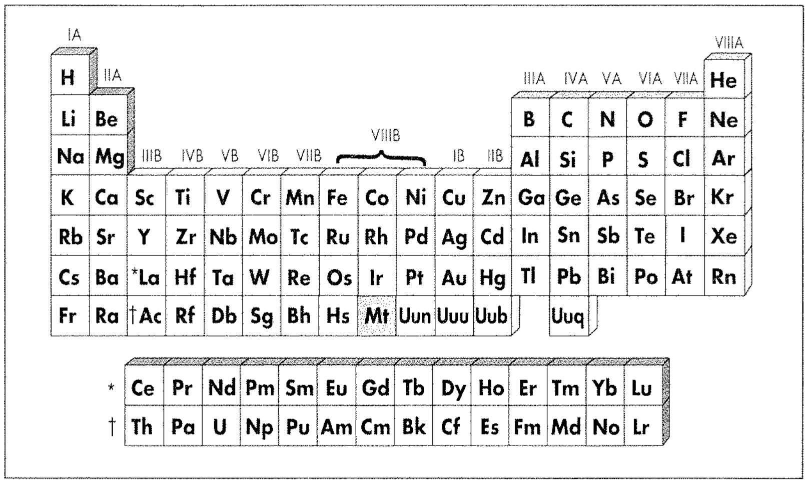
MEITNERIUM



Mt

In 1982, the team of physicists that had discovered transactinide elements 107 and 108, led by Peter Armbruster and Gottfried Munzenberg, working in Darmstadt, Germany, announced the synthesis and discovery of element 109, unnilennium. In the research that led to the discovery of this new element, they bombarded a bismuth-209 target with high-energy iron-58 ions to create unnilennium-266. Incredible as it might seem, only three atoms of unnilennium were created, and they decayed after only 3.4 thousandths of a second. This was a very brief existence but long enough to identify their structure.

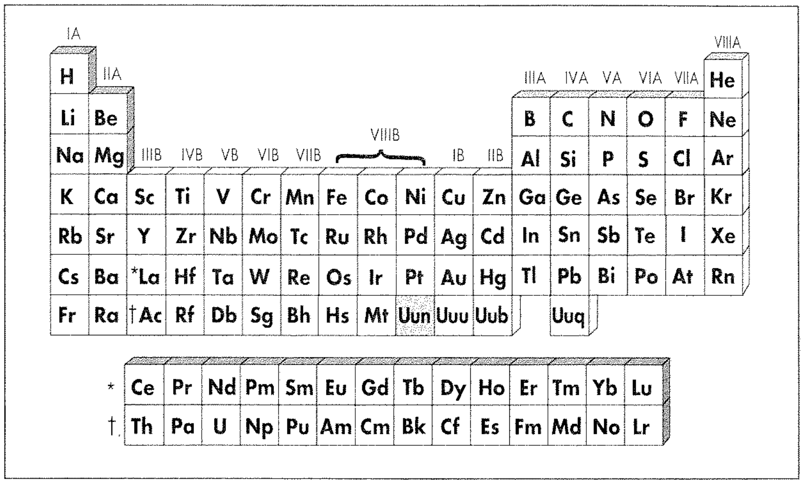
The German team confirmed the existence of unnilennium by following the series of decay products to which it gave rise. For the new element, they proposed the name *meitnerium,* in honor of Lise Meitner, the German physicist who, along with her nephew, Otto R. Frisch, had first envisioned nuclear fission as a splitting of the uranium nucleus.

In 1992, the International Union of Pure and Applied Chemistry confirmed the German team's research claims and both the IUPAC and the American Chemical Society approved the proposed name. Its chemical and physical properties remain unknown.

Atomic Number **109**

Chemical Symbol **Mt**

Group **VIIIB—**
A Transactinide



UNUNNILIUM

Uun

In November 1994, an international team of heavy ion physicists, led by Peter Armbruster, claimed to have created a new element with an atomic number of 110. The atom of this new element has a mass number of 267.

