

= 4) and hexameric (x = 6) forms .

The application of organosodium compounds in chemistry is limited in part due to competition from organolithium compounds , which are commercially available and exhibit more convenient reactivity . The principal organosodium compound of commercial importance is sodium cyclopentadienide . Sodium tetraphenylborate can also be classified as an organosodium compound since in the solid state sodium is bound to the aryl groups . Organometallic compounds of the higher alkali metals are even more reactive than organosodium compounds and of limited utility . A notable reagent is Schlosser 's base , a mixture of n -butyllithium and potassium tert -butoxide . This reagent reacts with propene to form the compound allylpotassium ($\text{KCH}_2\text{CHCH}_2$) . cis -2-butene and trans -2-butene equilibrate when in contact with alkali metals . Whereas isomerization is fast with lithium and sodium , it is slow with the higher alkali metals . The higher alkali metals also favour the sterically congested conformation . Several crystal structures of organopotassium compounds have been reported , establishing that they , like the sodium compounds , are polymeric . Organosodium , organopotassium , organorubidium and organocaesium compounds are all mostly ionic and are insoluble (or nearly so) in nonpolar solvents .

= = Extensions = =

Although francium is the heaviest alkali metal that has been discovered , there has been some theoretical work predicting the physical and chemical characteristics of the hypothetical heavier alkali metals . Being the first period 8 element , the undiscovered element ununennium (element 119) is predicted to be the next alkali metal after francium and behave much like their lighter congeners ; however , it is also predicted to differ from the lighter alkali metals in some properties . Its chemistry is predicted to be closer to that of potassium or rubidium instead of caesium or francium . This is unusual as periodic trends , ignoring relativistic effects would predict ununennium to be even more reactive than caesium and francium . This lowered reactivity is due to the relativistic stabilisation of ununennium 's valence electron , increasing ununennium 's first ionisation energy and decreasing the metallic and ionic radii ; this effect is already seen for francium . This assumes that ununennium will behave chemically as an alkali metal , which , although likely , may not be true due to relativistic effects . The relativistic stabilisation of the 8s orbital also increases ununennium 's electron affinity far beyond that of caesium and francium ; indeed , ununennium is expected to have an electron affinity higher than all the alkali metals lighter than it . Relativistic effects also cause a very large drop in the polarisability of ununennium . On the other hand , ununennium is predicted to continue the trend of melting points decreasing going down the group , being expected to have a melting point between 0 ° C and 30 ° C .

The stabilisation of ununennium 's valence electron and thus the contraction of the 8s orbital cause its atomic radius to be lowered to 240 pm , very close to that of rubidium (247 pm) , so that the chemistry of ununennium in the + 1 oxidation state should be more similar to the chemistry of rubidium than to that of francium . On the other hand , the ionic radius of the Uue + ion is predicted to be larger than that of Rb + , because the 7p orbitals are destabilised and are thus larger than the p -orbitals of the lower shells . Ununennium may also show the + 3 oxidation state , which is not seen in any other alkali metal , in addition to the + 1 oxidation state that is characteristic of the other alkali metals and is also the main oxidation state of all the known alkali metals : this is because of the destabilisation and expansion of the 7p³ / 2 spinor , causing its outermost electrons to have a lower ionisation energy than what would otherwise be expected . Indeed , many ununennium compounds are expected to have a large covalent character , due to the involvement of the 7p³ / 2 electrons in the bonding .

Not as much work has been done predicting the properties of the alkali metals beyond ununennium . Although a simple extrapolation of the periodic table would put element 169 , unhexennium , under ununennium , Dirac -Fock calculations predict that the next alkali metal after ununennium may actually be element 165 , unhexpentium , which is predicted to have the electron configuration [Uuo

] 5g¹⁸ 6f¹⁴ 7d¹⁰ 8s² 8p¹ / 22 9s¹ . Further calculations show that unhexpentium would follow the trend of increasing ionisation energy beyond caesium , having an ionisation energy comparable to that of sodium , and that it should also continue the trend of decreasing atomic radii beyond caesium , having an atomic radius comparable to that of potassium . However , the 7d electrons of unhexpentium may also be able to participate in chemical reactions along with the 9s electron , possibly allowing oxidation states beyond + 1 and perhaps even making unhexpentium behave more like a boron group element or group 11 element than an alkali metal . Due to the alkali and alkaline earth metals both being s @-@ block elements , these predictions for the trends and properties of ununennium and unhexpentium also mostly hold quite similarly for the corresponding alkaline earth metals unbinilium (Ubn) and unhexhexium (Uhh) .

