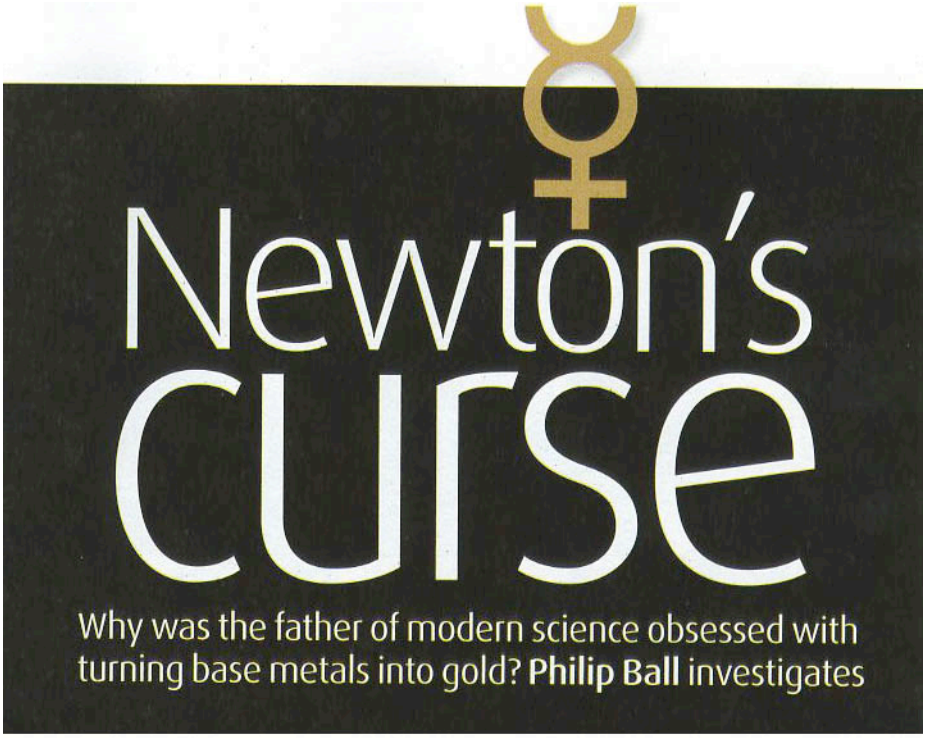


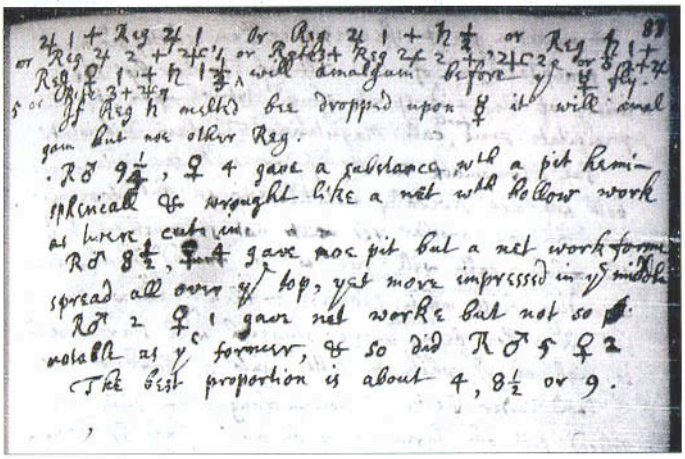
IT LOOKS as though, set among the modern Pyrex glass and fume cupboards in a chemistry lab at Indiana University in Bloomington, a piece of the Middle Ages has come unstuck in time. What is this crude furnace doing here, constructed from bricks and mortar? It gets worse: look past the furnace and you'll see a couple of experimenters surrounded by antiquated crucibles and arcane powders and poring over what appear to be the scrawlings of a madman. What's going on – is this the rebirth of alchemy?

Yes, in a way it is. The writings, set out in a laboratory notebook, describe an alchemical experiment that chemists William Newman and Cathrine Reck are hoping to carry out. But their author was no madman – he was arguably the most famous scientist of all time, Sir Isaac Newton.

Previous historians of science have tended to assume that Newton's interest in alchemy was motivated by abstract philosophical or religious objectives. John Maynard Keynes, who bought many of Newton's manuscripts, declared in 1946 that "Newton was not the first of the age of reason. He was the last of the magicians." Newman thinks otherwise. He says that Newton was simply trying to do chemistry – or as he prefers to call it, 'chymistry', a transitional science between the alchemy of the Middle Ages and the chemistry of the 18th-century Age of Reason.

Contrary to what historians have often believed, Newman is convinced that Newton's chymical enthusiasms were quite normal for scientists of his time, and that his primary concern was simply to uncover the chemical laws of nature. The notebooks certainly show that Newton made no distinctions between alchemy and what we now accept as 'real' science. The very same book in which he recorded his epoch-making experiment of reconstituting white light from its spectral components is filled with recipes culled from alchemical sources. "Alongside sober explanations of optical and physical phenomena such as freezing and boiling", Newman says, "we find 'Neptune's Trident', 'Mercury's Caducean Rod' and the 'Green Lion', all symbolising alchemical substances."

