= Group 3 element =

Group 3 is a group of elements in the periodic table . This group , like other d @-@ block groups , should contain four elements , but it is not agreed what elements belong in the group . Scandium (Sc) and yttrium (Y) are always included , but the other two spaces are usually occupied by lanthanum (La) and actinium (Ac) , or by lutetium (Lu) and lawrencium (Lr) ; less frequently , it is considered the group should be expanded to 32 elements (with all the lanthanides and actinides included) or contracted to contain only scandium and yttrium . The group itself has not acquired a trivial name ; however , scandium , yttrium and the lanthanides are sometimes called rare earth metals .

Three group 3 elements occur naturally , scandium , yttrium , and either lanthanum or lutetium . Lanthanum continues the trend started by two lighter members in general chemical behavior , while lutetium behaves more similarly to yttrium . This is in accordance with the trend for period 6 transition metals to behave more similarly to their upper periodic table neighbors . This trend is seen from hafnium , which is almost identical chemically to zirconium , to mercury , which is quite distant chemically from cadmium , but still shares with it almost equal atomic size and other similar properties . They all are silvery @-@ white metals under standard conditions . The fourth element , either actinium or lawrencium , has only radioactive isotopes . Actinium , which occurs only in trace amounts , continues the trend in chemical behavior for metals that form tripositive ions with a noble gas configuration ; synthetic lawrencium is calculated and partially shown to be more similar to lutetium and yttrium . So far , no experiments have been conducted to synthesize any element that could be the next group 3 element . Unbiunium (Ubu) , which could be considered a group 3 element if preceded by lanthanum and actinium , might be synthesized in the near future , it being only three spaces away from the current heaviest element known , ununoctium .

= = History = =

In 1787 , Swedish part @-@ time chemist Carl Axel Arrhenius found a heavy black rock near the Swedish village of Ytterby , Sweden (part of the Stockholm Archipelago) . Thinking that it was an unknown mineral containing the newly discovered element tungsten , he named it ytterbite . Finnish scientist Johan Gadolin identified a new oxide or " earth " in Arrhenius ' sample in 1789 , and published his completed analysis in 1794 ; in 1797 , the new oxide was named yttria . In the decades after French scientist Antoine Lavoisier developed the first modern definition of chemical elements , it was believed that earths could be reduced to their elements , meaning that the discovery of a new earth was equivalent to the discovery of the element within , which in this case would have been yttrium . Until the early 1920s , the chemical symbol " Yt " was used for the element , after which " Y " came into common use . Yttrium metal was first isolated in 1828 when Friedrich Wöhler heated anhydrous yttrium (III) chloride with potassium to form metallic yttrium and potassium chloride .

In 1869 , Russian chemist Dmitri Mendeleev published his periodic table , which had empty spaces for elements directly above and under yttrium . Mendeleev made several predictions on the upper neighbor of yttrium , which he called eka @-@ boron . Swedish chemist Lars Fredrik Nilson and his team discovered the missing element in the minerals euxenite and gadolinite and prepared 2 grams of scandium (III) oxide of high purity . He named it scandium , from the Latin Scandia meaning " Scandinavia " . Chemical experiments on the element proved that Mendeleev 's suggestions were correct ; along with discovery and characterization of gallium and germanium this proved the correctness of the whole periodic table and periodic law . Nilson was apparently unaware of Mendeleev 's prediction , but Per Teodor Cleve recognized the correspondence and notified Mendeleev . Metallic scandium was produced for the first time in 1937 by electrolysis of a eutectic mixture , at 700 ? 800 ° C , of potassium , lithium , and scandium chlorides .

Lutetium was independently discovered in 1907 by French scientist Georges Urbain , Austrian mineralogist Baron Carl Auer von Welsbach , and American chemist Charles James as an impurity in the mineral ytterbia , which was thought by most chemists to consist entirely of ytterbium .