The probable properties of further alkali metals beyond unhexpentium have not been explored yet as of 2015 ; in fact , it is suspected that they may not be able to exist . In periods 8 and above of the periodic table , relativistic and shell @-@ structure effects become so strong that extrapolations from lighter congeners become completely inaccurate . In addition , the relativistic and shell @-@ structure effects (which stabilise the s @-@ orbitals and destabilise and expand the d- , f- , and g @-@ orbitals of higher shells) have opposite effects , causing even larger difference between relativistic and non @-@ relativistic calculations of the properties of elements with such high atomic numbers . Interest in the chemical properties of ununennium and unhexpentium stems from the fact that both elements are located close to the expected locations of islands of stabilities , centered at elements 122 (306Ubb) and 164 (482Uhq) .

= = Other similar substances = =

= = = Hydrogen = = =

The element hydrogen , with one electron per neutral atom , is usually placed at the top of Group 1 of the periodic table for convenience , but hydrogen is not normally considered to be an alkali metal ; when it is considered to be an alkali metal , it is because of its atomic properties and not its chemical properties . Under typical conditions , pure hydrogen exists as a diatomic gas consisting of two atoms per molecule (H₂) ; however , the alkali metals only form diatomic molecules (such as dilithium , Li₂) at high temperatures , when they are in the gaseous state .

Hydrogen , like the alkali metals , has one valence electron and reacts easily with the halogens but the similarities end there . Its placement above lithium is primarily due to its electron configuration and not its chemical properties . It is sometimes placed above carbon due to their similar electronegativities or fluorine due to their similar chemical properties .

The first ionisation energy of hydrogen (1312 @. @ 0 kJ / mol) is much higher than that of the alkali metals . As only one additional electron is required to fill in the outermost shell of the hydrogen atom , hydrogen often behaves like a halogen , forming the negative hydride ion , and is sometimes considered to be a halogen . (The alkali metals can also form negative ions , known as alkalides , but these are little more than laboratory curiosities , being unstable .) It was expected for some time that liquid hydrogen would show metallic properties ; while this has been shown to not be the case , under extremely high pressures , such as those found at the cores of Jupiter and Saturn , hydrogen does become metallic and behaves like an alkali metal ; in this phase , it is known as metallic hydrogen . The electrical resistivity of liquid metallic hydrogen at 3000 K is approximately equal to that of liquid rubidium and caesium at 2000 K at the respective pressures when they undergo a nonmetal @-@ to @-@ metal transition .

The 1s¹ electron configuration of hydrogen , while superficially similar to that of the alkali metals (ns¹) , is unique because there is no 1p subshell . Hence it can lose an electron to form the hydron H⁺ , or gain one to form the hydride ion H⁻ . In the former case it resembles superficially the alkali metals ; in the latter case , the halogens , but the differences due to the lack of a 1p subshell are important enough that neither group fits the properties of hydrogen well . Group 14 is the best fit in terms of thermodynamic properties such as ionization energy and electron affinity , but none of the

three placements are entirely satisfactory . As an example of hydrogen 's unorthodox properties stemming from its unusual electron configuration and small size , the hydrogen ion is very small (radius around 150 fm compared to the 50 ? 220 pm size of most other atoms and ions) and so is nonexistent in condensed systems other than in association with other atoms or molecules . Indeed , transferring of protons between chemicals is the basis of acid @-@ base chemistry . Also unique is hydrogen 's ability to form hydrogen bonds , which are an effect of charge @-@ transfer , electrostatic , and electron correlative contributing phenomena . While analogous lithium bonds are also known , they are mostly electrostatic . Nevertheless , hydrogen can perform the same structural role as the alkali metals in some molecular crystals , and has a close relationship with the lightest alkali metals (especially lithium) .

