Educación Química

Julien-François Jeannel

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Resumen

Julien-François Jeannel (1814-1896) fue un médico y farmacéutico francés que estudió la asimilación de alimentos en los organismos vivos, particularmente del calomel; la química del sesquióxido de hierro; la producción de nitratos y nitritos en la naturaleza; el fenómeno de la sobresaturación y su aplicación en la cristalización y el almacenamiento de calor; y las propiedades del acetato de sodio. Descubrió que la asimilación de alimentos estaba precedida por la formación de una emulsión, favorecida por los carbonatos alcalinos, y que el Hg(I) se transformaba en Hg(II), cuya acción se mitigaba por la albúmina y los materiales grasos. En presencia de agua y HCl, el hidrato de sesquióxido de hierro se transformaba en cloruro de sesquióxido de hierro, $Fe_2Cl_3 \cdot 9Fe_2O_3$, muy soluble en agua. Postuló que los nitratos y nitritos se formaban naturalmente en el suelo al contacto con el aire, que era posible nutrir plantas con soluciones minerales y que crecen mejor en arena pura que en tierra negra. Demostró que la sobresaturación y cristalización se producían por siembra con cristales del mismo compuesto y sugirió usar acetato de sodio para almacenar energía solar.

Palabras clave: Jeannel, calomel, sobresaturación, óxido, acetato.

Abstract

Julien-François Jeannel (1814-1896) was a French physician and pharmacist who studied the assimilation of food in living organisms, particularly calomel; the chemistry of iron sesquioxide; the production of nitrates and nitrites in nature; the phenomenon of supersaturation and its use in crystallization and heat storage; the physical and chemical properties of sodium acetate; and more. He found that food assimilation was preceded by the formation of an emulsion, highly favored by alkaline carbonates, and that Hg(I) was transformed into Hg(II), the action of which was mitigated by albumin and fatty material. In the presence of water and HCl, iron sesquioxide hydrate transformed into iron sesquioxide chloride, ferric chloroxide, $Fe_2Cl_3 \cdot 9Fe_2O_3$, highly soluble in water. Jeannel postulated that nitrates and nitrites were formed naturally in the topsoil upon contact with air, that it was possible to feed plants with suitable mineral solutions providing them with the solid elements needed to grow, and that plants vegetated much better in pure sand than in loam. Jeannel demonstrated that supersaturation and crystallization were not caused by particles floating in the air but by seeding with crystals of the same compound or solid bars. He also suggested that sodium acetate could be used to store solar energy.

Keywords : Jeannel, calomel, supersaturación, óxido, acetate.

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Life and career (Anonymous, 2024; Galmiche, 1998; Anonymous, 1898)

Jean-François Jeannel (Figure 1) was born on February 14, 1814, in Paris, the second son of Charles Jeannel and Marie Anne Vasseur (1781-1851). After finishing his basic education, he participated and won by competition a place as pharmacy student at the Val de Grace Army Teaching Hospital. In 1835 he graduated as a laurate pharmacist (1838) and begun a brilliant military career, which culminated with his promotion to General Inspector of Pharmacy. During this period, he was assigned to pharmacist position in many locations in France and abroad (Lille, Colmar, Sarreguemines, Phalsbourg, Bordeaux, Toulouse, Metz, Algiers, etc.). The garrison life gave him enough free time to study medicine and eventually obtain his doctoral degree from the Faculté de Médecine in Paris, after successfully defending, a thesis about the healing of abdominal hernias in adults by simple application of bandages (Jeannel, 1838a). In the same year, he earned by competition a position of agregé at the University of Strasbourg, after presenting a dissertation about the laws common to inorganic and organic chemistry (Jeannel, 1838b). In 1842, Jeannel returned to France where he was assigned to Toulouse and promoted to pharmacien major. The next year he moved to Bordeaux as a pharmacien major at the local military hospital, where he spent 26 consecutive years, becoming pharmacien principal de 2^{e} Class in 1852, and being appointed substitute professor of physics, chemistry, and materia medica at the School of Medicine, and practicing medicine as chief physician at the municipal dispensary, focusing mainly on venereal diseases. In 1854, he was appointed chief pharmacist of the Eastern Army, which left for the Crimean War, and whose medical base was established in Varna in Bulgaria. In 1869, Julien Jeannel was promoted to head pharmacist of the Saint-Martin hospital in Paris (in 1872 he returned to this position during the Commune regime), and quickly left as head pharmacist of the Imperial Guard to join the headquarters of Metz at the start of the Franco-Prussian war of 1870. In 1884, he retired as honorary professor at the Lille University.