Welsbach proposed the names cassiopeium for element 71 (after the constellation Cassiopeia) and aldebaranium (after the star Aldebaran) for the new name of ytterbium but these naming proposals were rejected , although many German scientists in the 1950s called the element 71 cassiopeium . Urbain chose the names neoytterbium (Latin for " new ytterbium ") for ytterbium and lutecium (from Latin Lutetia , for Paris) for the new element . The dispute on the priority of the discovery is documented in two articles in which Urbain and von Welsbach accuse each other of publishing results influenced by the published research of the other . The Commission on Atomic Mass , which was responsible for the attribution of the names for the new elements , settled the dispute in 1909 by granting priority to Urbain and adopting his names as official ones . An obvious problem with this decision was that Urbain was one of the four members of the commission . The separation of lutetium from ytterbium was first described by Urbain and the naming honor therefore went to him , but neoytterbium was eventually reverted to ytterbium and in 1949 , the spelling of element 71 was changed to lutetium . Ironically , Charles James , who had modestly stayed out of the argument as to priority , worked on a much larger scale than the others , and undoubtedly possessed the largest supply of lutetium at the time .

Lawrencium was first synthesized by the Albert Ghiorso and his team on February 14 , 1961 , at the Lawrence Radiation Laboratory (now called the Lawrence Berkeley National Laboratory) at the University of California in Berkeley , California , United States . The first atoms of lawrencium were produced by bombarding a three @-@ milligram target consisting of three isotopes of the element californium with boron @-@ 10 and boron @-@ 11 nuclei from the Heavy Ion Linear Accelerator (HILAC) . The nuclide 257103 was originally reported , but then this was reassigned to 258103 . The team at the University of California suggested the name lawrencium (after Ernest O. Lawrence , the inventor of cyclotron particle accelerator) and the symbol " Lw " , for the new element , but " Lw " was not adopted , and " Lr " was officially accepted instead . Nuclear @-@ physics researchers in Dubna , Soviet Union (now Russia) , reported in 1967 that they were not able to confirm American scientists ' data on 257103 . Two years earlier , the Dubna team reported 256103 . In 1992 , the IUPAC Trans @-@ fermium Working Group officially recognized element 103 , confirmed its naming as lawrencium , with symbol " Lr " , and named the nuclear physics teams at Dubna and Berkeley as the co @-@ discoverers of lawrencium .

So far , no experiments were conducted to synthesize any element that could be the next group 3 element ; if lutetium and lawrencium are considered to be group 3 elements , then the next element in the group should be element 153 , unpenttrium (Upt) . However , after element 120 , filling electronic configurations stops obeying Aufbau principle . According to the principle , unpenttrium should have an electronic configuration of [Uuo] 8s25g186f147d1 and filling the 5g @-@ subshell should be stopped at element 138 . However , the 7d @-@ orbitals are calculated to start being filled on element 137 , while the 5g @-@ subshell closes only at element 144 , after filling of 7d @-@ subshell begins . Therefore , it is hard to calculate which element should be the next group 3 element . Calculations suggest that unpentpentium (Upp , element 155) could also be the next group 3 element . If lanthanum and actinium are considered group 3 elements , then element 121 , unbiunium (Ubu) , should be the fifth group 3 element . The element is calculated have electronic configuration of [Uuo] 8s28p1 / 21 , which is not associated with transition metals , without having a partially filled d @-@ subshell . No experiments have been performed to create unpenttrium , unbiunium or any element that could be considered the next group 3 element ; however , unbiunium is the element with the lowest atomic number that has not been tried to be created and thus has chances to be , while unpenttrium , unpentpentium or any other element considered if preceded by lawrencium is very unlikely to be created due to drip instabilities that imply that the periodic table ends soon after the island of stability at unbihexium .

= = Characteristics = =

= = = Chemical = = =

Like other groups , the members of this family show patterns in their electron configurations , especially the outermost shells , resulting in trends in chemical behavior . However , lawrencium is an exception , since its last electron is transferred to the 7p1 / 2 subshell due to relativistic effects .

Most of the chemistry has been observed only for the first three members of the group ; chemical properties of both actinium and especially lawrencium are not well @-@ characterized . The remaining elements of the group (scandium , yttrium , lutetium) are reactive metals with high melting points (1541 ° C , 1526 ° C , 1652 ° C respectively) . They are usually oxidized to the + 3 oxidation state , even through scandium , yttrium and lanthanum can form lower oxidation states . The reactivity of the elements , especially yttrium , is not always obvious due to the formation of a stable oxide layer , which prevents further reactions . Scandium (III) oxide , yttrium (III) oxide , lanthanum (III) oxide and lutetium (III) oxide are white high @-@ temperature @-@ melting solids . Yttrium (III) oxide and lutetium (III) oxide exhibit weak basic character , but scandium (III) oxide is amphoteric . Lanthanum (III) oxide is strongly basic .

