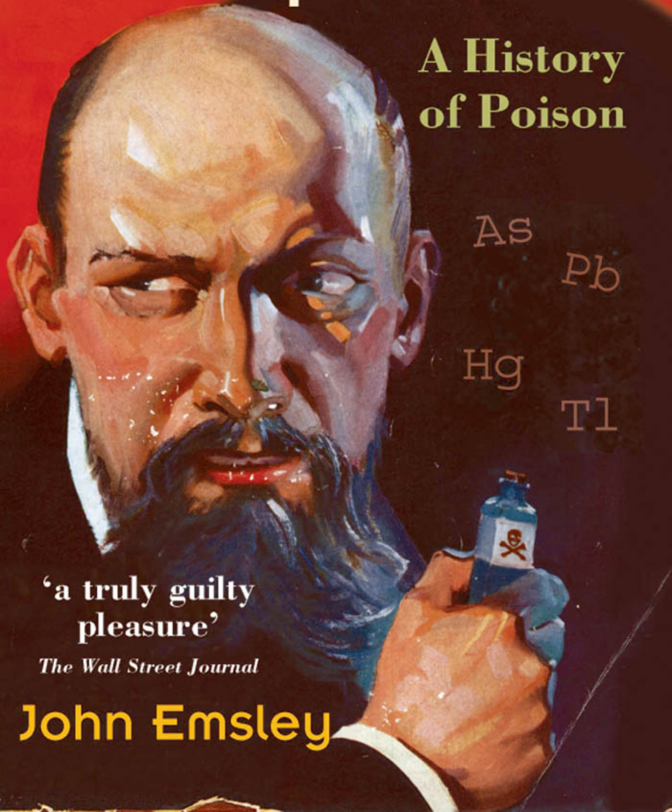
The Elements of Murder

A History of Poison



'a truly guilty pleasure'
The Wall Street Journal

John Emsley

THE ELEMENTS OF MURDER

John Emsley won the Science Book prize in 1995 for his *Consumer's Good Chemical Guide*, and followed this with a series of popular science books: *Molecules at an Exhibition*, *Was it Something You Ate?* (co-authored with Peter Fell), *The Shocking History of Phosphorus*, *Nature's Building Blocks*, and *Vanity, Vitality, and Virility*, all of which have been translated worldwide.

John spent 20 years as a researcher and lecturer in chemistry at London University before becoming a freelance popular-science writer and a Science Writer in Residence, first at Imperial College London and then in the Chemistry Department of the University of Cambridge. In 2003 he was awarded the German Chemical Society's Writer's Award.

'. . . fascinating, wide-ranging and, let's not mince words, macabre new history of poison . . . a truly guilty pleasure.' *The Wall Street Journal*

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Times Higher Educational Supplement

'A fascinating brew of academic research and titillating murder mysteries . . . A vivid and anecdotal history of poison.' *The Daily Mail*

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JOHN EMSLEY

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Introduction

An earlier book of mine *The Shocking History of Phosphorus* (published as *The Thirteenth Element* in the USA) dealt with the way that that dangerous element had impinged on human beings over the centuries. There were chapters on its environmental impact, together with those on its uses, misuses, and abuses in everyday life – not least by murderers. These chapters provided most of the human interest stories and it was this that led me to think about other dark elements and *The Elements of Murder* is the result. Just as with phosphorus, the story of the dangerously toxic elements began in the days of alchemy when for hundreds of years they were used in vain attempts to discover a way of creating unlimited wealth via the Philosopher's Stone, or securing health and longevity via the Elixir of Life. Of course both searches failed but along the way these alchemical experiments poisoned famous scientists and even killed a king, as we shall discover.

There are currently 116 chemical elements in the periodic table. Thirty of them are unstable and dangerously radioactive and are rarely encountered outside nuclear facilities or research laboratories. Thankfully most of the remainder are harmless, but some are moderately toxic and a few are highly toxic. There are about 80 elements that comprise the Earth's crust and each of us has detectable traces of all of them in our body including gold, platinum, and even uranium. We also have measurable amounts of the poisonous elements such as arsenic, mercury, and lead and these are the ones which most of this book is about. Before you begin your journey into the darker side of the periodic table it may be helpful to know a little about the chemical composition of the human body. This requires 25 chemical elements for its growth and maintenance, and these are called the *essential* elements. They are listed in the Appendix on page 386.

As you might expect, the toxic elements antimony, lead, mercury, and thallium are not essential, although arsenic might be – the jury is still out on that one – but there are elements that are both essential and highly toxic, such as fluorine, selenium, and chromium. Even elements such as sodium and potassium can be deadly under certain circumstances. Elements like these will be dealt with in the final chapter of the book.

Murder by poison may be a dying art, thanks in no small part to advances in forensic analysis that make it almost certain that a toxic agent will be identified if poisoning is suspected as the cause of death. In *The Elements of Murder* we will see that all kinds of food, drink, and medicines were employed to create a fatal brew, and in one of the murders described the poison was even administered as an enema. What is fascinating about the classical poisoning cases is that we are now able to reassess them in a way that enables us to understand them in ways that earlier generations could not. In former times it was always difficult to prove that someone had been murdered by poison and good legal counsel could play upon the lack of scientific knowledge to ensure that a murderous client walked free.

Things to bear in mind

The Elements of Murder is a popular science book and as such will be using terms that you may not be familiar with; these are to do with names, money, and units of measurement.

Names: The histories of some of the elements will take us back to the times when the names used to describe chemicals were very different to those of today. In the Glossary there are tables giving these historical and medical names, the correct chemical name, and the chemical formulae.

Money: I have endeavoured to relate currencies of the past to those of today but such conversions can never be exact even in the case of the pound sterling which has been around for more than a thousand years. (A pound was equal to 20 shillings, and a shilling was made up of 12 pence.) A pound in Saxon times (1000s) was wealth indeed; a pound in Elizabethan times (1600s) was still many times the average weekly wage; a pound in Victorian times (1900s) was what an ordinary man could earn in a week and support a family on; a pound today will not even buy a Sunday newspaper. By the time you are reading this, the pound sterling may have disappeared into history and the euro taken its place. Throughout the book I have tried to give some guidance as to the current value of the amounts of money that are being quoted in terms of pounds sterling or US dollars. If I have been somewhat inconsistent then the fault is mine.

Units of measurement: Very little of a poison may be present in a victim's body after death and small units are needed to discuss the tiny amounts detected by forensic analysis, such as the milligram (mg), which is a thousandth part of a gram, and the microgram (μg), which is a millionth (10^{-6}) part of a gram, and the nanogram (ng), which is a billionth (10^{-9}) part of a gram. In Imperial units these correspond roughly to a 28 000th part of an ounce and 2.8 millionth part of an ounce respectively. Earlier generations who used pounds and ounces, had the *grain* as their smallest measure but even this is relatively large in modern terms being around 65 mg. Alternatively, in discussing the amount of a toxin which is present in a sample that has been analysed, it is more informative to talk in terms of parts per million (ppm) which is equivalent to a milligram of a substance in a kilogram (or a litre), and parts per billion (ppb) which is equivalent to a microgram in a kilogram (or a litre), and parts per trillion (ppt), which is equivalent to a nanogram in a kilogram (or a litre).

You are about to enter a world that was once a closed book to the human mind. Today we can unravel the mysteries that early generations struggled to understand, and appreciate all that has been done to remove toxic elements from our lives. While we have made the world a safer place, we can still learn from tales of the days when chemical elements poisoned millions – and sent a few inconvenient individuals to an early grave.

