

Sir Johan Gadolin of Turku:  
The Grandfather of Gadolinium

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## The Discovery of Gadolinite and Gadolinium

Johan Gadolin was still 33 years old in the spring of 1794 when his most important work was published.<sup>1</sup> In 28\_ pages he carefully described his detailed chemical analysis of a new, black, heavy mineral which had been recently discovered at the Ytterby quarry on the island of Roslaga near Stockholm. A rather small sample had been given to him by the supervisor of the quarry in 1792. From it he concluded that 38% of the mineral consisted of a previously undiscovered element. He named this substance ytterbia after the village near the quarry, but the name was soon shortened to yttria. The substance which he discovered was actually yttrium oxide, and it was the first of the so-called rare earths to be discovered and isolated.<sup>2</sup> The mineral from which he had isolated yttrium oxide soon acquired the name gadolinite in his honor.

Although Gadolin and other chemists initially believed he had discovered a new element, in 1808 Sir Humphry Davy showed that metallic earths are oxides, not pure elements. The rare-earth elements caused chemists considerable confusion for the next half century until the introduction of the spectroscope in 1859 (99 years after Gadolin's birth) and Dmitry Mendeleev's first report of his periodic table in 1870.

It was not until 1880, 120 years after Gadolin's birth, that the Swiss chemist Jean-Charles-Galinard de Marignac isolated gadolinium oxide. The French chemist Paul-Émile Lecoq de Boisbaudran, a co-discoverer of gadolinium oxide, persuaded de Marignac to name this *gadolinia*. This occurred in 1886, 34 years after Gadolin's death. Pure elemental, metallic gadolinium was first purified in 1935 by the French chemist F. Trombe.<sup>2</sup>

Gadolinium is not particularly rare, ranking 43 among the elements in abundance, and is ten times more abundant than iodine. Among its many uses it is a fluorescent agent in television screens and X-ray intensifying screens.<sup>2</sup> Since Hanns-Joachim Weinmann's pioneering work in 1981<sup>3</sup>, chelates of gadolinium have been introduced as the first and, until 1995, the only commercial paramagnetic contrast media used for MRI.

## **Family Background and Education**

Johan Gadolin was born into an exceptional family<sup>4</sup> in Turku, Finland, on June 5, 1760.

Turku was at that time the capital of the Swedish province of Finland, as it had been for more than 500 years. The University of Turku had been founded in 1640, only four years after the founding of Harvard University. Jakob Gadolin, Johan's father, was the professor of both astronomy and physics, and would also become the professor of theology two years after Johan's birth.

When Johan Gadolin was 11 years old, his father became a leader in a plot against the King Gustav III of Sweden, for which he was briefly imprisoned but later pardoned. Jakob Gadolin eventually became the Bishop of Turku when Johan was 28 years old.<sup>5</sup> The Diocese of Turku, the oldest in Finland, was first mentioned in the Vatican archives in the year 1229, and it had become Protestant (Lutheran) during the Reformation.

Johan Gadolin's paternal grandfather Jakob was a Lutheran minister who had taken the surname Gadolin from the Hebrew word "gadol", meaning "magnus" in Latin or "great" in English. This name came from the family farm near Turku. Johan Gadolin's maternal grandfather, Johan Browallius, himself a student of Linnaeus, had been the foremost natural scientist in the Swedish realm, president of the Swedish Royal Academy of Sciences, professor of both physics and theology at the University of Turku, and Bishop of Turku.<sup>6,7</sup>

Johan Gadolin's formal education began at the age of 5 with a private tutor, 10 hours a day. This consisted mostly of rote memorization, which he later wrote as being very difficult for him, as "my memory was not the quickest." He entered the University of Turku while still 14 years old, at which time he had already studied the entire opus of Euclid and Archimedes. Although his father encouraged his mathematical studies, Johan felt that the intense concentration necessary for mathematics was causing him attacks of dizziness or vertigo. Instead, he chose chemistry as more interesting and less difficult. He was also inspired by Pehr Gadd, the professor, and attended all his lectures as well as the demonstrations which

Gadd, “although seldom”, held in his laboratory. Gadolin also studied every book on chemistry he could find in his father’s library and which Gadd loaned to him.<sup>1\*</sup>

Shortly after his 19th birthday Johan Gadolin transferred to the University of Uppsala, which had been founded in 1477 as the first in Scandinavia. The professor of chemistry was Torbern Bergman, himself the leading teacher of his day. Gadolin worked with Bergman until his return to Turku in 1783, having published his academic dissertation on the analysis of iron under Bergman’s supervision in 1781. A second dissertation on philosophy the following year won first honors.<sup>8</sup>

### **Climbing the Academic Ladder in the 18th Century**

In spite of his outstanding academic merits and influential family and friends, the youthful Gadolin was passed over for three positions, including the professorship of chemistry in Uppsala after Bergman’s death, by much older but evidently less qualified applicants. At Turku he initially obtained sinecures at the university library, and finally, at the mature age of 25 he was appointed acting professor (*pro tem.*),<sup>8</sup> which was still not a position corresponding to his qualifications.