= = = Physical = = =

Elements that show tripositive ions with electronic configuration of a noble gas (scandium , yttrium , lanthanum , actinium) show a clear trend in their physical properties , such as hardness . At the same time , if group 3 is continued with lutetium and lawrencium , several trends are broken . For example , scandium and yttrium are both soft metals . Lanthanum is soft as well ; all these elements have their outermost electrons quite far from the nucleus compared to the nuclei charges . Due to the lanthanide contraction , lutetium , the last in the lanthanide series , has a significantly smaller atomic radius and a higher nucleus charge , thus making the extraction of the electrons from the atom to form metallic bonding more difficult , and thus making the metal harder . However , lutetium suits the previous elements better in several other properties , such as melting and boiling points . Very little is known about lawrencium , and none of its physical properties have been confirmed .

= = Group borders = =

It is disputed whether lutetium and lawrencium should be included in group 3 , rather than lanthanum and actinium . Other d @-@ block groups are composed of four transition metals , and group 3 is sometimes considered to follow suit . Scandium and yttrium are always classified as group 3 elements , but it is controversial which elements should follow them in group 3 , lanthanum and actinium or lutetium and lawrencium . Scerri has proposed a resolution to this debate on the basis of moving to a 32 @-@ column table and consideration of which option results in a continuous sequence of atomic number increase . He thereby finds that group 3 should consist of Sc , Y , Lu , Lr . The current IUPAC definition of the term " lanthanoid " includes fifteen elements including both lanthanum and lutetium , and that of " transition element " applies to lanthanum and actinium , as well as lutetium but not lawrencium , since it does not correctly follow the Aufbau principle . Normally , the 103rd electron would enter the d @-@ subshell , but quantum mechanical research has found that the configuration is actually [Rn] 7s25f147p1 due to relativistic effects . IUPAC thus has not recommended a specific format for the in @-@ line @-@ f @-@ block periodic table , leaving the dispute open .

Lanthanum and actinium are sometimes considered the remaining members of group 3 . In their most commonly encountered tripositive ion forms , these elements do not possess any partially filled f @-@ orbitals , thus continuing the scandium ? yttrium ? lanthanum ? actinium trend , in which all the elements have relationship similar to that of elements of the calcium ? strontium ? barium ? radium series , the elements ' left neighbors in s @-@ block . However , different behavior is observed in other d @-@ block groups , especially in group 4 , in which zirconium , hafnium and rutherfordium share similar chemical properties lacking a clear trend .

In other tables , lutetium and lawrencium are classified as the remaining members of group 3 . In these tables , lutetium and lawrencium end (or sometimes succeed) the lanthanide and actinide series , respectively . Since the f @-@ shell is nominally full in the ground state electron

configuration for both of these metals , they behave most similarly to other period 6 and period 7 transition metals compared to the other lanthanides and actinides , and thus logically exhibit properties similar to those of scandium and yttrium .

Some tables , including the official IUPAC table refer to all lanthanides and actinides by a marker in group 3 . This sometimes is believed to be the inclusion of all 30 lanthanide and actinide elements as included in group 3 . Lanthanides , as electropositive trivalent metals , all have a closely related chemistry , and all show many similarities to scandium and yttrium , but they also show additional properties characteristic of their partially filled f @-@ orbitals which are not common to scandium and yttrium .

Exclusion of all elements is based on properties of earlier actinides , which show a much wider variety of chemistry (for instance , in range of oxidation states) within their series than the lanthanides , and comparisons to scandium and yttrium are even less useful . However , these elements are destabilized , and if they were stabilized to more closely match chemistry laws , they would be similar to lanthanides as well . Also , the later actinides from californium onwards behave more like the corresponding lanthanides , with only the valence + 3 (and sometimes + 2) shown .

