rarely is plagiarism involved. When the background knowledge is complete, the subsequent discovery is almost inevitable (10).

References and Notes

Presented as a Perspectives Lecture to the Division of Chemical Education at the 198th National Meeting of the American Chemical Society in Miami Beach, FL, 10-15 September 1989.

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JEAN-BAPTISTE DUMAS (1800-1884): THE VICTOR HUGO OF CHEMISTRY

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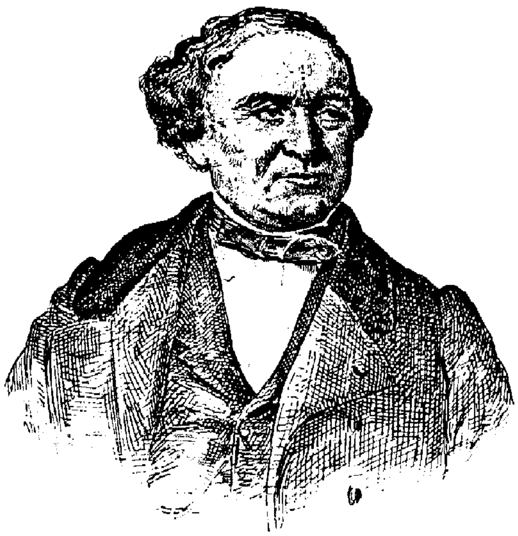
Romanticism is the term used to gather together a whole series of literary and artistic movements of the late 18th to late 19th centuries. These various movements, which spread throughout Europe and even to America, had one common element - the rejection of the traditions and rules of classicism, of the "Establishment", as it were. Romanticism produced Wordsworth, Keats, and Shelley; Goethe and Heine; Hugo and Dumas (Alexandre, that is); Pushkin; and Poe. It produced Delacroix, Constable, and Turner; Schumann, Chopin and Liszt; and, of course, Wagner, who tried to put it all together in his musical dramas. The Romantics' emphasis on emotion over reason, and on subjectivity and imagination over objectivity and intellect, would seem to rule out any inclusion of the sciences in these movements. But we know better. We know that science is not just a collection of facts and techniques; that it is a human endeavor, carried out in the context of a specific society or culture. We know that scientists are not (or at least not always) one-dimensional, narrowly trained and focused, and cooly objective; but are three-dimensional human beings with interests in, and with attitudes affected by, the arts, literature, religion, and politics.

In that wonderful volume of biographical essays, *Great Chemists*, edited by Eduard Farber, there is a short piece on Jean-Baptiste Dumas and Charles-Adolphe Wurtz, written by Georges Urbain and first presented to the Société Chimique de France in May of 1934. Urbain gave an unusual and provocative summary of his two subjects when he wrote (1):

> Living in the brilliant period of romanticism, they did not escape its influence. Dumas was the Victor Hugo of chemistry and Wurtz its Sainte-Beuve.

Because I knew a bit about Hugo, my first reaction to this statement was perhaps a little odd: I wondered whether Wurtz had tried to steal Dumas' wife (as Sainte-Beuve did to Hugo). I have seen no evidence that this was the case; apparently all that was implied was that Wurtz was a pupil and a friend of Dumas. The parallels between Wurtz and Sainte-Beuve will have to await another paper. But the statement intrigued me. In what sense was Dumas the Victor Hugo of chemistry? This essay is my attempt to answer that question.

There are, in fact, a number of parallels in the lives of these two men (2,3). First of all, they were almost exact contemporaries; Dumas was born in July 1800, 19 months before Hugo, and died in April 1884, 13 months before Hugo. Their childhood and adolescence spanned the rise and fall of Napoleon I. Hugo's father was an officer in Napoleon's army; Dumas at the age of 14 was determined to join the navy, but was



Jean-Baptiste Dumas

prevented by the upheavals of 1814-1815 (Napoleon's abdication, exile, escape, and Waterloo).

Both men showed early signs of brilliance. Hugo's poetry won the recognition of the French Academy when he was just 15; Dumas' name appeared on many journal articles (in pharmacy and physiology) before he was out of his teens.