The work was done in Darmstadt, Germany, at the Heavy Ion Research Laboratory, known as GSI, which stands for the German name of the laboratory (Gesellschaft für Schwerionenforschung). The GSI facility has become one of the world's leading centers for the creation of new elements. It is also credited with the creation of elements 107, 108, and 109 in the 1980s.

The new element has not yet been officially named, but it is known as ununnilium (1-1-0-ium), according to the system designated by the International Union of Pure and Applied Chemistry for naming new elements (see the section on rutherfordium).

After a search that took almost 10 years, the research team in Germany successfully created and identified four or five atoms of the new element. Using a large accelerator to accelerate nickel atoms to high speeds, they bombarded a thin foil of lead with these fast-moving atoms of nickel. They managed to fuse the nuclei of these nickel and lead atoms to produce element 110.

Ununnilium is extremely unstable. It quickly breaks apart and decays into lighter atoms after approximately half of a thousandth of a second. It was detected by the four alpha particles it emits during its decay process.

Atomic Number **110**

Chemical Symbol **Uun**

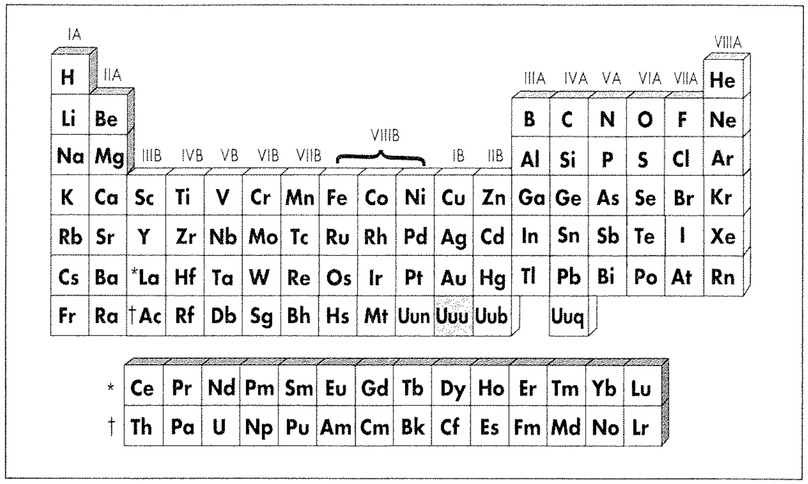
Group **VIIIB—**
A Transactinide

UNUNUNIUM

Atomic Number **111**

Chemical Symbol **Uuu**

Group **IB— A Transactinide**



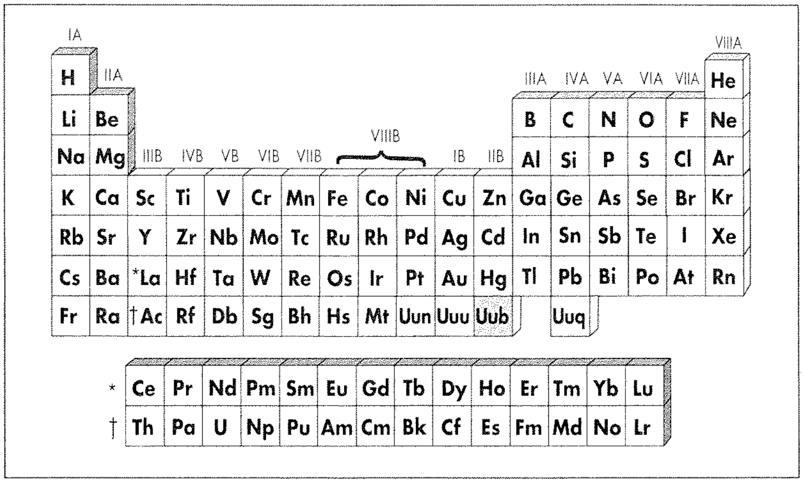
Uuu

On December 8, 1994, approximately one month after announcing the creation of element 110, a team of German scientists working at the Gesellschaft für Schwerionenforschung (GSI) facility at Darmstadt, Germany, claimed to have created element 111. An atom of this new element has 111 protons and 161 neutrons in its nucleus, giving it a mass number of 272.