FIGURE 1. Julien François Jeannel (1814-1896). Credit: contributeurs aux projets Wikimedia, 2025.

In 1846, he married Anne Renée Ruelle in Bordeaux; two children (Charles and Maurice) were born of this union.

Jeannel actively participated in many professional and public activities. He was a member of the Société de Médecine de Bordeaux (1846); of the Société de Pharmacie de Bordeaux (1862); of the Société de Sciences Physiques et Naturelles of Bordeaux (1866) and its Vice-President; of the Société de Médecine Légale de Paris (1868); of the Association des Médecins de la Gironde; of the Associations des Médecine de France; of the Commission des Médecins de la Gironde; and of the Conseil d'Hygiène et de Salubrité du Département de la Gironde (1857). Together with the physician Pierre Rayer (1793-1867), they founded the French General Practitioner's Association (AGMF), which served as an Association, Order, and Union at the same time. In 1891, he founded the Société Forestière Française des Amis des Arbres, of which he was the first president. During 1863-1864, he used a vast area in the center of Bordeaux to turn it into a walking park with an acclimatization garden. Together with the physicians Féreau and Papillon, he founded the Lille Faculty of Medicine. Jeannel was also editor-in-chief of the Journal de Médecine de Bordeaux. In 1854, he was appointed Chevalier de la Legion of Honneur and in 1868, he was promoted to Officier.

Jeannel passed away on March 24, 1896, in Villefranche sur Mer (Alpes-Maritimes).

Scientific contribution

Jean-François Jeannel carried out most of his research on the subjects of inorganic, organic, and physical chemistry, syphilis, prostitution, and forensic medicine. This work led to the publication of about seventy-five scientific papers and many books about worker's medicine, public medicine, suicide, syphilis, prostitution, as well as a French Codex the Army used until 1918 (i.e., Jeannel, 1848, 1859b, 1862, 1867ab, 1870b, 1876a, 1896). As customary to candidates to a scientific Académie, Jeannel prepared a booklet describing his research activities and services (Jeannel, 1870ac). In addition to the few subjects described below, Jeannel described the preparation of gelatin and smoked meat from horses to feed the French troops during the siege of Médéa (Jeannel, 1840); designed a new aerometer providing the true density of liquids and the volume of one kilogram (Jeannel, 1859ab), and a new thermostatic regulator able to measure temperatures from the atmospheric to above the boiling point of mercury (356.7 ^{o}C) (Jeannel, 1872a); determined the solubility of lead iodide in water at 20 ^{o}C and found this salt was insoluble in a diluted solution of potassium iodide (Jeannel, 1864); the cooking of foodstuff at 100 ^{o}C (Jeannel, 1872b); the influence of sound vibrations on the operation of a radiometer (Jeannel, 1876b); the influence of deforestation on the climate, on poverty, and population migration (Jeannel, 1891); the permeability of the soil, humus, and chemical fertilizers (Jeannel, 1893); etc.

Assimilation

Jeannel, first with Mosel and then alone, studied the emulsification of fatty substances by alkaline carbonates and on fatty substances considered as vehicles for inorganic and organic bases (Jeannel & Monsel, 1857; Jeannel, 1859cd, 1866c).