= = = Ammonium = = =

The ammonium ion (NH_4^+) has very similar properties to the heavier alkali metals , acting as an alkali metal intermediate between potassium and rubidium , and is often considered a close relative . For example , most alkali metal salts are soluble in water , a property which ammonium salts share . Ammonium is expected to behave stably as a metal (NH_4^+ ions in a sea of electrons) at very high pressures (though less than the typical pressure where transitions from insulating to metallic behaviour occur around , 100 GPa) , and could possibly occur inside the ice giants Uranus and Neptune , which may have significant impacts on their interior magnetic fields . It has been estimated that the transition from a mixture of ammonia and dihydrogen molecules to metallic ammonium may occur at pressures just below 25 GPa .

= = = Thallium = = =

Thallium displays the + 1 oxidation state that all the known alkali metals display , and thallium compounds with thallium in its + 1 oxidation state closely resemble the corresponding potassium or silver compounds stoichiometrically due to the similar ionic radii of the Tl^+ (164 pm) , K^+ (152 pm) and Ag^+ (129 pm) ions . It was sometimes considered an alkali metal in continental Europe (but not in England) in the years immediately following its discovery , and was placed just after caesium as the sixth alkali metal in Dmitri Mendeleev 's 1869 periodic table and Julius Lothar Meyer 's 1868 periodic table . (Mendeleev 's 1871 periodic table and Meyer 's 1870 periodic table put thallium in its current position in the boron group and leave the space below caesium blank .) However , thallium also displays the oxidation state + 3 , which no known alkali metal displays (although ununennium , the undiscovered seventh alkali metal , is predicted to possibly display the + 3 oxidation state) . The sixth alkali metal is now considered to be francium . While Tl^+ is stabilized by the inert pair effect , this inert pair of 6s electrons is still able to participate chemically , so that these electrons are stereochemically active in aqueous solution . Additionally , the thallium halides (except TlF) are quite insoluble in water , and TlI has an unusual structure because of the presence of the inert pair in thallium .

= = = Copper , silver , and gold = = =

The group 11 metals (or coinage metals) , copper , silver , and gold , are typically categorised as transition metals given they can form ions with incomplete d @-@ shells . Physically , they have the relatively low melting points and high electronegativity values associated with post @-@ transition metals . " The filled d subshell and free s electron of Cu , Ag , and Au contribute to their high electrical and thermal conductivity . Transition metals to the left of group 11 experience interactions between s electrons and the partially filled d subshell that lower electron mobility . " Chemically , the group 11 metals behave like main @-@ group metals in their + 1 valence states , and are hence somewhat related to the alkali metals : this is one reason for their previously being labelled as " group IB " , paralleling the alkali metals ' " group IA " . They are occasionally classified as post @-@

transition metals . Their spectra are however analogous to those of the alkali metals .

In Mendeleev 's 1871 periodic table , copper , silver , and gold are listed twice , once under group VIII (with the iron triad and platinum group metals) , and once under group IB . Group IB was nonetheless parenthesized to note that it was tentative . Mendeleev 's main criterion for group assignment was the maximum oxidation state of an element : on that basis , the group 11 elements could not be classified in group IB , due to the existence of Cu (II) and Au (III) compounds being known at that time . However , eliminating group IB would make group I the only main group (group VIII was labelled a transition group) to lack an A ? B bifurcation . Soon afterwards , a majority of chemists chose to classify these elements in group IB and remove them from group VIII for the resulting symmetry : this was the predominant classification until the rise of the modern medium @-@ long 18 @-@ column periodic table , which separated the alkali metals and group 11 metals .

