4. The decomposition and recomposition of water.
5. The production and the decomposition of earths.
6. The formation and the decomposition of alkalis.
7. Acidification: the formation and decomposition of acids; the nature of these salts, their differences, etc.
8. The combination of acids with earths and alkalis.
9. The oxidation and reduction of metals.
10. The solution of metals by acids.
11. The formation of the immediate principles of vegetables by vegetation.
12. The several species of fermentation.
13. The formation of animal matters by the life of animals.
14. The purefaction and decomposition of animal matters.

Each of these is considered briefly, and the relationship of each to the properties of gases is shown. It is a really beautiful summary of the state of chemical knowledge at the time, expressed in the new system.

A fourth edition of *Élémens* was published in 1791, with only a few minor changes; a fifth edition in 1793 was merely a reprint of the fourth. This fifth edition was reprinted in Switzerland in 1798. English translations of each edition had appeared within a year or two of the French publication. There were also translations into Italian, German, and Spanish. Incidentally, the first publication in America of the new theories came in Philadelphia in 1791 in a pirated edition of the *Encyclopaedia Britannica*, which reproduced a nomenclature table from the English translation of the third edition of Fourcroy's *Élémens*. Thus it can be argued that Fourcroy, with his large audiences in Paris and his very popular textbook circulated throughout Europe, did more to spread the new nomenclature and the new chemistry than anyone else. All I wish to claim is that it is this third edition, published 200 years ago last December, which was the "first textbook of the revolution".

One final word - in Bernard Cohen's marvelous book, *Revolution in Science*, he states that although Bucquet used the word "revolution" in referring to Lavoisier's work as early as 1777, and Lavoisier himself used it in his lab notebook as early as 1773, it was Fourcroy, through his textbook and other writings who "was most effective in canonizing the expression 'the revolution in chemistry'..." (9).

The third paper in this series will look at the most famous book of the chemical revolution, Lavoisier's own *Traité Élémentaire de Chimie*.

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2. Most of the biographical information in this paper is from W. A. Smeaton, *Fourcroy, Chemist and Revolutionary, 1755-1809*, Heffer, Cambridge, 1962. This excellent book also contains a detailed bibliography of Fourcroy's works and is recommended to all who wish further information.

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5. The title page of this translation reads, *Elements of Chemistry and Natural History. To which is Prefixed, the Philosophy of Chemistry, Fifth Edition, with Notes, by John Thomson, Surgeon, Edinburgh.* 3 vols., 1799. The quote is from Vol. 1, p. xi.

6. Ibid., p. xiii.

7. Ibid., p. xiii-xiv.

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## BOCHARD DE SARON AND THE OXYHYDROGEN BLOWPIPE

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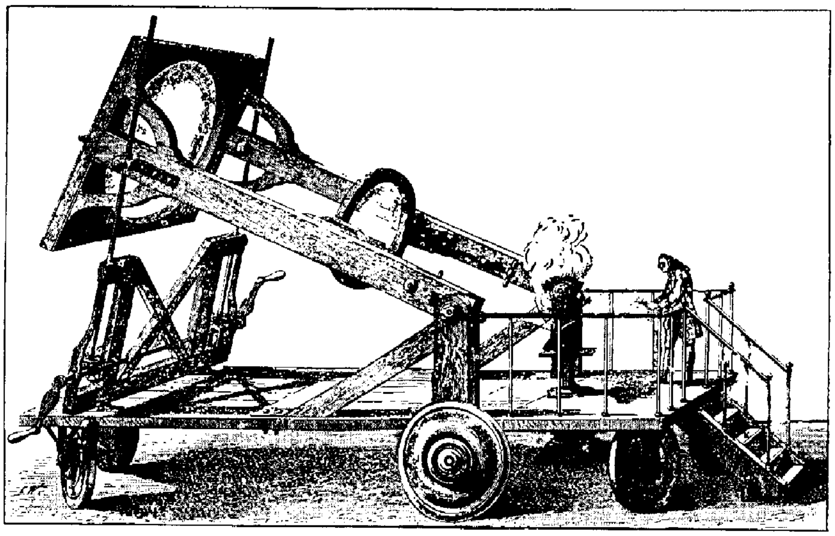
It was Joseph Priestley who first noted in 1775 that a mixed flame of dephlogisticated air (oxygen) and inflammable air (hydrogen) exhibited an unusually high temperature, and who first suggested that one might obtain a useful high temperature source by directing a stream of oxygen into a hydrogen flame by means of a bellows (2, 3). However, the practical construction of such a device was first accomplished by the French scientist, Jean Baptiste Gaspard Bochard de Saron, who was also the first to use an oxyhydrogen torch to successfully fuse platinum (1). Prior to Bochard's work, scientists wishing to work at high temperatures had to rely instead on the use of burning mirrors and lenses to concentrate the heat of the sun.