Both had wide-ranging talents and interests. Indeed, it can be argued that neither man's most important work is widely known today. To the general public (certainly in the English-speaking world) Hugo is most famous for two novels - *Notre Dame de Paris* with its hunchbacked bellringer Quasimodo, and *Les Miserables* (especially since it has been given a musical score in a pop soft-rock idiom). But it was Hugo's plays which established him as the leader of the Romantic movement in France, and it is his poetry which makes secure his exalted position in French literature. We know of his plays mainly because Verdi chose two of them as the basis for his operas - *Le Roi s'amuse* became *Rigoletto* and *Hernani* became *Ernani*. The poetry, however, apparently loses too much in translation, since it is almost unknown in English.

To the general chemical public of today, Dumas is known for two analytical methods which he developed or refined - one for the determination of molecular weights by vapor density and the other for the determination of nitrogen in organic compounds. Yet he was also a brilliant teacher. He held professorships at the Athanaeum, the Sorbonne, the École Polytechnique, and the École de Médecine (some simultaneously) and was a prolific writer on many philosophical and scientific subjects. Indeed, it is his work on the theory of organic chemistry which secures his place in the history of chemistry.

Both Hugo and Dumas became famous and widely known in the intellectual circles of their day when they challenged the Establishment, the orthodoxies of their respective fields. Though the Romantic movement in literature had begun in France with Mme. de Stael and Chateaubriand, the official model for poetry and drama was still the pseudo-classicism of Voltaire. Then, in the Preface to his 1827 play *Cromwell*, Hugo produced an extensive and strongly argued manifesto for romanticism in which he claimed that in the progression of man from the primitive to the civilized modern, romanticism was historically inevitable - a new phase in social evolution. The result was that, suddenly, at the age of 25, Hugo was freely acknowledged as the leader of the Romantics in France.

Chemistry, in its modern sense, was a relatively young science in the 1820s; Lavoisier and his followers had set it on its feet only a generation earlier. But, like literature, it had its orthodoxy, its official models, too. In molecular structure, there was the electrochemical dualism of the great Swedish chemist Berzelius. Briefly, this explained chemical combination by assuming that atoms had electrical polarity.

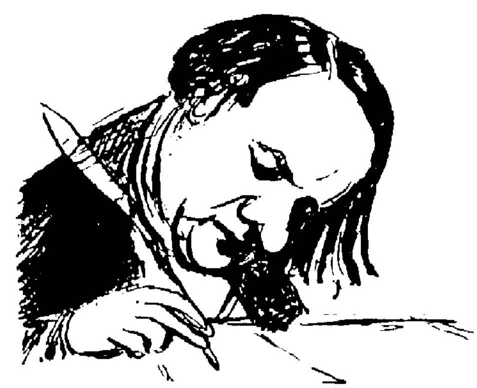
Oxygen was the most negative atom, potassium the most positive, with the others falling between. In general, metals were positive and even when they combined with oxygen, the oxide showed a residual positive character:

$$K(+) + O(-) \rightarrow K_2O(+)$$

Nonmetals might be positive toward oxygen, but negative toward metals. Nonmetal oxides always showed negative character:

$$S(+) + O(-) \rightarrow SO_3(-)$$

Salts were the result of the combination of positive metallic oxides with negative nonmetallic oxides, but were not necessarily neutral:



Victor Hugo caught in a characteristic pose at
the Académie française by the caricaturist Mérimée

$K_2O(+) + SO_3(-) \rightarrow K_2O{\cdot}SO_3(+)$ or $K_2SO_4(+)$

Double salts, like the alums, were seen as the combination of a positive and a negative salt:

$K_2SO_4(+) + Al_2(SO_4)_3(-) \rightarrow KAl(SO_4)_2(+)$

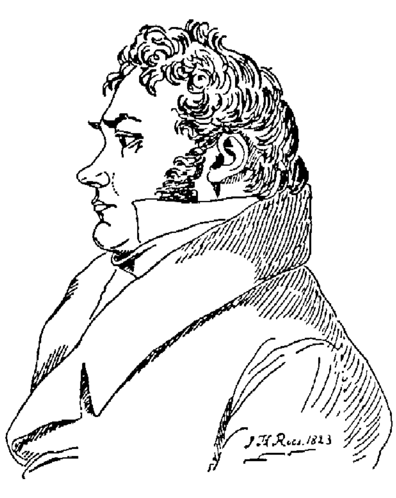
As can be seen, this is not all that different from our current concepts of electronegativity and simple acid-base theory. But in the growing field of organic chemistry, difficulties arose.