The work with Monsel led to the following main conclusions (Jeannel & Monsel, 1857): (1) All alkaline reagents of inorganic or organic origin were able to emulsify oils in distilled water, while strong insoluble metallic bases did it partially; (2) the phenomenon did not occur in the presence of acidity; (3) the emulsification begun with a partial saponification at room temperature and was accelerated by higher temperatures; (4) the high alkalinity of pancreatic juice made it the most useful of the intestinal juices for the digestion of fatty substances. Nevertheless, the experimental results indicated that other alkaline juices could supplement it for the digestion of fatty substances; (5) the introduction of a moderate proportion of alkali into the stomach with food, or only the abstention from acidic foods, indirectly promoted the emulsification of fats in the stomach; (6) oil was a more general solvent than water, it dissolved all components of the animal organism, including many mineral oxides, alkaloids, stearates, and oleo-stearates with mineral or organic bases; (7) these stearates and metallic or organic oleo-stearates were insoluble in water and therefore, assimilable in the intestine. They were easily prepared by reacting bases with fatty acids or by double decomposition of soluble salts with a soap solution (8) the inorganic oils were generally tasteless or had a disgusting taste, did not irritate tissues, and emulsified like pure oils in distilled water, using minimal proportions of alkaline carbonate; and (9) doses of 0.05 to 0.10 grams of alkaline carbonates were enough for instantly obtaining non-viscous emulsions with the oils, facilitating the administration of medicinal oils and copahu (Jeannel & Monsel, 1857).

The next project was a study of the physiological consequences of injecting the above oily solutions, previously emulsified in distilled water, into the small intestine. Using very small doses of alkaline carbonate or soap. This procedure permitted the direct study of their absorption through intestinal digestion, avoiding ligation of the esophagus and its consequences. The first results indicated that this technique resulted in a prompt absorption of the emulsion not only in the small intestine but also in the peritoneum (Jeannel, 1859d).

Jeannel did not detail his experimental techniques but only the results, for example: (1) Mercury oleostearate did not irritate the exposed dermis or wounds, was not absorbed there in significant proportions, and its primary action was essentially emetic and purgative; (2) a dose of two to five grams in dogs of medium size caused extremely violent emetic and purgative effects, corresponding to those of acute mercurial poisoning; (3) injection of mercury fatty salts into the jugular proved that mercury exerted mainly a very energetic emetic-cathartic action accompanied by hemorrhage of the entire surface of the jugular; (4) death was preceded by a weakening or the beginning of paralysis of the hind limbs; (5) the immediate elimination of mercury injected into the vessels in the fatty salt state was probably done by saliva and certainly by gastric fluids; and (6) administration of fatty salts of mercury in high doses quickly caused swelling of the gums, or produced the specific effects of mercury in the treatment of syphilis, and other minor side effects (Jeannel, 1859cd).

Assimilation of calomel ($H_{g2}Cl$)

Louis Mialhe (1807-1886), wrote that scientists agreed that all alkaline chlorides, particularly ammonium chloride, transformed mercury (I) chloride into mercury (II) chloride, accompanied by an equivalent amount of metal. Nevertheless, he had some doubts regarding the veracity of this statemen (Mialhe, 1841, 1842). For this reason, he conducted a series of experiments on the subject and concluded: (a) both oxides of mercury, Hg2O and HgO, reacted with aqueous ammonium chloride, yielding HgCl2, or more precisely, ammonium-mercury chloride (alembroth salt, the salt of wisdom of the alchemists). The yield from HgO was larger than the one from Hg2O; (b) all the salts of Hg(I) and Hg(II) produced the same results, they generated HgCl2, and the conversion of the Hg(II) salts was higher than that of the Hg(I) ones. According to Mialhe, these results indicated that the salts of mercury (II) were much more energetic than those of mercury (I). The latter could also be completely inoffensive; (c) metallic mercury digested with a solution of ammonium chloride was also converted partially into HgCl2, a reaction allowing the transformed metal to enter the animal body; (d) all the above reactions occurred at room temperature, even better at body temperature, and in a very short time. Human liquids contained ammonium and sodium chlorides, accompanied or not by HCl and other acids, which could facilitate their action, hence the result of these experiments was considered likely to be of importance in modifying the use of mercury, calomel, etc. as medicines (Mialhe, 1841,1842) .

