F. Nucleophilicity and Electrophilicity Scales

The kinetic methods developed in D were analogously employed to determine rate constants for the attack of carbocations and Michael acceptors at various C-nucleophiles (allylsilanes, allylstannanes, carbocyclic and heterocyclic arenes, enol ethers, enamines, enamides, diazoalkanes, metal-π-complexes, carbanions, isonitriles, ylides), hydride donors, halide and pseudohalide anions, N-nucleophiles (amines, pyridines, amide anions, azoles) as well as P-, O-, and S-nucleophiles. By defining benzhydrylium ions, quinone methides, and benzylidene malonates as reference electrophiles, which cover a reactivity range of more than 30 orders of magnitude, it has become possible to generate the most comprehensive nucleophilicity scale, presently available (reviews: # 124, 191, 219, 250, 262).

\[
\log k = s_N (N + E)
\]  

Figure 1. Rate constants for Electrophile-Nucleophile Combinations

It has been shown that equation 1, where electrophiles are characterized by one parameter \(E\) while nucleophiles are characterized by the solvent-dependent nucleophilicity parameter \(N\) and the nucleophile-specific sensitivity parameter \(s_N\) can be used to predict absolute rate constants with an accuracy of factor 10 – 100 in an overall reactivity range of 40 orders of magnitude.

\[
\log k_{20^\circ} = s_N (N + E) \quad (1)
\]

For qualitative analyses, the sensitivity factor \(s_N\) can be neglected, and as a rule of thumb one can expect electrophile-nucleophile combinations to take place at room
temperature if \((N + E) > -5\). Since diffusion limit is reached at \(k = 10^9 - 10^{10} \text{ M}^{-1}\text{s}^{-1}\), chemo-, regio- and stereoselectivity often break down when \((N + E) > 10\). As a consequence, most synthetically used reactions are found in the green corridor of Figure 2.

**Figure 2.** Where to find synthetically useful reactions

Open access to our database of electrophilicity and nucleophilicity parameters is provided at [http://www.cup.lmu.de/oc/mayr/DBintro.html](http://www.cup.lmu.de/oc/mayr/DBintro.html).

Poster presentations of our reactivity scales which can be used for synthesis planning can be downloaded [http://www.cup.lmu.de/oc/mayr/CDmayrPoster.html](http://www.cup.lmu.de/oc/mayr/CDmayrPoster.html).