Nittala S Sarma
School of Chemistry
Andhra University,
Visakhapatnam 530 003, India
Email: nittalas@lycos.com

Chemistry Concepts and Vocabulary from Root Words

Although chemistry impacts largely on the society and civilization, the subject is still viewed with awe. This is because the language of chemistry of which the technical terms are an integral component, is not easily comprehensible even for the practicing scientists; let alone the layman. However, many of these terms, in English, can be noted as derived from a few affixes of Greek and Latin origin, e.g., *ortho, tropo, mer, meta, iso, para, hetero, syn, homo, topo, dia* and *pseudo*. Identifying the roots from which a term is formed can help understand it better, and even predict what a new term to be encountered stands for. The meanings and significance of various root words occurring in technical terms as also several unique words of chemistry are explained.

1. Introduction

The word alchemy is Arabic but its actual source is traced to more than one, e.g., Khem (Egypt) or Khemia (Greek word for melting and alloying of metals).

– Editor's note

Alchemy (Arabic: *al* the; *chymia* fluid)[1] was the Egyptian art of 'pouring' to convert other metals into gold and in the preparation of the elixir of life. Xenobiotics (Greek: *xenos* guest/stranger; *bios* life) are man-made chemicals foreign to the Earth's ecosystem. From alchemy to the xenobiotics, the journey of chemistry was an intimate involvement with the progress of civilization. Several common terms of the day got into chemical vocabulary and in course of time, the *vice versa* also happened, enriching the language. Over the years, chemists have enjoyed exclusivity – social as well as scientific. This is not only a tribute to them for their achievements, but also a reminder of their inaccessibility and tendency to treat good chemistry as their preserve. In the present chemical age, more than ever before, chemistry needs to be taken to the masses, and particularly to the non-specialists, including but not limited to the specialists of other branches working on the borders of chemistry. This can probably be promoted by explaining the language of chemistry in more simple terms. Chemistry language consists of (i) symbols, formulae and chemical equations, on which several reviews/

Keywords
Introductory chemistry, interdisciplinary, vocabulary, language of chemistry, curriculum.

monographs are available, and (ii) vocabulary of chemical terms, on which the available information is extremely limited. Dictionaries [1,2] or glossaries [3] and standard textbooks of chemistry [4-7] do serve as reference material, but do not provide a systematic vocabulary learning *vis a vis* the concepts. In fact, it is the common experience that many terms might be understood *per se* but that their origins are not known so well. This acts as a limiting factor as one advances. For in all phenomena, including the learning process, the law of diminishing returns applies restricting the continued ability of the learner. On the other hand, acquiring new knowledge can become a child's play if the structure and the organization of the chemical terms are known well.

As classical Greek and Latin languages are not spoken now having been replaced by modern Greek and Italian, the meanings of the classical Latin and Greek roots have not changed, unlike what could have happened if the languages were in common use.

The word English itself is from 'Angleish', the Germanic language of the immigrant Anglo Saxons (AD 450-550) of the British Isles. Hence, it is no wonder that upon the Norman conquest (AD 1066) of England, and the consequent influence of scientific scholars and their scholarly languages of Latin and Greek that followed, classical Greek and Latin terms were adopted for the new scientific concepts that developed. As these classical languages are not spoken now having been replaced by modern Greek and Italian, the meanings of the classical Latin and Greek roots have not changed, unlike what could have happened if the languages were in common use. Hence, from the language point of view, the terms have a sort of permanence. But from the (dynamic) science point of view, the terms can at best indicate the level of knowledge that existed. For, as the concepts get more and more refined due to advancement of science, the terms coined originally may not fully explain, nay mislead occasionally. In such a situation, stretching the etymology approach beyond a point may prove counter-productive. The IUPAC have done yeomen service by standardizing the chemistry terms, defining them precisely and in quite a few cases, recommending the use of new terms in place of old confusing ones [3]. However, in the case of most chemistry terms in use, the etymology approach can be extremely useful to a new starter, and perhaps educators.

The origin of each term, and in a few cases their historical background were probed from available literature.

2. Methodology

An extensive list of technical terms in current popular usage was initially prepared from the IUPAC Compendium [3] and standard textbooks of various branches of chemistry [4-7]. From this list, such terms involving not-so-obvious etymology were sifted out. The origin of each term, and in a few cases their historical background were probed from available literature. [3-7] The chemistry terms for which the information is thus available in a piecemeal fashion, were then grouped under substantive topics with minimum possible overlap. The inclusion of a term in a particular topic and sequence was based on continuity of the cumulative account and its effectiveness in terms of clarity, objectivity and freedom from redundancy. Due to the space constraint, illustrations of chemical structures are avoided, even though it could have added to the clarity of the terms (concepts) being described. The abbreviations Gr., L., and Ger. stand respectively for Greek, Latin and German throughout.

3. Approach

In a stand alone article, I have recently presented a few foreign (Greek, Latin, French and German) roots from which many organic chemistry terms are formed [8]. In the present article, I concentrate on the generic origin and significance of various general chemistry terms from the domains of physical chemistry and inorganic chemistry.

