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EDITORIAL

Chemical jargon: thinking out loud

Alexander Yu. Rulev[1]

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Abstract
Language is an important part of the human culture. It serves for the expression and communication of thoughts. In is article, the problem of chemical jargon as a tool for communication between scientists is discussed.

Keywords Scientific communication · Language of chemistry · Jargon · Interdiscipline

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An elderly woman enters a pharmacy:
- Tell me, do you have Acidum acetylsalicylicum?
- Do you want to say "aspirin"? – asks the pharmacist.
- Yes, indeed, aspirin. I keep forgetting this name.

Introduction

Just as small molecules are valuable building blocks in organic synthesis, words are the special bricks needed to construct phrases in written and spoken language - from the first gentle word "mommy" to the unpronounceable hippopotomomonstrosesquippedaliophobia (fear of long words). Naturally, our vocabulary is constantly enriched with new words and stable phrases. And depending on the type of human activity, a specialized vocabulary is formed, otherwise called jargon: subcategories youth, scientific, aristocratic, technical and, God forbid, thieves or prison one. In this essay I want to address the problem of the emergence of buzzwords in the professional vocabulary of chemists - theorists and practitioners. Is the introduction of a new term always justified or would it be wiser to do without it? But first, a few words about the jargon itself.

✉ Alexander Yu. Rulev
rulev@irioch.irk.ru

1 A. E. Favorsky Institute of Chemistry, Siberian Branch of the Russian Academy of Sciences, Irkutsk 664033, Russia

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Jargon: intuitive and scientific definition

There is no consensus among linguists regarding the etymology and meaning of this word. It is believed that it came from the Old French *gargun* – "*chirping*, *chattering*" (Hirst 2003; Etymological online dictionaries of the Russian language). Modern dictionaries distinguish two main meanings. The former defines jargon as the specialized language of any profession (including science) or hobby, often difficult to perceive by the uninitiated people. The second one has a pejorative, negative connotation, representing jargon as an offensive use of specialized vocabulary. Thus, the Modern Dictionary of the French Academy interprets this word as "Langage affecté et inutilement compliqué", which in the Middle Ages denoted the special slang of criminals, created by them exclusively for communication with each other (Dictionnaire de l'Académie française). This may be partly due to the fact that until the 18th century, the word "jargon" was used, among other things, to denote an encrypted speech or letter considered secret or difficult to understand. This was, for example, the language of the alchemists. Seeking to make their writings as little comprehensible as possible, they began to speak and write in parables. What is worth at least an ancient recipe for obtaining the Philosopher's Stone, which is said to be owned by the Spanish thinker Ramon Lull (ca. 1235–1315) and reproduced by the English alchemist G. Ripley (ca. 1415–1490) in the "Book of the Twelve Gates":

Take philosophical mercury and heat it until it turns into a red lion. Digest this red lion in a sand bath with sour grape alcohol, evaporate the liquid, and the mercury will turn into a gummy (gum-like) substance that can be cut with a knife. Place it in a retort coated with clay and slowly distill it. Collect separately the liquids of different nature that will appear at this. You will get tasteless phlegm, alcohol and red drops. The Cimmerian shadows will cover the retort with their dark veil, and you will find a true dragon inside it, for it devours its own tail. Take this black dragon, grind it on a stone and touch it with a hot coal. It will light up and, soon taking on a magnificent lemon color, will again reproduce the green lion. Make it eat its tail and distill the product again. Finally, rectify thoroughly and you will see the appearance of flammable water and human blood.

To decipher the secret of his great-great-great colleague, a modern chemist must have mastered the deductive method of Sherlock Holmes. This is how the famous French organic chemist and statesman Jean-Baptiste Andre Dumas (1800–1884) interpreted this alchemical text:

