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A SEMIOLOGY OF THE SIGN SYSTEM CHEMISTRY

For the last twenty years Luis Prieto, in his published work in French, has reiterated that the systematic study of the codes (other than natural languages) which were invented by men for communication purposes is in and of itself an undertaking essential for an understanding of both the laws of communication in general and of the mechanisms of these systems of communication—the totality of which would make up the (Saussurian) semiology of communication (Prieto 1966, 1968, 1975). Among these systems the symbols of chemistry—referred to as such for a long time—and their combinatory rules constitute a very ancient code or series of codes (Crosland, 1962). Up to now this code has not been subjected to a genuine semiological study, except for the essay by Dagognet (1969, see Mounin 1970) which is more literary or poetical and metaphysical than scientific.

Renée Mestrallet, who holds a PhD in organic chemistry (Montpellier, 1952) and who is at present a member of the faculty of modern languages at the Universidad Autonoma of Barcelona, has just given us this "semiological study of the system of signs of chemistry" (Barcelona, 1980). Thanks to her training both as a chemist and as linguist and semiologist, she has been able to

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produce a work that will, from now on, be among those that cannot be overlooked in the field of general semiology.

To begin with, she gives, probably for the first time, the analysis of the units used in the system or systems of notation of chemistry. This, after first differentiating—as Bloomfield did—between the *informal* discourse of chemistry (when one speaks of chemistry solely through the units [the names] and the rules of a natural language) and its *formal* discourse (the use of symbols and formulas).

One of these systems is the one of the nomenclatures of chemistry. As a sub-system of chemical notation in general it overlays part of the lexicon of natural and, more and more as the history of chemistry progresses, the formal language specific to chemistry. In fact modern chemistry has no less than four layers of names. First, a layer of lay terms which represent either a specialization of the names in natural languages (*water, ammoniac, salt*, etc.) or a neologism from alchemy or archaic chemistry (*acqua forte, Fehling's or Fowler's solution, tincture of litmus,* etc.): These names are entirely arbitrary, that is, their signifier gives no indication of the *chemical* composition of the substance. Next, a layer of semi-lay terms which generally combine the root of a lay lexeme with a prefix, a suffix or a compositional element connected to a paradigm; for instance the suffix *-ene* indicates a double linkage component such as *benzene, ethylene, propylene*, etc.; but nothing in this system gives information on the number of carbons, or their arrangement, nor the number "or localization of[...] the linkages" (Mestrallet, p. 110). Then comes the layer of "functional" names which designate and "categorize", assign a place and explain substances on the basis of the criterion of their main chemical function: *Phosphoric acid, Benzoate of soda, Silver chloride*, etc. (Mestrallet, p. 230). Finally there is the layer of "systematic" names, i.e. those that exhibit and "describe" in their signifier "the sum of the elements" that make up the substance and that allow the "rigorous and absolutely unambiguous reconstruction of the substance" (*ibid.*, pp. 112 and 212); for instance *2-methyl pentane* makes possible the reconstruction of the formula $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH(CH_3)\text{-}CH_3$ and *vice versa* (*ibid.*, p. 215).

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Chemical names in themselves already present various specifically semiological problems. We will put aside here a terminological problem: the author seems to reject the term "nomenclature" for the whole of the lay and even the semi-lay terms since "they do not pertain to any organizational system" (*ibid.*, p. 155). This attitude is too puristic because it is inaccurate not only when it comes to the semi-lay terms but even for the lay terms. In French the word "nomenclature" is a general term that indicates the totality of the technical terms of a science or an art regardless of whether this whole is organized or not: thus we refer to the grammatical nomenclature used for teaching purposes, or to the botanical nomenclature of the common terms of plants, etc. One could very well subistitute "nomenclature" for "semantic field". On the other hand, the word "terminology", which ought to suggest a greater level of organization in a list of names, is unfortunately defined in all dictionaries as a synonym of "nomenclature". In order to indicate that a nomenclature is constrained by rules of formation one uses the terms "standardized" (*modelized*)* terminology, "methodic" terminology, and, as the author does, "systematic" terminology (p. 211).