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The poisonous elements of alchemy

The South Sea Bubble of 1720 saw prices on the London stock market rise to unsustainable heights and new companies were launched to take advantage of the public's willingness to invest. As in the dot.com bubble of the late 1990s, many of the companies were little more than hope and hype and among them was one for 'transmuting of quicksilver into a malleable fine metal'. Back in the early 1700s the idea that it was possible to convert mercury into gold was still widely accepted, even by eminent scientists such as Isaac Newton. He had spent much of his earlier life carrying out alchemical experiments, as we shall see. Nor was he alone. Indeed alchemy was actively encouraged by dukes, emperors, monarchs, and popes.

The company that sought to make gold was banned, along with a hundred others, in July 1720 as the Government tried to control the South Sea Bubble (which finally burst in September of that year). Just how insane things had become was demonstrated by another company whose prospectus declared that it was 'for carrying on an undertaking of great advantage, but nobody to know what it is'. The fraudster who set that one up didn't issue shares, only the right to buy its shares at some future date, and these rights he sold at £2 per right per share. He took £2000 within 5 hours of opening an office in Cornhill (now equivalent to something like £1 million) and at the close of the day he simply pocketed the money and disappeared.

That was sometimes the way that alchemists behaved once they had found a gullible patron, but not all alchemists were conmen. Some of them genuinely tried to make gold, and such alchemists were driven towards three, ultimately unattainable, goals: the Philosopher's Stone that could turn base metals into gold; the Elixir of Life that would confer longevity on those who drank it; and the Alkahest, the universal solvent that could dissolve anything and everything. Because these aims were incapable of ever being realized it is little wonder that most of what they did was scientifically meaningless. Nevertheless, down the centuries the alchemists developed basic types of laboratory apparatus and discovered a few important chemical compounds.

The risks to their health were great because their research invariably involved particularly poisonous elements, especially mercury. They were very fond of this metal because they believed that all other metals, including gold, were composed of mercury, sulphur, and salt, with mercury being the most important. Much of this chapter will be concerned with the effects that this highly poisonous metal had on some of them.

So when did alchemy begin? Who were the alchemists? And did they really poison themselves?

The alchemists

Alchemy flourished in China, India, the Middle East, and Europe, wherever gold was valued and the desire for more was ever present. In the West, alchemy can trace its roots to ancient Egypt where one of the earliest identifiable alchemists lived. He was Democritus and he dwelt in the Nile Delta about 200 BC. He wrote *Physica et Mystica* [*Natural and Mystical Things*], which included not only useful recipes for dyes and pigments, but also some for making gold, although his instructions were written in obscure language making them difficult to understand. This might have been done because they were really recipes for making *fake* gold.

A later Egyptian alchemist was Zosimos who lived around 300, and he described such chemical processes as distillation and sublimation, crediting an earlier alchemist, Maria the Jewess, as the inventor of these. She too had lived in Egypt about 100 and she had experimented with mercury and sulphur, although her best known invention was the *bain-marie* which is still used in cooking when gentle heating is required. Zosimos also left obscure writings on how to turn base metals into gold, and he wrote of 'the tincture' and 'the powder' which later generations of alchemists took to be the Elixir of Life and the Philosopher's Stone respectively. Another alchemist who lived about this time was Agathodiamon who wrote of a mineral that, when fused with natron (naturally occurring sodium carbonate), gave a product that was a 'fiery poison' and which dissolved in water to give a clear solution. It seems certain that he had made arsenic trioxide and that the mineral he had used was either realgar or orpiment which are arsenic ores. Of this we can be certain because when he put a piece of copper into the solution it turned a beautiful green colour, which is what would happen if copper arsenite were formed. This pigment was to turn up again 1500 years later, and to lead to massive contamination of the domestic environment and to many deaths – as we shall see.

By the time of Zosimos, alchemy was starting to decline, along with the Roman Empire, but a lot of its writings were saved by a sect of dissident Christians, the Nestorians, who fled to Persia around 400. This information eventually passed to the Arabs, in whose hands alchemy again flourished and the word alchemy comes from Arabic. Early Muslim rulers encouraged all branches of learning and as their empire expanded into Spain around 700 so it brought the new alchemy to the attention of those in Western Europe. The two great Arab alchemists were Abu Musa Jabir ibn Hayyan (721–815), known in Europe as Geber, and Abu Bakr Muhammad ibn Zakariya Ar-Razi (865–925), known in Europe as Rhazes. Their writings were translated into Latin and became widely known throughout Europe, and influenced all who followed.

More than 2000 works are attributed to Geber. He said that everything was composed of the four elements, fire, earth, water, and air, and that these combined to form mercury and sulphur, from which all metals were made, varying only in the proportions of these basic components. Geber knew that when mercury and sulphur were combined, the product was the red compound cinnabar (mercuric sulphide) yet he believed that if the perfect proportion could be found, then gold would be the result.

Rhazes wrote the influential *Secret of Secrets*, which contained a long list of chemicals, minerals, and apparatus, including several kinds of glassware. He was the first to distil alcohol and use it as an antiseptic, and he also recommended mercury as a strong laxative. Another product he knew about was a mercury chloride called corrosive sublimate. An ointment made from this was used to cure 'the itch', which we know as scabies and which thankfully is now rare. It is caused by a mite which burrows below the surface of the skin and produces almost unbearable itching especially in the genital region, and it is often transmitted during sexual intercourse. The poisonous nature of mercury and its ability to penetrate the skin made it an effective treatment of the disease.

Indian alchemists were also active by 700 and their ancient lore is encapsulated in a text written around 800 and called *Rasaratnakara*. This dealt mainly with mercury and its reactions with other compounds, again claiming that mercury was endowed with the power to make gold. It was also capable of making humans immortal, once it had been transformed into a 'nectar'. Traditional Indian medicines, and those of China, still use mercury and its compounds as ingredients.

In the early Middle Ages in Europe there were several noted alchemists, such as Avicenna (985–1037), Albert Magnus (1193–1280), Roger Bacon (1220–92), and Thomas Aquinas (1225–74), some of whom became better known for their theological writings. The most famous alchemist of this period was a Spaniard who also called himself Geber, hoping thereby to give his writings more credence by association with the earlier Geber. As a result his works were widely read and he was in fact the first person to report how to make nitric acid, silver nitrate, and red mercury oxide. His books were best known for the clear descriptions he gave of the apparatus he designed and how these were to be used, and this made them influential beyond the field of mere alchemy.* In effect Geber made alchemy respectable.

European alchemists slowly added to the body of chemical knowledge and one of their most notable discoveries was *aqua regia*, a mixture of concentrated nitric and hydrochloric acids that was capable of dissolving gold itself. This discovery fuelled the belief that gold was transmutable. When this solution was diluted with oil of rosemary the gold stayed soluble and this potion, called *aurum potabile*, was even prescribed as a cure-all. Unfortunately most alchemists were wedded to arcane language and it is almost impossible to understand the manuscripts they wrote, often because they used several different names to describe the same substance. Mercury, for example, was known as the doorkeeper, May-dew, mother egg, green lion, and bird of Hermes, to name but a few.

Nicholas Flamel (1330–1418) was one of the most famous French alchemists and it was widely believed that he had found both the Philosopher's

* His books were: *Summa perfectionis magisterii* [The Sum of Perfection], *Liber fornacum* [Book of Furnaces], *De investigatione perfectionis* [The Investigation of Perfection], and *De inventione veritatis* [The Invention of Truth].

