Etymology as an Aid to Understanding Chemistry Concepts

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1 Understanding concepts and coming to grips with the subject of chemistry requires a thorough knowledge of the range of technical terms encountered. These terms are often derived from languages other than English, such as Greek, Latin, German, and French. Knowing the word origin of a particular term helps to identify its etymological roots and can make it easier to understand its use in science generally, and chemistry specifically. For example, consider the term *atom.* According to Dalton's theory, the atom is indivisible. Atom is derived from *a* for "without" and the Greek root *tomos* meaning "to slice". Once we understand that the atom is *unsliceable,* we can readily grasp the concepts behind *to*-*mo*graphy, micro*tome,* or ec*tomy.* In *tomography,* as applicable in magnetic resonance imaging (MRI), scanning is done of each slice of a body part along several gradients to a network of axes. By repeating the process across several slices of the body part, a complete image is reconstructed with the help of a computer. A *microtome* is an instrument for cutting thin sections of specimens. *Ectomy* means surgical removal; the suffix is found in many medical terms, such as *appendectomy.*

This paper describes how using etymology to understand
2 the meanings and relationships of chemistry terms can aid students in strengthening and expanding their grasp of chemistry concepts, particularly in organic chemistry. The discussion is not wholly new; the origins of some terms, briefly described, can be found in textbooks *(1–3).* The origins of many chemical terms, however, are overlooked or forgotten. Hence, I have undertaken the present effort to organize in a unified perspective word roots gathered from standard dictionaries *(4, 5).* Because of space constraints only the origins of terms most frequently found in chemical discussions are presented without resort to details and illustrations.

Terms of Contradiction

Continuing with *a,* the "negative" or "absence of" meanings attached to *asymmetric,* and *anisotropic,* and so on, can be understood. Using this approach students may realize that *azeotrope* also belongs to this category but only when knowing that *zeein* means "to boil" and *tropos,* "a turn" in Greek.
3 An *azeotrope* is a mixture of solvents (one of them usually water) that does not boil at any of its component's boiling points; rather, the mixture boils collectively at another single temperature.

Allos in Greek means "different" and is present in terms like *allomer* (*meros* means "part"), the *allo* series of compounds (*allosterols* and *alloamino* acids), *allosteric enzymes* and *allosteric effector. Allosteric* indicates a change of stereochemistry at the active site.

In *analog* and *anion* the common (Greek) root is *ana.*
4 That root in *analog* (*logos* has several meanings, including "word" and "reason") has the sense of "anew", while in *anion* (*ion* means "to go" in Greek) *ana* has the alternate sense of "against" or "negative".

Neo (*neos* means "new" in Greek) as a prefix to names of previously known compounds is used rather sloppily. *Neo* compounds are often isomers involving branching: *neopentane,* or unsaturation as in *neovitamins* A and B. They may be simple substitution–derivatized products, such as *neosaxitoxin,* or they may be completely new analogs, such as *neomycin* (*mykes* means a "mushroom" or "fungus" in Greek).

Ortho, Meta, Para, and *Peri* Prefixes

5 These terms are also of Greek origin. The first three prefixes, in most frequent use, describe the relationship between the two groups on a disubstituted benzene. *Orthos* means "straight", "upright", and "correct". *Para* means "beside" and *meta* is "after" or "beyond". The order of preference and ease with which electrophilic substitution takes place in substituted benzenes seem to suggest that the directive influences were probably understood before the positions were designated, although I could not obtain evidence of this from the literature.

In *ortho effect* and *orthofusion*, the *ortho* positions are involved. The prefix *ortho* is used to indicate complete (i.e., correct) hydration: for example, *orthoacids* (and *ortho-esters*), and *orthophosphoric acid.* With *meta*, the hydration is not complete, as in *metavanadate*. A *metastable ion* in unstable during its transit in the mass spectrometer. *Peri* translates as "around" and occurs in *perifusion* and *pericyclic* (reactions).

Iso, Topo, Pro, Proto, and *Caten* Prefixes

6 *Isomerism* is a hallmark of organic chemistry. In Greek *isos* means "equal" and *meros* means "part". The names of some isomers take the prefix *iso,* for example, *isoborneol.* In special cases of stereoisomerism given below, the stereoisomers are described by their relationships: *enantiomers, epimers,* and so forth. *Isotopes* (*topos* means "place" in Greek) have a single place (in the periodic table)—that of the element they represent. *Topochemistry* and *topological* (isomers) are also place-related terms.