The new element is as yet unnamed and is referred to as unununium (1-1-1-ium), which was devised according to the system adopted by the International Union of Pure and Applied Chemistry for naming new elements. The code is outlined in the section on rutherfordium. Only three atoms of this element have been made to date; its chemical properties are not known. Unununium-272 does lie in the same column as gold and silver in the periodic table, and so it is presumably a metal as well.

After accelerating nickel atoms to high speeds, the researchers bombarded bismuth with these fast-moving nickel atoms. They succeeded in fusing the nuclei of these atoms to produce the massive unununium atom. Like all the superheavy atoms, it is very unstable, decaying into smaller atoms after roughly four-thousandths of a second.

The identification of unununium is considered significant by many physicists because it supports the theory that there exists an "island of stability" for elements close to element 114. Although unununium is unstable, it has a half-life that is approximately eight times that of ununnilium.



UNUNBIIUM

Uub

The search for new elements goes on. On February 9, 1996, only a little more than a year after creating element 111, the Gesellschaft für Schwerionenforschung (GSI) announced the creation of element 112.

The Heavy Ion Research Lab, as it is known in English, is centered in Darmstadt, Germany. Over the years, various groups working at this facility have also been responsible for the creation of elements 107, 108, 109, and 110. Credit for the latest discovery goes to an international team of scientists under the leadership of German physicist Peter Armbruster. Combining enormous effort, ingenuity, and sophisticated equipment, they were able to confirm the new element by detecting the presence of just one single atom.

Element 112 is as yet unnamed, but according to the system adopted by the International Union of Pure and Applied Chemistry should be referred to as ununbiium (un-un-bi-ium, or 1-1-2-ium). Since element 112 lies in the same column in the periodic table as zinc, cadmium, and mercury, it is presumably a metal.

The researchers created ununbiium by accelerating zinc atoms to high speeds, and then bombarding lead with these fast-moving bullets. During the collision, a zinc atom managed to fuse with a lead atom. Since zinc contains 30 protons in its nucleus, and lead contains 82 protons in its nucleus, the new nucleus formed by this fusion contained 112 protons. Little is known of the properties of the new element, but like all superheavy atoms it should be extremely unstable, and quickly decay into smaller atoms.

In Germany, Russia, and the United States, physicists are continuing their search for new elements. It is very likely that even heavier atoms will eventually be created.