Stone and the Elixir of Life because of the great age to which he lived and the wealth he accumulated, which he used to endow churches and build hospitals. There were reports that in January 1382 he had converted mercury to silver and three months later he was reported to have converted a large amount of mercury to gold. It is more than likely that his wealth, and old age, stemmed from his miserly and abstemious lifestyle. He probably became rich through money-lending and debt collecting, but there is no doubt that in his early years he was an alchemist, and used his alchemy in later life to disguise the real source of his wealth.

England too had its famous alchemists, such as George Ripley (born in the early 1400s) who came from Bridlington, Yorkshire. He studied in Italy for 20 years, where he eventually became a domestic chaplain of Pope Innocent VIII. He returned to England in 1477 and published *The Compound of Alchymy; or the Twelve Gates Leading to the Discovery of the Philosopher's Stone*. The 12 gates were the various chemical techniques such as distillation and sublimation. Because he was very rich it led contemporaries to believe that he too had discovered how to make gold, but on his deathbed he confessed to wasting his life on futile ventures and urged those who came across his writings to burn them, saying they were based not on actual experiment but on mere speculation.

Bernard of Treves (1406–91) began searching for the Philosopher's Stone in his early teens and was still looking when he died aged 85. He was lucky in that he was born into a wealthy family and so could afford to spend his whole life as an alchemist, although there is plenty of evidence that some of those who joined him in his search were simply conmen. One of these was a man known as Master Henry, whom he met in Vienna in 1464, and with his help Bernard performed an experiment that failed miserably. He gave Master Henry 42 gold marks, which he sealed in a vessel with mercury and olive oil, and heated them for 21 days. Surprisingly, when the vessel was opened there were only 16 gold marks to be found.

Fraudulent alchemists like Master Henry had several tricks for conning the gullible, such as using double-bottomed crucibles in which gold could be hidden, or inserting gold leaf inside pieces of charcoal that were added to the crucible, or, simplest of all, pre-dissolving some gold in mercury and then distilling this off leaving gold behind. No one doubted that transmutation was possible and in 1404 a law was passed in England in the reign of King Henry IV that forbade the making of gold or silver by alchemical methods.

This law, known as the Act of Multipliers, remained on the statute books until the 1660s when it was repealed thanks to the efforts of scientist Robert Boyle (1627–91) who was convinced that it was discouraging research that might well make the nation wealthy.

Alchemy flourished in the 1500s and 1600s and its practitioners became noted figures of their day: Georg Agricola (1494–1555), Paracelsus (1493–1541), John Dee (1527–1608) and his close associate and conman Edward Kelley (1555–95), Michael Sendivogius (1566–1636), Jan Baptista van Helmont (1577–1644), and Joseph Francis Borri (1616–95). The last of these came from Milan and he spent much of his life searching for the elusive Philosopher's Stone under the patronage of various dukes and monarchs, including his most protective patrons the ex-Queen Christina of Sweden and King Frederick III of Denmark, although he spent the last 20 years of his life a prisoner of the Pope in the Castle of St Angelo. Paracelsus became famous for his *medical* use of alchemical materials such as mercury, and we will hear more of him in later chapters. Sendivogius probably discovered oxygen, which he made by heating nitre (potassium nitrate).

Scams were often perpetrated on alchemists, and they appear to have been easily fooled. The Swiss scientist Johann Helvetius lived in The Hague, and in December 1666 he was visited by a man who said he had discovered the Philosopher's Stone. He sold a small piece to the scientist to investigate, with the promise that he would return the next morning to show him how to make more. Helvetius' wife urged her husband to try it out that evening, and indeed they used it to convert half an ounce of lead into the finest gold. A local goldsmith pronounced it genuine, and Helvetius became famous when the news got out. Sadly the mysterious visitor never returned to reveal how the Stone had been made.

Alchemical fraudsters have continued in business right up to modern times. Long after alchemy had given way to chemistry there were those who still claimed transmutation was possible. The Emperor Franz Joseph was conned out of the equivalent of $10 000 in 1867 by three supposed alchemists, and as late as 1929 a German plumber, Franz Tausend, was still conning people. He persuaded a group of financiers to allow him to demonstrate his method. At the State Mint, and before an audience which also included a judge, the state attorney, and a police detective, he produced a tenth of a gram of gold from a gram of lead. All his equipment had been thoroughly tested beforehand and it appeared he had achieved a genuine transmutation. In fact the gold had been smuggled into the room inside one of his cigarettes.

The 1600s saw the gradual emergence of chemistry from alchemy and in this period we find several men we now recognize as true scientists who were in their time secret alchemists, such as Robert Boyle, John Mayow (1641–79), and Isaac Newton (1642–1727). By the end of the 1700s, however, alchemy was no longer respectable, at least in scientific circles, although even in the late nineteenth century some alchemists were still at work, including August Strindberg (1849–1912) the great Swedish writer. He devoted a considerable amount of effort to the project and believed he had succeeded in 1894 when he sent samples of his 'gold' to the University of Berlin and published his method in a fringe journal, *L'Hyperchimie*. Like all before him he was deluded, and later analysis of his samples showed them to be iron compounds, which can sometimes appear a deep gold colour.

The chemistry of the alchemists was really quite superficial in that it consisted of heating mercury with sulphur and any other ingredient that the alchemist had to hand. Mercury was known to dissolve all metals except iron and the amalgams so formed were then heated with sulphur. The resulting material could take on a variety of hues, especially if arsenic oxide was also added to the vessel, so much so that they would lead the alchemist to think a different process had occurred each time. Alchemical elixirs can still be purchased on the Internet, where there are recipes for making gold, and the subject can still be studied at the Paracelsus College Australia, which is based in Adelaide and has its own website at <elevity.com/alchemy/parcoll.hmtl>. This gives useful access to translations of many of the writings of the alchemists of the Middle Ages.

Mercury vapour is known to be highly dangerous. What is somewhat surprising is that many alchemists lived to old age, suggesting that either this toxic metal did them little harm or, more likely, that they spent more time theorizing about transmutation than attempting to carry it out. It seriously affected some of them, as we know from the experiences of those who were practising alchemists in England in the late 1600s.

The first chemist

Today Robert Boyle is regarded as one of the founding fathers of chemistry. He was the brother of Lady Ranelagh and he lived at her London home, Ranelagh House, which was situated in the fashionable St James's district. Robert Boyle was a complex character. He was a life-long bachelor, a staunch Christian, a giver to charity on a large scale, a scholar, a world-renowned scientist – and an alchemist. Despite his ground-breaking work on the study of gases that led to Boyle's law, which relates volume to pressure, he spent a great deal of his life searching for the Philosopher's Stone. He too was conned out of a great deal of money by a Frenchman, George Pierre des Clozets, who promised to reveal the recipe for making gold and admit him to a secret society of true alchemists. Boyle fell for the scam and paid dearly for it.

The fact that Boyle had been an alchemist for most of his life was to prove an embarrassment to the scientific establishment in later years because of the need to present him as the first true chemist. His book *The Sceptical Chymist* is today regarded as the seminal work that severed the link between chemistry and alchemy but is not just an attack on alchemy. Indeed among Boyle's papers when he died there was one he had partly written called *Dialogue on Transmutation and Melioration of Metals* in which he described a well-documented transformation of base metal into gold performed by a French alchemist, and which he said had been witnessed by several eminent people. Boyle believed his search for the Philosopher's Stone was justified because it would not only transmute metals but would be an 'incomparable' medicine.

Boyle himself published a paper in the Royal Society's *Philosophical Transactions* of 21 February 1676 entitled 'On the Incalescence of Quicksilver with Gold'. This reports a 'mercury' which, when mixed with gold, causes it to react and evolve heat. Lord Brouncker, President of the Royal Society, attested to the efficacy of Boyle's new 'mercury' in that when it was mixed with gold powder on the palm of his hand, he felt the heat it generated.

