

## PART TWO

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In Part 2 of this book, we will be directly concerned with organic reactions and their mechanisms. The reactions have been classified into 10 chapters, based primarily on reaction type: substitutions, additions to multiple bonds, eliminations, rearrangements, and oxidation–reduction reactions. Five chapters are devoted to substitutions; these are classified on the basis of mechanism as well as substrate. Chapters 10 and 13 include nucleophilic substitutions at aliphatic and aromatic substrates, respectively. Chapters 12 and 11 deal with electrophilic substitutions at aliphatic and aromatic substrates, respectively. All free-radical substitutions are discussed in Chapter 14. Additions to multiple bonds are classified not according to mechanism, but according to the type of multiple bond. Additions to carbon–carbon multiple bonds are dealt with in Chapter 15; additions to other multiple bonds in Chapter 16. One chapter is devoted to each of the three remaining reaction types: Chapter 17, eliminations; Chapter 18, rearrangements; Chapter 19, oxidation–reduction reactions. This last chapter covers only those oxidation–reduction reactions that could not be conveniently treated in any of the other categories (except for oxidative eliminations).

Each chapter in Part 2 consists of two main sections. The first section of each chapter (except Chapter 19) deals with mechanism and reactivity. For each reaction type the various mechanisms are discussed in turn, with particular attention given to the evidence for each mechanism and to the factors that cause one mechanism rather than another to prevail in a given reaction. Following this, each chapter contains a section on reactivity, including, where pertinent, a consideration of orientation and the factors affecting it.

The second main section of each chapter is a treatment of the reactions belonging to the category indicated by the title of the chapter. It is not possible to discuss in a book of this nature all or nearly all known reactions. However, an attempt has been made to include all the important reactions of standard organic chemistry that can be used to prepare relatively pure compounds in reasonable yields. In order to present a well-rounded picture and to include some reactions that are traditionally discussed in textbooks, a number of reactions that do not fit into the above category have been included. The scope of the coverage is apparent from the fact that more than 90% of the individual preparations given in *Organic Syntheses* are treated. However, certain special areas have been covered only lightly or not at all. Among these are electrochemical and polymerization reactions, and the preparation and reactions of heterocyclic compounds, carbohydrates, steroids, and compounds containing phosphorus, silicon, arsenic, boron, and mercury. The basic principles

involved in these areas are of course no different from those in the areas more fully treated. Even with these omissions, however, some 580 reactions are treated in this book.

Each reaction is discussed in its own numbered section.<sup>1</sup> These are numbered consecutively within a chapter, each section number preceded by the chapter number, so that reaction **16-1** is the first reaction of Chapter 16 and reaction **13-21** is the twenty-first reaction of Chapter 13. The order in which the reactions are presented is not arbitrary, but is based on an orderly outline that depends on the type of reaction. Within each section, the scope and utility of the reaction are discussed and references are given to review articles, if any. If there are features of the mechanism that especially pertain to that reaction, these are also discussed within the section rather than in the first part of the chapter where the discussion of mechanism is more general.

## IUPAC NOMENCLATURE FOR TRANSFORMATIONS

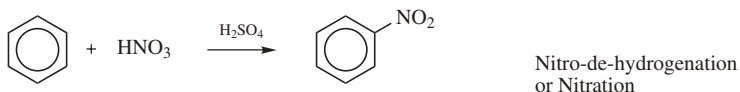
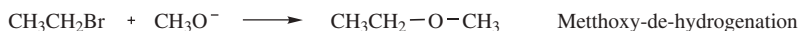
There has long been a need for a method of naming reactions. As most students know well, many reactions are given the names of their discoverers or those who popularized them (e.g., Claisen, Diels–Alder, Stille, Wittig, Cope, Dess–Martin). This is useful as far as it goes, but each name must be individually memorized, and there are many reactions that do not have such names. The IUPAC Commission on Physical Organic Chemistry has produced a *system* for naming not reactions, but transformations (a reaction includes all reactants; a transformation shows only the substrate and product, omitting the reagents). The advantages of a systematic method are obvious. Once the system is known, no memorization is required; the name can be generated directly from the equation. The system includes rules for naming eight types of transformation: substitutions, additions, eliminations, attachments and detachments, simple rearrangements, coupling and uncoupling, insertions and extrusions, and ring opening and closing. We give here only the most basic rules for the first three of these types, which, however, will suffice for naming many transformations.<sup>2</sup> The complete rules give somewhat different names for speech writing and indexing. In this book, we give only the speech-writing names.