The use of the term "radical" to designate atoms or groups of atoms that acted as a unit in chemical combination, had been around since the 1787 book on nomenclature by Guyton de Morveau et al. (4). In 1817 the dualistic theory was extended by Berzelius to organic compounds (5):

All organic substances are oxides of compound radicals. The radicals of vegetable substances generally consist of carbon and hydrogen, those of animal substances of carbon, hydrogen, and oxygen.

In 1827-28, Dumas and Polydore Boullay (a pharmacist) advanced the suggestion that compounds related to alcohol might be understood as addition products of ethylene (etherin), just as ammonium compounds were addition products of ammonia (Table 1). They even concluded that ethylene was a base, and would show the same alkaline behavior as ammonia if only it were soluble in water. All this was explained in dualistic terms (it was Berzelius who named the radical etherin) but the continuing search for and study of other hydrocarbon "radicals" caused much confusion, and led ultimately to the downfall of the dualistic model (6).

In 1834 Dumas caused great consternation - wrote his "Cromwell Preface", though he didn't recognize it fully at the time - by proposing his "Law of Substitution". As the story goes, there was a ball held at the Tuileries in Paris, and fumes given off by the candles caused the guests to cough and choke. The King asked his friend Alexandre Brogniart, director of the testing laboratories of the royal porcelain works at Sévres, to investigate. He passed the problem on to his son-in-law, Jean-Baptiste Dumas, who soon identified the irritant as hydrogen chloride, the candle wax having been bleached with chlorine. He made further studies of the chlorination of waxes, oils, and the like, and found that chlorine was absorbed and hydrogen chloride emitted in equal amounts. He also looked at Liebig's discovery of the two-stage reaction between chlorine and alcohol (viewed as a hydrate of etherin) to produce chloral:



Jöns J. Berzelius

Table 1. The Etherin Theory of Dumas and Boullay (1828)

"etherin"	C_2H_4	ammonia	NH_3
alcohol	$C_2H_4{\cdot}H_2O$	hydroxide	$NH_3{\cdot}H_2O$
ether	$2C_2H_4{\cdot}H_2O$	oxide	$2NH_3{\cdot}H_2O$
chloride	$C_2H_4{\cdot}HCl$	chloride	$NH_3{\cdot}HCl$
nitro-	$C_2H_4{\cdot}HNO_2$	nitrite	$NH_3{\cdot}HNO_2$
acetate	$C_2H_4{\cdot}C_2H_4O_2$	acetate	$NH_3{\cdot}C_2H_4O_2$

$C_2H_4{\cdot}H_2O + Cl_2 \rightarrow C_2H_4O + 2HCl$

$C_2H_4O + 3Cl_2 \rightarrow C_2HCl_3O + 3HCl$

As a result of these studies, he stated his law of substitution:

* When a substance containing hydrogen is exposed to the dehydrogenizing action of chlorine, bromine, or iodine; for every volume of hydrogen that it loses, it takes up an equal amount of the halogen.

* When the substance contains water, it loses the hydrogen corresponding to this water without replacement.

Note that in the oxidation of alcohol to aldehyde, the chlorine removes the oxygenated hydrogens without substitution, but in the second reaction to produce chloral (trichloroacetaldehyde) the chlorine atoms substitute one-for-one the hydrogens attached to carbon. Dumas even went further and considered the oxidation of alcohol to acetic acid as a substitution in which each hydrogen is replaced by one-half atom of oxygen:

$C_2H_4{\cdot}H_2O + O_2 \rightarrow C_2H_4O_2 + H_2O$

These ideas were taken up by other chemists, especially Auguste Laurent. Now Berzelius was not at all happy with this theory, for it seemed to imply that electropositive hydrogen could be substituted by electronegative oxygen or halogens without any drastic alteration in the structure, and his dualism would not allow this.