In another of his publications, *Producibleness of Chymical Principles*, Boyle reports on a 'mercury' that could dissolve gold instantly but refuses to reveal its nature because he feels it would 'disorder the affairs of mankind, favour tyranny and bring a general confusion, turning the world topsy-turvy'. We can only guess what this 'mercury' was but it was probably an antimony–copper–mercury amalgam. Boyle's instructions for making it, though, were written in alchemical language:

> Take pure Negerus, Dakilla, imbrionated banasis ana, mix them very well together & drive off all that you can in a retort with a strong fire of sand. It dissolves gold readily and that with sensible heat.

Negerus was mercury, Dakilla was copper, and imbrionated banasis was antimony. The danger inherent in carrying out such an experiment was breathing the mercury vapour that would be given off during the experiment, and indeed Boyle's regular exposure to mercury might well explain his chronic sickness. Undoubtedly Boyle was exposed to mercury fumes but there is no evidence that he was disabled by them and indeed most of his experiments were performed by an apprentice. He had taken up residence at Ranelagh House in 1671 and lived there until his death in 1691. In 1676 he persuaded his sister to allow him to build a laboratory in the garden and then to enlarge it in 1677. It was equipped with a furnace, retorts, flasks, and other alchemical apparatus together with a range of simple chemicals. It was there that he carried out a series of experiments that revealed him to be a true chemist rather than an alchemist.

In 1669 Hennig Brandt, an alchemist of Hamburg, discovered phosphorus, which he believed would lead him to the Philosopher's Stone on account of its almost miraculous ability to shine in the dark and spontaneously burst into flames. He sold some of this to a Daniel Kraft who demonstrated it around the courts of Europe; Kraft eventually arrived in London in 1671, where he even put on a private demonstration for Boyle at Ranelagh House, to which other members of the Royal Society were invited. Boyle was duly impressed and asked how it was made, only to be told that it was derived from 'something that came from the body of man'. Boyle deduced, rightly, that this was urine, but he could not extract phosphorus from it no matter how he tried until his apprentice, Ambrose Godfrey, went to Hamburg and met Brandt who told him that it required high temperatures. In fact phosphorus was obtained by heating to red heat the residues from boiled-down urine, and in this way Boyle obtained what he desired. What he did next distinguished him as a true chemist: he researched the properties of phosphorus and its reactions with other materials and published his findings not in the secret language of the alchemists but in plain English, and in a manner that would allow even a modern chemist to repeat what he had done. Whether they would want to repeat his observation that 'if the privy parts be rubb'd [with phosphorus] they will be inflamed for a good while after', is doubtful.

Phosphorus came too late in the age of alchemy to have much impact. It was neither the Philosopher's Stone nor the Elixir of Life although others assumed it might well be and experimented accordingly. It was not recognized to be a *chemical* element for another century. Indeed there were only a few elements as we know them which they used in alchemical recipes, and these were mercury, arsenic, and antimony. Of these, mercury was the material that forever tantalized, promising so much and yet delivering so little, and all the while it may have been affecting health and mental stability. It is worth examining this remarkable liquid a little more closely before looking at two men whom it seriously affected.

Mercury

Mercury was known to the earliest civilizations in China, India, and Egypt. The oldest known sample of mercury metal was found by the German archaeologist Heinrich Schliemann (1822–90) in an ancient Egyptian tomb at Kurna which dated from around 1600 BC. The name mercury, by which we know this element, comes from the name of the planet and its first recorded use was by the Greek philosopher Theophrastus around 300 BC. The Romans called it *hydrargyrum* and it is from this word that today's chemical symbol for mercury, Hg, is derived. The early English name of quicksilver derived from the old English word *cwic*, meaning living, as in the phrase: 'the quick and the dead'. The Romans knew that heating cinnabar reduced it to globules of metallic liquid mercury. At the other side of the world, the Chinese were also observing the same phenomenon and the alchemist Ko Hung (281–361) wrote of the wonder of turning bright red cinnabar into silver mercury simply by heating.*

Mercury has a strong affinity for sulphur atoms, and the two combine to form insoluble mercury sulphide, HgS, which is how it occurs as the main mercury ore, bright red cinnabar. When used as a pigment, cinnabar is known as vermilion and it was even used by cave painters 20 000 years ago in Spain and France. Vermilion was especially popular with the Romans, who decorated whole rooms in their villas with it. The Roman writers Vitruvius and Pliny refer to mercury metal but were of the opinion that the mercury which was found naturally in the mines of Spain was somehow superior to that which was obtained by roasting cinnabar; the former they referred to as *argentum vivum* (living silver) and the latter as *hydrargyrum*

* The sulphur is oxidized by the oxygen of the air, forming sulphur dioxide gas, and mercury metal is left behind.

(silver water). Pliny was clearly familiar with mercury and wrote of it as follows:

> It acts as a poison upon everything, and pierces vessels, even making its way though them by the agency of its malignant properties. All substances float upon the surface of quicksilver, with the exception of gold, this being the only substance it attracts to itself. Hence it is an excellent refiner of gold, for on being briskly shaken in an earthen vessel with gold it rejects all the impurities that are mixed with it. When once it has expelled these superfluities, there is nothing to do but to separate it from the gold.

Pliny reported that more than four tonnes of mercury metal were imported into Rome every year. He also said that men who worked with the ore protected themselves against the dust by covering their heads with bladders.

Down the centuries mercury continued to fascinate all those who were attracted to alchemy. There was nothing quite like it and it seemed to have almost magical properties. Mercury chloride still has its uses in magic even today, witness the 'psychic' Uri Geller who used it to demonstrate his supposed mind-over-matter mental powers in night clubs in Israel in the 1970s. According to Joe Schwarcz in his book *The Genie in the Bottle*, Geller would demonstrate his remarkable ability to heat metal by thought alone. A member of the audience would be invited on stage to hold a piece of aluminium foil which would mysteriously get hotter and hotter until it was too hot to hold, during which time Geller closed his eyes and supposedly focused his mind on the metal, supposedly willing it to heat up. The trick was to put a tiny amount of mercury chloride* powder on the aluminium and fold it over. A chemical reaction between the aluminium and the powder slowly begins to take place and eventually it gives off a lot of heat.

Mercury was important to the Scientific Revolution for barometers and thermometers, and while these uses could coexist with alchemy there was a discovery about mercury which fatally undermined belief that this metal was somehow forever different from all other metals. For alchemical theory it was *the* element, a component of all metals, and so held the key to the transmutation of base metals into gold. It uniquely represented the quintessential property of *fluidity*. Reports from Siberia, that mercury could freeze solid and become like any other metal were dismissed as little more than travellers' tales.

* This is the higher chloride, mercury(II) chloride, formula $HgCl_2$.

What could not be discounted was a report from two Russian scientists, A. Braun and M. V. Lomonosov, of St Petersburg. In December 1759 they had experimented with snow to see how low a temperature they could achieve. Mixing snow with salt causes its temperature to fall by several degrees and they thought that mixing acids with snow might produce even lower temperatures – and so it did. Suddenly the mercury in their thermometer stopped moving, and indeed it appeared to be solid. When they broke away the glass they found it had become a solid metal ball with a protruding piece of wire, which they could bend, just like other metals. Mercury was just a metal with a low freezing point of −39°C.

What was still not truly appreciated was the toxicity of mercury vapour and it is this which could have insidious effects on alchemists, and even on amateur dabblers including a famous king and his most intelligent subject.