Atomic Number **112**

Chemical Symbol **Uub**

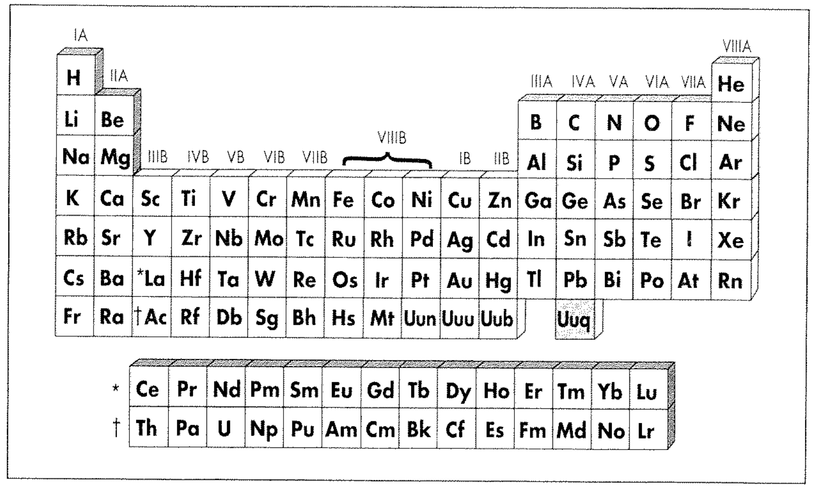
Group **IIB—**
A Transactinide

UNUNQUADIUM

Atomic Number **114**

Chemical Symbol **Uuq**

Group **IB— A Transactinide**

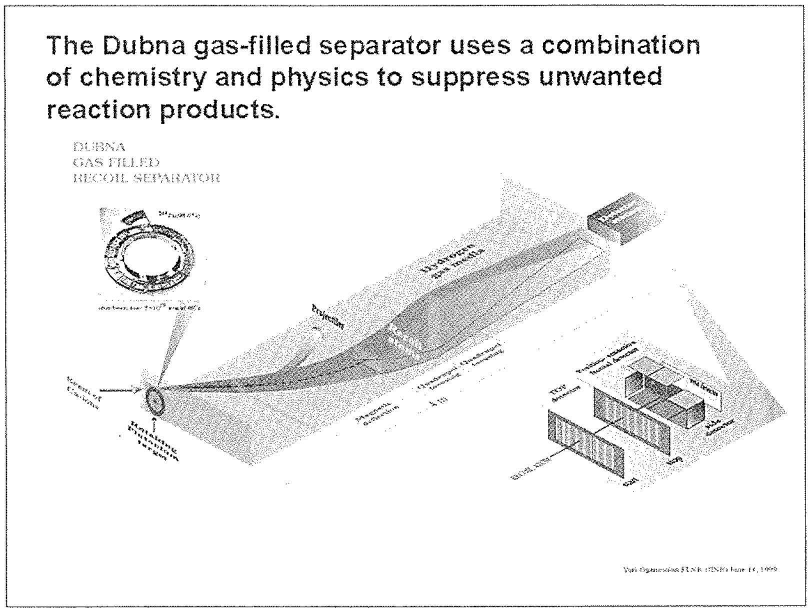


Uuq

A team of scientists working at Dubna, the Joint Institute for Nuclear Research near Moscow in Russia, announced in January 1999 that they had created a new ultra-heavy atom, element 114. Under the leadership of Yuri Oganessian, a Russian nuclear physicist, the team of 18 Russian and 5 American scientists identified a single atom of the long-sought-for new element. Although the discovery has yet to be duplicated by other laboratories, the American participants in the experiment, all from the Lawrence Livermore National Laboratory in California, felt confident that the data "identifies element 114 to greater than 99 percent probability."

The experiment that produced the new element used the large Russian cyclotron housed at Dubna to bombard a rare neutron-enriched form of plutonium, plutonium-244, with a beam of calcium-48 nuclei. The American team supplied both of these rare radioactive isotopes. After some 40 days of bombardment, a calcium nucleus with its 20 protons fused with a plutonium nucleus with 94 protons, producing an atom with 114 protons and 184 neutrons. The reaction is generally termed a "hot" fusion reaction because of the high energies involved.

The creation of element 114, tentatively named ununquadium, is an important step forward in the study of extremely heavy elements. Although unstable, as are all the superheavy elements, ununquadium survived a relatively long time for such a heavy element. When it decayed it formed a chain of three successive unstable daughter isotopes, elements 112, 110, and 108. The measurements of the time intervals between these three successive decays followed by spontaneous fission was estimated to be the relatively long half-lives of about 30 seconds, then 10, 1, and 11



Strong magnetic fields in the separator can focus the elements being searched for and separate them from the large number of intervening reaction products also created.

minutes, respectively, for element 114 and its daughters.

Many scientists felt that this longevity bore out theoretical predictions, first made in the 1940s, of an "island of stability," a region of unusually stable superheavy elements. This prediction of stability was based on the theory that nuclei contained spherical quantum shells similar to those occupied by the electrons of an atom. When neutrons and protons filled these shells, the resulting nucleus was predicted to be more stable than nuclei with only partially filled shells. These so-called "magic numbers" occurred at atomic numbers 114 or 126 and neutron number 184.