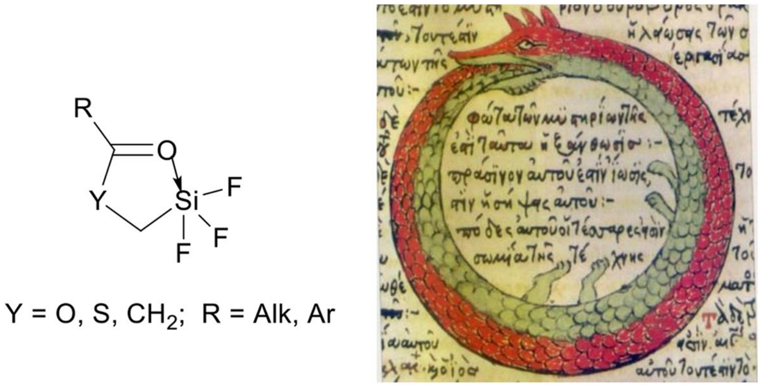
Philosophical mercury is lead. By calcining it, we obtain yellow lead oxide. This green lion, upon further calcination, turns into a red lion—red lead (Pb_3O_4). The alchemist then heats the red lead with sour grape spirit – wine vinegar, which dissolves the lead oxide. After evaporation, lead sugar (lead acetate) remains. When it is gradually heated in solution, water of crystallization (reflux/phlegm) is first distilled, then combustible water - burnt acetic alcohol (acetone) and, finally, a red-brown oily liquid. A black mass, or black dragon, remains in the retort. This is finely crushed lead. When it comes into contact with hot coal, it begins to melt and turns into yellow lead oxide: the black dragon devoured its tail and turned into a green lion. It can be converted back into lead sugar and repeated all over again (Rabinovich 1979).

Since antiquity, scientific theories and concepts have constantly evolved, but changes in terminology have not always kept pace with modern scientific thought. "The creation of science is nothing more than the creation of a language, and the study of science is nothing more than the study of a well-composed language", – this is the statement of the French philosopher Étienne Bonnot de Condillac (1714–1780) often quoted in modern literature (Dehon et al. 2018). Language is one of the means for expressing scientific concepts. It is absolutely impossible to imagine science without specialized vocabulary. Jargon is undoubtedly an integral part of science. It is necessary for communication with colleagues, and its importance is undeniable. The language of chemists is the language of equations and formulas. It is chemical formulas, according to Dmitry Mendeleev, that are "an international language that gives chemistry, in addition to accuracy of understanding, simplicity and clarity based on the study of the laws of nature" (Mendeleev 1932).

The most charming and mysterious

It is highly probable that, in terms of jargon, chemistry holds the lead among other sciences. Just look at its phenomenological world, its symbolism and nomenclature of inorganic and especially organic compounds. For example, one of the longest chemical names published in Chemical Abstracts refers to a modified nucleotide sequence, 1,578 characters long in English. At the same time, the chemists themselves, coping with strict scientific names, prefer to assign common names to substances having remarkable properties. For example, no professor would ask a laboratory assistant to bring him a 2-hydroxypropane-1,2,3-tricarbonic acid. Instead of being recommended by the IUPAC, he undoubtedly uses the trivial name citric acid. And instead of "α-D-glucopyranosyl-β-D-fructofuranoside" say simply "sucrose". Fanciful names have not remained in the past. Like alchemists, modern scientists often give colorful names to the classes of compounds they study. A well-known example of an organic compound of hypervalent silicon with O→Si coordination is dragonoids, discovered in the mid-20th century (Picture 1). They received their name from the light hand of academician Mikhail Voronkov for their obvious similarity with the image of a dragon devouring its own tail, beloved by alchemists (Voronkov 1991).

Around the same time, American chemist Charles Pedersen had a lucky chance to discover an original type of macrocycle, and with it a new piece of jargon: crown ethers – heterocycles containing several ether groups -(R-O-R')-. The author of the discovery was inspired by the similarity between the structure of the crown ether bound to an alkali metal cation and the crown sitting on the head of a monarch (Pedersen 1988). It could be that



Picture 1 Dragonoids are compounds of hypervalent or hypercoordinated silicon

the idea of such a structure of crown-ethers was suggested by the favored conformation of sulfure S_8 (Picture 2).