The madness of Isaac Newton

Isaac Newton was one of the greatest scientists of all time. His achievements were impressive: he explained the nature of light and colour; he established the theory of gravity and deduced how the solar system works; he devised the laws of motion; and he invented an early form of differential calculus. What is less well known is that he spent most of his time when he was Professor of Mathematics at Trinity College, Cambridge, as an alchemist. When, in 1940, the economist John Maynard Keynes opened a box of Newton's papers that had lain undisturbed for 250 years, he was amazed to discover a collection of notebooks in which Newton had recorded his numerous attempts to make gold. In the years when he was writing his great works on physics and mathematics, he was actually spending much of his time carrying out alchemical experiments and copying out ancient alchemical texts.

Newton believed that the ancient alchemists knew how to make gold but that the secret had been lost. Nor was he alone in this belief. As we saw above, the great Robert Boyle thought it was possible, and John Locke the philosopher believed likewise. Indeed, Newton even cautioned Boyle about the need to remain silent about their alchemical interests.

Newton first experimented with mercury by dissolving it in nitric acid and then adding other things to the solution. When such experiments produced nothing worthwhile he turned to heating mercury with various metals in a furnace, and his assistant and room-mate John Wickins tells how he would sometimes work through the night. In one of his experiments he produced a kind of 'living' mercury that made gold swell. When nothing came of this, he turned his attention to antimony and by 1670 he had made the so-called Star Regulus, a dramatic form of antimony – see below.

In 1675 Newton wrote up his findings in a 1200-word manuscript known as the *Clavis* [Key]. He was 32-years-old but had gone grey, which he jokingly said was due to quicksilver. Although there is no connection between the two, there is a link between the body burden of several metals and their level in hair. Mercury, lead, arsenic, and antimony, are particularly attracted to the sulphur atoms in the keratin of hair and so it is possible by the analysis of a strand of hair to show whether that person had been exposed to a large dose of these toxic metals.

Newton's alchemical experiments appear to have reached a climax in the summer of 1693 when he wrote an account that is a combination of bizarre alchemical symbols and comments and is known as the *Praxis* [Doings] and this showed how unbalanced he had become. Isaac Newton was well known for being temperamental. Criticism of his work aroused in him an abnormal hatred of a rival and his feuds with other eminent scientists of the day such as Robert Hooke and Gottfried Leibniz were more emotional than rational. At times, Newton withdrew into virtual isolation and in 1693, when he was 50-years-old, his behaviour became so abnormal that his sanity was even questioned.

The published correspondence of Newton contains a noticeable gap from 30 May to 13 September 1693, when he wrote a letter to Samuel Pepys in which he said that he had been suffering from poor digestion and insomnia for the past year and admitted that he had not been 'of my former consistency of mind'. In the same letter he displayed evidence of this by rebuking Pepys for suggesting that he had ever asked favours from him or from King James, and ended the letter by saying that he never wanted to see Pepys or any of his friends again. He later wrote to the philosopher John Locke, among others, to apologize for the things that he said to them earlier. He asked Locke to forgive him for saying that Locke had been trying to 'embroil me with women'. In another letter, written to a friend of Pepys, he asked him to explain to Pepys his odd behaviour and said that he had suffered 'a distemper that seized his head, and that kept him awake for about five nights together'.

From these and other letters, Newton's physical symptoms are revealed to be severe insomnia and loss of appetite, while his mental symptoms were delusions of persecution, extreme sensitivity to remarks that he saw as implied criticisms, and loss of memory, all typical symptoms of mercury poisoning. In 1979, two articles appeared together in the *Notes and Records of the Royal Society of London* which confirmed that Newton had indeed suffered this way. The first was by L. W. Johnson and M. L. Wolbarsht, the second by P. E. Spargo and C. A. Pounds. According to Johnson and Wolbarsht, Newton's symptoms were consistent with mercury poisoning. Proof that this might well have been the cause comes from the paper by Spargo and Pounds. They analysed samples of Newton's hair by neutron activation and atomic absorption analysis and found high levels of toxic elements (see Table 1.1) which show that he had about four times more lead, arsenic, and antimony than normal, and 15 times more mercury. Two authentic samples of Newton's hair had been preserved in the Earl of Portsmouth's family along with other relics of Newton's that went to his niece, whose daughter married the first Earl of Portsmouth. Samples of Newton's hair are also kept at Trinity College Cambridge, and a single hair found in one of his original note books was assumed to be from his head. One of Newton's hairs had a mercury level of 197 ppm and another had a lead level of 191 ppm, both of which would be a strong indication of chronic mercury and lead poisoning at some stage in his life.

These findings are not surprising because we read in his alchemical notebooks that he experimented with lead, arsenic, and antimony, and some of these he tried to volatilize by heating to high temperatures. He also admits to evaporating mercury over a fire, which was a particularly dangerous thing to do. Although there is no date for when these samples of hair were collected, most would probably have been cut from his head when he died in 1727. This being so then the level of mercury to which he was exposed in the critical period of 1693 would certainly have been much higher. In all cases

Table 1.1 Analysis of toxic elements in Newton's hair

	Mercury	Lead	Arsenic	Antimony
Normal level/ppm	5	24*	0.7	0.7
Level in Newton's hair/ppm	73	93	3	4

* This refers to the average level in hair in 1979; today it would be much less.

they reveal a remarkably high level of exposure, suggesting that he was in fact exposed to other sources of mercury. One of those might well have been from the decorations in his rooms. Newton had a desire to be surrounded by the colour red and to this end he had the walls of his rooms painted red, and it is more than likely that vermilion was the pigment used.

Yet if Newton's strange behaviour in 1693 represented the effects of mercury, it did him little permanent harm because he lived to the ripe age of 84. It is not easy to say to what extent Newton's paranoid behaviour was due to mercury poisoning. He had such a sad childhood that his behaviour throughout life can be explained as due to his upbringing. His father died before he was born, his mother married again when he was two, and his stepfather, a parson, wanted nothing to do with him, so it was left to his grandmother to raise him. All his life he had pronounced psychotic tendencies but his exposure to mercury may well have contributed to his mental instability. Newton was never insane and indeed he was entrusted with overseeing the operations of the Royal Mint, was elected President of the Royal Society in 1703, and was knighted in 1705.

The strange death of King Charles II

King Charles II was not an alchemist as such, but he was very interested in science and especially 'chymistry'. He had a laboratory built in the basement of his palace at Westminster and there, with the aid of one or two assistants, he spent time smelting and refining mercury, and indeed he became accomplished in the experimental techniques of the alchemists. Charles had his laboratory staff extract mercury from cinnabar and even distil it. No doubt his aim was to transmute base metals into gold, and thereby solve his financial difficulties. He was at odds with Parliament, who had the power to vote him money, and had to rely on massive financial subsidies from his old friend King Louis XIV of France, for whom he was in effect a client king.

In fact Charles's interest in 'chymistry' had started in 1669 when he had established the office of Chemical Physician to the King, appointing Dr Thomas Williams to it, and providing him with a salary of 20 marks per year and research facilities where he could 'compound and invent medicines', some of which he did with the help of the King himself. Charles's laboratory was even visited by the diarist Samuel Pepys who, on the morning of Friday, 15 January 1669, was walking to Whitehall when he met the King who invited him to come and inspect his new laboratory. This he did and he described it as 'the King's little laboratory under his closet, a pretty place, and there saw a great many Chymicall glasses and things, but understood none of them.'

In 1684, Charles began to exhibit some of the symptoms we now recognize as due to chronic mercury poisoning: he became irritable and easily depressed which was quite out of character for the man who was renowned for his cordiality, his many mistresses, and his love of the good life. Something clearly happened when he was in his laboratory during the last week of January 1685, something that exposed him to a lot of mercury vapour.