Attempts at capturing the heat of the sun's rays are apparently quite ancient. Myth tells us that Prometheus caught the heat of the sun to light the Vestal Fire and, when the Olympic Games started, the heat of the sun was used to light the Olympic flame, as it still is today (4). Likewise, Aristophanes refers, in *The Clouds*, to "That stone, that splendidly transparent stone, By which they kindle fire?" (5) and Plutarch claims that Archimedes used burning mirrors to set fire to the fleet of Marcellus in the sea off Syracuse (6).

Prior to the introduction of gas and Bunsen burners, only coal-burning furnaces, ventilated with bellows, were available to fuse such materials as metals, minerals, glasses, bones, etc. If one wished to avoid contamination by the combustion products of burning coal, the only alternative was the use of burning glasses and mirrors.

The use of lenses and mirrors as standard laboratory heat sources was already well established by the 17th century (7) and descriptions of their use can be found in the writings of such scientists as Robert Boyle, Robert Hooke and John Mayow. Even Galileo mentioned them, noting, in passing, that lead could be "melted instantly by means of a concave mirror only three hands in diameter" (8).

17th century burning lenses and mirrors came in all sizes, ranging from the hand-held magnifying glass used by Mayow to ignite antimony and sulfur in sealed vessels (9), to the large burning mirrors made by Francois De La Villette (1621-1698) of Lyon for the use of the Hessen family of Kassel (10). An example of a Villette mirror, built around 1670, is still preserved in the Staatliche Kunstsammlungen in Kassel, Germany. It has a diameter of 1.5 meters and a focal depth of 3.45 meters and was bought by Landgraf Wilhelm VIII about 1713 in Brabant as a gift for his father, Landgraf Carl, for use in his alchemical and metallurgical experiments. The same museum also houses two Tschirnhausen burning mirrors.



An example of a large 18th century burning glass described by Lavoisier.

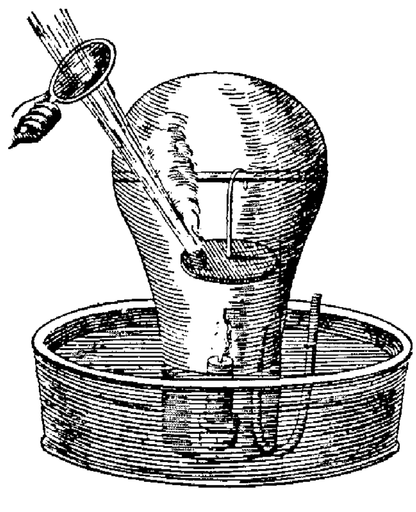
The efficiency of a typical Villette instrument was described by Henri Justel in a letter sent to Henry Oldenburg, the Corresponding Secretary of the Royal Society, on 18 July 1665 (11):

We examined its effects several times, in the morning, at noon, and in the afternoon. It always burned things most effectively, melting and liquefying any object with very few exceptions. In our presence it melted silver (a 15 sous coin), copper (a liard), brass, bits of a cast iron kettle, small bits of steel, heads of small iron nails ... it calcines glass and building stone (which it turns into glass by melting, and so it does the bones of animals); and it melted glass polished on both sides ... It lighted a candle very quickly, and thick sticks of wood which it set afire in a moment made a pretty sight. The radius of the mirror is four feet eight inches, and the focus is at two feet four inches. The diameter is two feet six inches and about two lines; the mirror was also found to be polished on the convex side ... The mirror itself is now finished on its stand; it is valued at 150 Louis d'or.