<sup>1</sup>The classification of reactions into sections is, of course, to some degree arbitrary. Each individual reaction (e.g.,  $\text{CH}_3\text{Cl} + \text{CN}^- \rightarrow \text{CH}_3\text{CN}$  and  $\text{C}_2\text{H}_5\text{Cl} + \text{CN}^- \rightarrow \text{C}_2\text{H}_5\text{CN}$ ) is different, and custom generally decides how we group them together. Individual preferences also play a part. Some chemists would say that  $\text{C}_6\text{H}_5\text{N}_2^+ + \text{CuCN} \rightarrow \text{C}_6\text{H}_5\text{CN}$  and  $\text{C}_6\text{H}_5\text{N}_2^+ + \text{CuCl} \rightarrow \text{C}_6\text{H}_5\text{Cl}$  are examples of the “same” reaction. Others would say that they are not, but that  $\text{C}_6\text{H}_5\text{N}_2^+ + \text{CuCl} \rightarrow \text{C}_6\text{H}_5\text{Cl}$  and  $\text{C}_6\text{H}_5\text{N}_2^+ + \text{CuBr} \rightarrow \text{C}_6\text{H}_5\text{Br}$  are examples of the “same” reaction. No claim is made that the classification system used in this book is more valid than any other. For another way of classifying reactions, see Fujita, *S. J. Chem. Soc., Perkin Trans. 2* **1988**, 597.

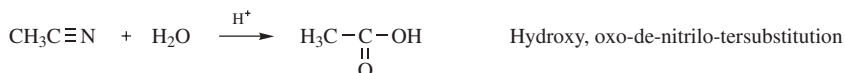
<sup>2</sup>For the complete rules, as so far published, see Jones, R.A.Y.; Bunnett, J.F. *Pure Appl. Chem.* **1989**, *61*, 725.

## Substitutions

A name consists of the entering group, the syllable “de,” and the leaving group. If the leaving group is hydrogen, it may be omitted (in all examples, the substrate is written on the left).



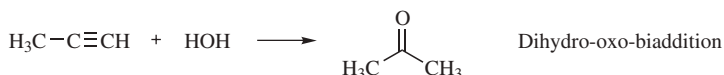
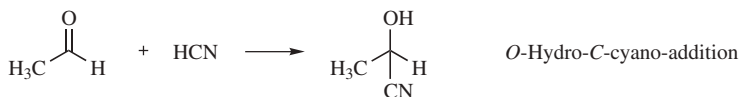
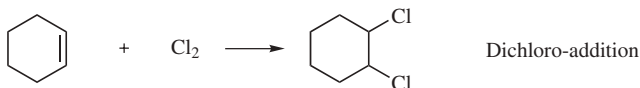
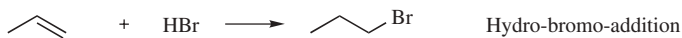
Multivalent substitutions are named by a modification of this system that includes suffixes, such as “bisubstitution” and “tersubstitution.”



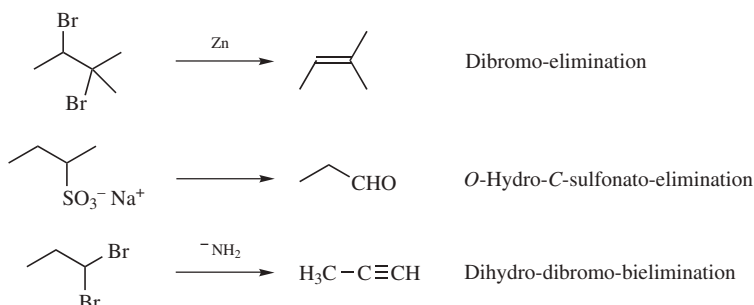
(Note: The nitrilo group is  $\equiv\text{N}$ .)

## Additions

For simple 1,2-additions, the names of both addends are given followed by the suffix “addition.” The addends are named in order of priority in the Cahn–Ingold–Prelog system (p. 155), the lower ranking addend coming first. Multivalent addition is indicated by “biaddition,” and so on.



*Eliminations* are named the same way as additions, except that “elimination” is used instead of “addition.”



In the reaction sections of this book, we will give IUPAC names for most transformations (these names will be printed in the same typeface used above), including examples of all eight types.<sup>3</sup> As will become apparent, some transformations require more rules than we have given here.<sup>2</sup> However, it is hoped that the simplicity of the system will also be apparent.