On Sunday, 1 February, he spent the evening with three of his courtesans listening to love songs and enjoying a meal with them, but going to bed alone. He awoke the following morning feeling quite ill. *The Calendar of State Papers – Domestic* reported what happened:

> When his Majesty arose yesterday morning, he complained that he was not well and it was perceived by those in his chamber that he faltered somewhat in his speech, notwithstanding which he went into his closet, where he stayed a considerable time. When he came out he called for Follier, his barber, but, before he got to the chair, he was taken with a fit of apoplexy and convulsions which drew his mouth to one side (this was about ten minutes past eight), and he remained in the chair while he had three fits, which lasted nearly an hour and a quarter, during which time he was senseless. His physicians blooded him and he bled 12 oz freely. Then they cupped him on the head, at which he started a little, then they gave him a vomit [an emetic] and a glyster [an enema] and got him to bed by ten. He spoke before one. He called for a China orange and some warm sherry, in which time both the vomit and the glister wrought very kindly, which his physicians say are very good symptoms. He mended from one to ten last night, when they were laying him to rest, his physicians having great hopes that the danger of the fit is over, since that hand they feared was dead, he of his own accord moved and drank with it and complained of soreness, which they say is an extraordinary good symptom. Last night they sat up with him three Privy Councillors, three doctors, three chirurgeons [surgeons], and three apothecaries, and this morning, Dr Lower, one of the physicians that sat up, says that he rested very well, and that naturally, and not forced. This morning he spoke very heartily, so that they hope the danger of this fit is over.

But Charles had been fatally poisoned and the remission of his symptoms that Tuesday was not to last. On the Wednesday, the King took a turn for the worse, suffering more convulsions, and his skin became cold and clammy. He was given a strong laxative, which 'had good operation', and two doses of quinine ('the Jesuits' powder'). On the Thursday he had more convulsions and his life was now clearly in danger, so much so that he was visited by his brother, James, heir to the throne, who brought along a Roman Catholic priest who received him into the Church of Rome and he took the Eucharist. (Charles, who had ruled as a Protestant king throughout his entire reign, was secretly a Catholic.) The following morning, Friday, 6th February, he was propped up in bed to watch the sun rise and even ordered that his eight-day clock be wound up, but by seven o'clock he was having difficulty breathing, by eight-thirty he was clearly failing, and by ten o'clock he was unconscious and obviously dying. Extreme remedies were administered including King's Drops, which was an extract of human skull and had been invented by a Dr Jonathan Goddard (and even prepared in Charles's own laboratory), and Oriental Bezoar Stone, which was made from the stones sometimes found in the stomachs of animals. These were remedies of last resort and clearly useless as antidotes to mercury poisoning, which of course had not been diagnosed as such by his physicians. Charles died just after noon that Friday.

Frederick Holmes, in his book *The Sickly Stewarts*, has considered the various accounts of Charles's death, including the report of his autopsy, which was carried out the day after he died and observed by a group of physicians. While the original report was lost in a fire at Whitehall in 1697, a copy has survived and is now in the archives of the College of Physicians of Philadelphia, USA. Holmes, who was the Edward Hashinger Distinguished Professor of Medicine at the University of Kansas Medical Center, and a Fellow both of the American College of Physicians and of the Royal Society of Medicine, says there is only one conclusion that fits all the facts: Charles's death was due to mercury poisoning.

Charles died of an acute insult to his brain, which caused the epileptic seizures he exhibited during his last few days of life. The hand paralysis following the first of these is a common complication of epileptic seizures known as Todd's Palsy. However, it is the autopsy which explains why the 54-year-old king, who up to then was in remarkably good health for a man of his age, was suddenly taken ill and died. The autopsy showed the outer parts of the brain to be engorged with blood while the ventricles of the brain contained much more water than normal. The rest of his organs were sound.

Until the twentieth century, it had been assumed that Charles had suffered a stroke but, says Holmes, this was not the case and the onset of epileptic seizures suggests a serious disease of the brain. It has been suggested that he died of malaria and that this was the cause of the brain disease, but that does not fit with the facts either. Holmes concludes that the King died of mercury poisoning, caused by his exposure to it in his laboratory. This theory was first put forward in the 1950s by the romantic novelist Barbara Cartland in her book *The Private Life of Charles II*, but it was more seriously argued by two American scientists, M. L. Wolbarsht and D. S. Sax, in 1961 in a paper published in the *Notes and Records of the Royal Society of London*. They noted that Charles often spent his mornings in his laboratory where he was obsessed with the idea of 'fixing' mercury, in other words combining it with other materials, a process that included distilling large quantities of it. The air of that room must have been heavily polluted with mercury vapour and he would be totally unaware of it because it has no smell. Other great scientists were to suffer some degree of mercury poisoning due to poor laboratory conditions in the centuries to follow, including Michael Faraday (1791–1867). They were exposed to enough vapour to cause the symptoms of mild mercury poisoning although it was not recognized as such.

Breathing mercury vapour causes no respiratory symptoms, unless the dose is very high. The metal is absorbed by the lungs and passes into the blood stream and thence to all parts of the body but the nervous system is particularly affected. The brain is most vulnerable because mercury can move across the blood–brain barrier which is there specifically to protect this vital organ against toxins, and once inside the brain it causes all kinds of symptoms such as lack of energy, unsteady gait, insomnia, etc. In his last year of life, Charles showed some of the signs of mild mercury poisoning, and he became less physically active. We know he was exposed to mercury because the analysis of a strand of his hair showed ten times the expected level. John Lenihan and Hamilton Smith, of the University of Glasgow, used nuclear activation analysis techniques to measure this in 1967. The sample of hair had been obtained through a radio broadcast the previous year, which had prompted a listener in Wales to send them a lock of Charles's hair attached to a card which bore the words:

> This lock of hair was taken from the head of King Charles the 2nd, by the mother of Sir John Jennings Kt, and given to Miss Steele of Bromley by Phillip Jennings Esq. nephew to the Admiral Sir John Jennings above said 1705.

The analysis showed the hair to contain 54 ppm of mercury, which is about ten times greater than normal, and while there is no record of when the hair was cut from the King's head, it was probably after he died and it certainly provides evidence that he was exposed to the metal during his final months of life.

While such analysis reveals exposure, it does not prove that he was necessarily putting his life at risk with his experiments. What killed him was *acute* mercury poisoning. In other words, in the days before he became ill he had done something in his laboratory which filled the air with mercury fumes and these he breathed in, maybe for an hour or more. The other possible explanation of mercury in the King's body could be mercury-based medication taken to treat syphilis, but neither his medical history, nor his autopsy, nor state records, indicated that any of his several mistresses had infected him with venereal disease.

Holmes uses his expert knowledge to show how the King's deathbed symptoms are consistent with mercury poisoning caused by breathing a lot of the vapour. This was the only route by which it could have entered his body without affecting other organs and yet kill him so quickly. When the blood–brain barrier is breached by mercury, the protein-containing part of the blood, the serum, leaks into the crystal-clear fluid surrounding the brain, the cerebrospinal fluid. This is exactly what the post-mortem revealed, all the cerebral ventricles were filled with a kind of serous matter, and the substances of the brain itself were quite soaked with similar fluid. The mercury that found its way into his brain then damaged the brain cells themselves causing the seizures that were observed. These seizures were not due to the other likely causes such as an abscess, tumour, meningitis, or internal bleeding because these would have been noted at autopsy. It was quicksilver that killed the King.