The following year he departed on a two-year research and study journey through northern Europe. He visited universities in Göttingen, Amsterdam, London and Dublin as well as mines in Germany, England and Ireland. He spent his longest stay in London, where he worked with Adair Crawford and Richard Kirwan, and participated in meetings of the Royal Society. Gadolin presented his own theory on the importance of oxygen in combustion, which was an important step in the abandonment of the phlogiston theory. He soon revised his theory with the advent of new data on combustion.<sup>6</sup> He visited Wedgwood’s clay mines and toured Ireland with Kirwan, who shortly thereafter helped found the Royal Irish Society

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<sup>1\*</sup> Gadolin, J. Autobiographical essay (In Swedish: Själfbiografisk uppsats). Manuscript, Helsinki University Library, Helsinki, Finland

in Dublin. Gadolin also became a freemason in London.<sup>8</sup>

Gadolin wrote in Latin, German, English, French, Russian and Swedish and could even speak Finnish. He carried on an extensive correspondence with the leading scientists of his day, and was the first chemist in Scandinavia to accept and popularize Lavoisier's theory on combustion. Strangely, he never visited France,<sup>8</sup> and we can only speculate that the pre-revolutionary political climate may have caused him to hesitate to make this short trip from Amsterdam.

Upon returning home to Turku, Gadolin gradually continued his steps up the many rungs of the academic ladder, and in 1789, while still at the age of 28, he was appointed professor of chemistry "in survivance". This deceptive title meant he was not to actually become full professor until after the death of the incumbent, his first teacher in chemistry, Pehr Gadd. This finally happened in 1797, although he was to wait for nearly another year for his final appointment as professor of chemistry with full academic privileges.<sup>8</sup>

### **Family, Fame and Fortune**

At the age of 34 Johan Gadolin finally found the time to get married. His bride Hedvig Tihleman was the 17-year-old daughter of a local businessman. They had nine children of whom 7 survived to adulthood. Three years after his wife's death Gadolin, at the age of 59, married Ebba Palander, who was 24 years his junior. Gadolin was not much of a family man, for although his office was in his home and his laboratory was nearby, he saw his family mainly at mealtimes. He spent his waking hours mostly in his study with his desk full of papers and the walls full to overflowing with books. His concentration was such that he would often be unaware of a visitor for up to half an hour. His children would sit quietly in his office admiring their father and his many books and papers. He did not exercise but ate, drank and smoked in moderation. He was nearsighted but refused to wear glasses. His health was excellent aside from his attacks of vertigo, and he never consulted a physician nor took medicine.<sup>8</sup>

Gadolin's discovery of yttrium oxide in the mineral gadolinite brought him considerable renown in his own time. He organized a large mineral collection in his laboratory, which he had built on his own property.<sup>9</sup> He carried on an extensive correspondence with other scientists and published regularly.<sup>8</sup> He supervised a total of 61 academic dissertations,<sup>2\*</sup> which in those days were often written by the professor but financed by the student.<sup>9</sup>

Gadolin published several books, the most important being his textbook on chemistry<sup>10</sup> published at the time of his finally receiving the professor's chair in 1798. This was the first modern chemistry textbook in Scandinavia, where it remained in use for nearly half a century.<sup>6</sup> He made extensive handwritten notes, corrections and updates in his personal copy of this text, although he did not publish a second edition. Gadolin was also the first to introduce formal laboratory exercises in chemistry in which the students participated rather than merely observed.<sup>7</sup> He was also the forgotten inventor of countercurrent distillation, an elegant and extremely practical principle which revolutionized the distillation of alcohol and is one of the most basic principles of industrial chemistry.<sup>11</sup>