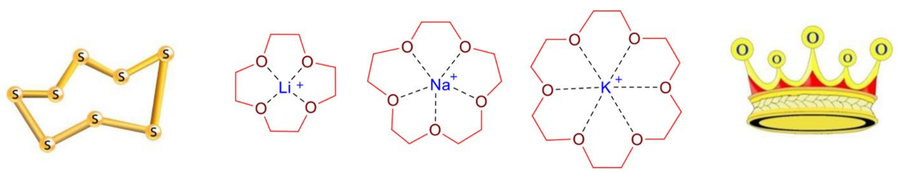
The common name can be given not only to a group of compounds but to the chemical reaction. For example, the self-explanatory name – narcissistic reaction – had been assigned to the class of transformations in which a reactant was converted into a product whose structure was a mirror image of the reactant molecule (Salem et al. 1970; UIPAC Gold Book).

Colorful or trivial names allow you to avoid cumbersome word combinations. This is their attractive feature. However, without knowing what is behind the beautiful sign, it is impossible to understand what is at stake. And therefore, the IUPAC name compilation by common rules (nomenclature) is undoubtedly preferable to the invention of a new, albeit bright term.

Chemical language: from birth to modern times

Modern chemical language originated in the Age of Enlightenment. The new rational nomenclature cleared it of vague alchemical terms, which often made no sense. The creator of the language of chemistry is the well-known French chemist Antoine Laurent Lavoisier (1743–1794), as well as his compatriots Bernard Guyton de Morveau (1937–1816), Claude Louis Berthollet (1748–1822) and Antoine François de Fourcroy (1755–1809). Lavoisier wrote in his famous textbook "Traité Élémentaire de Chimie": "… toute science physique est nécessairement formée de trois choses: la série des faits qui constituent la science; les idées qui les rappellent; les mots qui les expriment. […] il en résulte qu'on ne peut perfectionner le langage sans perfectionner la science, ni la science sans le langage, & que quelque certains que fussent vijles faits, quelque justes que fussent les idées qu'ils auroient fait naître, ils ne transmettroient encore que des impressions fausses, si nous n'avions pas des expressions exactes pour les render" (Lavoisier 1789).[1]

Later, the Swede Jöns Jakob Berzelius (1779–1848) made his contribution to improving the language. It was he who proposed the writing formulas, which, in a slightly modified form, are still used in chemistry. However, today Berzelius would hardly recognize his brainchild: often in scientific articles, the organic compound formulas used in reaction schemes do not contain a single chemical element symbol familiar from the school bench. For example, the primary amine and Michael acceptors, which contain a good exit group in α-position, have only nitrogen and hydrogen symbols in the aziridine production scheme



Picture 2 Crown shaped sulfur molecule S_8 and crown ethers as macrocyclic polyethers with four, five or six oxygen atoms

[1] "…all physical science is necessarily formed of three things: the series of facts which constitute the science; the ideas that recall them; the words that express them. […] it follows that we cannot perfect language without perfecting science, nor science without language, and that however certain the facts were, however correct the ideas they would have given rise to, they would not have been would still transmit only false impressions, if we did not have exact expressions to render them".

(Scheme 1). It is no wonder that to an inexperienced reader in chemistry, strange letters, numbers, arrows, lines, points and geometric figures seem like mysterious alchemical signs. But for synthetic chemists, these acronyms and abbreviations have become familiar and common.

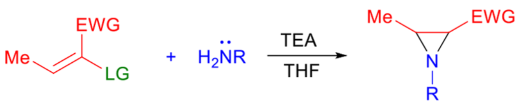
Organic chemistry operates with a large number of abbreviations and acronyms that are understandable to chemists in any country. They are used to denote both compounds and processes. For example, the acronym PS is not a postscript at all, as someone might think ignorant of chemical terminology, but simply a designation for polystyrene (PolyStyrene). The abbreviation PACE is not related to the political organization – Parliamentary Assembly of the Council of Europe, but refers to the process that meets the principles of «green chemistry» (Pot, Atom and Step Economy). If you learn from the description of the synthesis technique that it is carried out in the presence of TEA, do not rush to pour a handful of tea leaves into the flask with a reaction mixture: the abbreviation TEA is just the abbreviation triethylamine (TriEthylAmine).