As an illustration of the approach, let us examine the Greek root *kata* (or *cata*). It has different related meanings: down/back/in order. Catalyst (*lein* to loosen), cataphoresis (*phorein* to bear), catabolism and katamorphism are words in the first sense. A catalyst helps break bond(s). In cataphoresis (which is the same as electrophoresis), migration (of the charge-bearing suspended particles, e.g., protein macromolecules) takes place under the influence of an electric field. Catabolism is the breakdown of complex organic molecules by living organisms (resulting in the liberation of energy). Katamorphism (*morphe* shape), in the field

Let us examine the Greek root *kata* (or *cata*). It has different related meanings: down/back/in order.

of geology, is the breaking-down process of metamorphism, as opposed to the building up process of anamorphism (*ana* up). In the sense of 'back', *cata/kata* is present in catacoustics/cataphonics – the branch of acoustics that deals with echoes. In the third sense of 'in order', the catalogues (*legein* to reckon) of books, chemicals etc. are well known.

The now common word 'atom' (Gr. *a* without, *tomos* to slice) coined by Dalton, means unsliceable. The knowledge of the etymology of 'atom' is helpful to comprehend terms like tomography, microtome, hysterectomy, etc [8]. The term 'molecule' is from *moles* that means mass in Latin.

4. Discussion

4.1 *Lighting Up*

'Lumen' is light in Latin. 'Luminescence' is emission of light otherwise than by incandescence (and so at a relatively cool temperature); its mechanism is chemical in chemiluminescence and biochemical in bioluminescence (Gr. *bios* life). In triboluminescence (Gr. *tribein* to rub), light results from the rubbing together of the surface of certain solids. 'Piezoluminescence' (Gr. *piezein* to press; piezochemistry is the study of the effect of high pressures on chemical reactions; piezoelectricity is the electric polarization of some anisotropic stress-deformed crystals) is the luminescence observed when certain solids are subjected to a change in pressure. Sonoluminescence (L. *sonare* to sound) is induced by sound waves.

In triboluminescence (Gr. *tribein* to rub), light results from the rubbing together of the surface of certain solids.

The suffix 'escence' of these terms, of Latin origin, indicates an inchoative meaning, [1] and is present in terms e.g., iridescence, opalescence, fluorescence, effervescence, etc. In iridescence (Gr. *iris* rainbow), a play of colours is caused by interference as on bubbles. Opalescence is milky iridescence. Fluorescence of substances such as fluor (spar) is the emission of light of larger wavelength than that to which the substance is exposed. On removal of the source, the fluorescence disappears. But in phosphorescence of substances such as phosphor, the luminescence

The suffix 'escence' of these terms, of Latin origin, indicates an inchoative meaning, [1] and is present in terms e.g., iridescence, opalescence, fluorescence, effervescence, etc.

The solutions exert pressure, called osmotic pressure (Gr. *osmos* impulse, to push).

persists for more than 0.1 nano seconds after excitation. The action of acid on carbonates causes effervescence (L. *fervere* to boil) of carbon dioxide.

4.2 *Principle Bound*

Colligative (Gr. *col* together; *ligare* to bind) properties are the properties coming under a general principle. In a solution, these properties are dependent on the concentration of solute, and not on its nature. The solutions exert pressure, called osmotic pressure (Gr. *osmos* impulse, to push). (As a side note, *osme*, in Greek means odour, a reason why the element osmium was called so). The osmotic pressure depends on the tone differential (Gr. *tonos* pitch, tension; L. *tonus*) of two solutions across a semi-permeable membrane. Osmolality and osmolarity (now replaced with osmotic concentration) are quantitative expressions based on the rational activity of water [3].

Cryoscopy (Gr. *cryos* frost) is the study of the effect of dissolved substances on the freezing points of solvents. Ebullioscopy (L. e out; *bullier* to boil) is the study of the effect of dissolved substances on the boiling point of solvents.

4.3 *Bound in Deed*

A ligand (Gr. *ligare* to bind) is an atom/molecule/radical/ion, which forms a complex with a central atom. The suffix *and* (that signifies the specific purpose) of ligand is present in coronand, cavitand, cryptand, podand, spherand, etc. They rhyme with errand (Old Norrish *arr* messenger). A coronand (L. *coranus* crown) is a monocyclic ligand assembly that contains three or more binding sites, e.g., the O atoms of crown ether; the resulting adduct is called coronate. Cavitands are compounds having a cavity large enough to host/accommodate other molecules. The products are inclusion compounds. A cryptand (Gr. k*ryptos* hidden) like a coronand, is also a molecule with three or more binding sites held together by covalent bonds, and having a cavity; but in which another molecular entity can hide by bonding with the binding sites. The terms podand and

A ligand (Gr. *ligare* to bind) is an atom/molecule/radical/ion, which forms a complex with a central atom. The suffix *and* (that signifies the specific purpose) of ligand is present in coronand, cavitand, cryptand, podand, spherand, etc.

spherand are used for certain specific ligand assemblies [4].

In mathematics, similar rhyming terms are operand, multiplicand, radicand, summand, etc. An operand is a quantity upon which a mathematical operation is performed. A multiplicand is a number to be multiplied by another. A radicand is the quantity under a radical sign. A summand is a part of a sum. In psychology, analysand is a person undergoing psychoanalysis.