The coinage metals were traditionally regarded as a subdivision of the alkali metal group , due to them sharing the characteristic s¹ electron configuration of the alkali metals (group 1 : p⁶s¹ ; group 11 : d¹⁰s¹) . However , the similarities are largely confined to the stoichiometries of the + 1 compounds of both groups , and not their chemical properties . This stems from the filled d subshell providing a much weaker shielding effect on the outermost s electron than the filled p subshell , so that the coinage metals have much higher first ionization energies and smaller ionic radii than do the corresponding alkali metals . Furthermore , they have higher melting points , hardnesses , and densities , and lower reactivities and solubilities in liquid ammonia , as well as having more covalent character in their compounds . Finally , the alkali metals are at the top of the electrochemical series , whereas the coinage metals are almost at the very bottom . The coinage metals ' filled d shell is much more easily disrupted than the alkali metals ' filled p shell , so that the second and third ionization energies are lower , enabling higher oxidation states than + 1 and a richer coordination chemistry , thus giving the group 11 metals clear transition metal character . Particularly noteworthy is gold forming ionic compounds with rubidium and caesium , in which it forms the auride ion (Au⁻) which also occurs in solvated form in liquid ammonia solution : here gold behaves as a pseudohalogen because its 5d¹⁰6s¹ configuration has one electron less than the quasi @-@ closed shell 5d¹⁰6s² configuration of mercury .

= = History = =

Sodium compounds have been known since ancient times ; salt (sodium chloride) has been an important commodity in human activities , as testified by the English word salary , referring to salarium , money paid to Roman soldiers for the purchase of salt . While potash has been used since ancient times , it was not understood for most of its history to be a fundamentally different substance from sodium mineral salts . Georg Ernst Stahl obtained experimental evidence which led him to suggest the fundamental difference of sodium and potassium salts in 1702 , and Henri Louis Duhamel du Monceau was able to prove this difference in 1736 . The exact chemical composition of potassium and sodium compounds , and the status as chemical element of potassium and sodium , was not known then , and thus Antoine Lavoisier did include the alkali in his list of chemical elements in 1789 .

Pure potassium was first isolated in 1807 in England by Sir Humphry Davy , who derived it from caustic potash (KOH , potassium hydroxide) by the use of electrolysis of the molten salt with the newly invented voltaic pile . Previous attempts at electrolysis of the aqueous salt were unsuccessful due to potassium 's extreme reactivity . Potassium was the first metal that was isolated by electrolysis . Later that same year , Davy reported extraction of sodium from the similar substance caustic soda (NaOH , lye) by a similar technique , demonstrating the elements , and thus the salts , to be different . Later that year , the first pieces of pure molten sodium metal were similarly prepared by Humphry Davy through the electrolysis of molten caustic soda (now called sodium hydroxide) .

Petalite (LiAlSi₄O₁₀) was discovered in 1800 by the Brazilian chemist José Bonifácio de Andrada in a mine on the island of Utö , Sweden . However , it was not until 1817 that Johan August Arfwedson , then working in the laboratory of the chemist Jöns Jacob Berzelius , detected the presence of a new element while analysing petalite ore . This new element was noted by him to form

compounds similar to those of sodium and potassium, though its carbonate and hydroxide were less soluble in water and more alkaline than the other alkali metals. Berzelius gave the unknown material the name "lithion / lithina", from the Greek word $\lambda\theta\omicron\varsigma$ (transliterated as lithos, meaning "stone"), to reflect its discovery in a solid mineral, as opposed to potassium, which had been discovered in plant ashes, and sodium, which was known partly for its high abundance in animal blood. He named the metal inside the material "lithium". Lithium, sodium, and potassium were part of the discovery of periodicity, as they are among a series of triads of elements in the same group that were noted by Johann Wolfgang Döbereiner in 1850 as having similar properties.

Rubidium and caesium were the first elements to be discovered using the spectroscope, invented in 1859 by Robert Bunsen and Gustav Kirchhoff. The next year, they discovered caesium in the mineral water from Bad Dürkheim, Germany. Their discovery of rubidium came the following year in Heidelberg, Germany, finding it in the mineral lepidolite. The names of rubidium and caesium come from the most prominent lines in their emission spectra: a bright red line for rubidium (from the Latin word rubidus, meaning dark red or bright red), and a sky @-@ blue line for caesium (derived from the Latin word caesius, meaning sky @-@ blue).

Around 1865 John Newlands produced a series of papers where he listed the elements in order of increasing atomic weight and similar physical and chemical properties that recurred at intervals of eight; he likened such periodicity to the octaves of music. His version put all the alkali metals then known (lithium to caesium), as well as copper, silver, and thallium (which show the + 1 oxidation state characteristic of the alkali metals), together into a group. His table placed hydrogen with the halogens.