Pre means before, as in *precursor* (*currere* means "to run" in Latin), and *precalciferol. Pro* is "supporting" (or "favoring") and occurs in *prochiral, proenzyme,* and *provitamin. Protoporphyrin (protos* means "first"*)* has the first model porphyrin skeleton in the biogenetic–synthetic sequence. *Proto* is also used as a prefix when the *proton* is meant, as in *prototropy* (*tropos* means "turn" in Greek). *Protium* is indeed the *proto*-element.

In Greek *caten* means "chain" or "ring". Without *cat*-
7 *enation* (of carbon), organic chemistry would be limited to single carbon compounds: CO, CO_2, CH_4, CH_2O, CH_3OH, HCO_2H, and so forth. *Catenanes* are large ring compounds.

Terms about Three-Dimensional Views

Stereos in Greek means "solid", that is, three-dimensional. *Stereoisomerism* is spatial isomerism due to the directional (co)valency of carbon. In Latin, *cis* means "on this side of" and *trans,* "on the other side of (across)". The *cis–trans* stereochemical notation has almost been completely replaced and extended by the more general E–Z notation in which *E* stands for *entgegen* ("opposite" in German) and *Z* for *zusammen* ("together" in German). *Syn* and *anti* are synonymous with *cis* and *trans,* respectively; they also denote orientation (folding) in fused multiple ring systems, for example, perhydrophenanthrene. *R* (*rectus* means "straight", i.e., "right") and *S* (*sinister* means "left" in Greek) reflect the chiral relationships of asymmetric carbons and are based on the direction in which the priority of the sizes of the groups attached to the asymmetric center would decrease, when viewed with the smallest group away from the eye.

Chiros in Greek means "hand" and *chirality* indicates
8 "handedness". In Latin *dexter* means "on the right" and *laevus,* "on the left"; hence *dextrorotatory* and *laevorotatory* optical isomers. *Racemic*, *enantiomeric* (*enantio* means "opposite" and *meras* means "part" in Greek), *enantiomorphic* (*morphe* means "shape"), *enantiotopic* (*topos* means "place"), *diastereomeric* (*dia* means "through" or "across"), *diastereotopic*, *isochronous* (*khronos* means "time"), and *anisochronous* are other terms used in stereoisomerism. *Racemus* in Latin means "a bunch of grapes". It was in grapes that the optically inactive form of tartaric acid was first noticed; hence, *racemization.*

Epimers (*epi* means "upon" or "peripheral" in Greek) have
9 inversion at only one asymmetric carbon; for example, *epiandrosterone* in which the $3\beta_{eq}$–OH is inverted to the $3\alpha_{ax}$–OH.

From Latin we can denote a functional group (i.e., a double bond) as *endo* ("internal"), or *exo* ("external"), to a ring. The *endo–exo* pair is also used to signify proximity of groups to rings in bridgehead systems. *Atropisomerism* is due to the restriction in turning (rotation) around a single bond. *Isotropy* and *anisotropy* are the turning (orientation) equally (i.e., no effect; *isotropy*) or unequally (*anisotropy*) of molecules or functional groups, for example, under the influence of an external magnetic field.

Terms That Indicate Pairs of Opposites

10 *Hetero* and *homo* are prefixes derived, respectively, from *heteros* meaning "other" and *homos* meaning "similar" in Greek: *heterocycles* and *homocycles, heteropolar* (electrovalent) and *homopolar* (covalent) bonds, *hetero* and *homo* polymers, and so forth. In *heterovalent* and *isovalent* resonances, the resonating structures have different or the same number of bonds, respectively. The azeotropes can be *homo* or *hetero* depending on whether there is one or more component(s) (apart from water) in the liquid phase distilling without change of composition. In the field of peptides and proteins, *homo* is used if amino acids are the sole constituents. If acyclic, such peptides are *homomeric;* if cyclic, *homodetic. Hetero* is used if in addition to amino acids, hydroxy acids are also present: *heteromeric* for acyclic and *heterodetic* for cyclic peptides. The *heterodetic* peptides are also called *depsipeptides* since they contain the depside groups (*depsein* means "to knead" in Greek). *Homo* compounds, by convention, contain one carbon (methylene group) more than their parents. In *homo* steroids, specifically, the five-membered Ring D is enlarged.

11 *Hyper* and *hypo* mean "over" and "under", respectively, in Greek. *Hyperchromic* and *hypochromic shifts* are about the increase or decrease of absorption coefficients.

Inter and *intra* are Latin prefixes referring to "between" and "within", respectively: *inter-* and *intramolecular* reaction, hydrogen bonding, and so forth. *Anchimeric* ("anchor" plus *meric*, or "part") *assistance* of neighboring groups is seen in some *intramolecular* reactions.