Gadolin was active in many subjects, including mathematics, physics, mineralogy, metallurgy and industrialization; a true Renaissance man. He was the prime mover behind the founding of the Finnish Chamber of Commerce and became its president, and was a capable, respected and active businessman. He was also a founding member of the Turku Musical Society. He was a corresponding or honorary member of scientific societies in Dublin, Stockholm, Uppsala, Brussels, Göttingen, Moscow, Lund, Marburg, St. Petersburg, Jena and Helsinki. He received many academic honors during his own lifetime, including a honorary doctorate in medicine from his own university as a tribute to his excellent teaching of chemistry to the medical students. He had the distinction of refusing the professorship in chemistry at the renowned University of Göttingen in 1804, citing the unstable political situation in Germany as an excuse, although it is likely that he had no desire to leave his home in Turku. He was

<sup>2\*</sup> *Dissertationes Praeside Joh. Gadolin*, bound copy of 61 academic dissertations supervised by Johan Gadolin, in The Gadolin Collection, Åbo Akademi Library, Turku, Finland

twice appointed university rector (president) and thrice knighted. Sir Johan Gadolin, knight of the orders of St. Wladimir and St. Anne, retired as professor emeritus at the obligatory age of 62, although he published his last book five years later. He lived for 30 years in retirement at his two country estates, and died peacefully at the age of 92, leaving his heirs a large fortune and an even greater heritage.<sup>8</sup>

Although Gadolin had attained fame and respect at an early age, his tenure as professor was beset by many hardships. Funding for his laboratory was difficult or often impossible to obtain, and the equipment necessary to perform analytical chemistry at the cutting edge of early nineteenth century technology was beyond his departmental budget and personal finances. His original experimental output began to decline for many reasons: in addition to the lack of equipment and his own advancing age he continued to acquire an increasing number of responsibilities in the university administration and in his other public commitments. He began to consider industrial chemistry as his primary responsibility, which tended to drain his resources and divert his attention from research, which he found time for mainly during the long summer vacations. His acute sense of self-criticism evidently kept him from publishing mediocre results. His international reputation and his wide-ranging correspondence with the leading scientists of his day also earned him much antagonism and jealousy from less enlightened local individuals, particularly some of the less successful fellow faculty members.<sup>6-8</sup>

### **Gadolin's Legacy**

Gadolin's career has much that is relevant to our present day. He was a true workaholic; he understood the importance of precise laboratory methods; he realized the necessity for further training abroad; he was an exacting scientist of the highest integrity; he published extensively; he was a well-liked teacher who trained a large number of students; he understood the potential of profiting financially from his scientific work and made many attempts to do so; in spite of many unsuccessful industrial and business ventures, financial hardships and much bad luck he eventually became a very wealthy man through his own skill and perseverance; he had many foes jealous of his accomplishments and renown; as a young

man he had difficulty in obtaining grant support and academic tenure; and as a middle-aged and old man he was covered with honors but became heavily overcommitted, to the detriment of his original research.

His enormous personal library has survived nearly completely extant as a bequest to the Swedish University of Turku, consisting of 3,611 volumes which he numerically catalogued in alphabetical order. The books are mostly from the latter half of the 18th century. Two of his laboratory buildings have survived to this day. One of these became a hospital and is now a childrens' day-care center. Another building was torn down in 1962 by unscrupulous land speculators the same day that it had been declared a national monument, hours before the writ could be presented in person to the owners of that irreplaceable property. His two country estates are still in existence, the main buildings of each essentially unchanged over the past two centuries. His gravestone is the largest in the cemetery of Wirmo (Mynämäki). On it is his epitaph "mors reparatio vitae".

Johan Gadolin was the second person to have an element named in his honor, a distinction which he shared with the Russian geologist W. Samarski (Samarium) for more than half a century. Other elements have since been named after the following scientists: Marie Curie, Albert Einstein, Enrico Fermi, Dmitry Mendeleev, Alfred Nobel, Ernest Lawrence, Ernest Rutherford, and Otto Hahn. These heavier elements are all radioactive, and samarium found in nature is always combined with its own radioactive isotopes. Gadolinium is the only naturally occurring nonradioactive element which has been named after an individual; the dedicated Finnish scientist and father of rare-earth chemistry, Johan Gadolin.

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Legend to the figures

Figure 1: Portrait of Johan Gadolin at the age of 19 when he left Turku to continue his studies at the University of Uppsala. It is likely that this portrait was painted to ease his mother's heartache when her oldest surviving child first left home. There are no other surviving portraits or photographs, even though he lived to the age of 92.

Figure 2: Finnish postage stamp honoring Johan Gadolin, issued on the 200th anniversary of his birth in 1960.

[Larger images are available on the web at <http://homepage.mac.com/dtrapp/people/JG.html> dwt]



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