Then a few years later (1839), Dumas reported that he had taken the known reaction in which trichloroacetic acid is decomposed into chloroform and carbon dioxide and repeated it with acetic acid, producing methane and carbon dioxide:

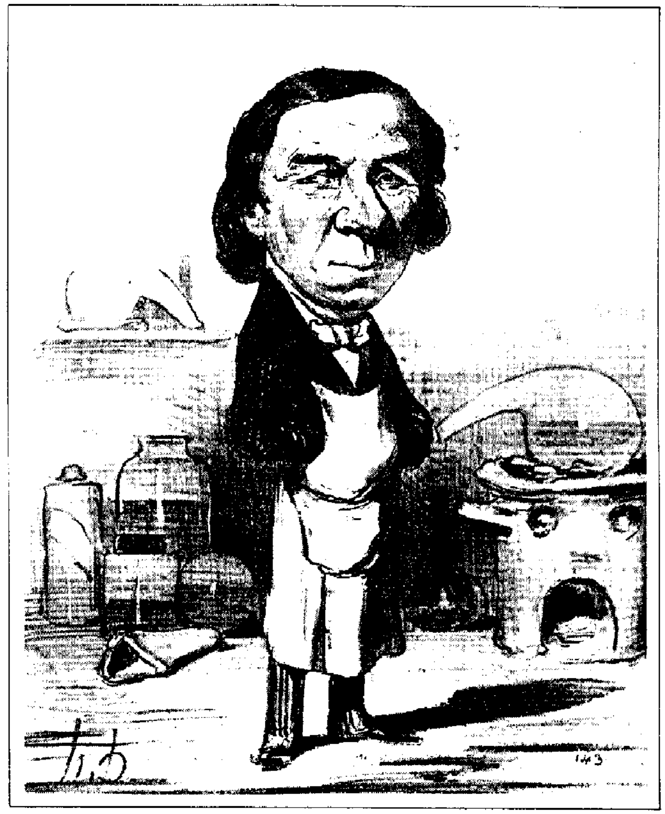
$$CCl_3CHO_2 + \text{alkali} \rightarrow CO_2 + CHCl_3$$

$$CH_3CHO_2 + \text{alkali} \rightarrow CO_2 + CH_4$$

Here chlorine and hydrogen obviously play the same role. The theory of types, as it became known, was a definite challenge to the dualism of Berzelius, for it considered molecules to be unitary structures whose properties depend on the position and arrangement of the atoms rather than their intrinsic positive or negative character. The battle raged between the classical dualists and the revolutionary unitarians with the French chemists largely championing the unitary theory and Dumas as their acknowledged leader. (There was also a rather nasty internal argument between Dumas and Laurent as to which of them really originated the type theory, but that's another story.)

Hugo and Dumas each belonged to the appropriate prestigious French Academy and Dumas was eventually made permanent secretary of the Academie des Sciences. Both men were egotists and were not above using their positions and prestige for their own purposes. Dumas was practically the dictator of French chemistry from 1840 to about 1865. He was responsible for the "exile" from Paris to provincial universities of Auguste Laurent, Charles Gerhardt, and others with whom he quarreled. Hugo in his later years became an insatiable womanizer, bedding chambermaids, leading actresses, and great ladies who found him, or rather his aura of literary demigod, irresistible. But let's be more positive.

Both Dumas and Hugo devoted large portions of their lives to politics and public service and made important contributions to life in France quite aside from their major fields of endeavor. Despite the high position his father had held under Napoleon, Victor Hugo was in his youth a firm Royalist and had been given a sort of fellowship (a pension) by the King so that he could devote himself to his writing. But his political views began to shift, especially after the July Revolution of 1830 in which Charles X was replaced by Louis-Phillipe. His writings became more liberal and more republican. Some of his friends were shocked in 1845 when he became a Peer of France (was appointed to the House of Lords) and felt that he was betraying his beliefs for the sake of position. However, he proved to be politically independent and actually had more contact with the leftist utopian reformers than with the moderates. After the 1848 Revolution and the establishment of the Republic, Hugo campaigned as a middle-of-the-road independent and was elected to the new Assembly along with a man who had just returned to France, one Louis-Napoleon Bonaparte (nephew of the late Emperor). He backed Louis in his campaign for the Presidency of the Second Republic, but when, after his election, Louis began to follow in his uncle's footsteps and undermine parliamentary rule, Hugo turned against him. When Louis was declared Emperor Napoleon III in 1851, Hugo had to flee for his life. He lived first in Brussels, then in the Channel Islands, which belong to England but lie within sight of France. On the Isle of Guernsey he wrote poetry, novels (including *Les Miserables*), and some anti-Imperial broadsides. He returned to France in 1870 during the tumultuous birth of the Third Republic and moved back permanently in 1873 to live out his years as the "Grandpere", the Grand Old Man, revered by all. He continued to write, mostly poetry, until his death in 1885.