In addition to the possibility of producing exotic new materials, many scientists feel that the study of the superheavy elements is important because it can lead to crucial information on relativistic effects in atomic physics and quantum chemistry.

EPILOGUE

Elements for a New Century

On July 27, 2001, a group of scientists from the Lawrence Livermore National Laboratory in Berkeley, California, published a short paper in *Physics Review Letters* retracting their announcement, made in 1999, that they had discovered a new element, element 118. Ununoctium, as it was to be named, had the distinction of being the heaviest transuranium element ever observed. As an added bonus, the original experiment was thought to initiate a chain of events in which element 116, ununhexium, also a previously unknown element, was produced.

These major discoveries, unfortunately, were illusory. "In great pain," the crestfallen team wrote a brief note to the same publication in which they had originally announced their discovery, stating that subsequent experiments had failed to confirm their results. In other words, the "re-analysis of their primary data" had failed to produce evidence that the new superheavy elements were there.

This was certainly a most disappointing conclusion to what seemed a brilliant triumph for the team. Working with the Berkeley Lab's 88-inch Cyclotron and its newly installed Gas-Filled Separator (BGS), they collided krypton atoms with lead atoms in the hope that they would fuse. In the original paper, in which they mistakenly thought they had seen telltale signs of this fusion, the authors also stated that "we jumped over a sea of instability onto an island of stability that theories have been predicting since the 1970s." It was perhaps the excitement generated by data that seemed to be consistent with this exhilarating "leap" that led the scientists to their faulty conclusion. Whatever the reasons for their embarrassing errors, the researchers stated rather humbly that in clearing the record, "the path forward is to learn from the mistakes and to strengthen the resolve to find the answers that nature still hides from us."

And indeed, the resolve to find nature's hidden answers has not abated. Major scientific establishments all over the world are actively seeking to answer such questions as "how big can a nucleus be?" and "is there really an 'island of stability'?". Stated more simply, the quest remains the ever-continuing search for new superheavy elements. Berkeley is not the only facility engaged in this work, but many other laboratories, such as the Gesellschaft für Schwerionenforschung (Society for Heavy Ion Research or GSI) in Darmstadt, Germany, and the Joint Institute for Nuclear Research in Dubna, Russia, are actively competing in the search.

The motivation to continue this major effort to produce monster nuclei is that the answers being sought are of fundamental importance to our understanding of the universe. These giant atoms, occupying the region of the periodic table that has been dramatically named "an island of stability," have been discussed and theorized about for more than 30 years. They are, as the name implies, predicted to be unusually stable.

Demonstrating the existence of such an "island of stability" would, in the opinion of many scientists, validate the theoretical work of a whole generation of physicists.

There is little doubt in the minds of many scientists that this magic island really exists, and that reaching it is an attainable goal. Demonstrating this will require experimenters of great imagination and almost virtuoso-like skill. New accelerating machines and detectors are constantly being developed, often at great expense. The driving force behind this effort to create superheavy atoms remains the search for knowledge that will initiate a rich new field of study of the nuclear and chemical properties of the elements.

There is also a more utilitarian component that motivates the search for the elements that make up this stable island. Many scientists believe, for example, that these new elements will form unusual materials with exotic properties never before seen. There is the hope that they might possibly have many practical uses in industry and technology, and perhaps even serve as a source of energy in the form of new nuclear fuels.

The motivation to continue the major effort to produce monster nuclei is that the answers being sought are of fundamental importance to our understanding of the universe.

GLOSSARY

Acid Any substance that produces hydrogen ions when dissolved in water.

Acid rain Rain that is made acidic when such pollutants as sulfur dioxide and nitrogen oxides are present in the atmosphere.