After 1869, Dmitri Mendeleev proposed his periodic table placing lithium at the top of a group with sodium, potassium, rubidium, caesium, and thallium. Two years later, Mendeleev revised his table, placing hydrogen in group 1 above lithium, and also moving thallium to the boron group. In this 1871 version, copper, silver, and gold were placed twice, once as part of group IB, and once as part of a "group VIII" encompassing today's groups 8 to 11. After the introduction of the 18 @-@ column table, the group IB elements were moved to their current position in the d @-@ block, while alkali metals were left in group IA. Later the group's name was changed to group 1 in 1988. The trivial name "alkali metals" comes from the fact that the hydroxides of the group 1 elements are all strong alkalis when dissolved in water.

There were at least four erroneous and incomplete discoveries before Marguerite Perey of the Curie Institute in Paris, France discovered francium in 1939 by purifying a sample of actinium @-@ 227, which had been reported to have a decay energy of 220 keV. However, Perey noticed decay particles with an energy level below 80 keV. Perey thought this decay activity might have been caused by a previously unidentified decay product, one that was separated during purification, but emerged again out of the pure actinium @-@ 227. Various tests eliminated the possibility of the unknown element being thorium, radium, lead, bismuth, or thallium. The new product exhibited chemical properties of an alkali metal (such as coprecipitating with caesium salts), which led Perey to believe that it was element 87, caused by the alpha decay of actinium @-@ 227. Perey then attempted to determine the proportion of beta decay to alpha decay in actinium @-@ 227. Her first test put the alpha branching at 0 @-@ 6 %, a figure that she later revised to 1 %. It was the last element discovered in nature, rather than by synthesis.

The next element below francium (eka @-@ francium) is very likely to be ununennium (Uue), element 119, although this is not completely certain due to relativistic effects. The synthesis of ununennium was first attempted in 1985 by bombarding a target of einsteinium @-@ 254 with calcium @-@ 48 ions at the superHILAC accelerator at Berkeley, California. No atoms were identified, leading to a limiting yield of 300 nb.

254

99Es + 48

20Ca ? 302

119Uue * ? no atoms

It is highly unlikely that this reaction will be able to create any atoms of ununennium in the near future, given the extremely difficult task of making sufficient amounts of 254Es, which is favoured

for production of ultraheavy elements because of its large mass , relatively long half @-@ life of 270 days , and availability in significant amounts of several micrograms , to make a large enough target to increase the sensitivity of the experiment to the required level ; einsteinium has not been found in nature and has only been produced in laboratories . However , given that ununennium is only the first period 8 element on the extended periodic table , it may well be discovered in the near future through other reactions ; indeed , another attempt to synthesise ununennium by bombarding a berkelium target with titanium ions is under way at the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt , Germany . Currently , none of the period 8 elements have been discovered yet , and it is also possible , due to drip instabilities , that only the lower period 8 elements , up to around element 128 , are physically possible . No attempts at synthesis have been made for any heavier alkali metals , such as unhexpentium , due to their extremely high atomic number .

= = Occurrence = =

= = = In the Solar System = = =

The Oddo ? Harkins rule holds that elements with even atomic numbers are more common than those with odd atomic numbers , with the exception of hydrogen . This rule argues that elements with odd atomic numbers have one unpaired proton and are more likely to capture another , thus increasing their atomic number . In elements with even atomic numbers , protons are paired , with each member of the pair offsetting the spin of the other , enhancing stability . All the alkali metals have odd atomic numbers and they are not as common as the elements with even atomic numbers adjacent to them (the noble gases and the alkaline earth metals) in the Solar System . The heavier alkali metals are also less abundant than the lighter ones as the alkali metals from rubidium onward can only be synthesized in supernovae and not in stellar nucleosynthesis . Lithium is also much less abundant than sodium and potassium as it is poorly synthesized in both Big Bang nucleosynthesis and in stars : the Big Bang could only produce trace quantities of lithium , beryllium and boron due to the absence of a stable nucleus with 5 or 8 nucleons , and stellar nucleosynthesis could only pass this bottleneck by the triple @-@ alpha process , fusing three helium nuclei to form carbon , and skipping over those three elements .