Dumas caricaturized by Honoré Daumier

Dumas' political career did not really begin until almost all his scientific work had been accomplished. By 1840, as we have seen, he was the most powerful chemist in the country. His politics had been moderately conservative; he had prospered under the Monarchy. But after the 1848 Revolution he, like Hugo, was elected to the Assembly, and he served as Minister of Agriculture from 1850-1851. Unlike Hugo, he backed Louis-Napoleon and became a Senator in the Second Empire. He was on the Municipal Council of Paris for many years and became its President (in effect, the mayor) in 1859.

During his administration, the drainage and lighting systems of the city were greatly improved and work was begun on the system of aqueducts and tunnels to supply Paris with spring water. In 1870, the upheaval which brought Hugo back to France led to the resignation of Dumas from public service and his return to chemistry. He too remained active almost until his death, publishing papers on topics such as fermentation and the occlusion of oxygen in silver.

It seems to me that there are enough parallels to make a good case for Urbain's statement. Let me close with a curious twist. In *Les Miserables* there is a character called Grantaire who drinks a lot and, when in his cups, is given to eloquent flights of discourse, ranging over history, philosophy and, in at least one instance, science. In Part Four, Book XII, Chapter 3, he says (7):

> Comrades, we're going to throw out the Government and that's the truth, as true as the fact that between margaric acid and formic acid there are 15 intermediate acids. Not that I care a straw about that. My father always abominated me because I couldn't understand mathematics.

Now *Les Miserables* was written in 1862. In 1842, three years before Gerhardt coined the phrase "homologous series" for sets of compounds whose composition differed only by a multiple of CH_2, Dumas had shown that such a relation exists among fatty acids, and in his paper had affirmed that between formic and margaric acids there were exactly 15 intermediate acids, of which nine were known at that time and six remained to be found (8). Dumas, as an educated man of his time, must have almost certainly read Hugo's works and, as the above quote suggests, it seems that the converse must also be true!

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8. Quoted in reference 1, p. 527.

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VICTOR SERRIN AND THE ORIGINS OF THE CHAINOMATIC BALANCE

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With a history of thousands of years, the conventional, or two-pan, balance is known to everyone; it is the symbol of justice. Various forms of this instrument are in worldwide use, although the so-called single-pan balance and, latterly, the electronic balance, have largely displaced the two-pan version in the laboratory.

Trade in small but valuable objects, such as gemstones and gold coins, encouraged the development of the balance. Instruments of quite high sensitivity were in use by the 16th century. The introduction of regional or national standards of weights and measures further emphasized the need for precision balances, taxing the skill of 18th- and early 19th-century instrument makers such as Jesse Ramsden (1), Thomas Robinson (2), and Henry Barrow (3).

Instruments designed for chemical work are routinely expected to be able to detect a mass difference of one part in a million. For a 100-gram maximum load, this means weighing to the nearest 0.1 milligram. The results obtained in the use of even the finest two-pan balance depend ultimately upon the self-consistency and accuracy of the associated standard weights. These are added or removed by tweezers. However, very small weights are difficult to handle in this fashion and are easily lost. Conventionally, this problem is minimized by the use of a "rider" that can be suitably placed on a graduated scale on the beam of the balance. For example, a 10-milligram rider placed very near to the center knife or fulcrum of the beam could exert the same turning force as a 0.3-milligram weight that was placed directly on the balance pan. Manley (4) attributes the introduction of the principle of the rider to Berzelius. It is certain that British balance maker Ludwig Oertling received a medal for his balance "with graduated beam and sliding apparatus", shown during the 1851 Great Exhibition in London (1).