As linguistic signs, the names of chemistry bring up other interesting semiological problems. First Renée Mestrallet observes that their diachrony survives in their synchrony in a different manner than is the case in natural languages. In natural languages diachrony manifest itself only through etymology while in chemistry lay and semi-lay terms coexist today as clear synonyms with and to the functional and systematic names, and the choice of terms is determined by the efficiency rationale of the various communication situations pertaining to the field of chemistry as is shown quite clearly by Mestrallet's analysis (pp. 114-119, 187). Furthermore, she makes a very important semantic observation when she notes that because of the greater and greater thrust of chemistry towards scientific elaboration there is, in the linguistic aspect of chemical names, a tendency for the signified of the name to coincide more and more perfectly with the concept that this signified represents (this is not the case in natural languages where there is often, even for the most everyday terms, a gulf between concept

* Translator's note: in English in French text.

and signified; for instance *cow, cypress, lemonade, alcohol, flower,* etc.) (cf. Mounin, 1979). The author also insists that the linguistic controversy about whether the referent must be taken into account in the linguistic data itself, is not relevant here. In chemistry it is reality, the referent, the (extra-linguistic) object which is the basis both for the extraction of the defining traits of the concept (for instance of the metal *lead*) and for the pertinent traits of the name (of the metal *lead*)—defining and pertinent traits being the same in chemistry.

The author also considers at length the problem of the motivation or the unmotivation of chemical names. I have always felt that this linguistic controversy has been from the outset obscured rather than clarified by Saussure himself, who made the mistake of connecting the problem of the motivation of a sign to the problem of *arbitrariness*. The opposite of *arbitrary* is not *motivated* blt rather *iconic* ("symbolic" in Saussure). *Unmotivated* is thus not synonymous with *arbitrary,* it is only the opposite of *motivated*. The opposition *arbitrary/iconic* pertains to the fundamental structure of the sign in general, while the opposition *unmotivated/motivated* is relevant only to the structure of the lexical formation of specific linguistic signs. Furthermore the opposition *motivated/unmotivated* often entails the risk of confusing motivation in synchrony with etymology in diachrony: *chlorine* is motivated towards *green* only for someone who knows Greek, *cordonnier* (shoe-maker) has nothing to do with *cordon* (string), *huissier* (doorman) is motivated only for philologists and the rare lay person who might know the old word *huis* (and many people who use the expression *a huis clos* [closeted] ignore that *huis=porte* [door].* However, the problem is probably much more important in chemistry than in linguistics because the history of chemistry since Lavoisier has gone hand-in-hand with a sustained effort at terminological rectification aiming at making the nomenclature "transparent." This term has been perhaps wrongly taken to mean motivated, that is, where the signified can be rediscovered through the analysis of the signifier. Renée Mestrallet extends the notion of motivation by inventing the

* Translator's note: Except for chlorine, the listed examples only work in French. English translations of the examples have been added in parentheses by the translator.

risky concept of "motivation external to the (linguistic) system" (p. 185) in cases where a term refers to a physical or medical property of a product: *Prussian blue, eau de vie, milk of lime*; or to its origin: *Spanish white, Glauber's salt*, etc. But she does perceive that there is a linguistic "motivation" only for the functional and the systematic names, and that the motivation stemming from the rules of name formation has nothing to do with the arbitrariness of the linguistic sign: *-ic, -ide, -ate*, etc. are as arbitrary as *sulf-* or *thio-*, which can be verified when one passes from one language to another, and particularly from one language family to another (on this see Claude Tchékoff, 1971).