Hapticity (Gr. *haptein* to fasten) is the number of ligand atoms simultaneously bound to a metal cluster. *Chela* is the latinised form of *chele* in Greek. It is the prehensile claw of an arthropod (animal). Chelate is a coordination compound in which a central metallic ion is attached to an organic molecule at two or more positions. In Latin, *clathrare* is to furnish with a lattice. Clathrate is a molecular compound having one component enclosed in the cavities of another component. Clathrochelates have both the features of chelate and clathrate, e.g., the cage complex formed from dimethylglyoxime, BF_3 and Co (III). They are also called cryptates, since the metal (Co) is hidden at the center of the cage. *Agostos* in Greek is to clasp/to draw towards/to hold oneself. Agostic designates structures in which a H atom is bonded to a C (or Si) atom as well as (an unsaturated) metal centre.

Catena, in Latin, means chain. Catenation (of carbon) is involved in most organic and some inorganic compounds. In naming the inorganic and co-ordination polymers, as per the IUPAC nomenclature, the constitutional repeating unit (CRU) is first selected and suitably prefixed. For example, the polymer $[Sn(CH_3)_2]_n$ is named as catena-poly[dimethyl tin] [9].

Catena, in Latin, means chain. Catenation (of carbon) is involved in most organic and some inorganic compounds.

4.4 *Kinds of Sorption*

Sorption (L. *sorbere* to suck in) is of different types – absorption (*ab* from), adsorption (*ad* to), physisorption, chemisorption and perisorption. The ab/ad duo is illustrated with the Latin phrases *ab initio* (from the beginning, i.e., from scratch) models, and *ad infinitum* (to limitless end, i.e., infinite) dilution. In absorption, the whole of the absorbing medium (solid or liquid) is engaged,

Sorption (L. *sorbere* to suck in) is of different types – absorption (*ab* from), adsorption (*ad* to), physisorption, chemisorption and perisorption.

The prefix 'syn' (Gr. *syn* together) is associated with synchronous (*chronos* time), synopsis/ synoptic (*opsis* view), synthesis (*thesis* a placing; if the placing is only an assumption that is yet to be tested, it becomes hypothesis), etc.

e.g., (photometric) absorption coefficient. In adsorption, the surface layer only is involved, e.g., adsorption chromatography, adsorption hysteresis, adsorption isostere, adsorption isotherm, and adsorption potential. In hysteresis, the effect lags behind its cause; adsorption hysteresis (Gr. *hysteros* later) occurs when adsorption and desorption values deviate from one another. *Stereos* is solid in Greek. Adsorption isostere (Gr. *isos* equal) is for a given (the same) amount of solid – its capacity of adsorbing a constant (or costant excess) amount of substance under different pressure-temperature conditions.

Physisorption is the abbreviation of physical adsorption, and chemisorption of chemical adsorption. Perisorption (Gr. *peri* thorough) is an extremely effective adsorption of a gas by a solid with the formation of an almost molecular mixture of the two substances.

4.5 *Placing Together*

The prefix 'syn' (Gr. *syn* together) is associated with synchronous (*chronos* time), synopsis/synoptic (*opsis* view), synthesis (*thesis* a placing; if the placing is only an assumption that is yet to be tested, it becomes hypothesis; biosynthesis and photosynthesis are mediated through the action of *bios* and *photos*, i.e., life and light respectively), etc. *Sym* is an identical prefix, as in symbiosis and symposium (*posis* drinking). Perhaps, the symposia were meant to celebrate the scientific successes than for deliberations!

4.6 *Good to be*

'*Eu*' is a Greek prefix, meaning good. 'Eutectic' (Gr. *tekein* to melt) relates to a mixture of two or more substances having a minimum melting point. Such a mixture behaves in some respects like a pure compound. Because of the sharp melting point, the eutectic mixture was originally thought to be a single compound. A eutectic mixture, in aqueous solution, is called cryohydrate, and the eutectic point as the cryohydric point (see above for *cryo*). The property of being easily melted is called 'eutexia'. A eucolloid (Gr. *kolla* glue, *eidos* form) has a large

particle diameter, more than 250 nm. In a euatmotic reaction, a single vapour phase is produced during an isothermal, reversible reaction between two (or more) solid phases. A euhedral (*hedra* base) crystal has well defined faces (it is also called an idiomorphic crystal; *idios* own, distinct in Greek), formed due to the free room available during crystallisation. Its opposite is allotriomorphic (see before) crystal.

'*Isos*' in Greek is for equal. With iso as prefix, several terms occur.

4.7 *Equal in Some Way*

'*Isos*' in Greek is for equal (see above). With iso as prefix, several terms occur, e.g., isobar (Gr. *baros* weight), isoelectric point, isohydric solutions, isenthalpic reactions, isomerism (*meros* part), isomorphism (*morphe* shape), isopleth (*plethos* great number), isotactic/isotaxy (*taxis* arrangement), isothermal (*therme* heat; read temperature!), isotonic (*tonos* pitch), isotope (*topos* place) and so on.