= = = On Earth = = =

The Earth formed from the same cloud of matter that formed the Sun , but the planets acquired different compositions during the formation and evolution of the solar system . In turn , the natural history of the Earth caused parts of this planet to have differing concentrations of the elements . The mass of the Earth is approximately 5.97×10^{24} kg . It is composed mostly of iron (32 @. @ 1 %) , oxygen (30 @. @ 1 %) , silicon (15 @. @ 1 %) , magnesium (13 @. @ 9 %) , sulfur (2 @. @ 9 %) , nickel (1 @. @ 8 %) , calcium (1 @. @ 5 %) , and aluminium (1 @. @ 4 %) ; with the remaining 1 @. @ 2 % consisting of trace amounts of other elements . Due to mass segregation , the core region is believed to be primarily composed of iron (88 @. @ 8 %) , with smaller amounts of nickel (5 @. @ 8 %) , sulfur (4 @. @ 5 %) , and less than 1 % trace elements .

The alkali metals , due to their high reactivity , do not occur naturally in pure form in nature . They are lithophiles and therefore remain close to the Earth 's surface because they combine readily with oxygen and so associate strongly with silica , forming relatively low @-@ density minerals that do not sink down into the Earth 's core . Potassium , rubidium and caesium are also incompatible elements due to their large ionic radii .

Sodium and potassium are very abundant in earth , both being among the ten most common elements in Earth 's crust ; sodium makes up approximately 2 @. @ 6 % of the Earth 's crust measured by weight , making it the sixth most abundant element overall and the most abundant alkali metal . Potassium makes up approximately 1 @. @ 5 % of the Earth 's crust and is the seventh most abundant element . Sodium is found in many different minerals , of which the most common is

ordinary salt (sodium chloride) , which occurs in vast quantities dissolved in seawater . Other solid deposits include halite , amphibole , cryolite , nitratine , and zeolite . Many of these solid deposits occur as a result of ancient seas evaporating , which still occurs now in places such as Utah 's Great Salt Lake and the Dead Sea . Despite their near equal abundance in Earth 's crust , sodium is far more common than potassium in the ocean , both because potassium 's larger size makes its salts less soluble , and because potassium is bound by silicates in soil and what potassium leaches is absorbed far more readily by plant life than sodium .

Despite its chemical similarity , lithium typically does not occur together with sodium or potassium due to its smaller size . Due to its relatively low reactivity , it can be found in seawater in large amounts ; it is estimated that seawater is approximately 0 . 014 to 0 . 025 parts per million (ppm) or 25 micromolar . Its diagonal relationship with magnesium often allows it to replace magnesium in ferromagnesium minerals , where its crustal concentration is about 18 ppm , comparable to that of gallium and niobium . Commercially , the most important lithium mineral is spodumene , which occurs in large deposits worldwide .

Rubidium is approximately as abundant as zinc and more abundant than copper . It occurs naturally in the minerals leucite , pollucite , carnallite , zinnwaldite , and lepidolite , although none of these contain only rubidium and no other alkali metals . Caesium is more abundant than some commonly known elements , such as antimony , cadmium , tin , and tungsten , but is much less abundant than rubidium .

Francium ${}_{87}^{223}\text{Fr}$, the only naturally occurring isotope of francium , is the product of the alpha decay of actinium ${}_{89}^{227}\text{Ac}$ and can be found in trace amounts in uranium and thorium minerals . In a given sample of uranium , there is estimated to be only one francium atom for every 10^{18} uranium atoms . It has been calculated that there is at most 30 g of francium in the earth 's crust at any time , due to its extremely short half life of 22 minutes .

== Production and isolation ==

The production of pure alkali metals is difficult due to their extreme reactivity with commonly used substances , such as water . The alkali metals are so reactive that they cannot be displaced by other elements and must be isolated through high energy methods such as electrolysis .

Lithium salts have to be extracted from the water of mineral springs , brine pools , and brine deposits . The metal is produced electrolytically from a mixture of fused lithium chloride and potassium chloride .