Renée Mestrallet, while attempting to give the most precise description possible of the general code of chemical notation, is also very much concerned about the problem of criteria specific to natural languages as opposed to those of non-linguistic codes. Because of this she attaches much importance to the problem of the articulation of the code in chemistry. She demonstrates (pp. 176-182) that, while the double articulation of the semes into signifying units (*calcium, hydride*) then into non-signifying units or phonemes (/k/, /a/, /l/, /s/, etc.) is present in the names, it doesn't exist in the formulas (H_2Ca)—even though the symbols (Ca, Br, Fe, etc.) show a partial double articulation which, because of its classificatory function, does not reflect the one of natural languages (pp. 286-292). She also attaches importance to the question as to whether the code of chemical notation is—using Buyssens' terminology—a purely substitutive code (substitutive of the spoken language), or is—using Prieto's terminology—a parallel code (pp. 172-182) even though it is articulated differently from the first code (the natural language). This analysis leads her to point out an important property of the code of chemistry: contrary to what is the case for natural languages, and this for reasons specific to chemistry (economy of wording, reading difficulties, non-linearity of the formulas), in this case it is the oral that is the substitutive code and the written the primary code (pp. 169-172).

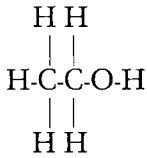
This four-nomenclatures sub-system described at the same time diachronically and synchronically does not give a solution to all of the representational problems (i.e. designational or naming problems) stemming from chemistry's own development. The

function based classification (acid, salt, etc.) faced enormous difficulties during the transition from the handful of functions of mineral chemistry to the scores of functions of organic chemistry (about forty for the most common ones). Moreover, chemistry had to cope with differing terminology that had named *picric acid* and/or phenic acid, phenols; or *perchlorate* a product such as silver perchlorate which some consider an acid, and had to do this, in addition to dealing with more and more complex molecules entailing for instance six to ten different functions. Systematic names that aimed at correcting these imperfections, posed other problems pertaining to the non-linearity of symbolic representation of the molecule when one wants to name it or read it orally. It is these difficulties that lead to the frequent use of formulas that replace the names (though in some specific cases, only partially).

The base for all the formula sub-systems is the sub-system of the "symbols" of chemistry. These are the universal graphic representation of the names of the elements (which themselves may not be universal: cf. *fer, iron, hierro; tungstene, wolfram,* etc.) These "symbols" are not iconic as in the Sausserian definition of symbol but are arbitrary. Since they are extracted from the name (*fer* > Fe, *cuivre* > Cu, etc.) one could speak here of motivation if it weren't for the fact that it varies much in different languages, particularly in those that are not derived from Latin: for instance in German, *Blei, Kupfer, Zinn,* etc. These representations through abbreviations or shortcuts, of which there have been many systems since the alchemists, were codified at the time of Berzelius (1819) and are made up of the initial of the Latin name, followed by the first letter (vowel) or by the first different consonant in cases where there is a risk of confusion (*Si*=*silicum, St*=*stibium, Sn*=*stannum,* etc.) The author correctly notes that these chemical symbols do not pose any important semiological problems (motivation, pp. 279-286; articulation, pp. 286-298; economy, pp. 289-292).

The formulas built from these symbols in order to represent the more and more complex materials of chemistry, particularly of organic chemistry, constitute themselves several semiological sub-systems. One of these is the system of "flat" formulas where the substance is represented on the two dimensions of the sheet

of paper, regardless of the structure of the substance in molecular space. In this system, a distinction is made between the "rough" formulas of linear reading which indicate only the nature and the number of the atoms: for instance lactic acid, $C_3H_6O_3$, and between "developed" formulas that indicate in a more precise manner the non-linear linkage order of the atoms: for instance, for ethylic alcohol:



There are even "semi-developed", intermediary formulas that emphasize a specific chemical characteristic: for instance for ethylic alcohol, the function alcohol is emphasized by isolating OH; thus we have C_2H_5OH (instead of the rough formula C_2H_6O).

"Stereochemical" formulas are representations on a piece of paper and that use the conventions of projective geometry so as to show an image of the ordering of the atoms in the three dimensions of space, with rules that allow the visualization of the elements located forward or backwards of those that are on the plane of the sheet of paper, as well as the (approximate) angles of the direction of the linkages between atoms.