In atmospheric chemistry, charts are prepared of property isolines. Isochore (Gr. *chora* space) is a curve relating quantities measured under conditions in which the volume remains constant. Isohaline (Gr. *halos* salt) is a line drawn on a map through points of equal salinity in the sea. Isohyet (Gr. *hyetos* rain) is a contour line of equal rainfall. Isopiestic (Gr. *piezein* to press) is of a system (with conditions described) having equal pressure throughout. Isopycnic (or isopycnal) (Gr. *pyknos* dense) is a line on a chart joining points of the same atmospheric (or ocean water) density. Isotach (Gr. *tachys* swift) is a line on a chart joining points of equal wind speed.

Isotopomer (Gr. *meros* part) is the contraction of isotopic isomer. Isotopomers have the same number of each isotopic atom but differing in their positions.

4.8 *Similar and Different*

4.8.1 ***Similar (Iso/homo):*** Isotopes (*topos* place) occupy the same place (position) in the periodic table; that of the same element. Isobars (*baros* heavy) have the same number of the mass contributing neutrons and protons together. Isotones are nuclei of different elements but with the same number of neutrons. Isodiapheres (Gr. *pherein* to carry) are nuclides having the same difference between totals of neutrons and protons. Isologues are

Isozyme, or isoenzyme is one of a group of related enzymes catalysing the same reaction but having different chemical, physical, and biochemical properties.

compounds with similar molecular structure but containing different atoms of the same valency. Isotopomer (Gr. *meros* part) is the contraction of isotopic isomer. Isotopomers have the same number of each isotopic atom but differing in their positions. Isotopomers can be either constitutional isomers or isotopic stereoisomers. The suffix mer occurs in various other terms, e.g., elastomer (Gr. *elastikos* to drive), rotamer, etc. This affix, in co-ordination nomenclature, means meridional (*mer*-isomer), as opposed to facial (*fac*-isomer), two geometrical descriptors, apart from *cis* and *trans*. Isotopologue is a molecular entity that differs only in isotopic composition, e.g., H_2O, HOD, D_2O. Isozyme, or isoenzyme is one of a group of related enzymes catalysing the same reaction but having different chemical, physical, and biochemical properties.

Isohydric solutions have the same H^+ ion concentration (pH value). Isoelectric point is the pH at which conductivity (and viscosity) is minimum. An isodisperse substance is dispersible in solutions having the same pH. Isovalent resonance is the form of resonance in which all resonance structures contain the same number of bonds. Isosteric (Gr. *stereos* solid) molecules have similar size and shape.

In crystallography, isometric system is the cubic system. Isodimorphous substances exist in two isomorphous crystalline forms. Isodesmic structure (Gr. *desmos* a chain; *desme* bundle) is crystal structure with equal lattice bonding in all directions (and no distinct internal groups).

Isohydric solutions have the same H^+ ion concentration (pH value). Isoelectric point is the pH at which conductivity (and viscosity) is minimum.

Isocycles have the same element in the ring structure. Isopolyanions are polymeric anions in which no extra elements are present. Isopoly anions are very stable complexes, e.g., heptamolydate, also called as the paramolybdate ($(Mo_7O_{24})^{6-}$).

A prefix of similar meaning is homo (Gr. *homos* similar), e.g., homocycles, homovalent resonance, homopolar bond, etc. The homopolar bond is more commonly known as covalent bond. A homoazeotrope (Gr. *zeiin* to boil; see zeolites below) has only one liquid phase distilling without change of composition.

Homopolymers contain a single monomer as the repeating unit, e.g., polythene (ethylene is the monomer) and natural rubber (isoprene is the monomer). Homochiral is when the optical isomers are enantiomerically (in old literature, enantiomers were referred to as antipodes) pure (enantiopure). Complexes with only one type of ligand are called homoleptic (Gr. *leptos* slender). Superposable ligands are called homomorphic. Homotopic groups (or atoms) of a molecule are those related by an n-fold (n=2,3, etc.) rotation axis, e.g., Cl atom in $CHCl_3$ (3-fold) and COOH group in chiral tartaric acid (2-fold).

The opposite of iso/homo is hetero (Gr. *heteros* other), e.g., heterocycles, heterovalent resonance, etc.

4.8.2 ***Different (Hetero):*** The opposite of iso/homo is hetero (Gr. *heteros* other), e.g., heterocycles, heterovalent resonance, etc. Heterovalent resonance is when the various resonance structures contain different number of bonds. Heteropolar bond is an ionic bond and is known by other names also, e.g., electrovalent bond, polar bond, and electrostatic bond. A heteroazeotrope has two or more liquid phases distilling without change of mean composition. The opposite of this is heterozeotrope with liquid constituents of limited miscibility. Heteropolymers contain monomers of different structures and heteroleptic complexes have different ligands.

Homocatenation is when only one element/structural moiety is involved, and heterocatenation is when different elements (as in pyrophosphate) are involved. Heteropoly anions, with appropriate elements embedded in the cage structure e.g., $(PMo_{12}O_{40})^{3-}$ are more stable than isopolyanions.