Jeannel heavily criticized Mialhe conclusions, he believed that not only they were incomplete, but also they were also erroneous (Jeannel, 1869b). He conducted a variety of experiments under different conditions and concluded as follows: (1) Alkaline carbonates were the main decomposers of calomel; in relative terms, alkaline chlorides in solution dilute or concentrated, hardly decomposed calomel; (2) in the presence of alkaline liquids, fatty substances dissolved the mercury oxide originating from the decomposition of calomel. For example, five decigrams of calomel dissolved in fifty grams of distilled water and mixed with one gram of potassium bicarbonate. Turned the calomel gray. Digestion of the mixture at 40 °C for one hour followed by treatment with stannous chloride, precipitated 40 milligrams of metallic mercury. Similarly, a solution of 0.29 g of calomel (1 equivalent) in 50 g of distilled water was mixed with 146 mg of sodium chloride (2 equivalents) and kept at 14 ^{o}C. The filtrate did not give a precipitate with stannous chloride or with ammonia sulfide. Jeannel remarked that the reagent stannous chloride was able to detect 1/80,000 parts mercuric chloride in aqueous solution (Jeannel, 1869b).

Jeannel added that the calcium bicarbonate present in drinking water acted like sodium bicarbonate. In an example, a mixture of one liter of common water with 0.5 grams of calomel were kept and 40 °C for one hour and filtered. The filtrate was found to contain 12 mg of metallic mercury. Jeannel remarked that he had not tested Mialhe's claims regarding the action of ammonium chloride (Jeannel, 1869b).

Jeannel wrote that he had carried out a long series of experiment (without giving details) on the influence that addition of fatty materials had on the above results. He remarked that in a liquid mixture of water, alkaline bicarbonate, and fatty oil, a very notable proportion of mercury oxide coming from decomposed calomel was able to dissolve in fatty substances. Afterwards, this specific solute lost its combination ability and was emulsified and absorbed. Jeannel believed that his theory explained why calomel acted so slowly and was generally harmless: Its action was almost zero as long as it stayed in the stomach in contact with acidic and slightly chlorinated liquids. Once it had reached the intestine, having an alkaline nature, the calomel oxidized to dichloride. The irritating nature of the latter, and of the oxide resulting from the decomposition of calomel, was mitigated, or nullified by albumin and fatty substances; Mercury was hence absorbed in the form of albuminate or fatty salt (Jeannel, 1869b).

Iron sesquioxide

In 1868 Jeannel reported that he had discovered the reason why some of the varieties of hydrated iron sesquioxide reacted with acids in very different ways (some dissolved easily in acids giving more or less unstable salts while others were partially soluble or insoluble) (Jeannel, 1868c). Jeannel believed that the cause of this phenomenon was the presence of traces of sulfuric acid, free or in a combined state. Thus, ferric oxide hydrate formulated from raw materials completely free of sulfates and in vases washed with distilled water, was very soluble in HCl and in medical (French Codex) ferric chloride. Mixing 85 grams of pure HCl (specific weight 1.20, 40% acid by weight), with 1000 grams of iron sesquioxide hydrate containing 75% of water, and 500 grams of distilled water, resulted in a very exothermic reaction and a solution of relative density1.26 of a new complex substance composed of ferric chloride and an indeterminate amount of iron sesquioxide Fe_2O_3. This substance was stable and very soluble in water and could be represented by the formula (sic) Fe_2Cl_3, $9Fe_2O_3$, which Jeannel named *ferric chloroxide* (Jeannel, 1868abc).

Chloroxide had all the chemical and physical properties of the sesquichloride described in the French Codex and contained nine times more iron than the neutral medical sesquioxide. The resulting liquor was dark garnet red, had a stringent flavor, and turned litmus paper red. Boiled, or in contact with sulfuric acid or sulfates, converted it into a jelly substance insoluble in water. Chloroxide coagulated blood, blood serum, and egg whites. Jeannel added that while the application of iron sesquioxide was very painful, that of the chloroxide was painless (Jeannel, 1868bc).

