Understanding Modern Classification and Ambiguities in Chemistry

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Opinion Article

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DESCRIPTION

Vitalism was a widespread conception that substances found in organic nature are formed from the chemical elements by the action of a "vital force" or "life-force" (vis vitalis) that only living organisms possess. In the 1810s, Jöns Jacob Berzelius argued that a regulative force must exist within living bodies. Berzelius also contended that compounds could be distinguished by whether they required any organisms in their synthesis (organic compounds) or whether they did not (inorganic compounds).Vitalism taught that formation of these "organic" compounds were fundamentally different from the "inorganic" compounds that could be obtained from the elements by chemical manipulations in laboratories. Vitalism survived for a short period after the formulation of modern ideas about the atomic theory and chemical elements. It first came under question in 1824, when Friedrich Wöhler synthesized oxalic acid, a compound known to occur only in living organisms, from cyanogen.

A further experiment was Wöhler's 1828 synthesis of urea from the inorganic salts potassium cyanate and ammonium sulfate. Urea had long been considered an "organic" compound, as it was known to occur only in the urine of living organisms. Wöhler's experiments were followed by many others, in which increasingly complex "organic" substances were produced from "inorganic" ones without the involvement of any living organism, thus disproving vitalism.

The L-isoleucine molecule, $C6H13NO2$, showing features typical of organic compounds. Carbon atoms are in black, hydrogens gray, oxygens red, and nitrogen blue. Although vitalism has been discredited, scientific nomenclature retains the distinction between organic and inorganic compounds. The modern meaning of organic compound is any compound that contains a significant amount of carbon—even though many of the organic compounds known today have no connection to any substance found in living organisms. The term carbogenic has been proposed by E. J. Corey as a modern alternative to organic, but this neologism remains relatively obscure.

The organic compound L-isoleucine molecule presents some features typical of organic compounds: carbon–carbon bonds, carbon–hydrogen bonds, as well as covalent bonds from carbon to oxygen and to nitrogen.

As described in detail below, any definition of organic compound that uses simple, broadly-applicable criteria turns out to be unsatisfactory, to varying degrees. The modern, commonly accepted definition of organic compound essentially amounts to any carbon-containing compound, excluding several classes of substances traditionally considered 'inorganic'. However, the list of substances so excluded varies from author to author. Still, it is generally agreed upon that there are (at least) a few carbon-containing compounds that should not be considered organic. For instance, almost all authorities would require the exclusion of alloys that contain carbon, including steel (which contains cementite, Fe_3C), as well as other metal and semimetal carbides (including "ionic" carbides, e.g, Al_4C_3 and CaC_2 and "covalent" carbides, e.g. B_4C and SiC, and graphite intercalation compounds, e.g. KC_8). Other compounds and materials that are considered 'inorganic' by most authorities include: metal carbonates, simple oxides (CO, CO_2, and arguably, C_3O_2), the allotropes of carbon, cyanide derivatives not containing an organic residue (e.g., KCN, $(CN)_2$, BrCN, CNO^-, etc.), and heavier analogs thereof (e.g., CP^- 'cyaphide anion', CSe_2, COS; although CS_2 'carbon disulfide' is often classed as an organic solvent). Halides of carbon without hydrogen (e.g., CF_4 and $CClF_3$), phosgene ($COCl_2$), carboranes, metal carbonyls (e.g., nickel carbonyl), mellitic anhydride ($C_{12}O_9$), and other exotic oxocarbons are also considered inorganic by some authorities. Nickel carbonyl ($Ni(CO)_4$) and other metal carbonyls are often volatile liquids, like many organic compounds, yet they contain only carbon bonded to a transition metal and to oxygen, and are often prepared directly from metal and carbon monoxide. Nickel carbonyl is typically classified as an organometallic compound as it satisfies the broad definition that organometallic chemistry covers all compounds that contain at least one carbon to metal covalent bond; it is debatable whether organometallic compounds form a subset of organic compounds, however. For example, the evidence of covalent Fe-C bonding in cementite, a major component of steel, places it within this broad definition of organometallic, yet steel and other carbon-containing alloys are seldom regarded as organic compounds. Thus, it is unclear whether the definition of organometallic should be narrowed, whether these considerations imply that organometallic compounds are not necessarily organic, or both.

Metal complexes with organic ligands but no carbon-metal bonds (e.g., $Cu(OAc)_2$) are not considered organometallic; instead, they are classed as metalorganic. Likewise, it is also unclear whether metalorganic compounds should automatically be considered organic.

The relatively narrow definition of organic compounds as those containing C-H bonds excludes compounds that are (historically and practically) considered organic. Neither urea nor oxalic acid are organic by this definition, yet they were two key compounds in the vitalism debate. The IUPAC Blue Book on organic nomenclature specifically mentions urea[9] and oxalic acid. Other compounds lacking C-H bonds but traditionally considered organic include benzenehexol, mesoxalic acid, and carbon tetrachloride. Mellitic acid, which contains no C-H bonds, is considered a possible organic substance in Martian soil. Terrestrially, it, and its anhydride, mellitic anhydride, are associated with the mineral mellite ($Al_2C_6(COO)_6·16H_2O$). A slightly broader definition of the organic compound includes all compounds bearing C-H or C-C bonds. This would still exclude urea. Moreover, this definition still leads to somewhat arbitrary divisions in sets of carbon-halogen compounds. For example, CF_4 and CCl_4 would be considered by this rule to be "inorganic", whereas CF_3H, $CHCl_3$, and C_2Cl_6 would be organic, though these compounds share many physical and chemical properties.