So is it possible that Newton's alchemical experiments led to scientific discoveries as profound as his more familiar works? The first step in answering that question is to decipher the notebooks. It is no easy task: Newton didn't always record his chymical experiments in the most transparent way. Alchemists were notorious for veiling their writings in impenetrable jargon, but Newton made matters even worse by inventing symbols and systems of his own. That is part of the reason why, despite Newton's reputation, many of his manuscripts have still not been properly edited and interpreted. "They are in a state of considerable disorder," Newman says.



♃1 + Regulus ♃1, Or Regulus ♃1 + ♄½, or Regulus ♄1 +
Regulus ♀1 + ♄1⅓ or Regulus ♃2 + ♐1 or Rete 3 + Regulus ♃2 + ♐2
or ♁2 + ♃5 or Rete 3 + ♐ will amalgam before the ☿ fly.
If Regulus ♄ melted bee dropped upon ☿ it will amalgam but
noe other Regulus. R ♂ 9 ¼, ♀ 4 gave a substance with a pit
hemispherical & wrought like a net with hollow work as twere cut in
R ♂ 8 ½, ♀ 4 gave noe pit but a net work forme spread all over
the top, yet more impressed in the middle R ♂ 2 ♀ 1 gave net worke
but not so notable as the former, & so did R ♂ 5 ♀ 2
The best proportion is about 4, 8 ½ or 9

An extract from one of Newton's notebooks, and the transcription.

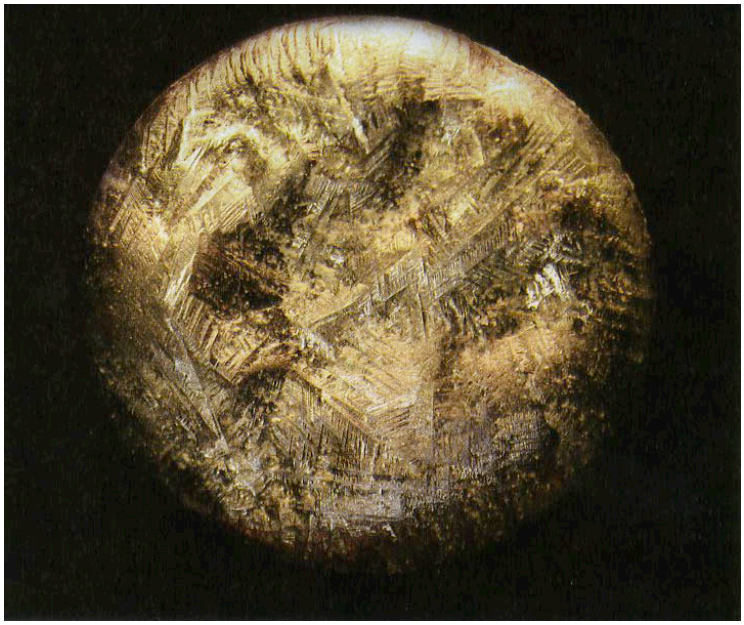
Even where the text can be deciphered, this only gets you so far. "Although we can make educated guesses about his chymical work from reading," Newman says, "there are often too many variables in chemical research to make it possible to predict an exact outcome from Newton's notes." So Newman and his colleagues set out to repeat the experiments Newton described – using exactly the same conditions.

Newman insists that to do this it is necessary first to reproduce the apparatus Newton would have worked with. So the researchers have, for starters, reconstructed Newton's furnace from bricks and mortar. "Modern electrical furnaces don't produce the complex mix of gases that resulted from charcoal-burning furnaces, which can generate reducing atmospheres," Newman observes.

Following Newton's recipes in every detail, they have produced a pellet of the substance Newton called the "net". It is a purplish alloy of copper and antimony with a dimpled, reticulated surface from which it got its name. According to his notebooks, Newton learned of it from the Bermudan-born, Harvard-educated alchemist George

Starkey, who proposed that the synthesis of the net was, like many other alchemical processes, encoded in a story in Greek mythology.

The researchers have also used Newton's notebooks to recreate the tree-like metal structures that may have influenced his manuscript *Of Nature's Obvious Laws and Processes in Vegetation*. Some of the trees grow as precipitates of metal salts in a gel of sodium silicate, which chymists in the 17th century called oil of sand; similar branching structures are familiar today in so-called chemical gardens. To Newton and his contemporaries, their organic appearance confirmed the old alchemical idea that metals have a kind of life and can "vegetate". Another of Newman's experiments has replicated Newton's alchemical synthesis of a crystalline alloy of antimony and iron called the Star Regulus, which forms as radiating, star-like crystalline shards. "These replications can teach us about the actual successes and failures that Newton experienced," Newman says.



The Star Regulus, a crystalline alloy of antimony and iron.