Jeannel added that iron sesquioxide hydrate was very soluble in ferric chloride, the mixing process was exothermic and never formed a definite compound because the iron sesquioxide hydrate dissolved in any amount in HCl. Anyhow, he proposed that the present Codex formulation of this medicine be replaced by the one corresponding to $Fe_2Cl_3,5Fe_2O_3$, which could be prepared using 100 grams of pure HCl (relative density 1.15) with 522 grams of ferric sesquioxide hydrate containing 75% of water. In powder form, it constituted an excellent topical medicine for the treatment of bad ulcers, the early-stage syphilis sores, etc. (Jeannel, 1868bc).

The last paper on the subject summarized the known and the new information about ferric hydrate, ferric chloride, and chloroxide (Jeannel, 1869a). For example, (a) ferric hydrate always contained ammonia, sulfuric acid, and sulfates, no matter how many times it was washed with distilled water; these impurities induced a molecular change in the hydrate that manifested in its insolubility in water and diluted acids; (b) contact with ammonia or ammonium chloride produced similar effects; (c) the ammoniacal ferric hydrate could be purified by treatment with a dilute solution of nitric or acetic acids; (d) the chloroxide reacted with arsenic acid yielding a soluble compound, not precipitable by ammonia; (e) the chloroxide provided industry with a soluble iron sesquioxide that attached to fabrics without the need of a mordant, etc. (Jeannel, 1869a).

Production of nitrates and nitrites in nature

According to Jeannel (Jeannel, 1872c), there were conflicting opinions regarding the possibility of utilizing sterile soils for horticulture purposes, particularly regarding the presence/addition of basic components such as nitrates and nitrites. Some believed that this goal could be achieved by the addition of aqueous solutions of mineral substances; others, like the agronomist George Ville (1824-1897) (Ville, 1850) and the chemist Jean-Baptiste Boussingault (1802-1887), believed that the plants were able to assimilate mineral elements and did not require a soil containing putrescible organic materials (Boussingault, 1857). Jeannel decided to further investigate the question (Jeannel, 1872c).

For this purpose, he conducted horticultural experiments using different kinds of soils, plants, and conditions, for example, (a) duplicating the natural conditions for the formation of nitrates in the arable soil, without the intervention of ammonia, at the expense of the air elements and their reduction by humus. For this purpose, he utilized topsoil or compost, which had been exhausted by washes with distilled water, (b) plants raised comparatively in sand and in loam (*Pelargonium zonale* and *Agave corniculata*), (c) plants raised in sand, some receiving the weekly ration of a mineral solution, others receiving only common water (*Arum italicum*, *Ivies, Begonias, Tradescantias, Veronicas*, *Sages, Corn, Hartwegia*, etc.), (d) plants like *Sedum acre*, grown in soil, some receiving, in addition to common water, a weekly ration of mineral fertilizer, others receiving only common water, and (e) plants that always vegetated in the same soil for two years, and which developed out of all proportion to the vases that contained them (*Aspidistra elatior* and *Arum esculentum*). Whenever necessary, he utilized an artificial fertilizer composed of 400 parts of ammonia nitrate, 250 parts of potassium nitrate, 200 parts of ammonia biphosphate, 50 parts of ammonia chloride, 60 parts of calcium sulfate, and 40 parts of iron sulfate (Jeannel, 1872c).

The main result of these experiments indicated that the nitrates and nitrites were formed naturally in the topsoil upon contact with air that it was possible to feed plants with suitable mineral solutions that provided them with the solid elements they needed to grow, and that plants vegetated much better in pure sand than in loam. Thus, horticulture was provided with an easy to use and powerful tool to improve its capability and the range of its activities (Jeannel, 1872c).

