deamination, would be a chain reaction of some sort.



The effect of the configuration of the molecule containing nitrogen or NH_2 groups is shown by our experimental results as follows. Urea is very radio-resistant judged by its low protective power when mixed with the enzyme carboxypeptidase, whereas thiourea proved to be highly protective¹, liberating sulphur on irradiation², but neither of these compounds liberates ammonia. If, however, NH_2 is in the α -position of an amino-acid, ammonia is liberated, whereas the formation of ammonia from lysine-mono-hydrochloride is not increased when compared with glycine or alanine in equi-molar solution. Furthermore, glycine anhydride only gives traces of ammonia, and the peptide linkage in dipeptides (for example, leucyl-glycine) does not contribute to the ammonia yield. β -Alanine is less reactive than α -alanine. Histidine hydrochloride appears to be outstanding among the amino-acids examined, yielding a greater amount of ammonia in comparison with glycine, as if the glyoxaline part of the molecule is contributing to the effect. Glyoxaline on its own, however, yields too small an amount of ammonia to account for the increase of ammonia from histidine unless it becomes more reactive to an OH radical when joined to the alanine residue. The presence of the guanidine group in arginine does not raise the ammonia yield above that of glycine.

The X-ray dose applied in these experiments was of the order of 16×10^4 r.

These and related experimental results will be published elsewhere in detail.

*Note added in proof.—The ionic yield of this reaction also rises to more than 3 on increasing the concentration to 8 per cent.

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¹ Dale, *Brit. J. Rad.*, Supp. I, 46 (1947); *Biochem. J.*, **36**, 80 (1942).

² Stein and Weiss, *Nature*, **162**, 184 (1948).

³ Weiss, *Nature*, **153**, 748 (1944); **157**, 584 (1946); *Trans. Farad. Soc.*, **43**, 314 (1947).

Strengths of the Chloro-acetic Acids

It is well known that the introduction of chlorine atoms into acetic acid causes a rapid rise of dissociation constant (see accompanying table). If changes in the value of K are taken as a measure of the effect of the chlorine atoms, it would appear that the second chlorine atom has a *greater* effect than the first, and the third a *greater* effect than the second.

This particular phenomenon was discussed by Jenkins¹, who suggested that the progressive replacement of hydrogen by chlorine resulted in the stabilization of the ion by resonance among a rapidly increasing number of structures. We would like to suggest that this hypothesis is not really necessary, since we consider that the effect of structure upon ionization is truly measured, not by changes in K but by changes in $\ln K$, that is, by changes in the free energy of ionization ($-RT \ln K$). The justification for this is that changes in the free energy of ionization reflect directly changes in the energy and entropy factors, which are the fundamental quantities governing the equilibrium.

Further, we have shown, in a paper to be published elsewhere, the importance of additive relations in the free energy of ionization in interpreting the effect of structure on the dissociation of polysubstituted benzoic acids. In a similar manner, Stubbs and Hinshelwood² showed the significance of additive relations in the free energy of *activation* in explaining the effect of structure on reactivity for the benzoylation of disubstituted anilines.

The relevant free energy data for the chloro-acetic acids are given in the accompanying table (values of K_{25} taken from Watson, ref. 1).

Acid	$10^4 K_{25}$	Free energy of ionization ($-RT \ln K$) cal./mole	Change in the free energy of ionization for successive chlorine atoms. $\Delta(-RT \ln K)$ cal./mole
Acetic	1.82	+6450	—
Monochloro-acetic	155	+3830	-2620
Dichloro-acetic	5,140	+1760	-2070
Trichloro-acetic	121,000	-110	-1870

It will be seen that, when the effect of each successive chlorine atom is measured by the change in free energy of ionization it produces, the second chlorine atom is *less* effective than the first, and the third *less* effective than the second. In other words, the influence of chlorine atoms on the ionization shows a saturation effect.

This effect can readily be explained. The carbon-chlorine dipoles within each molecule, being in close proximity to one another, will be subject to mutual induction effects; and each dipole will reduce to some extent the influence of the others on the ionization. Thus the effect of two chlorine atoms will be less than the sum of the effects of the atoms taken singly.

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¹ Jenkins, *Nature*, **145**, 625 (1940), quoted by Watson, "Modern Theories of Organic Chemistry", 27 (Oxford, 1941).

² Stubbs and Hinshelwood, *J. Chem. Soc.* (in the press).