Dual Roots

Ambi and *amphi* are similar prefixes, the former of Latin and the latter of Greek origin, meaning "on both sides". While *ambi* appears to be mostly confined to literature (cf., "ambivalent", "ambience", "ambidextrous", etc.), *amphi* occurs in several chemical terms: *amphipathic* (a surfactant), *amphiprotic–amphoteric* substance, and *ampholyte*, an amino acid.

Hemi means "half", as in *hemisphere, hemiacetal, hemiketal, hemicellulose,* and *hemihydrate.*

12 *Meso* is from *mesos*, which in Greek means "middle": *mesobilirubin* and *mesoporphyrin, mesotartaric* (acid), *mesomethylene* (group), *mesohydric* (tautomerism), *mesomechanism. Resonance* (*re* means "back", *sonare* means "to sound") of Latin origin is synonymous with *mesomerism.* In *tautomerism, tauto* is the Greek root meaning "the same".

Quasi is a Latin prefix meaning "in appearance only". It occurs in *quasi-axial* bond, *quasi-equatorial* bond, *quasi-chair* conformation, and *quasi-boat* conformation. In these terms dealing with conformation, *pseudo* (meaning "false" in Greek) is also used. But, in the case of optical isomers, *quasi* is reserved for the term *quasi racemate.* On the other hand, *pseudo* is specific to *pseudo* acids (cf., *pseudo*nitrolic acid), *pseudoasymmetric* (carbon), *pseudoracemic* (compound), *pseudorotation* (e.g., in cyclopentane), and *pseudo* (first) order reaction.

Prefixes for More and Fewer in Count

13 An *apo* (meaning "from" in Greek) compound bears the name of the compound from which it is derived: *apocarotenoids* (by degradation), and *apomorphine* (by rearrangement).

The prefix *nor* is used in two contexts—as the short form of "normal" chain (when branched chain is the more usual), for instance, *norleucine,* and in the negative sense (cf., neither *nor*). *Nor, dinor, trinor* (or *trisnor*), and *tetranor* compounds have one, two, three, or four carbons fewer than the parent substance being referred. In the field of steroids, *nor* is specifically used to indicate a particular carbon (methylene group) beyond which the side chain has disappeared or to indicate the loss of angular Me groups: *18-nor* and *19-nor* steroids. *Nor* also indicates reduction in the size of the ring. In A-nor steroids, the A-ring is contracted from the usual six-membered to the five-membered carbocycle.

Bis is "twice" in Latin: *bisbenzimide. Kis* is a general pre-
14 fix from Greek that means "times". Several *tetrakis, pentakis,* and *heptakis* compounds have been synthesized.

Oligos in Greek is for few and is found in *oligomers, oligomeric proteins,* and *oligosaccharides.*

Per is a Latin prefix meaning "thorough". It indicates the highest degree of substitution, for example, perchloroethylene. Alternately, *per* can indicate combination with oxygen (peroxyacid, peroxide, and endoperoxide) or the addition of hydrogen (perhydronaphtahalene and perhydrovitamin A1) or any other element or radical.

Water, Fire, and Splitting Terms

15 Hydrolysis (*hydros* means "water" and *lysis* means "to loosen" or "to cleave" in Greek) is a special case of solvolysis. From esters, ammonolysis, alcoholysis, and acidolysis lead to the formation of amides, alcohols (by transesterification), and acids, respectively. Lysine owes its name to the fact that it is the product of *lysis* ("cleavage") of proteins. In Greek *lye* means separation, and occurs in *lyophilic* (colloid), and *lyophilization*. *Pyr* in Greek is fire: *pyrolysis* and *pyrocalciferols.* Pyruvic acid (*uva* means "grape" in Latin) is produced by heating (racemic) tartaric acid, found in grapes.

Hydrophilic (*philos* means "friend" in Greek) substances are soluble in water. Also from Greek we get *hydrophobic* (*phobia* means "fear" or "aversion"): these substances are *lipophilic* (*lipos* means "fat"). *Hygroscopic* (*hygros* means "wet" and *skopos* means "looking, observing, or seeking" in Greek) substances become wet when exposed to moist air.

Colorful Chemistry Terms

16 The pigments of flowers include *anthocyanins* (*anthos* means "flower" and *kyanos* means "blue" in Greek) and *anthoxanthins* (*xanthos* means "yellow"). In the *xanthoproteic* reaction of proteins, a yellow color is produced. *Khroma* is "color" and *phoros* means "a carrier" in Greek, yielding *chromophore*. *Auxochromes* (*auxien* means "to increase" in Greek) help intensify the absorption of color. A *bathochromic* (*bathos* means "depth" or "lowering") shift implies a shift to a lower frequency; its opposite is a *hypsochromic* shift (*hypsos* means "height" in Greek). The prefix *batho* occurs in dyes, for example, *bathophenanthroline* and *bathocuproin,* in which the color of the parent compounds is intensified by the presence of substituents.