Additional important results (Jeannel, 1872c) indicated that on contact with humus, dead leaves or straw were promptly reduced by alkaline nitrates to the state of nitrites; calcareous humus or topsoil provoked the combination of the air elements, without the intervention of ammonia, into nitric or nitrous acid, which were immediately neutralized by calcium; the ammonia nitrate brought by dew and rain was retained by the humus in the surface layers of the soil; this renewal of the oxygenated combinations of nitrogen in the calcareous humus explained the accumulation of fertilizing principles in fallows and the fertilizing effects of plowing, hoeing, etc., which increased the surfaces exposed to the alternatives of humidity and drought, etc. (Jeannel, 1872c).

Supersaturation

In 1815, Johann-Baptist Ziz (1779-1829) reported that the sudden crystallization of aqueous solutions of sodium sulfate was not due to agitation and did not take place when the solutions were kept under a bell glass or without contact with air. Solids contacted with the solution caused instant crystallization when dry and lost this ability when wet or previously heated. Crystals of the solute were the best agents to provoke crystallization (Ziz, 1815). Desiré Gernez (1834-191 studied in detail the causes and uses of the phenomenon of supersaturation in saline solutions (Wisniak, 2018) and agreed with Ziz's statement that the crystallization of a supersaturated solution of sodium sulfate was determined by the contact with a particle of anhydrous sodium sulfate or its decahydrate. Nevertheless, he added that the phenomenon was really caused by the *fall* of a solid particle from the air into the liquid. For this to occur it was necessary for the particle to be soluble in water and fall *vertically* on the surface of the liquid. Larger surfaces produced faster crystallizations and the phenomenon did not occur when the neck of the vessel was located at such an angle that the falling particle did not affect the liquid surface (Gernez, 1865). Henri Löwel (1795-1856) studied in detail the solubility of sodium sulfate in water and concluded that the product of the crystallization of a solution of this salt was its decahydrate (Löwel, 1850-1855). Agitation did not cause precipitation of the decahydrate, but precipitation occurred upon addition of a particle of sodium sulfate or by simple contact with a glass or metal rod. This rod, heated previously to 40^0 to 100^0C, lost its precipitation power; cooling it to room temperature returned its crystallization capability. Other salts, such as magnesium sulfate, sodium carbonate, aluminum-potassium, and chromium alum, also exhibited the phenomenon of supersaturation (Löwel, 1850-1855).

Jeannel believed that the information about supersaturation and its origin was incomplete and confusing, particularly Gernez's one requiring the presence of salt particles in the air. For this reason, he decided to conduct his own experiments under a wide variety of conditions, e.g., temperature, contact with air, dry or humid, agitation with and without glass rods, evaporation conditions, foreign particles in the atmosphere, dimensions of the vessel, its orifices, use of filters, crystallization over plates, etc. Part of these conclusions were illustrated with sodium acetate, alum, and potassium tartrate as solutes (Jeannel, 1865, 1866a-d).

Jeannel main conclusions were the following (Jeannel, 1865, 1866abc): (1) Contact with an ordinary cold saturated solution of a salt determines the crystallization of the supersaturated solution of the same salt. Only salts whose crystals retain a large quantity of water of crystallization present the phenomenon of supersaturation. (2) The crystallization of supersaturated solutions is not caused by contact with saline particles floating in the atmosphere (Jeannel named this theory *pancrystallia*). This hypothesis requires the presence in the atmosphere of particles of countless salts (e.g., selenate, sodium carbonate, tartrate, and acetate; potassium arsenate; ammonia acetate, oxalate, and phosphate; alum, zinc sulfate, lead acetate; uranium nitrate, etc.), which originate from human actions or physico-chemical phenomena. All these compounds are decomposable by the air humidity and common impurities (e.g., ammonia, hydrogen sulfide, etc.). In addition, some of them are deliquescent. The presence and actions of these particles may be diminished or eliminated by the size of the orifices of the flask and/or the presence of filters. Supersaturation is shown to occur in closed vessels or in ones provided with filters (Jeannel, 1865, 1866ab). (3) The solid walls with which the supersaturated saline solutions come into contact in the vases, oppose their crystallization. When the surface of the walls predominates over the mass of the saline liquid (e.g., plates), ordinary crystallization does not take place by the same mechanism, it occurs by evaporation (Jeannel, 1865, 1866ab). For example, a supersaturated alum solution freezes and dries in the open air without crystallizing, when spread in a thin layer on a slightly heated glass slide. Hot solutions of alum or neutral lead acetate, containing only 10 to 20% water, exhibit similar phenomena. The contact with the wall clearly prevents ordinary crystallization from taking place by cooling, despite the contact with free air (Jeannel, 1865, 1866ab). (4) Supersaturated solutions do not contain salts in the same state of hydration as before the solution. In this new state of hydration, the salts are more soluble than in their ordinary state (Jeannel, 1865, 1866ab). (5) Pancrystallia cannot explain crystallization in the absence of contact with air. All hydrated salts are able to produce the phenomenon of supersaturation crystallization by a sufficient lowering of temperature, while remaining protected from atmospheric dust. For example, a supersaturated solution of sodium tartrate crystallizes in a flask deprived of air and sealed in the alcohol lamp (Jeannel, 1865, 1866ab).