Arsenic

Humans appear to have been exposed to arsenic for more than 5000 years and we know this because hair from the Iceman, who was preserved in a glacier in the mountains of the Italian Alps for this length of time, contained high levels of the element. His exposure to arsenic is thought to indicate that he was a coppersmith by trade since the smelting of this metal is often from ores that are rich in arsenic. The arsenic is volatilized as arsenic trioxide and it deposits in the flue of the furnace or on nearby surfaces.

Theophrastus, Aristotle's pupil and successor and who lived around 300 BC, recognized two forms of what he referred to as 'arsenic' although these were not the pure element, but the arsenic sulphide minerals orpiment (As_2S_3) and realgar (As_4S_4). The ancient Chinese also knew of them and the encyclopaedic work of Pen Ts'ao Kan-Mu mentions them, noting their toxicity and use as pesticides in rice fields. The mineral realgar was recommended as a treatment for many diseases as well as for banishing grey hair. Arsenic compounds are also referred to in Democritus's *Physica et Mystica*, and the Roman writer Pliny wrote that the Emperor Caligula (12–41 AD) financed a project for making gold from orpiment and while some was produced it was so little that the project was abandoned.

The link between arsenic and gold was not forgotten and arsenic really came into its own in the Middle Ages. Realgar was found to yield so-called white arsenic by fusing it with natron (natural sodium carbonate). Petrus Oponus (1250–1303) showed that both orpiment and realgar could be converted to white arsenic, which we now know as the dangerously toxic arsenic trioxide, and which in the hands of the unscrupulous was to wreak such havoc down the ages. If white arsenic was mixed with vegetable oil and heated it yielded another sublimate, arsenic metal itself, and this may be how the discoverer of the element, Albertus Magnus, first made it. What was also noted in the Middle Ages was that when arsenic was applied to copper metal it turned it silver, and this too appeared to be a kind of transmutation.

Antimony

The origin of the word antimony is uncertain. One theory is that it came from the Greek *anti – monos* meaning not-alone. Another theory is that it is derived from its use as mascara in preference to the mineral minium (red lead), in other words it was anti-minium and so became anti-mony. A more likely derivation of the word is from the Greek *anthemonion* meaning 'flower-like' because of the beautiful flower-like crystals of the antimony ore stibnite. Constantine of Africa, who died in 1078, first used the word antimony and he is believed to have coined the name, although he was not referring to the element itself. He was born a Muslim, and was educated in Baghdad, but eventually embraced Christianity and became a monk. The chemical symbol, Sb, comes from the Latin word *stibium* which was the name of the mineral by which antimony sulphide was known in ancient times.

One of the first to write about antimony was Roger Bacon in the 1200s; and he was well aware of the metal and several of its compounds, and wrote about them openly. His interests were purely scientific. In the more secret world of alchemy, antimony played a key role. Like gold, it could only be dissolved by the king of acids, *aqua regia*, which suggested some affinity between the two metals, but of course no matter what the alchemists did to antimony it stubbornly refused to be transmuted into the much more desirable element. Others viewed antimony as a possible route to the Elixir of Life, but again they were to be disappointed, although John of Rupescissa, writing around 1340, suggested that the medical men might use some of its compounds to treat their patients.

The compounds of antimony that were known in the Middle Ages probably derived their names from those used by the alchemists, so we have regulus of antimony for the metal itself, golden sulphuret for antimony sulphide, butter of antimony for antimony chloride, and Powder of Algaroth for antimony oxide chloride. But antimony had a much more ancient pedigree than the alchemists of the Middle Ages realized.

The Chaldean civilization, which flourished in the sixth and seventh centuries BC, in what is now Iraq, had craftsmen who were capable of working with antimony metal, as shown by a vase of that period which was analysed in 1887 by a French chemist, Pierre Berthelot (1827–1907), who showed it to be almost pure antimony. Whether the ancient metallurgists were capable of extracting the metal from stibnite (antimony sulphide, Sb_2S_3), or whether they used samples of native antimony, which are sometimes to be found, is not known. Egyptian women of the oldest profession certainly had a fondness for stibnite powder which they applied as a form of mascara known as *kohl*. One of the most infamous practitioners of her craft, and user of *kohl*, was the temptress Jezebel whose exploits are recorded in the Bible, which twice (2 Kgs. 9: 30 and Ezek. 23: 40) warns of women who painted their eyes.

The Chaldean craftsmen were able to make yellow lead antimonate and this was used in the glaze of the ornamental bricks which adorned the walls of Babylon during the reign of Nebuchadnezzar (604–561 BC). This pigment was still being made in the 1900s and became known as Naples yellow. How the Chaldeans made it can only be guessed at but they probably heated together stibnite and red lead (lead oxide, Pb_3O_4) and produced it from the chemical reaction of these.

The Ancient Greeks and Romans regarded antimony metal as a type of lead but made little use of it. Their successors in the Byzantine navy, however, found a new use for antimony sulphide as an ingredient of the famous weapon they employed against enemy ships. So-called Greek fire was a burning liquid that was squirted from their warships, rather like a flame-thrower, and which brought terror to those exposed to it because it was impossible to extinguish and it even burned on the surface of water. How it was made has remained a secret to this day; indeed it was a capital offence to reveal it. It was last used in the defence of the capital, Constantinople, in 1453. The most likely composition of Greek fire was crude oil, stibnite, and saltpetre (potassium nitrate), a combination that would be highly flammable and almost impossible to extinguish with water. Once it is ignited, antimony sulphide generates a lot of heat, and its flammability was put to use in the early forms of household matches, whose red tips were due to the colour of this compound.*

The alchemists were always fascinated by antimony and one of their names for the metal, which they obtained by heating stibnite with iron powder, was *regulus* (king) *of antimony* or *martial regulus* (king of Mars) implying an impure form of regal gold. Needless to say, they never achieved their objective of converting one into the other, but the spin-off from their researches greatly added to the store of knowledge about antimony. The alchemists had another name for antimony, *lupus metallorum* (wolf of metals), based on its remarkable ability to alloy with other metals and change their character. The alchemists were probably the first to discover butter of antimony, which they got by heating the metal with corrosive sublimate. They purified the product and then heated it in a sealed vessel for several

* Antimony trisulphide has a different role to play in modern warfare. It is used in camouflage paints because it reflects infrared radiation in the same way as green vegetation.

months until it had become a red powder, which they called the 'powder of projection'. It was said that if this was sprinkled on other metals, along with the addition of mercury, it would transform the metal into gold. Of course they were wrong.

Antimony sprang to prominence quite openly in the 1400s when it became an essential part of the new craft of printing. Molten antimony has a unique chemical property of expanding as it solidifies, and by adding it to molten lead it produced a cleaner type face. This property of antimony had also been appreciated in the ancient world, where it was used to produce finely cast objects. Not only that but the lead alloy it produces is much harder than lead itself, again something that was appreciated by printers because it made stronger type. The preferred alloy for type consisted of 60% lead, 30% antimony, and 10% tin and this was used for more than 400 years.

The accumulated knowledge about antimony appeared in a very influential book published in 1604 and called *The Triumphal Chariot of Antimony*. It opens with an introduction about the author, a mysterious monk called Basil Valentine who apparently lived in the 1400s, and belonged to the Order of St Benedict. We are told that Valentine hid his manuscript inside a pillar of the church in Erfurt where the monastery was located, and there it rested until one day a bolt of lightning split open the pillar and it was revealed. In fact there never was a Benedictine monastery at Erfurt and no monk of this name has ever been traced, although that did not prevent other writers mentioning him and his book and even putting his date of birth at around 1400. The book popularized the use of antimony and its compounds in the treatment of disease, and thus started the widespread use of antimony which continued for 300 years.