Decoding the lab books and then recreating the experiments is hard work, but Newman reckons it is worth the effort. Unravelling the identity of Newton's chemical materials and lab methods will eventually help to illuminate the relationship between his experiments and the literature of chrysopoeia--the transmutation of metals into gold-- that inspired him. Newman has already found from the notebooks that, while Newton learned the alchemical term "The Green Lion" from Starkey, he used it to mean a different substance from Starkey's antimony and its ores. "Until we understand the meaning of such cryptic terms in Newton's notebooks, we will not completely understand his experimentation in alchemy, nor what his ultimate goals were,"Newman says. "Modern laboratory replication of Newton's experiments will help us eventually to crack this enigma."

Will these investigations reveal Newton to have been as innovative in chemistry as he was in physics? With many of the experiments in his notebooks yet to be repeated, the jury is still out on that question, but historian of science Lawrence Principe of Johns Hopkins University in Baltimore doubts it. "I frankly don't think that Newton made significant contributions to chemistry," Principe says. "Much of

the material in his chymical manuscripts was dependent on work already known or performed on the Continent."

Even if Newton is shown to have been something of a plodder in chemistry, that will still give us a more complete picture of a man who has since been all but deified. Newman's studies mean we now know far more about the context in which Newton did research and wrote his treatises, says Rob Iliffe, a science historian and Newton scholar at Imperial College London. He may not, after all have been a genius who plucked ideas out of thin air. "But on the other hand", says Iliffe, "we will have a more detailed and subtle understanding of exactly what his brilliance and creativity consisted in."

Further reading:
The Chymistry of Isaac Newton: http://webapp1.dlib.indiana.edu/newton/index.jsp
The Newton Project: http://www.newtonproject.ic.ac.uk/prism.php?id=1
William Newman's web pages on experimental reconstructions:
http://mypage.iu.edu/~wnewman/lab.html

The Royal Society of Alchemists?
Isaac Newton -- an alchemist? Confronted by Newton's alchemical musings while writing his biography in 1855, the physicist Sir David Brewster complained: "We cannot understand how a mind of such power, and nobly occupied with the abstractions of geometry, and the study of the material world, could stoop to be even the copyist of the most contemptible alchemical poetry." To Brewster and his contemporaries, Newton was the paragon of rational thought and mathematical precision, far removed, so they thought, from suspect alchemical musings.

Sir Isaac Newton.

This assessment now seems to have misunderstood the state of knowledge in Newton's time. Alchemy was waning in the late 17th century, but it wasn't particularly frowned on. Many of the greatest scientists continued to believe not only in the possibility of transmuting lead into gold, but also in a host of other ideas that are now regarded as "occult", such as astrology and prophecy. Studies by Lawrence

Principe have revealed that even Newton's colleague Robert Boyle, whose famous book of 1661, The Sceptical Chymist, has long been interpreted as a damning critique of alchemy, attempted to transform other metals into gold – chrysopoeia, as it became known – all his life.

Boyle and Newton regularly exchanged information about chrysopoeia, often encoded in the arcane terminology of the alchemists. When Boyle died in 1691, Newton was desperate to find out what he had known, scanning through his papers and inveigling from Boyle's friend John Locke a sample of a red material that he thought might be a crude form of the Philosopher's Stone, the catalyst of transmutation. It was shortly after Locke sent him Boyle's recipe that Newton seems to have succumbed temporarily to mental illness, perhaps brought about by his extensive distillations of mercury in his efforts to replicate Boyle's procedure.

Both Boyle and Newton were strongly influenced by the chymist George Starkey, who became a member of the group of scientific, religious and utopian thinkers associated with the Prussian exile Samuel Hartlib. Some of these men were among the founders of the Royal Society in London in 1660 - an organisation that, far from being a beacon of what we would now consider to be scientific rationalism, was thus set up in an atmosphere of mysticism, occultism and utopian fantasies about secret brotherhoods.

Balancing alchemy

One in 10 of the books in Newton's vast library was devoted to alchemy. His copy of *On the Transmutations of Metals* by Paracelsus, arch-alchemist-wizard of the Renaissance, was dog-eared from extensive use. The American historian Betty Jo Dobbs, one of the first people to tackle Newton's alchemical work seriously, concluded that his alchemy was primarily a spiritual concern. Newton had unorthodox Christian views – he was an anti-Trinitarian who believed that Jesus was created by God as a mortal man – and was interested in the biblical prophecies in the books of Daniel and Revelation.

It would not be surprising if his strongly held religious convictions impinged on his alchemical work, but William Newman insists that it is a mistake to interpret all of Newton's alchemy as a kind of coded religion. Newman and Principe argue that "esoteric" alchemy such as chrysopoeia, with its attendant secrecy and cryptic symbolism, cannot be split off from practical early chemistry of the sort practised by metal-workers, dye-makers and apothecaries. Both are aspects of chymistry, they say, and by separating them Dobbs and other Newton scholars have presented a distorted view of what he was up to. "Newton was involved in all of chymistry's major branches," says Newman. "Including all of Newton's work in chemical technology and metallurgy alongside his chrysopoeia will provide a far more balanced picture of his interests."