Finally, to get closer to a representation of the real structure of a molecule, chemists have come up with a kind of macromodel (p. 143) composed of assembly elements (color coded balls for the elements, colored sticks of scaled length for the linkages between elements). Renée Mestrallet rightfully points out that even though these various sub-systems have a history that progresses from the older to the more recent ones, they still coexist today in the different usages of chemical discourse lecture, demonstration, discussion, research, etc.) and thus they do not in any way represent successive "articulations" parallel or similar to the articulations of spoken language.

The author also carefully investigates other important units of chemical notation: hyphens indicating linkages, parentheses, brackets, arrows and other signs (pp. 238-245)—all the units re-

presenting relations between elements of atoms. As we mentioned, she devotes particular care in elucidating the historically variable relationships of chemical reality, as it is known at a given time, and of both the representations that aim at reproducing this reality more and more faithfully and the problems stemming from this. She also examines the semiological status of representation within formulas of such things as simple substance, element, atom, and gives a very refined analysis of the various usages in this domain. In addition, she analyzes the semiological signification of what are called, probably incorrectly, chemical reaction equations, and wonders if it is legitimate to compare these equations to sentences where the arrows would stand for predicates. Even though she goes along, perhaps wrongly, with this analogy, she emphasizes (pp. 412-413) the great poverty of these pseudo-"predicates".

It would be difficult to make major changes in Renée Mestrallet's semiological analysis of chemical notation. We have noted the semiological problems (arbitrariness, iconicity, motivation, linearity, relation to the referent, etc.) that she has covered along the way. But her work has the great merit of bringing up—using the concrete example of a complex non-linguistic code—the problem of identifying the criteria that would make possible the specific characterization of natural languages (Turkish, English, Samoan, etc.) in relation or in opposition to all other systems of communication.

It is common knowledge that since at least the time of Aristotle, and until very recently (Colin Cherry, Chomsky, Gardner, Premack), it was generally claimed that natural languages are totally different from all other "codes" but without backing this claim with operational criteria for this differentiation, except for vague ones (such as the richness of natural languages and the poverty of codes, the possibility of expressing thinking itself [*la pensée*], etc.) Renée Mestrallet reviews all the more rigorous criteria (except those of Charles Hockett—on this cf. Mounin, 1975) that have been advanced on this point during the past thirty years and confronts them with chemical notation. The first was the double articulation or *duality of pattern** pro-

* Translator's note: in English in French text

posed by André Martinet whereby the decisive distinctive trait of natural languages would be a double coding into monemes (morphemes) and then of those into phonemes (cf. Martinet, 1960; Mounin, 1968 a, 1968 b, 1971). Renée Mestrallet shows that chemical "symbols" made up of graphemes (Ma, S, Na, K, etc.)—and consequently also the formulas and the equations—are *partially* based on non-signifying distinctive units that can be used again in various symbols: for instance, the *a* in *Ca, Na, Ba, Ga, La, Ra, Ta, Au* (these units are non-signifying even if they have etymological motivation in some usages of some languages—pp. 228, 286-293, 474-476). Prieto had already attempted to show that this criterion is not absolute through the not very convincing example of phone numbers. We will come back later to the partial second articulation of chemical notation.

Prieto himself has proposed another criterion to differentiate what is language from what is non-language: natural languages would be the only codes having units the signifieds of which relate to each other either in a relation of inclusion or in a relation of intersection (*goat* is included in *animal*; in "give *it* to me", *it* can include *goat*, etc.; these are frequent phenomena in discourse). This criterion has also been argued (Tullio De Mauro, 1974), and also not very convincingly. On the contrary Renée Mestrallet points out that in the overall code of chemical notations, there are very frequent units that function in a relation of inclusion with others: these are the "roots," symbolized by R- or A-, and which designate, in a formula, that part also called "skeleton" which one wants to avoid repeating after naming it the first time (cf. R-CH_2OH, etc.). As the author clearly perceives, R- functions as "arch-symbol" or even better as "pronoun-symbol" since it sends back to any aliphatic root, while A- sends back to aromatic roots (pp. 296-300 and 455-456). Furthermore, the possibility of genuine *elisions* of the symbols in some formulas—because these symbols can be taken for granted: for instance the obligatory locations of the symbol H, or the sufficient but incomplete outline of the carbonaceous skeleton in some formulas—leads her to an alternative way of showing that the code of chemical notation possesses a veritable flexibility, while Pierre Guiraud (1963) opposed this characteristic of natural languages to the simplicity of all codes (pp. 295-296). In fact, this amounts to a reformulation