Adsorption The attraction of one substance to the surface of another.

Allotrope One of several possible physically distinct forms of an element.

Alloy A metallic substance that is either a compound or a mixture.

Alpha particle A particle consisting of two neutrons and two protons that is emitted by certain radioactive substances. It is essentially a helium nucleus.

Anion A negatively charged ion.

Atom The smallest and most basic unit of an element.

Atomic number The number of protons in the nucleus of one atom of an element.

Atomic weight The average weight of all the isotopes of an element.

Base A substance that produces hydroxyl ions $(OH)^-$ when dissolved in water.

Beta particle The electron emitted during the radioactive decay of certain radioisotopes.

Catalyst A substance that increases the rate of a chemical reaction without being changed chemically itself.

Cation A positively charged ion.

Compound A substance composed of two or more elements chemically bound together in a fixed ratio.

Corrosion The oxidation of metals in the atmosphere.

Crystal An important structure of certain solids in which the atoms or molecules that are its basic building blocks are arranged in regular repeating intervals.

Cyclotron A machine that accelerates nuclear particles to extremely high speeds. It is used to investigate the nature of matter and to form new elements.

Deuteron The nucleus of the isotope of hydrogen known as deuterium. It contains one proton and one neutron.

Electrolysis A process in which the passage of electric current through a cell causes a chemical reaction to occur.

Element A substance that cannot be decomposed into a simpler substance by any chemical or physical reaction.

Gamma rays A form of electromagnetic energy given off by certain radioactive atoms. They resemble X rays in their great penetrating power.

Group The elements that make up a column in the periodic table.

Half-life For radioactive elements, the time required for half of the element to decay.

Ion An atom or group of chemically bound atoms that has either a positive or negative electrical charge.

Isotopes Atoms of the same element that contain the same number of protons but different numbers of neutrons.

Mass number The sum of the number of neutrons and protons that make up the nucleus of an atom.

Molecule A group of atoms (of the same element or a combination of elements) that are chemically bound together in a fixed ratio.

Neutron One of the basic particles that make up the nucleus of an atom. It is distinguished by having no electric charge.

Nucleus The central core of an atom, composed of protons and neutrons, that contains all its positive charge and most of its mass.

Oxidation This term once referred to a chemical reaction in which a substance combined with oxygen but now refers to any reaction in which a substance loses electrons.

pH A measure of the acidity of a solution. A pH of 7 is said to be neutral. The pH decreases as the solution becomes more acidic.

Period A horizontal row in the periodic table.

Polymer A large chain-like molecule made up of repeating smaller molecules that link together.

Radioactive decay The spontaneous breaking apart of a nucleus of an atom to form a different element. Usually accompanied by the emission of particles and gamma rays.

Reduction A chemical reaction that once referred to reducing an ore to its pure metal. It now is more generally conceived of as a reaction that involves the gain of electrons.

Salt A crystalline compound formed from the ions released into solution by an acid or a base.

Transition elements The elements located between Group IIA and Group IIIA in the periodic table.

Transuranium elements The elements that follow uranium in the periodic table. These elements are all made artificially.

Valence electrons The electrons that occupy the outermost shell of an atom. They often determine the chemical behavior of the element.

CHRONOLOGY

Some elements—**carbon, iron, copper, silver, gold, tin, antimony, mercury,** and **lead**—have been known and used for thousands of years. It is impossible to date their discovery. This chart lists the dates of discovery of all the other elements.

1250

Arsenic discovered by Albertus Magnus.

1669

Phosphorus discovered by Hennig Brand.

1739

Cobalt discovered by Georg Brandt.

1741

Platinum discovered by Charles Wood.

1746

Zinc discovered by Andreas Marggraf.

1751

Nickel isolated by Axel Fredrik Cronstedt.