= = Occurrence = =

Scandium , yttrium , and lutetium tend to occur together with other lanthanides (except promethium) tend to occur together in the Earth 's crust , and are often harder to extract from their ores . The abundance of elements in Earth 's crust for group 3 is quite low ? all the elements in the group are uncommon , the most abundant being yttrium with abundance of approximately 30 parts per million (ppm) ; the abundance of scandium is 16 ppm , while that of lutetium is about 0 @.@ 5 ppm . For comparison , the abundance of copper is 50 ppm , that of chromium is 160 ppm , and that of molybdenum is 1 @.@ 5 ppm .

Scandium is distributed sparsely and occurs in trace amounts in many minerals . Rare minerals from Scandinavia and Madagascar such as gadolinite , euxenite , and thortveitite are the only known concentrated sources of this element , the latter containing up to 45 % of scandium in the form of scandium (III) oxide . Yttrium has the same trend in occurrence places ; it is found in lunar rock samples collected during the American Apollo Project in a relatively high content as well .

The principal commercially viable ore of lutetium is the rare earth phosphate mineral monazite , (Ce , La , etc .) PO4 , which contains 0 @.@ 003 % of the element . The main mining areas are China , United States , Brazil , India , Sri Lanka and Australia . Pure lutetium metal is one of the rarest and most expensive of the rare earth metals with the price about US $ 10 @,@ 000 / kg , or about one @-@ fourth that of gold .

= = Production = =

The most available element in group 3 is yttrium , with annual production of 8 @,@ 900 tonnes in 2010 . Yttrium is mostly produced as oxide , by a single country , China (99 %) . Lutetium and scandium are also mostly obtained as oxides , and their annual production by 2001 was about 10 and 2 tonnes , respectively .

Group 3 elements are mined only as a byproduct from the extraction of other elements . The metallic elements are extremely rare ; the production of metallic yttrium is about a few tonnes , and that of scandium is in the order of 10 kg per year ; production of lutetium is not calculated , but it is certainly small . The elements , after purification from other rare earth metals , are isolated as oxides ; the oxides are converted to fluorides during reactions with hydrofluoric acid . The resulting fluorides are reduced with alkaline earth metals or alloys of the metals ; metallic calcium is used most frequently . For example :

$Sc_2O_3 + 3 HF \rightarrow 2 ScF_3 + 3 H_2O$

$2 ScF_3 + 3 Ca \rightarrow 3 CaF_2 + 2 Sc$

= = Applications = =

= = Biological chemistry = =

Group 3 elements are generally hard metals with low aqueous solubility , and have low availability to the biosphere . No group 3 element has any documented biological role in living organisms . The radioactivity of the actinides generally makes them highly toxic to living cells , causing radiation poisoning .

Scandium has no biological role , but it is found in living organisms . Once reached a human , scandium concentrates in the liver and is a threat to it ; some its compounds are possibly carcinogenic , even through in general scandium is not toxic . Scandium is known to have reached the food chain , but in trace amounts only ; a typical human takes in less than 0 @.@ 1 micrograms per day . Once released into the environment , scandium gradually accumulates in soils , which leads to increased concentrations in soil particles , animals and humans . Scandium is mostly dangerous in the working environment , due to the fact that damps and gases can be inhaled with air . This can cause lung embolisms , especially during long @-@ term exposure . The element is known to damage cell membranes of water animals , causing several negative influences on reproduction and on the functions of the nervous system .

Yttrium has no known biological role , though it is found in most , if not all , organisms and tends to concentrate in the liver , kidney , spleen , lungs , and bones of humans . There is normally as little as 0 @.@ 5 milligrams found within the entire human body ; human breast milk contains 4 ppm . Yttrium can be found in edible plants in concentrations between 20 ppm and 100 ppm (fresh weight) , with cabbage having the largest amount . With up to 700 ppm , the seeds of woody plants have the highest known concentrations .

Lutetium has no biological role as well , but it is found even in the highest known organism , the humans , concentrating in bones , and to a lesser extent in the liver and kidneys . Lutetium salts are known to cause metabolism and they occur together with other lanthanide salts in nature ; the element is the least abundant in the human body of all lanthanides . Human diets have not been monitored for lutetium content , so it is not known how much the average human takes in , but estimations show the amount is only about several micrograms per year , all coming from tiny amounts taken by plants . Soluble lutetium salts are mildly toxic , but insoluble ones are not .

The high radioactivity of lawrencium would make it highly toxic to living cells , causing radiation poisoning .

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