Though burning mirrors and lenses continued to be used as high temperature heat sources throughout the 18th century, the discovery of oxygen (or vital air) and its ability to support combustion resulted in a number of attempts in the 1780's to employ it to enhance the heating efficiency of conventional laboratory heat sources. The most common approach was to direct a stream of oxygen, rather than common air, through a conventional laboratory blowpipe onto a candle or oil flame and, in turn, to direct the resulting oxygen-enhanced flame onto the object to be fused (12). Experiments with devices of this type, which were in essence a kind of "oxygen blowpipe", were made by, among others, the German chemists, Friedrich Ehrmann (1741-1800) (13-14) and Franz Achard (1753-1821) (15), the Swedish chemist, B. R. Geijer (16), and by Lavoisier himself (17). Lavoisier's interest in high temperature fusion was, in part, related to his growing realization that solids, liquids and gases were actually three interconvertable states of matter. Materials were not inherently solid, liquid or gaseous but, depending on their temperatures, only relatively so. To thoroughly test this assumption required a high temperature source which could potentially melt even the most recalcitrant counter examples. In his 1782 memoir on the subject, entitled "A Method of Greatly Augmenting the Action of Fire and Heat in Chemical Operations", he first summarized the results that had been obtained to date by the use of burning mirrors and lenses (17):

The great burning lenses of Tschirnhausen have provided chemists with an agent much stronger than the fire of the furnace, by which they have discovered that a large number of bodies, regarded as infusable or as fixed, will yield to the action of very strong heat. The trials done by M. de Count Lauraguais and M. D'Arcet with a porcelain furnace have confirmed the same truth and the great lens of M. Trudaine, built by M. de Berniéres, under the inspection of the Commissaires de l'Academie Royale des Sciences, has completed the proof that the quality of being fixed or refractory, attributed to certain bodies, is relative to the degree of fire used.

However, despite these successes, Lavoisier was quick to point out that the use of lenses and mirrors was apparently limited, since attempts at increasing their size did not produce



John Mayow's use of a small magnifying glass to heat materials confined over water, circa 1674 (9).

a proportionate increase in temperature, but did make them correspondingly more expensive and difficult to work with. Consequently it was necessary to find some alternative based on the ability of the recently discovered gas, oxygen or vital air, to enhance combustion. The rest of the memoir is largely taken up in describing an elaborate system, developed by Lavoisier and J. Meusnier, for directing a stream of oxygen through a blowpipe and their unsuccessful attempts to use it to fuse platinum metal.

Only near the end of the memoir does Lavoisier mention yet another suggestion, based on the work of Bochard de Saron (17):

> President de Saron has told me of another very ingenious idea, to apply on bodies that cannot be placed in contact with charcoal. It consists of using a converging assembly of two blowpipes, one supplied with vital air and the other with inflammable air. One obtains a pointed flame, very white, very luminous, and very hot with which one can easily fuse iron but with which, nevertheless, it is not possible to fuse platinum. The manner of operation is so convenient and so rapid as to remove all objections and I prefer it to all others ...

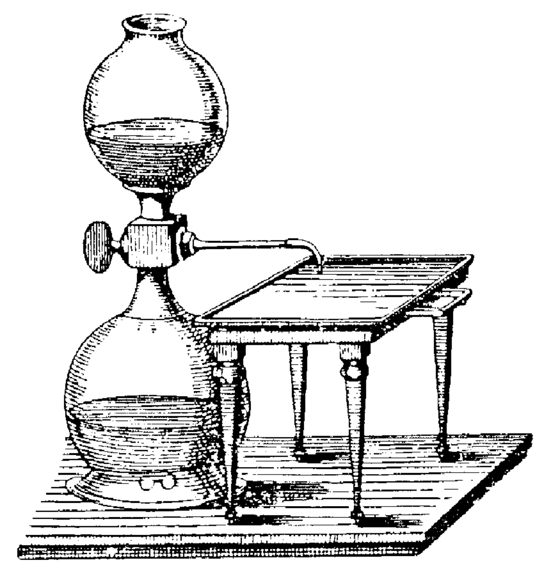
In short, like Priestley before him, Bochard had suggested an oxyhydrogen blowpipe but, unlike Priestley, had apparently actually built one. Regrettably, we have only second hand descriptions of Bochard's apparatus and procedure (17, 18-19). We do know that he and his laboratory assistant, M. Tillet, used leather bags to store each gas separately, and that, in contrast to Lavoisier's negative result, Bochard claimed to have successfully fused platinum. Nevertheless, Lavoisier was enthusiastic about Bochard's device, and in closing, outlined both a way of improving it and his intention to pursue the matter further (17):

> ... imagine an apparatus in which vital air could be made to surround the inflammable air on all sides, so that the latter in some way burns in an atmosphere of vital air. Perhaps a more considerable effect will obtained. With the help of M' le President de Saron's inspiration, I hope to further pursue the benefits of this new method.