Potassium occurs in many minerals , such as sylvite (potassium chloride) . It is occasionally produced through separating the potassium from the chlorine in potassium chloride , but is more often produced through electrolysis of potassium hydroxide , found extensively in places such as Canada , Russia , Belarus , Germany , Israel , United States , and Jordan , in a method similar to how sodium was produced in the late 1800s and early 1900s . It can also be produced from seawater . Sodium occurs mostly in seawater and dried seabed , but is now produced through electrolysis of sodium chloride by lowering the melting point of the substance to below 700°C through the use of a Downs cell . Extremely pure sodium can be produced through the thermal decomposition of sodium azide .

For several years in the 1950s and 1960s , a by product of the potassium production called Alkarb was a main source for rubidium . Alkarb contained 21 % rubidium while the rest was potassium and a small fraction of caesium . Today the largest producers of caesium , for example the Tanco Mine , Manitoba , Canada , produce rubidium as by product from pollucite . Today , a common method for separating rubidium from potassium and caesium is the fractional crystallization of a rubidium and caesium alum ($\text{Cs} , \text{Rb}) \text{Al} (\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, which yields pure rubidium alum after approximately 30 different reactions . The limited applications and the lack of a mineral rich in rubidium limits the production of rubidium compounds to 2 to 4 tonnes per year . Caesium , however , is not produced from the above reaction . Instead , the mining of pollucite ore is the main method of obtaining pure caesium , extracted from the ore mainly by three methods : acid digestion , alkaline decomposition , and direct reduction . Both metals are produced as by product

products of lithium production : after 1958 , when interest in lithium 's thermonuclear properties increased sharply , the production of rubidium and caesium also increased correspondingly .

Francium @-@ 223 , the only naturally occurring isotope of francium , is produced naturally as the product of the alpha decay of actinium @-@ 227 . Francium can be found in trace amounts in uranium and thorium minerals ; it has been calculated that at most there are 30 g of francium in the earth 's crust at any given time . As a result of its extreme rarity in nature , most francium is synthesized in the nuclear reaction $^{197}\text{Au} + ^{18}\text{O} \rightarrow ^{210}\text{Fr} + 5\text{n}$, yielding francium @-@ 209 , francium @-@ 210 , and francium @-@ 211 . The greatest quantity of francium ever assembled to date is about 300 @,@ 000 neutral atoms , which were synthesized using the nuclear reaction given above .

From their silicate ores , all the alkali metals may be obtained the same way : sulfuric acid is first used to dissolve the desired alkali metal ion and aluminium (III) ions from the ore (leaching) , whereupon basic precipitation removes aluminium ions from the mixture by precipitating it as the hydroxide . The remaining insoluble alkali metal carbonate is then precipitated selectively ; the salt is then dissolved in hydrochloric acid . The result is then left to evaporate and the alkali metal can then be isolated through electrolysis .

Lithium and sodium are typically isolated through electrolysis from their liquid chlorides , with calcium chloride typically added to lower the melting point of the mixture . The heavier alkali metals , however , is more typically isolated in a different way , where a reducing agent (typically sodium for potassium and magnesium or calcium for the heaviest alkali metals) is used to reduce the alkali metal chloride . The liquid or gaseous product (the alkali metal) then undergoes fractional distillation for purification .

= = Applications = =

Lithium , sodium , and potassium have many applications , while rubidium and caesium are very useful in academic contexts but do not have many applications yet . Lithium is often used in batteries , and lithium oxide can help process silica . Lithium can also be used to make lubricating greases , air treatment , and aluminium production .

Pure sodium has many applications , including use in sodium @-@ vapour lamps , which produce very efficient light compared to other types of lighting , and can help smooth the surface of other metals . Being a strong reducing agent , it is often used to reduce many other metals , such as titanium and zirconium , from their chlorides . Sodium compounds have many applications as well , the most well @-@ known being table salt . Sodium is also used in soap as salts of fatty acids .

Potassium compounds are often used as fertilisers as potassium is an important element for plant nutrition . Potassium hydroxide is a very strong base , and is used to control the pH of various substances .

Rubidium and caesium are often used in atomic clocks . Caesium atomic clocks are extraordinarily accurate ; if a clock had been made at the time of the dinosaurs , it would be off by less than four seconds (after 80 million years) . For that reason , caesium atoms are used as the definition of the second . Rubidium ions are often used in purple fireworks , and caesium is often used in drilling fluids in the petroleum industry .