4.9 *Negation*

'A' (or 'an') is a prefix used for opposite meanings, e.g., amorphous (*morphe* shape), anharmonic (Gr. *harmos* a joint fitting), asymptotic (Gr. a+ *sym* together+ *ptotos* apt to fall), aneroid (Gr. *neros* wet+*eidos* form), etc. Agranular carbon is a monogranular or monolithic carbon material with homogeneous microstructure. Aglycon (or, aglycone) is the non-sugar compound remaining after replacement of the glycosyl group from a glycoside by a

'A' (or 'an') is a prefix used for opposite meanings, e.g., amorphous (*morphe* shape), anharmonic (Gr. *harmos* a joint fitting), asymptotic (Gr. a+ *sym* together+ *ptotos* apt to fall), aneroid (Gr. *neros* wet+*eidos* form), etc.

Il, im and in are similar-meaning prefixes, often in the negative sense like *un*, e.g., imbalance, immiscible, impermeable, inactive, incongruent. But in quite a few cases, they are also used in the positive sense.

H atom. Agonist, in English means attack/threat. In (bio)chemistry, it stands for a substance that can bind to cell receptors and produce its own response. The opposite of agonist is antagonist. Antagonist is a substance that reverses or reduces the effect induced by an agonist.

4.10 *Antagonism – But not Always*

De (L. off/from) is usually a prefix used when an opposite meaning is to be conveyed, e.g., decoupling, degenerate (=fallen from a noble state; degenerate orbitals have about the same energy), dehydration, denatured (spirit), demulsification, descending (order) etc. However, in desiccation (L. *sicca* dry) and deliquescent (L. *scendo* growing/ becoming), de is used as an affirmative prefix.

Il, im and in are similar-meaning prefixes, often in the negative sense like *un*, e.g., imbalance, immiscible, impermeable, inactive, incongruent (L. *conguere* to run together, e.g., incongruent melting), indistinguishable, indivisible, inelastic, inert, insignificant etc. But in quite a few cases, they are also used in the positive sense, e.g., illuminate , illustrate, implant, incandescent (L. *candere* to glow), incinerate (L. *cineris* ashes), incline (L. *clinare* to lean), inflammable, innoculate, inseminate, insect (L. *secare* to cut), etc.

4.11 *False (Pseudo)*

Pseudo means false in Greek. This prefix *pseudo* also occurs in a variety of other contexts, e.g., pseudoaxial, pseudoequatorial, pseudo (zero, first, second, etc.) order reactions, pseudopericyclic (transformation), pseudo-copolymer, pseudooligomer, pseudo-reversible (indicator), and pseudoureas (isoureas; now obsolescent).

In cyclopentane ring, *puckering* occurs due to the strain which, however, rotates among the 5 carbons in such a way that at any given time, no particular C is out-of-plane. This effect is called pseudorotation. A special case of pseudorotation is Berry pseudo

rotation. In the trigonal bipyramid (TBP) molecule like that of PF_5, two F atoms should behave differently from the 3 others. However, they behave identically (as shown in the ^{19}F NMR) due to a fast scrambling resulting in a new TBP structure (*via* a square planar transition state). Because the two TBP structures are related to each other by simple rotation, the process is called pseudorotation. As this was first suggested by Berry, it is also called Berry pseudorotation.

In the trigonal bipyramid (TBP) molecule like that of PF_5, two F atoms should behave differently from the 3 others. However, they behave identically (as shown in the ^{19}F NMR) due to a fast scrambling resulting in a new TBP structure (*via* a square planar transition state).

4.12 *Turning Related*

Tropos, in Greek means 'a turn'. This root word is one of the largest contributors of scientific terms, particularly of chemistry and biology. Allotropy (*allos* different) is the existence of an element in two or more solid, liquid or gaseous forms, in one phase of matter. Allotropy owes its origin to differing bond angles. For example in white phosphorus, P-P-P bond angle is 60^0 (tetrahedral) while in black phosphorus, the angle is 90-100°. Polytropic processes are those that satisfy the condition $PV=C$, where C is a constant. Isotropic (opposite: aniosotropic) medium is one for which the physical properties e.g., magnetic susceptibility or elastic constants do not vary with direction. Thixotropy (Gr. *thixis* action of touching) is the property of showing a temporary reduction in viscosity when shaken or stirred, e.g., paints.

Liquid crystals exhibiting thermotropy or lyotropy, do so when the transition to liquid crystalline phase occurs as the temperature is changed, or as the composition of the liquid is changed respectively. More terms based on tropos are included in Sections 4.13.1 and 4.15.

Tropos, in Greek means 'a turn' This root word is one of the largest contributors of scientific terms, particularly of chemistry and biology.

4.13 *Off a normal phenomenon (Ortho, Para, Meta and Dia as prefixes)*

In Greek, *orthos* means straight, upright and correct, *para* means beside, *meta* means after or beyond, and *dia* through. They are used as prefixes for terms denoting the extent to which the true phenomenon is away. *Ortho* denotes the most common form,

The acids formed by incomplete hydration are called *meta* acids, e.g., *meta*phosphoric acid (HPO_3), as opposed to orthophosphoric acid (H_3PO_4).

compared to *Para* and *meta*. The significance of these prefixes in organic (aromatic) nomenclature is given in the precursor paper [8].