Two further notes: (1) Many transformations can be named using either of two reactants as the substrate. For example, the transformation methylene-de-oxobisubstitution above, can also be named ethylidene-de-triphenylphosphoranylidenebisubstitution. In this book, unless otherwise noted, we will show only those names in which the substrate is considered to undergo the reactions indicated by the titles of the chapters. Thus the name we give to **11-11** ( $\text{ArH} + \text{RCl} \rightarrow \text{ArR}$ ) is alkyl-de-hydrogenation, not aryl-de-chlorination, though the latter name is also perfectly acceptable under the IUPAC system. (2) The IUPAC rules recognize that some transformations are too complex to be easily fitted into the system, so they also include a list of names for some complex transformations, which are IUPAC approved, but nonsystematic (for some examples, see reactions **12-44**, **18-34**).

## IUPAC SYSTEM FOR SYMBOLIC REPRESENTATION OF MECHANISMS

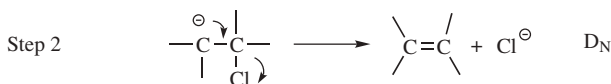
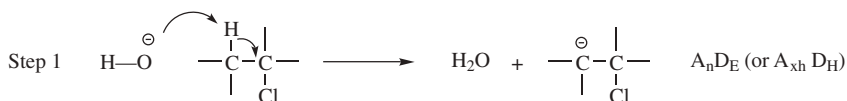
In addition to providing a system for naming transformations, the IUPAC Commission on Physical Organic Chemistry has also produced one for representing mechanisms.<sup>4</sup> As we will see in Part 2, many mechanisms (though by no means all) are commonly referred to by designations, such as  $\text{S}_{\text{N}}2$ ,  $\text{A}_{\text{AC}}2$ ,  $\text{E}_{1\text{cB}}$ , and  $\text{S}_{\text{RN}}1$ , many of them devised by C.K. Ingold and his co-workers. While these

<sup>3</sup>For some examples, see: attachments (**18-27**, **19-29**), detachments (**19-72**), simple rearrangements (**18-7**, **18-29**), coupling (**10-56**, **19-34**), uncoupling (**19-9**, **19-75**), insertions (**12-21**, **18-9**), extrusions (**17-35**, **17-38**), ring opening (**10-14**, **10-35**), ring closing (**10-9**, **15-60**).

<sup>4</sup>Guthrie, R.D. *Pure Appl. Chem.* **1989**, *61*, 23. For a briefer description, see Guthrie, R.D.; Jencks, W.P. *Acc. Chem. Res.* **1989**, *22*, 343.

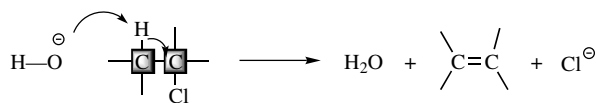
designations have been useful (and we will continue to use them in this book), the sheer number of them can be confusing, especially since the symbols do not give a direct clue to what is happening. For example, there is no way to tell directly from the symbols how  $S_N2'$  is related to  $S_N2$  (see p. 426). The IUPAC system is based on a very simple description of bond changes.<sup>5</sup> The letter A represents formation of a bond (association); D the breaking of a bond (dissociation). These are *primitive changes*. The basic description of a mechanism consists of these letters, with subscripts to indicate where the electrons are going. In any mechanism, the *core atoms* are defined as (1) the two atoms in a multiple bond that undergoes addition, or (2) the two atoms that will be in a multiple bond after elimination, or (3) the single atom at which substitution takes place.

As an example of the system, this is how an  $E1_{CB}$  mechanism (p. 1488) would be represented:



Overall designation:  $A_n D_E + D_N$  (or  $A_{xh} D_H + D_N$ )

In this case, the overall reaction is



and the core atoms are the two carbons in boldface.

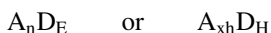
*Step 1, First Symbol.* A bond is being formed between O and H. Bond formation is represented by A. For this particular case, the system gives two choices for subscript. In any process, the subscript is N if a core atom is forming a bond to a nucleophile ( $A_N$ ) or breaking a bond to a nucleofuge ( $D_N$ ). If a noncore atom is doing the same thing, lowercase n is used instead. Since H and O are noncore atoms, the lowercase n is used, and the formation of the O—H bond is designated by  $A_n$ . However, because involvement of  $\text{H}^+$  is so common in organic mechanisms, the rules allow an alternative. The subscript H or h may

<sup>5</sup>There are actually two IUPAC systems. The one we use in this book (Ref. 4) is intended for general use. A more detailed system, which describes every conceivable change happening in a system, and which is designed mostly for computer handling and storage, is given by Littler, J.S. *Pure Appl. Chem.* **1989**, *61*, 57. The two systems are compatible; the Littler system uses the same symbols as the Guthrie system, but has additional symbols.

replace N or n. The symbol xh denotes that the  $H^+$  comes from or goes to an unspecified carrier atom X. Thus the term  $A_{xh}$  means that a bond is being formed between H (moving without electrons) and an outside atom, in this case O. The same subscript, xh, would be used if the outside atom were any other nucleophilic atom, say, N or S.