Francium has no commercial applications , but because of francium 's relatively simple atomic structure , among other things , it has been used in spectroscopy experiments , leading to more information regarding energy levels and the coupling constants between subatomic particles . Studies on the light emitted by laser @-@ trapped francium @-@ 210 ions have provided accurate data on transitions between atomic energy levels , similar to those predicted by quantum theory .

= = Biological role and precautions = =

The bioinorganic chemistry of the alkali metal ions has been extensively reviewed . Solid state crystal structures have been determined for many complexes of alkali metal ions in small peptides , nucleic acid constituents , carbohydrates and ionophore complexes .

Lithium naturally only occurs in traces in biological systems and has no known biological role, but does have effects on the body when ingested. Lithium carbonate is used as a mood stabiliser in psychiatry to treat bipolar disorder (manic @-@ depression) in daily doses of about 0 @.@ 5 to 2 grams, although there are side @-@ effects. Excessive ingestion of lithium causes drowsiness, slurred speech and vomiting, among other symptoms, and poisons the central nervous system, which is dangerous as the required dosage of lithium to treat bipolar disorder is only slightly lower than the toxic dosage. Its biochemistry, the way it is handled by the human body and studies using rats and goats suggest that it is an essential trace element, although the natural biological function of lithium in humans has yet to be identified.

Sodium and potassium occur in all known biological systems, generally functioning as electrolytes inside and outside cells. Sodium is an essential nutrient that regulates blood volume, blood pressure, osmotic equilibrium and pH; the minimum physiological requirement for sodium is 500 milligrams per day. Sodium chloride (also known as common salt) is the principal source of sodium in the diet, and is used as seasoning and preservative, such as for pickling and jerky; most of it comes from processed foods. The DRI for sodium is 1 @.@ 5 grams per day, but most people in the United States consume more than 2 @.@ 3 grams per day, the minimum amount that promotes hypertension; this in turn causes 7 @.@ 6 million premature deaths worldwide.

Potassium is the major cation (positive ion) inside animal cells, while sodium is the major cation outside animal cells. The concentration differences of these charged particles causes a difference in electric potential between the inside and outside of cells, known as the membrane potential. The balance between potassium and sodium is maintained by ion pumps in the cell membrane. The cell membrane potential created by potassium and sodium ions allows the cell to generate an action potential ? a " spike " of electrical discharge. The ability of cells to produce electrical discharge is critical for body functions such as neurotransmission, muscle contraction, and heart function.

Rubidium has no known biological role, but may help stimulate metabolism, and, similarly to caesium, replace potassium in the body causing potassium deficiency. Caesium compounds are rarely encountered by most people, but most caesium compounds are mildly toxic because of chemical similarity of caesium to potassium, allowing the caesium to replace the potassium in the body, causing potassium deficiency. Exposure to large amounts of caesium compounds can cause hyperirritability and spasms, but as such amounts would not ordinarily be encountered in natural sources, caesium is not a major chemical environmental pollutant. The median lethal dose (LD50) value for caesium chloride in mice is 2 @.@ 3 g per kilogram, which is comparable to the LD50 values of potassium chloride and sodium chloride. Caesium chloride has been promoted as an alternative cancer therapy, but has been linked to the deaths of over 50 patients, on whom it was used as part of a scientifically unvalidated cancer treatment. Radioisotopes of caesium require special precautions: the improper handling of caesium @-@ 137 gamma ray sources can lead to release of this radioisotope and radiation injuries. Perhaps the best @-@ known case is the Goiânia accident of 1987, in which an improperly @-@ disposed @-@ of radiation therapy system from an abandoned clinic in the city of Goiânia, Brazil, was scavenged from a junkyard, and the glowing caesium salt sold to curious, uneducated buyers. This led to four deaths and serious injuries from radiation exposure. Together with caesium @-@ 134, iodine @-@ 131, and strontium @-@ 90, caesium @-@ 137 was among the isotopes distributed by the Chernobyl disaster which constitute the greatest risk to health.

Francium has no biological role and is most likely to be toxic due to its extreme radioactivity, causing radiation poisoning, but since the greatest quantity of francium ever assembled to date is about 300 @,@ 000 neutral atoms, it is unlikely that most people will ever encounter francium.