17 Mixtures are separated into their individual compounds by *chromatography* (*graphein* means "to write"). *Pantos* in Greek means "all"; *panchromatic* photographic plates are sensitive to all parts of the visible spectrum. *Chlorophyll* is derived from *chloros* for "green" and *phullon*, "leaf". *Chlorine* also owes its name to its green color. *Phytochemistry* (*phyton* means "plant") means plant chemistry.

Krypto (*kryptos* means "hidden" in Greek) and *crypto* (Latin: *crypta*) are sometimes used interchangeably. The name *cryptocyanin* is based on its photosensitizing ability; *cryptocyanins* have the ability to sensitize the emulsions of photographic plates to invisible (infrared) radiation.

18 *Leuco bases* are colorless. *Leucine* is the decomposition product of albuminous proteins (such as egg white). *Leukemia* (*leuko* means "white" and *haema* means "blood" in Greek) is the type of cancer in which overproduction of white blood cells occurs. *Hemoglobin* (*globus* means "ball" in Latin) is red and *hemocyanin* (*kyanos* means "blue" in Greek) is blue.

Conclusion

Most chemical terms derive from meaningful word roots; some roots are conspicuous, while the meaning of others is not readily apparent. Learning the connection between the roots and the chemical meaning of terms can improve students' understanding of chemistry concepts, making them easier and more enjoyable to master.

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Literature Cited

1. Finar, I. L. *Organic Chemistry,* Volumes 1 and 2, 5th ed.; Pearson Education: London, England, 2000.
2. Morrison, R. T.; Boyd, R. N. *Organic Chemistry,* 6th ed.; Prentice Hall of India: New Delhi, India, 1994.
3. March, J. *Advanced Organic Chemistry–Reactions, Mechanisms, and Structure*, 4th ed.; John Wiley & Sons (Asia): Singapore, 2001.

Additional Resources

1. *Chambers Dictionary of Science and Technology;* Allied Publishers: New Delhi, India, 1986.
2. *Chambers English Dictionary;* Allied Publishers: Ahmedabad, India, 1989.

Etymologia:

1. Why is the understanding of the origins of names so important?
2. How the origin of “atom” helps to understand tomography?
3. Where could you find information on origin of chemical names?
4. Why does this paper not contain illustrations?
5. What is absent in asymmetry?
6. How does allo-threonine look like?
7. Is the usage of “neo” well defined?
8. Does the name indicate the ease of electrophilic substitution in meta-position in substituted benzene?
9. What could ortho mean?
10. How could you explain the name of pericyclic reactions?
11. Are enantiomers also isomers?
12. What could be prochiral?
13. Is the prochiral molecule chiral?
14. What does proliferation mean?
15. Are all stereoisomers chiral?
16. What is the difference between cis and trans?
17. What is the difference between the cis-trans and Z/E systems?
18. What kind of compounds is frequently described using syn and anti system?
19. Does R compound turn the light right? Why?
20. Name some chiral objects from everyday life.
21. Which acid is related to wine and racemate?
22. What is the difference between enantiomers and epimers?
23. Where does the endogenous compound come from?
24. Are all vitamins endogenous?
25. Are all crystals anisotropic? Why?
26. Which atoms are most frequently found in heterocyclic structures?
27. What kind of bonds is formed in homodetic peptides?
28. How does depsipeptide look like (*)?
29. How does homoserine look like?
30. Is it easy to make a hypersensitive person to react?
31. Name at least one intramolecular reaction.
32. What does amphibia mean?
33. What does hemisphere mean?
34. Which compounds have the well known mesomeric structures?
35. How to define a pseudoasymmetric compound?
36. How many carbon atoms are in leucine molecule? Is the number the same in nor-leucine?
37. What is the difference between the use of “di-“ and “bis-“ in chemical nomenclature (*)?
38. Is it easy to guess which meaning of “per” should be used? Why?
39. What is the product of ammonolysis of ethyl acetate?
40. What is the product of hydrolysis of protein?
41. What is separated during lyophilization?
42. What does pyrogen mean?
43. What should be used in xanthoproteic reaction?
44. Where does the colour of flowers come from?
45. How is the prefix “batho” used?
46. Where does the name “chromatography” come from? How was this method developed?
47. Which colours are recorded in panchromatic photography?
48. What is used to make the photographic emulsion sensitive to infrared light?
49. What kind of decomposition produces leucine from egg white?
50. Where could you find hemoglobin?