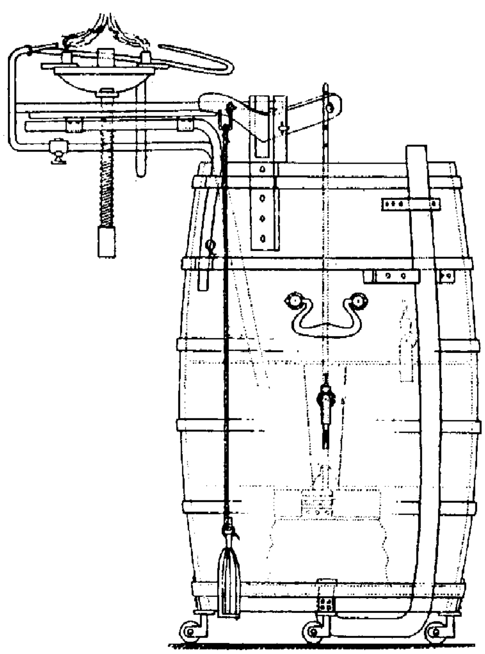
Here Lavoisier is, in effect, suggesting a premixing of the oxygen and hydrogen prior to combustion, a suggestion which he apparently did not develop, though 20 years later an inverted form of his proposal, with oxygen on the inside and hydrogen on the outside, was perfected by the American chemist, Robert Hare (20).

Jean Baptiste Gaspard Bochard de Saron was born in Paris in 1730 (21). The son of a wealthy family, he was best known for his work in astronomy, but he also dabbled in mathematics, natural philosophy, chemistry, art, music and book publishing. He served as President of the Parliament of Paris (hence Lavoisier's reference to his title), and as both Vice-President and President of the Academie Royal de Sciences. His development of the oxyhydrogen blowpipe stemmed from his interest in making corrosion resistant metal telescope mirrors from platinum and the consequent necessity of finding some means of melting the metal.

Both of Bochard's biographers (18-19) state that the first fusion of platinum took place in Bochard's secret laboratory, which he had installed in his home in the Rue de l'Université (22). He had inherited the house from his uncle, Canon Elie de Bochard, and had remodeled it in order to accommodate his large family, his observatory and astronomical instruments, his printing press and, of course, his metallurgical laboratory. The laboratory is referred to as "secret" because its entrance was disguised in the woodwork of Bochard's library. Interest-



Ehrmann's oxygen blowpipe of 1785 (13).



Part of Robert Hare's original oxyhydrogen blowpipe (1802). The double compartment barrel stores the two gases and the blowpipe itself is attached to the side at the upper left (24).

ingly, this house is still standing and is presently occupied by offices of Editorial Gallimard. The present occupants have indicated that the leather bags used by Bochard to collect oxygen and hydrogen are still hanging behind the woodwork of the library, which is now used by the firm's President as an office (23).

Like Lavoisier, Bochard came to grief at the hands of the French revolution. Accused of being a counterrevolutionary, he was arrested on 18 December 1793 and guillotined on 20 April 1794, the same year as Lavoisier, after first being allowed to make an inventory of his laboratory apparatus and astronomical instruments.

Most likely, because of his failure to write a memoir on the subject, posterity lost track of Bochard's contribution and several 19th century investigators, apparently unaware of his work, laid claim to having invented the first workable oxyhydrogen torch. The most notable of these was the American chemist, Robert Hare, mentioned earlier, who published an account of his oxyhydrogen blowpipe in 1802 (24) and whose claims to priority were vigorously defended in American textbooks against European claims for more than half a century (25).

The blowpipe was gradually improved throughout the 19th century, largely by refining the premixing of the gases. By 1852 the Johnson-Matthey Company of London was able to display a large nugget of fused platinum at the Great Exhibition at the Crystal Palace, and by 1859, the French chemists, Henri Sainte-Claire Deville and Henri Debray, were able, with their improved instrument, to reach temperatures of over 2000°C, or nearly 300°C above the melting point of platinum, (26).