of Prieto's argument in a different form: to oppose codes where the signifieds are in a relation of exclusion, i.e. unequivocal, to those in which they are not. Furthermore, and still concerning Pierre Guiraud, one could remark that in opposition to codes which are decisively closed, chemical notation through its naming rules for new products (of which there are potentially a million) is an open system.

Finally, Renée Mestrallet takes into consideration the criterion proposed by Tullio De Mauro: in contrast to all other codes, natural languages are "semiotically omnipotent," i.e. they can speak of everything—while one cannot say *I think therefore I am* in the highway code, or *Socrates is mortal* or *the earth is round* with chemical symbols. In logical terms, this amounts to saying that a code can speak of "*a* discursive universe" limited by convention to a class of facts that one has decided to take into account, while a natural language speaks of "*the* discursive universe;" that is, of all the facts perceived by the culture that expresses itself through this language, including the specific discursive universe dealt with by the codes. This is what Prieto (1975) calls the criterion of translatability, of the translation omnipotency of languages. This is in any case an old intuitive argument that has been well developed, probably after others, by Frédéric François (1968). Renée Mestrallet does not see quite clearly this aspect of the argument when she notes that all the chemical statements in natural languages are translatable into symbols, formulas, or equations, and reciprocally. Semiotic omnipotence, in any case, will be a criterion of a natural language only after the uncovering of the mechanism of this omnipotence—which, like Martinet, I believe to be deeply if not exclusively tied to the existence of this (total) second articulation.

On this point, Renée Mestrallet, who has shown, (as we have seen) a real mastery of theoretical reflection in semiology, makes an observation which is to my mind of capital import. She notes in conclusion, possibly a bit hastily in passing, that the codes which like the one of chemistry "have borrowed certain characteristics from natural languages" (p. 484)—such as the partial double articulation, or the semes in relation of inclusion—owe these characteristics to the fact that they were invented by users

who were already "speaking-subjects": they have imported in their codes traits to which they were already accustomed in natural languages. This observation goes a long way regarding the typology of codes. It will be necessary to clearly distinguish, in analysis, those codes that are for their users (animals, children before the age of speech) anterior or external to any possession of a natural language, from those codes—such as mathematical or chemical or graphic, etc. symbols—that are phylogenetically subsequent to languages (cf. Gardies, 1975).

On yet another point, Renée Mestrallet brings new facts that are worth pondering: these concern the thesis, for a long time classic in philosophy, according to which there could not be thinking without language, the latter term being understood as the totality of natural spoken languages. André Martinet (1960) still writes that "language serves so to speak as support to thinking to the point where one could wonder if a mental activity lacking the framework of a language would properly deserve to be called thinking." Only Marcel Cohen, at that time, alluded to the possibility of the existence of certain superior forms of thinking, such as mathematical formalism, that could probably be expressed without resorting to natural languages (Cohen, 1947). Even though, as Martinet rightfully noted, "it is up to the psychologist and not to the linguist to come to a conclusion on this" (*ibid.*). Renée Mestrallet brings up some things that are food for thought on this subject: developed formulas are *autonomous* in relation to their various designations in natural languages (p. 85); they can be manipulated independently from any recourse to oral enunciation (pp. 172, 183). From this viewpoint they are functioning like real international (p. 223) ideograms (pp. 268, 281) that "can totally do without translation into (spoken) language" (pp. 87, 90) and that in all probability skip over any such translation in certain contexts (problems, demonstrations, conferences, etc.) (pp. 92, 268, 269, 276). It is also certain that what she writes on the function of developed formulas as "tools" for the elaboration of thinking (p. 947), as "tools" for research (pp. 127, 130, 153), brings forth elements that are very interesting—because simpler than natural languages—for the study of how a semiological system is also a system of elaboration of thinking.