According to Jeannel, the phenomenon of supersaturation could be used industrially to purify large quantities of sodium sulfate and other salts (Jeannel, 1866d). He mentioned, for example, that the French Codex suggested that commercial sulfate be purified by dissolving it in its weight of hot water, filtering, and allowing the filtrate to crystallize by cooling. Since the solubility of the salt at 18 ^{o}C is 48 g in 100 g of water, this process left almost half of the raw material in the mother water, requiring repetition of the process. Jeannel suggested mixing instead 300 g of sodium sulfate with 100 g of distilled water, melting the salt by heating at 33 ^{o}C (at this temperature, which is that of the maximum solubility of sodium sulfate, 100 g of water dissolves 322 g of the sulfate) in a glass flask, and filtering. The filter is then washed with 500 g of hot water at about 50 °C and its filtrate added to the previous one. The whole is then left to cool in the air to produce purified sodium sulfate crystals. The same process may be applied to magnesium sulfate, zinc sulfate, and sodium carbonate (Jeannel, 1866d).

Supersaturation could also be used for separating salts, as illustrated with the following example: A mixture of 335 g of potassium nitrate and 100 g of water is heated to its boiling temperature (115.9 °C) and then mixed with 300 g of alum. The flask is then capped and left to cool. As a result, the alum remains in a supersaturated solution while the potassium nitrate crystals are salted out, the same as if they were in pure water (Jeannel, 1866d).

Sodium acetate

Jeannel reported in detail the physical properties of sodium acetate in its different states (Jeannel 1866c). The crystalline salt, exposed to the atmosphere, dried without appreciably oxidizing but efflorescing, and was deliquesced in very humid air. It began melting at 58 °C, floating in its transparent liquid; it turned all liquid around 75 °C and boiled at 123 °C under ordinary pressure. Further boiling led to partial dehydration of the salt and increase in the temperature, (today we know that sodium acetate has a trihydrate). The salt expanded by 7% of its volume between 0° and 123 °C. Left to cool in the open air after melting, it crystallized in prismatic needles at 58 °C, a temperature that remained stationary throughout all the phase change. According to Jeannel, this phenomenon could be used to verify or calibrate thermometers (Jeannel, 1866c).

Cooling the melted salt in a capped tube showed no crystallization, even down to 0 °C. It then turned into a soft translucent mass composed of large flakes, wetted by a transparent liquid. Seeding with a small crystal of sodium acetate returned the ordinary crystalline state as white opaque prismatic crystals, while releasing abundant heat. According to Jeannel, 100 grams of melted sodium acetate liberated enough heat to melt 36 grams of water. This remarkable phenomenon could be used to *store* solar heat. For this purpose, the salt was put, for example, under a glass bell and left to melt under the action of the sun. On cooling, seeding the non-crystalline mass with a crystal of sodium acetate released approximately 2844 calories (Jeannel, 1866c).

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