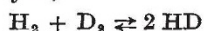


exchange (4). It might fail for some, conceivable but presumably rare, reaction mechanisms. It certainly does hold for a stepwise process, that is, one proceeding by consecutive reactions, or for any process in which only one isomer D_2 (and, consequently, D_{N-2}) exists, as is the case for methane.

Fig. 1 illustrates the application of the redistribution rate law (equation (6)) to literature data⁴ for methane. In this case ($N = 4$) u_2 equals: $1[\text{CH}_2\text{D}_2] + 3[\text{CHD}_2] + 6[\text{CD}_4]$. The complementary function $1[\text{CH}_2\text{D}_2] + 3[\text{CH}_2\text{D}] + 6[\text{CH}_4]$ may, of course, be used equally well. The previous⁴ analysis of these kinetic results, based on exponential kinetics for each of the isotopic species, is without foundation. Such kinetics will only hold for either special initial conditions or for special mechanisms.

The simplest redistribution reaction concerns $N = 2$. The example most frequently investigated, particularly in heterogeneous catalysis, is:



Exponential kinetics for [HD] (and the other isotopic species) are commonly observed. This result is another illustration of the redistribution rate law (equation (6)), since $u_2 = [\text{D}_2]$, and [HD] is linearly related to $[\text{D}_2]$ by the material balance.

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Partition Coefficients and Biological Activities

It was found¹ some time ago that the toxicities C_t of many physically toxic compounds could be estimated by the equation:

$$\text{Log}_{10} C_t/C_B = kP \quad (1)$$

where k is a constant equal to 0.012, C_B is a measure of the intensity of the toxicity, and P is the parachor, which is used as a measure of molecular volume. Equations similar to (1) have been used successfully for the estimation of partition coefficients², α , for organic compounds between organic solvents and water and of solubilities^{2,3} of organic compounds in water. When substances interact with a solvent, for example, by hydrogen bonding with the water, a further term E_A is required in the equation so that, for example:

$$\text{Log}_{10} \alpha = kP + E_A \quad (2)$$

This equation (2) was tested² on figures given by Collander⁴ for partition coefficients α between isobutanol and water and between ether and water with k equal to 0.012 as before. For simple esters and alcohols E_A values were found between -1 and -2.

Recently^{5,6}, the effects of substituents on the biological activity of phenoxyacetic acids as plant hormones and on the toxicities to bacteria for analogues of chloromycetin have been related to two variables. The first is the well-known Hammett sigma factor σ and the second π is the logarithm of the ratio of the partition coefficients of the substituted, x^S , and unsubstituted, x^H , compounds respectively between 1-octanol and water at about 27° C. From equation (2):

$$\pi = \text{Log}_{10} x^S - \text{Log}_{10} x^H = 0.012(P^S - P^H) + E_A^S - E_A^H \quad (3)$$

Table 1 shows that the values of π for unionized phenoxyacetic acid molecules do agree well with 0.012 ($P^S - P^H$) when the substituents contain only carbon and hydrogen. For such cases $E_A^S - E_A^H$ would be expected

to be zero. The parachors were calculated by a method previously described⁷. Except for fluorine attached directly to the aromatic nucleus $E_A^S - E_A^H$ for halogen compounds is about +0.35 (Table 2). The positive sign means that the interactions have increased the solubility in 1-octanol relative to water. All other interactions have so far been found to be negative. In the estimation of physical toxicities and solubilities no interaction terms seemed to be required for alkyl and aryl halides^{2,3}. Figures for ortho-substituents are not given in Table 2 or in the following list because the oxyacetic acid group will itself interact with water and groups close to each other do not appear to interact independently². The $E_A^S - E_A^H$ values calculated for the other groups are: 3-OCF₃, +0.28; 3-SCH₃, -0.49; 3-NO₂, -0.57; 4-NO₂, -0.61; 3-OCH₃, -0.64; 3-SO₂CF₃, -0.72; 3-OH, -0.78; 4-OCH₃, -0.79; 4-OH, -0.89; 3-CN, -0.92; 4-CN, -0.91; 3-COOH, -0.97; 4-N=NC₆H₅, -1.16; 3-COCH₃, -1.38; 4-COCH₃, -1.44; 3-NHCOCH₃, -2.21; 3-SO₂CH₃, -2.77. With the exception of 3-OCF₃, all these values are negative.

Substitution	π	0.012 ($P^S - P^H$)
None	0	0
2-CH ₃	0.68	0.48
3-CH ₃	0.51	0.48
4-CH ₃	0.52	0.48
2-C ₂ H ₅	1.22	0.96
3-C ₂ H ₅	0.97	0.96
3,4-(CH ₃) ₂	1.06	1.07
3,4-(CH ₃)	1.27	1.25
3,4-(CH ₃) ₄	1.40	1.55
3-n C ₆ H ₅	1.91	1.91
3-C ₆ H ₅	1.91	2.07

Substitution	π	0.012 ($P^S - P^H$)	$E_A^S - E_A^H$
3-F	0.13	0.06	+0.07
4-F	0.14	0.06	+0.08
3-Cl	0.76	0.42	+0.34
4-Cl	0.70	0.42	+0.28
3-Br	0.95	0.59	+0.36
4-Br	1.02	0.59	+0.43
3-CF ₃	1.09	0.67	+0.42
3-I	1.17	0.88	+0.29
4-I	1.26	0.88	+0.38
3-SF ₃	1.51	1.15	+0.36
3-SCF ₃	1.59	1.22	+0.37

The equation (3) should prove useful for the estimation of values of π . The term 0.012($P^S - P^H$) can be calculated immediately. It will be the same whenever a given substitution is made and equals π when the substitution involves only addition of carbon and hydrogen. The E_A values for an isolated interacting group and a given type of organic solvent appear to be nearly constant^{2,3} so that it will often be possible to suggest a value for $E_A^S - E_A^H$. However, interaction energies do depend on the solvent and too much confidence should not be placed in values obtained from the partition coefficients because 1-octanol might give interaction energies which differed considerably from those for the biophase. Hansch *et al.*⁶ realized this and when the value of π of -1.26 for 3-SO₂CH₃ from 1-octanol proved unsatisfactory, they suggested that a value of π equal to -0.47, which gave good agreement with all the biological results, should be used.

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