Finally, it remains to mention the only point on which the author has not convinced me. Renée Mestrallet thinks (pp. 483-484) that the opposition between languages on the one hand and codes on the other hand is a radical opposition; that their defining traits are totally distinct; and that, as all our predecessors believed, languages and codes are two concepts—two metaphysical essences—that can be totally opposed.

I assume that this attitude stems from the fact that Renée Mestrallet knows thoroughly only natural languages on the one hand and the system of chemical notation on the other. Contrary to what she believes, the ever more refined study of the codes of animal communication, of pre-linguistic forms of children's communication, as well as what she observes of the codes of chemical notation, lead me more and more to think that systems of communication form a continuum. And among all these systems, one probably discovers a gradation of defining traits, "a difference of degree rather than a difference of nature," as Renée Mestrallet phrases it, only to reject it (p. 484). In any case, it is at present this hypothesis that seems to me the most open and the richest in possibilities for the typology of the forms of communication.

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REFERENCES

CHERRY, C., 1957. *On Human Communication*, New York: Wiley and Sons.
CHOMSKY, N., 1968. *Language and Mind.* New York: Harcourt and Brace.
COHEN, M., 1947. "Faits linguistiques et faits de pensée", *Journal de Psychologie*, n. 400.
CROSLAND, M. P., 1962. *Historical Studies in the Language of Chemistry*, London, Melbourne, Toronto: Heinemann.
DAGOGNET, F., 1969. *Tableaux et langages de la chimie.* Ed. du Seuil.
FRANÇOIS, F., 1968. "Description" in *Le Langage.* Encyclopédie de la Pléiade, Gallimard, p. 11.
GARDIES, J.-L., 1975. *Esquisse d'une grammaire pure.* Vrin, p. 8, note 2.
GARDNER, R., 1969. "Teaching Sign-Language to a Chimpanzee," *Science*, vol. 165, n. 3894, 15 August 1969, p. 664-672.
GUIRAUD, P., 1963, *Études de linguistique appliquée*, vol. 2, p. 37.
MARTINET, A., 1960. *Éléments de linguistique générale.* A. Colin.
—. 1960. *Ibid.*, p. 13.

MESTRALLET, R., 1980. *Communication, linguistique et sémiologie: contribution à l'étude de la sémiologie, étude sémiologique des systèmes de signes de la chimie.* Universidad Autonoma de Barcelona, 2 vol. 501 p.

MOUNIN, G., 1968a, *Clefs pour la linguistique.* Seghers.

—. 1968*b*, *Ferdinand de Saussure.* Seghers.

—. 1970. *Introduction à la sémiologie.* Ed. de Minuit, p. 149-154.

—. 1975. *Linguistique et philosophie.* Presses Universitaires de France, p. 98.

—. 1979. "Éléments d'une sémantique structurale et fonctionnelle: l'axiologie d'André Martinet" in *Linguistique fonctionnelle*, débats et perspectives, présentés par Mortéza Mahmoudian. Presses Universitaires de France.

PREMACK, D., 1971. "Language in Chimpanzee", *Science*, vol. 172, p. 808-822.

—. 1972. "Teaching Language to an Ape", *Scientific American*, vol. 227, n. 4, October, 92-99.

PRIETO, L. J., 1966. *Messages et signaux.* Presses Universitaires de France.

—. 1968. "Sémiologie" in *Le Langage.* Encyclopédie de la Pléiade, Gallimard.

—. 1975. *Pertinence et pratique.* Ed. de Minuit.

TCHEKHOFF, C., 1971. "Les formations savantes gréco-latines en français, anglais, italien, espagnol, allemand et russe," *La Linguistique*, vol. 7, 2, p. 35-54.