1753

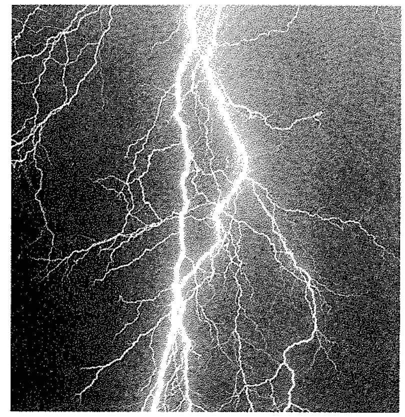
Bismuth identified by Claude Geoffroy.

1766

Hydrogen discovered by Henry Cavendish.

1772

Nitrogen discovered by Daniel Rutherford.



1774

Chlorine discovered by Carl Wilhelm Scheele; it was identified by Sir Humphry Davy in 1810.

Manganese discovered by Carl Wilhelm Scheele.

Oxygen discovered by Joseph Priestley.

1778

Molybdenum isolated by Carl Wilhelm Scheele.

1782

Tellurium discovered by Franz Joseph von Reichenstein.

1783

Tungsten discovered by Juan Jose and Fausto d'Elhuar y de Suvisa.

1787

Zirconium discovered by Martin Heinrich Klaproth.

1789

Strontium identified by Adair Crawford.

Yttrium identified by Johan Gadolin.

1791

Titanium discovered by Reverend William Gregor.

1797

Chromium discovered by Louis-Nicolas Vauquelin.

1798

Beryllium discovered by Louis-Nicolas Vauquelin.

1801

Vanadium discovered by Andres Manuel del Rio.

Niobium discovered by Charles Hatchett.

1802

Tantalum discovered by Anders Gustav Ekeberg.

1803

Rhodium and **palladium** discovered by William Hyde Wollaston.

Cerium simultaneously discovered by Jöns Jakob Berzelius, Wilhelm Hisinger, and Martin Klaproth.

Osmium and **iridium** discovered by Smithson Tennant.

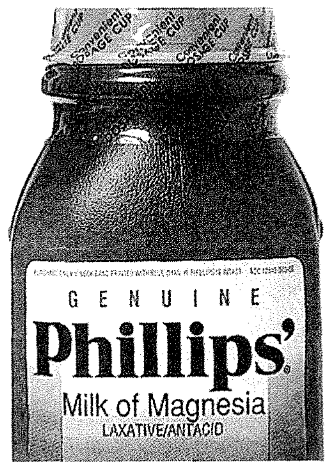
1807

Sodium and **potassium** isolated by Sir Humphry Davy.

1808

Boron isolated by Sir Humphry Davy, Joseph-Louis Gay-Lussac, and Louis Jacques Thénard.

Magnesium, calcium, and **barium** first isolated and identified by Sir Humphry Davy.



1811

Iodine discovered by Bernard Courtois.

1817

Lithium discovered by Johan August Arfwedson.

Selenium discovered by Jöns Jakob Berzelius.

Cadmium discovered by Friedrich Strohmeyer.

1824

Silicon isolated by Jöns Jakob Berzelius.

1826

Bromine discovered by Antoine-Jérôme Balard.

1827

Aluminum discovered by Hans Christian Oersted.

1828

Thorium discovered by Jöns Jakob Berzelius.

Beryllium discovered by Friedrich Wöhler.

1839

Lanthanum discovered by Carl Gustaf Mosander.

1841

Uranium isolated and identified by Eugène-Melchior Péligot. Henri Becquerel discovered that uranium was radioactive in 1896.

1843

Terbium and **erbium** discovered by Carl Gustaf Mosander.

1844

Ruthenium discovered by K. K. Klaus.

1860

Cesium discovered by Robert Bunsen and Gustav Kirchhoff.

1861

Rubidium discovered by Robert Bunsen and Gustav Kirchhoff.

Thallium discovered by Sir William Crookes.

1863

Indium discovered by Ferdinand Reich.

1868

Helium discovered by Pierre Janssen.