The book begins with a mixture of alchemy, pious utterances, and abuse directed at the physicians and apothecaries of the day. When the author eventually gets down to the origin and nature of antimony the tone becomes alchemical. The section on the compounds of antimony reveals a knowledge of these which suggests he had practical experience in dealing with them. He mentions antimony metal, the oxide-sulphide glass, an alcoholic solution of the glass, an oil, an elixir, the flowers, the liver, the white calx (oxide), a balsam, and others. In its pages are described antimony trichloride, prepared by heating a mixture of antimony sulphide and mercury dichloride in equal proportions.

The Triumphal Chariot of Antimony was in fact written by its publisher

Johann Thölde, who was also a pharmacist and part owner of a salt works at Frankenhausen in Thuringia. Two pieces of literary evidence prove it was a later work and that Thölde was the author. The first is the reference to syphilis as the new malady of soldiers, which only appeared during the French invasion of Naples in 1495. Second, and, more convincingly, parts of the text reproduce parts of Thölde's book *Haliographia*, particularly the section on how salts can be obtained from metals. *The Triumphal Chariot of Antimony* shows that not all the trials and tribulations of the alchemists had been in vain; but the compounds of antimony which they had discovered were quite poisonous, as we shall see in Chapters 7 and 8, and yet they were widely used by doctors.

And what of alchemy today? Despite its tenets being based on a completely false set of beliefs, which puts it quite outside the boundaries of scientific investigation, it continues to flourish. Peter Marshall, the author of *The Philosopher's Stone*, says that alchemy is alive and well and living in places like China, India, Egypt, Spain, Italy, France, and Prague, where he went to search out its secrets and interviewed several latter-day alchemists. While some still cling to the idea that transmutation is possible, others are more concerned with the alchemy of the human mind. The theory is that we must search within ourselves for the Philosopher's Stone which can transform our inner being from dross to noble metal. Alchemy continues to attract other adherents who still believe in the transmutation of metals and who search the ancient literature looking for clues to the supposed secrets of the Philosopher's Stone and the Elixir of Life, secrets that they believe to have been discovered on more than one occasion but which have then been lost. They will forever seek in vain.

Hg

Mercury

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Mercury poisons us all

For more technical information about the element mercury, consult the Glossary.

Mercury is everywhere and we cannot avoid it. The average adult contains around 6 mg of mercury – assuming they have no mercury amalgam fillings in their teeth – and this is something we have to live with because we can do almost nothing to reduce it. Our average intake of mercury is about 3 mg/day for adults, and about 1 μg for babies and young children. At these levels the amount we consume in a lifetime is less than a tenth of a gram, although in previous centuries people would consume more than this in a day in the form of medication, generally for embarrassing diseases, such as the unspeakable syphilis or, even worse, the unmentionable constipation. We shed mercury from our body through our urine, faeces, and even our hair. We could excrete mercury via our saliva glands, which are greatly stimulated by mercury, but the mercury in saliva tends to return to the stomach.

So where does it all come from? The answer is mainly from the food we eat, although a little comes from the air we breathe and the water we drink, and some may even come from our own body if we have mercury amalgam fillings in our teeth. Agricultural soils may hold as much as 0.2 ppm of mercury and this finds its way into plants and food crops. Grass contains relatively little mercury, around 0.004 ppm, which explains why grazing animals are not really contaminated, and meat and dairy products have low levels. Seawater contains even less mercury than the cleanest soil and has only 0.00004 ppm, yet some fish absorb mercury to the extent of concentrating it in excess of 1 ppm.

Are we harmed by this amount of mercury? Probably not. In December

1997, the US Environmental Protection Agency (EPA) published a seven-volume report on mercury and announced a safe daily dose of 0.1 μg/kg body weight, which for an ordinary adult would be 7 μg. Were this limit to be acted upon then it would outlaw the sale of all swordfish, shark, and most tuna, whereas the Food and Drugs Administration (FDA), which has a more pragmatic view of mercury, bans their sale only if their mercury content exceeds 1 ppm. As we shall see, the EPA guideline is somewhat unrealistically low in that it is probably exceeded by all those in the population with amalgam fillings in their teeth, and yet the EPA claims that more than 600 000 children are born each year in the USA with learning deficits due to exposure to mercury while in the womb.

A person's reaction to mercury is unpredictable. Some can tolerate it in large amounts without showing signs of poisoning, while others were so sensitive that when mercury-based drugs were injected into them they were dead within seconds of the injection. One boy aged four actually died as the hypodermic needle was being withdrawn from his arm!

In this chapter we will look at how mercury could be affecting us. However, before we look at the effects on humans we should first spare a thought for the environment.

Mercury in the environment

Every plant and living creature contains some mercury, and this has been true for millions of years. Mercury stirs restlessly through the environment, and through the biosphere, and can do this because it exists in different forms. It can be present as elemental mercury and as such is volatile, which means it can circulate via the atmosphere. Mercury can exist as methyl mercury compounds produced by bacteria and thereby become more soluble. It can exist in one of two oxidation states of which mercury(I) is less common and less soluble, while mercury(II) is more common and more soluble, unless it meets a sulphur atom and precipitates as the totally insoluble mercury(II) sulphide (formula HgS).

In the past 500 years the amount of mercury released to the environment has increased dramatically due to the activities of humans. William Shotyk of the University of Heidelberg has studied the mercury levels in peat bogs in remote areas of Canada, Greenland, and the Faroe Islands where it is possible to measure the amount of mercury being deposited from the atmosphere stretching back more than 14000 years. Shotyk has shown that soil accumulated around ~1 μg/m^2/year although this was sometimes as high as 8 μg following a major volcanic eruption. Then from around 1500 onwards the amount of mercury being deposited began to increase slowly so that it had doubled by the 1700s, thereafter rising with the onset of industrialization until it reached over 100 μg in the mid-1950s. It has since declined and is now ~10 μg/m^2/year.

Mercury liberated naturally into the environment every year has been estimated to be about 1000 tonnes, but this is far exceeded by the human contribution. Cathy Banic of the Meteorological Service of Canada, has been tracking airborne mercury, and reported in 2003 in the *Journal of Geophysical Research* that the Earth's atmosphere contains about 2500 tonnes of the metal of which one-third comes from natural sources.

The level of mercury in the air over the Atlantic Ocean still continues to increase by around 1% per year. Ninety per cent of this is elemental mercury which comes mainly from coal-fired power stations (65%) and waste incineration (25%). Coal-burning in the USA adds 48 tonnes of mercury per year to the atmosphere although set against the global total of several thousand tonnes it is relatively modest.

Mercury's behaviour in the atmosphere can be quite puzzling. Sometimes it disappears for no apparent reason. For instance, during the weeks of the Arctic winter, when the sun never rises above the horizon, the level of mercury in the atmosphere builds up, but as soon as the first ray of sunshine appears the mercury vanishes for about three months. This mystery remained unsolved until 1998 when it was discovered that the airborne mercury suddenly deposited itself on the surface of the snow. Nor does this happen only over the North Pole; a team of German researchers also showed it occurs in Antarctica.

The explanation is that the mercury builds up in the atmosphere as long as it is not oxidized and these are the conditions during the sunless winter days. Once the sun shines, however, it triggers a sequence of chemical changes that speedily bring about oxidation of the mercury. Some is oxidized by ozone (O_3) that is being formed and some by the chlorine and bromine radicals that are generated within the aerosols formed from sea spray. Together these produce mercury oxide, mercury chloride, and mercury bromide which fall to the snow-covered land. Then as the polar summer unfolds, they may be