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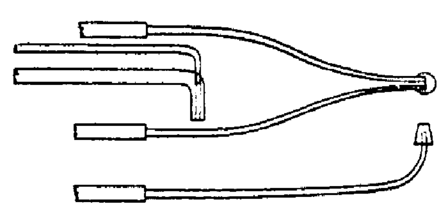
12. For background on the development of the conventional laboratory blowpipe, see W. B. Jensen, "The Development of Blow-



Some of the tips used by Hare in his compound blowpipe. Of particular interest is the second from the top in which the oxygen delivery tube is contained within the hydrogen delivery tube (24).

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13. F. L. Ehrmann, *Versuch einer Schmelzkunst mit Behülfe der Feuerluft*, Strasbourg, 1785.

14. F. L. Ehrmann, *Essai d'un Art de Fusion a l'Aide de l'Air du Feu ou Air Vital*, Treutel, Strasbourg, 1787. This is a French translation of reference 13, to which two memoirs by Lavoisier are added.

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19. J. D. Cassini, "Eloge de M. Le President de Saron", *Memoires Pour Servir A L'Histoire Des Sciences*, Colas, Paris, 1810.

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21. For further details of the life of Bochard, see E. L. Gonzalez, "Jean Baptiste Gaspard Bochard de Saron: Nobleman, Mathematician, Astronomer, Physicist, Chemist, Printer, Publisher, Artist and Musician", presented at the Midwest Junto in the History of Science, Iowa State University, Ames, Iowa, 28 April 1989.

22. The building is located at 17 Rue de l'Université, Paris, France, 75007.

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25. See, for example, T. D. Mitchell, *Elements of Chemical Philosophy*, Correy and Fairbank, Cincinnati, OH, 1832, footnote on p. 69.

26. For a brief summary of the early history of the oxyhydrogen blowpipe, see J. R. Partington, *A History of Chemistry*, Vol. 3, Macmillan, London, 1962, pp. 724-725.

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# KASIMIR FAJANS (1887-1975): THE MAN AND HIS WORK

## Part I: Europe

*Reynold E. Holmen, White Bear Lake, MN*

To some, the name of Kasimir Fajans calls to mind a man whose early achievements in radiochemistry secured for him a place in the history of chemistry. A very few may recall one of those blue volumes published under the aegis of the Baker Lectures at Cornell University and which evolved from lectures given by Fajans during his visit to the United States in 1930. Some may even have been contemporaneous with his teaching years at the University of Michigan, beginning in 1936. If so, his name may conjure up recollections of an outspoken critic of instruction in chemistry, particularly of the dominant qualitative approach to chemical bonding. To yet another group, those who were fortunate to have heard one or more lectures by him, the name recalls a person who left an indelible mark on his listeners.

None of these recollections, however, really gives much insight into what made this man "tick" or into the genesis of his major contributions to the progress of chemistry in our century. In this account I will try, among other things, to reduce this void by recounting some of the events said by him to have had a profound influence on the development and direction of his career (1).

Kasimir Fajans, the centennial of whose birth was celebrated in 1987 (2), was born in Warsaw, Poland, on 27 May 1887. He was the second child and the elder son of five children born to Herman and Wanda (Wolberg) Fajans. Both parents' families had members who had distinguished themselves at some period during the 18th, 19th, or 20th centuries: whether in science, medicine, music, photography, government, or in Polish patriotic movements. The Fajans family was part of the highly emancipated and "polonized" Jewish population. Polish, not Yiddish, was the daily language. Not surprisingly, as the elder son, Kasimir served as a role model for his younger siblings in what was reported to have been a loving and respectful family environment.

For the first years, private teachers taught Fajans at home. He later moved on to the Real-Gymnasium, a school where natural sciences, rather than Latin and Greek, were stressed. Nevertheless, the Russian dominance throughout the schools mandated that Russian be the official language. Polish was not allowed in the school building. The clash between Fajans' interests and that of the teacher's showed up in another way. In a Russian language class, Fajans was once given a poor grade for writing on "Climate" as an essay subject. Fortunately the director of the school was a scientist and responded favorably to Fajans' complaint about the grade. Beyond his early interest in science, Fajans was also a sports lover. He played tennis