1875

Gallium found and identified by Paul-Émile Lecoq de Boisbaudran.

1878

Ytterbium discovered by Jean de Marignac.

1879

Scandium discovered by Lars Fredrik Nilson.

Samarium discovered by Paul-Émile Lecoq de Boisbaudran.

Holmium and **thulium** discovered by Per Teodor Cleve.

1885

Praseodymium isolated and identified by Carl Auer von Welsbach.

Neodymium discovered by Carl Auer von Welsbach.

1886

Fluorine isolated by Henri Moissan.

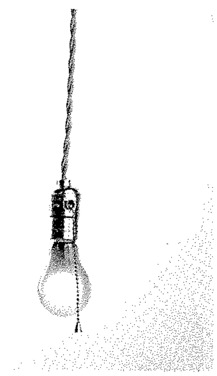
Germanium discovered by Clemens Winkler.

Gadolinium discovered by Paul-Émile Lecoq de Boisbaudran and Jean de Marignac.

Dysprosium discovered by Paul-Émile Lecoq de Boisbaudran.

1894

Argon identified by Lord Rayleigh and Sir William Ramsay.



1895

Helium discovered by William Ramsay.

1898

Neon, **krypton**, and **xenon** discovered by Sir William Ramsay.

Polonium and **radium** discovered by Marie and Pierre Curie.

1899

Actinium discovered by André Debierne.

1900

Radon discovered by Friedrich Ernst Dorn.

1901

Europium isolated by Eugène-Anatole Demarcay.

1907

Lutetium discovered by Carl Auer von Welsbach and Georges Urbain.

1913

Protactinium discovered by Kasimir Fajans and O. H. Gohring.

1923

Hafnium discovered by Dirk Coster and George Karl von Hevesy.

1928

Rhenium discovered by Otto Berg and Wilhelm Noddack.

1937

Technetium discovered by Emilio Segrè and Carlo Perrier.

1939

Francium discovered by Marguerite Perey.

1940

Neptunium first produced by Edwin M. McMillan and Philip H. Abelson.

Astatine created by a team of chemists that included Dale R. Corsun, K. R. Mckenzie and Emilio Segrè.

1941

Plutonium discovered by Glenn T. Seaborg.

1944

Americium created by a team of scientists led by Glenn T. Seaborg.

Curium created by Glenn T. Seaborg, Ralph A. James and Albert Ghiorso.

1947

Promethium discovered by J. A. Mirinsky, L. E. Glendenin and C. D. Coryell.

1949

Berkelium created by Glenn T. Seaborg, Stanley Thompson, and Albert Ghiorso.

1950

Californium created by Stanley Thompson, Kenneth Street, Jr., Albert Ghiorso and Glenn T. Seaborg.

1952

Einsteinium and **fermium** created by a team of scientists led by Albert Ghiorso.

1955

Mendelevium created by a team of scientists led by Albert Ghiorso.

1958

Nobelium identified by a team of scientists led by Albert Ghiorso.

1961

Lawrencium created by a team of scientists that included Albert Ghiorso, T. Sikkeland, A. E. Larsch, and R. M. Latimer.

1969

Rutherfordium created by a team of scientists led by Albert Ghiorso.

1970

Dubnium created by a team of scientists led by Albert Ghiorso.

1981

Bohrium created by a team of scientists led by Peter Armbruster and Gottfried Munzenberg.

1982

Meitnerium created by a team of scientists led by Peter Armbruster and Gottfried Munzenberg.

1984

Hassium created by a team of scientists led by Peter Armbruster and Gottfried Munzenberg.

1994

Ununnilium and **unununium** created by an international team of scientists led by Peter Armbruster.

1996

Ununbiium created by an international team of scientists led by Peter Armbruster.

1999

Ununquadium, element 114, created by a collaboration of scientists from the Joint Institute of Nuclear Research in Dubna near Moscow, Russia, and the Lawrence Livermore National Laboratory in California.