4.13.1 ***Ortho:*** Orthohydrogen molecule is the right (or more abundant) form; it has the more stable parallel spin combination (triplet state) of the two H nuclei constituting it. When hydration (of oxyacids to form acids) is complete, the corresponding acid is called orthoacid., e.g., orthophosphoric acid H_3PO_4, by hydration of P_2O_5. *Ortho* is often implied; cf., arsenite ($H_2AsO_3^-$), bisulphite (HSO_3^-), borate ($H_2BO_3^-$), silicate ($H_3SiO_4^-$), and vanadate ($H_2VO_4^-$), which are all orthoacid conjugates.

In orthogonal arrangement, right angles (90°) are involved. In colloids, orthokinetic aggregation implies collisions (between atomic/molecular entities) caused by hydrodynamic motions (and perikinetic aggregation implies collisions caused by Brownian motion).

4.13.2 ***Para:*** *Para*hydrogen molecule has the less stable antiparllel spin combination (singlet state) of the two H nuclei; it constitutes only ~25% at STP conditions, but an increasing fraction at low temperatures. Paramagnetism is another (i.e., other than ferro) magnetism, as in the O_2 molecule. When placed between the poles of a magnet, the molecules align themselves with the lines of (magnetic) force.

Metastable phases are thermodynamically unstable phases (but they do persist because the transition is kinetically hindered). Diamond is a metastable phase of carbon, the stable phase being graphite.

4.13.3 ***Meta:*** The acids formed by incomplete hydration are called *meta* acids, e.g., *meta*phosphoric acid (HPO_3), as opposed to orthophosphoric acid (H_3PO_4). The *meta* acids corresponding to the above ortho acid conjugates (Section 4.13.1) are *meta*arsenite (AsO_2^-), *meta* bisulphite (also called pyrosulphite, $S_2O_5^{2-}$), *meta* borate (BO_2^-), *meta* silicate ($HSiO_3^-$), and *meta* vanadate (VO_3^-). The periodate (IO_4^-) is referred only as *meta* periodate.

The oxide of tungsten WO_3 is the parent of (*ortho*) tungstic acid H_2WO_4, and *isopoly* acids (see above for *iso*), the conjugates of which are *meta*tungstate ($H_2W_{12}O_{40}^{6-}$), *para*tungstate A ($W_7O_{24}^{6-}$), and *para*tungstate B ($H_2W_{12}O_{42}^{10-}$). Their designation

follows the fact that for a uniform association of 3 molecules of H_2O, 3, 9, 7, and 6 molecules of WO_3 are required for the four tungstates respectively.

Metastable phases are thermodynamically unstable phases (but they do persist because the transition is kinetically hindered). Diamond is a metastable phase of carbon, the stable phase being graphite. Metatectoid (also called peritectoid; Gr. *tekton* craftsman of a building/construction) reaction is a solid state (isothermal, reversible) reaction of different phases producing a decreased (by one at a time) number of new solid phases, like a mason does to bricks while constructing a building.

4.13.4 ***Dia:*** In diamagnetism, the molecules (mostly) allow the magnetic lines of force through them without realigning themselves (at the finer level however, they experience weak repulsive forces and are realigned in the opposite direction).

Adiabatic (Gr. *batos* passable) is when no heat flow takes place during a change in state. As opposed to adiabatic boundary, the diathermic boundary permits energy transfer as heat. Dialysis is used to study the binding of small molecules to macromolecules. It is very slow and is accelerated by applying electricity, when it is called electrodialysis.

Adiabatic (Gr. *batos* passable) is when no heat flow takes place during a change in state. As opposed to adiabatic boundary, the diathermic boundary permits energy transfer as heat.

4.14 ***Shapes of Molecules***

4.14.1 ***General Shape:*** *Morphe* is shape in Greek, giving rise to terms, e.g., amorphous, isomorphic, idiomorphic (Gr. *idios* own, distinct) and polymorphic shapes taken by solid substances. Allotriomorphic (Gr. *allotrio* alien) means non-crystalline in outward form (but crystalline in internal structure). In a mesomorphic (Gr. *mesos* middle) substance, atoms/molecules are oriented in parallel planes of a layered structure. Such substances, e.g., a detergent, are associated with smectic phase (L. *smectus* cleansing; Gr. soapy).

The orderly close packed hexagonal arrangement of micelles in concentrated surfactant solutions as arrays of long cylinders is

Trigonal (bipyramidal), hexagonal and octagonal shapes of crystal geometry are common.

called a lyotropic mesomorph (*mesos* middle). A morphotropic transition is an abrupt change in the structure of a solid solution that occurs when the composition is gradually varied. A monotropic transition refers to a single morphotype that occurs in the irreversible transition from a metastable polymorphic form to the stable polymorph, e.g., transition of aragonite to calcite ($CaCO_3$). In polymorhic transition, a reversible transition occurs at a certain temperature and pressure (the inversion point) of a solid crystalline phase to another phase of the same chemical composition but with a different crystal structure. Polymorphic transition is synonymous with enantiotropic transition.