In addition to formulas, the choice of correct words and precise definitions of chemical concepts are necessary to avoid misunderstandings and misconceptions. It was easy to do when there was the only one chemistry – common and indivisible. But with the beginning of differentiation and the birth of organic and inorganic, organometallic and medical, physical and nutritional, theoretical and synthetic, as well as astro-, bio-, geo-, hydro-, radio-, phyto-, photo-, electro-, iatrochemistry and other branches of chemical science came up with terms that were often understood only by researchers directly involved in the field (Picture 3). Misunderstanding is unlikely only in the newly emerging new branch of chemistry – Pegniochemistry (Rulev 2015; Voronkov and Rulev 1999, 2011).

It is no coincidence that in 1860 in Karlsruhe, chemists gathered at an international congress to discuss the accumulated problems associated with chemical nomenclature and designations. For the first time in history, the Scientific Forum of Authoritative Chemical Scientists of European Countries agreed on the formulation of basic chemistry concepts. Paradoxically, this topic remains relevant today, more than a century and a half later. In fact, new pedagogical approaches are being developed today to avoid misconceptions about elementary (basic) chemical concepts such as element, atom, molecule or compound (Reina et al. 2022, 2024; Giunta 2022). Similarly, scholars argue about correct and incorrect terms, with enviable regularity appearing in the chemical literature.

Like any other chemical language, it does not remain frozen. It is constantly changing and improving. Progress could not be stopped, and the demand to ban the creation of new terms was ridiculous and foolish. This is reminiscent of the situation in which the German chemist Leopold Gmelin is said to have been. In the first half of the 19th century, he began compiling the "Handbook of Theoretical Chemistry", but became desperate for ever

Scheme 1 .



EWG (**E**lectron **W**ithdraving **G**roup) = C(O)H, C(O)Me, CO_2Me

LG (**L**eaving **G**roup) = Cl, Br

R = Cy, Ad

Picture 3 Branches of chemical science

increasing amounts of material. As a result, the scientist was forced to appeal to his colleagues to suspend their productive activities until he finished his work!

The famous Justus Liebig also considered it necessary to anticipate the future by putting in the preface of his textbook: "As for the completeness of the questions, everyone will find something incomplete here; at the moment it is absolutely impossible to give something complete, because even one day after publication it ceases to be complete; every day brings a new discovery" (Golembowicz 1968; Shorlemmer 1937).

The emergence of new terms as science develops and our knowledge of the outside world deepens is quite natural. The number of jargon words in chemistry is constantly increasing. New terms are born when scientists discover new laws and regulations, synthesize previously unknown classes of compounds, or encounter unusual, unexpected reactions. New concepts by default become jargonisms. Sometimes they are necessary but sometimes excessive.

The jargon is good

Good jargon should be universal. In order for specialists in different fields of chemistry to cooperate as easily and closely as possible with each other, it is necessary to avoid the possibility of confusion among professional chemists. One way to achieve this is to establish a glossary of common and precise terms. For example, the theory of an activated complex is often found in the vocabulary of both theorists and synthetics. Both use it uniformly in their work, referring to the short-term (how difficult to define!) configuration of atoms near the transition state, in the common graph showing the evolution of the reaction coordinate arising from the transition from the original reagents to the reaction products. So the theorists explained the essence and causes of the phenomena they observed to the experimental, taught them not to be afraid of the language of physicists.

The transition state theory is actively developing today. It has been hypothesized that commonly occurring phenomena for reactions of organic compounds in solution can create dynamical barriers to reaction. The existence of these barriers has long been recognized (Garcia-Meseguer et al. 2019; Carpenter 2013). Moreover, methods for calculating their effect have been developed. New hypotheses require new, more sophisticated experimental techniques, which are already beginning to detect some of the phenomena that were previously postulated in molecular dynamics simulation. Not surprisingly, today theorists and experimenters do not think of the existence of each other.

Good jargon can be attributed to short simplified names of complex molecules. They are very convenient. In fact, the cumbersome formula of $FeSO_4$. $(NH_4)_2SO_4$. 6 H_2O called "hexahydrate of double salt ammonium and iron (II) sulfate" can be replaced by simple term «Mohr's salt». The trivial names of many substances are still used in everyday life. For example, "Ochre" (Iron oxide hydrate $FeO(OH) \cdot nH_2O$), "minium" (Pb_3O_4 lead tetroxide), "baking soda" ($NaCO_3$ sodium hydrocarbonate), "lapis infernalis" or "lunar caustic" (silver nitrate $AgNO_3$), "marsh gas" (methane CH_4).