*Step 1, Second Symbol.* A bond is being broken between C and H. The symbol is D. In any process, the subscript is E if a core atom is forming a bond to an electrophile ( $A_E$ ) or breaking a bond to an electrofuge ( $D_E$ ). Since C is a core atom, the symbol here is  $D_E$ . Alternatively, the symbol could be  $D_H$ . The rules allow  $A_H$  or  $D_H$  to replace  $A_E$  or  $D_E$  if the electrophile or electrofuge is  $H^+$ . Because a core atom is involved in this primitive change the H in the subscript is capitalized.

*Step 1, Combined Symbols.* In step 1, two bond changes take place simultaneously. In such cases, they are written together with no space or punctuation:



*Step 2.* Only one bond is broken in this step and no bonds are formed. (The movement of a pair of unshared electrons into the C—C bond, forming a double bond, is not designated by any symbol. In this system bond multiplicity changes are understood without being specified.) Thus the symbol is D. The broken bond is between a core atom (C) and a nucleofuge (Cl), so the designation is  $D_N$ .

*Overall designation.* This can be either  $A_n D_N + D_N$  or  $A_{xh} D_H + D_N$ . The + symbol shows that there are two separate steps. If desired, rate-limiting steps can be shown by the symbol. In this case, if the first step is the slow step [old designation ( $E1_{CB}$ )], the designation would be  $A_n D_E + D_N$  or  $A_{xh} D_H + D_N$ .

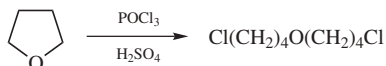
For most mechanisms (other than rearrangements), there will be only two A or D terms with uppercase subscripts, and the nature of the reaction can be immediately recognized by looking at them. If both are A, the reaction is an addition; if both are D (as in  $A_n D_E + D_N$ ) it is an elimination. If one is A and the other D, the reaction is a substitution.

Here, we have given only a brief description of the system. Other IUPAC designations will be shown in Part Two, where appropriate. For more details, further examples, and additional symbols, see Ref. 4.

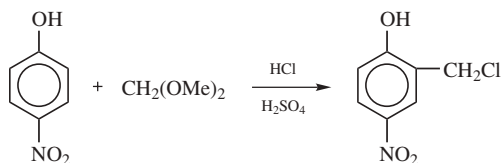
## ORGANIC SYNTHESIS REFERENCES

At the end of each numbered section there is a list of *Organic Syntheses* references (abbreviated OS). With the exception of a few very common reactions (**12-3**, **12-23**, **12-24**, and **12-38**) the list includes *all* OS references for each reaction. The volumes

of OS that have been covered are Collective Volumes **I–X** and individual volumes **80–81**. Where no OS references are listed at the end of a section, the reaction has not been reported in OS through volume **81**. These listings thus constitute a kind of index to OS.<sup>6</sup> Certain ground rules were followed in assembling these lists. A reaction in which two parts of a molecule independently undergo simultaneous reaction is listed under both reactions. Similarly, if two reactions happen (or might happen) rapidly in succession without the isolation of an intermediate, the reactions are listed in both places. For example, at OS **IV**, 266 is



This reaction is treated as **10-49** followed by **10-12** and is listed in both places. However, certain reactions are not listed because they are trivial examples. An instance of this is the reaction found at OS **III**, 468:



This is a chloromethylation reaction and is consequently listed at **11-14**. However, in the course of the reaction formaldehyde is generated from the acetal. This reaction is not listed at **10-6** (hydrolysis of acetals), because it is not really a preparation of formaldehyde.

<sup>6</sup>Two indexes to *Organic Syntheses* have been published as part of the series. One of these, Liotta, D.C.; Volmer, M. *Organic Syntheses Reaction Guide*, Wiley, NY, **1991**, which covers the series through Vol. 68, is described on p. 1896. There are two others. One covers the series through Collective Vol. V, Shriner, R.L.; Shriner, R.H. *Organic Syntheses Collective Volumes I-V, Cumulative Indices*, Wiley, NY, **1976**. An updated version covers through Collective Vol. VIII: Freeman, J.P. *Organic Syntheses Collective Volumes I–VIII, Cumulative Indices*, Wiley, NY, **1995**. For an older index to *Organic Syntheses* (through Vol. 45), see Sugasawa, S.; Nakai, S. *Reaction Index of Organic Syntheses*, Wiley, NY, **1967**.