4.14.2 ***Angles and Faces:*** The torsion angle (also called dihedral angle) between bonds of two groups (A and D in the A-B-C-D system) can be variable. Its designation is done depending on the range to which the torsion angle belongs – synperiplanar (sp, 0° to 30°), synclinal (sc, 30o to 90° and –30° to 90°), anticlinal (ac, 90° to 150° and –90° to –150°) and antiperiplanar (ap, ±150° to 180°).

Gonia is angle, and *hedra* is seat (face/base) in Latin. Agonist and antagonist are angle–related terms. [3] Trigonal (bipyramidal), hexagonal and octagonal shapes of crystal geometry are common. A *delta* (Δ) hedron is a polygon with all faces that are equilateral (*later* side) triangles. The common morphologies of crystals are tetrahedral (n=4) and octahedral (6), and trigonal bipyramid (5). A few eicosahedral (20 faces, n=12) molecules are known. They include some of the boranes and buckminsterfullerene. The latter name is from Buckminster Fuller, an American architect known for his designs of hemispherical domes consisting of pentagonal and hexagonal faces. Enneahedron (*ennea* nine) is a solid figure with nine faces.

The organometallic cage compounds are of different geometries depending on the number of framework electrons involved – *closo* (2n+2), *nido* (2n+4), *arachno* (2n+6) or *hypho* (2n+8). In Greek, *closo* means closed, *arachno* means spider's web and *hypho*

means net. In Latin, *nido* means nest, giving an indication of the morphology of the structures.

4.15 *Work is Done Anyway*

'*Ergon*', in Greek is work. In an exergonic (exo outside) reaction ($\Delta G<0$), energy is released that may be transferred as work or heat. If the transferred energy is in the form of heat, it is exothermic. In an endergonic (*endo* within) reaction ($\Delta G>0$), work is done on the system. If it is the heat that is consumed (from the surroundings), it is endothermic.

Trope of entropy is intended to mean that useful energy is turned to less useful energy.

4.16 *Enabling*

The prefix '*en*' is an enabling prefix used for words of Latin/ French origin in the sense of in/into/upon or words of Greek origin in the sense of in. Enthalpy (Gr. *enthalpein* to warm in), entropy (Gr. *tropos* a turning, see above). Enthalpy is a thermodynamic property or state function. Trope of entropy is intended to mean that useful energy is turned to less useful energy. Thus, entropy is a measure of the energy that is unavailable for doing work since it exists as the internal motion of molecules. It is thus a measure of the disorder of a system.

4.17 *It's about Fleeing Away*

The term 'centrifugal' (L. *fugere* flee) is associated with a tendency to flee away from the centre (the opposite of centrifugal is centripetal; L. *petere* to seek). Fugacity is the tendency of a gas to expand or escape. Leaving groups are termed '*fuges*'; one that carries away the bonding electron pair (e.g., Cl^- in the hydrolysis of RCl) is called a nucleofuge, and one (e.g., H^+ in the nitration of benzene) that carries away the positive charge is called an electrofuge [3]. The reagents' OH^- of the former reaction is a nucleophile (Gr. *philos* friend), and the NO_2^+ of the latter reaction, an electrophile. The tendency to depart as the charged species is termed as nucleofugality and electrofugality respectively [3].

The term 'centrifugal' (L. *fugere* flee) is associated with a tendency to flee away from the centre (the opposite of centrifugal is centripetal; L. *petere* to seek). Fugacity is the tendency of a gas to expand or escape.

In polymer nomenclature, atactic, syndiotactic, etc. indicate the tacticity. In epitaxy, a unified crystal growth or deposition of one crystal layer on another is effected.

4.18 *Cloud Physics at Work*

Talking of cloud to a chemist instantly brings the classical Wilson's cloud chamber, a simply named term to his attention. Cloud is *Nephele* in Greek; nephelometry is the measurement of concentration by the principle of scattering of light by the colloidal suspensions. Nephelauxetic effect (Gr. *auxein* to increase, cf., auxins, auxochrome etc.) is in particular reference to electron cloud.

4.19 *Roots of Common Biological Terms in Chemistry*

The *exo-endo* pair of prefixes (Section 4.15) is used extensively in biology. Endocytosis (Gr. *kytos* vessel, case) is the uptake by a cell of particles that are too large to diffuse through the cell wall. It includes both phagocytosis (*phagos* mouth; *phag* to eat) and pinocytosis. Exocytosis is the discharge from a cell of particles too large to diffuse through the cell wall.

'Taxis' (Gr. arrangement) is the noun form of tactic (Gr. *taktos* order), e.g., phototaxis, chemotaxis, etc. Phototaxis is moving towards light. The opposite phenomenon of moving away from light is by negative phototactic response. In polymer nomenclature, atactic, syndiotactic, etc. indicate the tacticity. In epitaxy, a unified crystal growth or deposition of one crystal layer on another is effected.