An example of good jargon can be a name reaction – a reaction which is named after a person who discovered, understood and/or developed it. In this case, a large amount of information is able to be conveyed. For example, it is enough for a synthetic chemist to inform that the target compounds have been prepared from a Michael reaction or a Favorski reaction to understand that in the first case it is a conjugate nucleophilic addition to electron-deficient alkenes, and in the second about the method for the synthesis of propargyl alcohols based on the interaction of terminal alkynes with carbonyl compounds in the presence of a strong base.

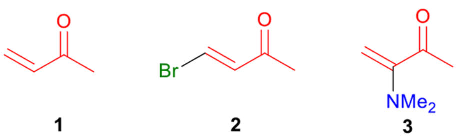
...and bad

However, in addition to «good» there is also «bad» jargon, which clogs the language of communication between scientists. Alas, modern chemical literature abounds with examples.

Jargon is bad when it is used incorrectly. For example, often in the text of the article and even in its title you can find the word «enaminones». Paradoxically, in Google it occurs 15 times more often than the correct term «aminoenone». In fact, enones are a large class of unsaturated carbonyl-bearing compounds (ketones). According to the name, the enone molecule is a conjugate system of alkene and ketone. The simplest enone is methyl vinyl ketone 1. If any heteroatom (such as halogen F, Cl, Br, I) or another functional group (such as the primary, secondary or tertiary amino group R^1R^2N) is introduced into the molecule, a substituted enone, such as 4-bromobutenone 2 or 3-dimethylaminobutenone 3 is a representative of two chemotypes of unsaturated ketones – push-pull haloenones and captodative aminoenones (Scheme 2).

Another example of bad jargon is the failure to borrow terms from a common vocabulary. One of them is the word "scaffold" which is a favorite word among modern synthetic chemists. In the dictionary under it is hidden either scaffolding, or "a flat raised structure on which criminals are punished by having their heads cut off or by being hung" (dictionary scaffold). The English-French dictionary translates it this way: "echafaud". Such an interpretation of a word included in chemical terminology can terrify any practicing chemist.

Scheme 2 .



Despite the vague definition, this term is often found in the text of the article or in a grant application. Apparently, the authors naively (or calculatedly?) believe that the more sophisticated the term used, the more likely it is to gain support from any scientific granting agency. For example, in one grant application I encountered the following: “The set of approaches proposed in the context of scaffold-oriented synthesis is based on the use of diazaheterocyclic reagents of various natures in a number of chemical transformations, resulting in structurally diverse heterocyclic derivatives based on privileged scaffolds”. This is too complicated! If you get rid of unnecessary jargon, the basic idea of the project can be conveyed in a short and clear way: “The proposed method of obtaining various heterocyclic derivatives is based on the use of diazaheterocycles as valuable initial reagents».

Finally, jargon is bad when it is excessive, when new unnecessary terms appear that need not be introduced. For example, the word “trigger” literally means “the part of a gun that causes it to fire when pressed” (Dictionary trigger). One of the meanings of another word, “promoter,” is someone “who tries to induce something to happen or develop” (Dictionary promoter). In chemistry, these terms have been introduced to denote something that initiates (induces) a chemical reaction, promotes it. According to the IUPAC Gold Book, promoter is “a relatively small quantity of one or more substances, which when added to a catalyst improves the activity, the selectivity, or the useful lifetime of the catalyst. In general, a promoter may either augment a desired reaction or suppress an undesired one” (goldbook IUPAC). What is wrong with the good old concept of “catalyst”, introduced into chemistry by Berzelius almost two centuries ago and understandable to any practitioner or theorist? (Wisniak 2010) Why not just call it a co-catalyst? The simple prefix “co,” indicating the relationship and commonality of concepts, has long been used without problems in the construction of a lot of words such as coenzyme, compatriots, co-authors, covalent bond etc. Very recently, a new word Coscientist appeared in English which does not need translation (Boiko et al. 2023). Is it better to add more unnecessary jargon to the dictionary, or to use an already existing and well-defined term?