Cytoplasm (Gr. *plassein* to mould, *plastos* moulded, c.f., plasma, chloroplast) is the protoplasm of a cell, apart from that of the nucleus. Erythrocytes (Gr. *erythros* red) are red blood corpuscles, leucocytes (Gr. *leukos* white) are white corpuscles of the blood or lymph. 'Gen' (Gr. *gennaine* to generate) occurs as suffix in androgen (Gr. *andros* man), and estrogen (*oistros* frenzy). The latter is a female steroid sex hormone that maintains the menstrual cycle; it was so named probably to imply that the women were off-balance during their periods. '*Moneres*' in Greek is single. A hormone (Gr. *horme* impulse) is an internal secretion which on reaching some part of a plant/animal body exercises a physiological action, while pheromone (Gr. *pherein* to bear) is a chemical

substance secreted by an animal which influences the behaviour of others of its species, e.g., queen bee substance. It can be termed as an ectohormone. In chemical ecology (Gr. *oikos* house, *logos* discourse), allomone (Gr. *allos* other) has a similar genealogy.

'*Soma*' in Greek is body, e.g., chromsome (Gr. *chroma* colour). '*Trophe*' (Gr. *trophos* food) is nourishment, e.g., autotroph, auxotroph, heterotroph, mesotroph (*mesos* middle), polytroph, oligotrophic (*oligos* few) and eutrophic (eu well). '*Voro*' in Latin is to devour, e.g., herbivore, insectivore, omnivore (L. *omnis* all). An enzyme (Gr. *zyme* leaven; *zymos* fermentation) is a substance that helps fermentation. A zymogen is a proenzyme. Isozymes are electrophoretically distinct forms of an enzyme with identical function.

The term valency is from *valere* (Latin) that means 'to be strong'.

4.20 *Some Left-outs*

Gravis is heavy in Latin, as in specific gravity and gravimetric (*metron* measurement). *Gyrus*, also of Latin is a circle, e.g., 'magnetogyric ratio' which is the ratio of magnetic moment to angular (gyric) moment. The term valency is from *valere* (Latin) that means 'to be strong'. Stoichiometry (Gr. *stoicheion* an element) is the determination of exact proportion of elements to make pure compounds, complexes, etc. The word 'canon' (Gr. *kanon* a straight rod), in music, is to piece with different parts. taking up the same theme successively. Canonical rate constant is the rate constant of a system in which the reacrtants are in thermal equilibrium at a given temperature. Canonical structures are rod-like.

Vulcanus in Latin is the God of fire. Vulcanisation is the heat-treatment of rubber with sulphur to increase the strength. 'Galvanic' is from Luigi Galvani, the discoverer of galvanic action. Zeolites are any of a large group of aluminosilicates of Na, K, Ca, and Ba, containing very loosely held water. The word is derived from the Greek root *zeiin* which means 'to boil' and *lithos*, 'a stone', and is an allusion to the fact that many zeolites intumesce (i.e., swell up) under the blow pipe. A zwitter ion (Ger. *zwitter* a hybrid) is an ion carrying both a positive and a

Vulcanus in Latin is the God of fire. Vulcanisation is the heat-treatment of rubber with sulphur to increase the strength.

The knowledge of the etymology of chemistry terms can potentially remove their often intimidating appearance and help understand the concepts represented by them succinctly.

negative charge, e.g., amino acid. Viscose (L. *viscosus* sticky) is the viscous sodium salt of cellulose xanthate.

5. Conclusion

Historically, most chemistry terms are derived from Classical Greek and Latin word roots. The trend still continues as newer concepts are being developed and given names. There are about a dozen most frequently used affixes – *ortho, tropo, mer, meta, iso, para, hetero, syn, homo, topo, dia* and *pseudo*. For a starter, the knowledge of the etymology of chemistry terms can potentially remove their often intimidating appearance and help understand the concepts represented by them succinctly. And this can be a basis for further development. As one progresses, it may appear in few cases that due to the advancement in science the original concepts got refined though, they still retain the original terms coined for them, and that the etymology approach may be misleading. Not taking the etymology approach so far that it is an added burden; on the other hand, a means to take positively on the heavily loaded chemistry curriculum is expected to be one step in replacing sobriety with a pleasurable learning experience.

Suggested Reading

[1] *Chambers Dictionary of Science and Technology*, Allied Publishers: New Delhi, 1986.

[2] *Chambers English Dictionary*, Allied Publishers: Ahmedabad, 1989.

[3] A D McNaught and A Wilkinson, *Compendium of Chemical Terminology*, The Gold Book, 2nd ed, IUPAC & Blackwell Science, 1997.

[4] I L Finar, *Organic Chemistry*, Vols. 1 and 2, 5th ed., Pearson Education: England, 2000.

[5] J March, *Advanced Organic Chemistry – Reactions, Mechanisms and Structure*, 4th ed.; John Wiley & Sons (Asia), Singapore, 2001.

[6] P Atkins and J de Paula, *Physical Chemistry*, 7th ed, Oxford Univ. Press., Oxford, 2002.

[7] J E Huheey, E A Keiter and R L Keiter, *Inorganic Chemistry, Principles of Structure and Reactivity*, 4th ed, Pearson Education Inc., New Delhi, 2000.

[8] N S Sarma, *J. Chem. Edu.*, Madison, USA, Vol.81, pp.1437-1439, 2004.

[9] G J Leigh, H A Favre and W V Metanomski, *Principles of Chemical Nomenclature*, A Guide to IUPAC Recommendations, Blackwell Science, 1998.