Jargon: is everything obvious?

However, some terms understood by experts can mislead the amateur. For example, in the early 60s of the last century, the American inorganic chemist R. Pearson developed the theory of hard and soft acids and bases, hiding today under the acronym HSAB. Pearson’s idea proved heuristic and very useful in predicting the reactivity of organic and inorganic compounds. According to the HSAB theory, hard acids react more readily with hard bases, and soft acids with soft bases. The causes of the observed phenomenon were successfully explained using molecular orbital theory, and quantum chemistry terminology. Around the same time, the Japanese theoretical chemist Kenichi Fukui developed frontier orbital theory, and American chemists Roald Hoffmann and Robert Woodward formulated the principle of orbital symmetry. Both theories explain many patterns of chemical reactions. However, for a young chemist or just an inquisitive student, the concept of hardness and softness is associated more with a stiff bicycle seat and a stuffed baby toy, and the chemical jargon remains for him full of abracadabra. A similar situation arises with the term «heavy metals». The media often frighten the public with their toxicity to all living organisms. The most widely known list of heavy metals includes mercury, lead, bismuth, tin and antimony. However, it remains unclear on above what number the arrow of the scales should land for metal to be considered «heavy». So far there is no authoritative definition to be found in the relevant literature. Thus, according to IUPAC Technical Report the term «heavy metals» is both meaningless and misleading (Duffus 2002).

It is also important to take into account the reaction of an amateur or student (who is still an amateur) to a slide shown by a professor during a lecture that contains several professional terms or symbols. The listener can attempt to either rise to the level of an specialist, or shut down their attention completely, not wanting to make a fool of themselves.

Of course, knowledge of professional jargon is not mandatory. Overcoming the barriers in the communication of the scientist and amateur can be done by popularizing science, increasing the erudition of the audience and carefully using technical terms. Nobel laureate Richard Feynman hated intellectual pretension, believing that everything could be explained in simple words, without professional jargon (The Feynman Technique). Famous Caltech physicist David Goodstein remembered: "Feynman prided himself on his ability to come up with ways to explain the deepest ideas to beginning students. Once I asked him: "Dick, explain to me so that I can understand why spin one-half particles obey Fermi-Dirac statistics." Feynman replied: "I will prepare a lecture for freshmen on this topic." But a few days later he returned and said: "I couldn't. I couldn't bring it down to freshman level. This means that we don't really understand it" (Goodstein et al 1996). Recently, Roald Hoffmann and Jean-Paul Malrieu discussed the intimate link between explanation and teaching in excellent essay (Hoffmann 2020).

Why to make a fuss?

The cherished goal, "The Holy Grail" of the theoretical and practical chemist, is *to understand* how the properties of molecules are changed when any functional group is modified. Or what needs to be done to ensure that the reaction occurs selectively on this atom. To achieve this goal, they work in tandem, perfectly understand and complement each other. At the same time, understanding does not require creating new jargon terms.

Enthusiastic about the use of new terms should not forget that any jargon can limit the transfer of scientific knowledge, because, as a rule, the appearance of new jargon in the title of an article makes it less attractive, and therefore less readable and, as a result, less quoted. Moreover, according to Roald Hoffmann, "the other side of new fashionable words in any language is that meanings become degenerate, the opposite of the Jahn - Teller effect. So for physicists, "hybridization" means just mixing of wave functions, not mixing of different angular momentum orbitals of same principal quantum number".[2]

Forbidding jargon is pointless. Fashionable words come and go. Only time will put everything back into place, preserving what is truly valuable and discarding what is unnecessary. But even today, before using any term in oral or written speech, it is better to inquire about its meaning, as well as whether its synonym already exists. The simple is not the equivalent of a silly word. The simplicity of the science language is truly elegance. The simpler scientists express themselves, the easier they understand each other. And not only scientists….

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[2] Roald Hoffmann, private communication.

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Competing interests The authors declare no competing interests.

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