Melting point trend in group 13

Learning Objectives To understand property trends and reactivity of group 13 elements. Group 13 is the first group to include a sorting line between metal and nonmetal, so the chemistry is more diverse than groups 1 and 2, which only include metal elements. Except for the lightest element (boron), the group 13 elements are all relatively electropositive; that is, they tend to lose electrons in chemical reactions rather than get them. Although the group of 13 included aluminum, the most abundant metal on Earth, none of these elements were known until the early 19th century because they were never found in nature in their free state. Elemental boron and aluminum, which were first prepared by reducing B2O3 and AlCl3, respectively, with potassium, cannot be prepared until potassium has been isolated and proven to be a potent reductant. Indium (In) and thallium (Tl) were discovered in the 1860s using spectroscopic techniques, long before methods were available to isolate them. Indium, named for the indigo emission line (deep blue-purple), was first observed in the zinc ball spectrum, while thallium (from Greek thallos, which means light green shoots from plants) was named for its brilliant green emission line. Gallium (Ga; Eka-aluminium Mendeleev) was discovered in 1875 by French chemist Paul Émile Lecoq de Boisbaudran during a systematic search for mendeleev's missing element in a group of 13. Group 13 elements are never found in nature in their free state. As a reducant, the group of 13 elements is less powerful than alkaline metals and base ground metals. Nevertheless, their compounds with oxygen are thermodinerationally stable, and a large amount of energy is needed to isolate even the two most accessible elements —boron and aluminum—from their ores oxides. Figure \(\PageIndex{1}\): Borax Deposit. (a) Concentrated crystalline borax deposits [Na2B4O5(OH)4·8H2O] were found at the bottom of ancient lakes, such as the Mojave Desert and Death Valley in the western United States. (b) Borax is used in a variety of cleaning products, including 20 Mule Team Borax, a laundry detergent named for a team of 20 donkeys that transported carts full of borax from desert sediment to the railway terminal in the 1880s. Although boron is relatively rare (about 10,000 times less abundant than aluminum), concentrated borax deposits [Na2B4O5(OH)4·8H2O] were found at the bottom of ancient lakes (Image \(\PageIndex{1}\)) and were used in ancient times to make pottery glass and glazing. Boron is produced on a large scale by reacting borax with acid to produce boric acid [B(OH)3], which is then dehydrated in oxides (B2O3). Reduction of oxides with magnesium or sodium provides amorphous borons that are only about 95% pure: \label{Eq1}\] \[\mathrm{B_2O_3(s)}+\mathrm{3Mg(s)}\xrightarrow{\Delta}\mathrm{2B(s)}+\mathrm{3MgO(s)} \label{Eq2}\] Pure, however, crystal boron is very difficult to obtain due to its high melting point (2300°C) and highly corrosive liquid boron properties. Usually prepared by reducing pure BCl3 with hydrogen gas at high temperatures or by thermal decomposition of boron hydride such as diborane (B2H6): \[\mathrm{BCl_3(g)}+\frac{3}{2}\mathrm{H_2(g)}\rightarrow\mathrm{B(s)}+\mathrm{3HCl (g)} \label{Eq3}\] \[B_2H_{6(g)} \rightarrow 2B_{(s)} + 3H_{2(g)} \label{Eq4}\] The reaction shown in the Equation \(\ref{Eq3}\) is used to prepare boron fibers, which are rigid and light. They are therefore used as structural reinforcing materials on objects as diverse as the US space shuttle and lightweight bike frames used in races such as the Tour de France. Boron is also an important component of many heat-resistant ceramics and extravagant glasses, such as Pyrex, which are used for ovenware and laboratory crockery. Unlike borons, aluminum ore deposits such as bauxics, a hydrated form of Al2O3, are abundant. With electrical conductivity about double that of copper by weight, aluminum is used in more than 90% of overhead power lines in the United States. However, because aluminum-oxygen compounds are stable, getting aluminum metal from bauxy is an expensive process. Aluminum is extracted from oxide ore with a strong base treatment, which results in a soluble hydroxide complex [Al(OH)4]−. Neutralization of solutions produced with CO2 gas produces al(OH)3 precipitation: \[2[Al(OH)_4]^−_{(aq)} + CO_{2(g)} \rightarrow 2Al(OH)_{3(s)s))} + CO^{2−}_{3(aq)} + H_2O_{(l)} \label{Eq5}\] Thermal dehydration Al(OH)3 produces Al2O3, and metal aluminum is obtained by reducing al2O3 electrolytes using the Hall–Heroult process. Of the group of 13 elements, only aluminum is used on a large scale: for example, each Boeing 777 aircraft is about 50% aluminum en masse. Figure \(\PageIndex{2}\): Source: Thomas D. Kelly and Grecia R. Matos, Historical Statistics for Mineral and Material Commodities in the United States, U.S. Geological Survey Data Series 140, 2010, accessed July 20, 2011, pubs.usgs.gov/ds/2005/140/. Other members of the group of 13 are rather rare: gallium is about 5000 times less than aluminum, and indium and thallium are even rare. As a result, these metals are usually obtained as by-products in the processing of other metals. Gallium melting points are very low (29.6°C), however, making it easy to separate from aluminum. Due to its low melting point and high boiling point, gallium is used as a liquid in thermometers that have a temperature range of almost 2200°C. Indium and thallium, a heavier group of 13 found as trace impurities in zinc sulpid excrement and lead. Indium is used as a crushable seal for high vacuum cryogenic devices, and the alloy is used as a low melt solder on electronic circuit boards. Thallium, on the other hand, is so toxic that the metal and its compounds have little use. Both indium and thallium oxide are released in flue dust when ores sulfide is converted to metal oxide and SO2. Until relatively recently, these and other toxic elements were allowed to spread through the air, creating a large dead zone down the smelter. Flue dust is now trapped and serves as a source of relatively rich elements such as In and Tl (as well as Ge, Cd, Te, and AS). The \(\PageIndex{1}\) table summarizes some important properties of the group element 13. Note the large differences between boron and aluminum in size, ionization energy, electronegativity, and potential standard reduction, which is consistent with the observation that boron behaves chemically like nonmetal and aluminum-like metals. All 13 group elements have an ns2np1 valence electron configuration, and all tend to lose their three valence electrons to form compounds in an oxidation state of +3. Heavier elements in the group can also form compounds in a +1 oxidation state formed by formal loss of single np valence electrons. Since the group of 13 elements generally contain only six valence electrons in their neutral compounds, these compounds are all pretty strong Lewis acids. Table \(\PageIndex{1}\): Selected Properties of the Group of 13 Aluminum Boron Property Elements* Gallium Indium Thallium *This is the name used in the United States; the whole world inserts an additional i and calls it aluminum. † The configuration conscript shown does not include the filled d and f subshells. ‡The values cited are for six coordinate ions in the most common oxidation state, except for Al3+, where values for four coordinate ions are given. Ion B3+ is not a known species; The radius quoted is an approximate value of four coordinates. •X is Cl, Br, or I. Reactions with F2 provide trifluorides (MF3) for all 13 group elements. atomic symbol B Al Ga In Tl atomic number 5 13 31 49 81 atomic mass (amu) 10.81 26.98 69.72 114.82 204.38 valence electron configuration† 2s2p1 3s23p1 4s24p1 5s25p1 6s26p1 melting point/boiling point (°C) 2075/4000 660/2519 29.7/2204 156.6/2072 304/1473 density (g/cm3) at 25°C 2.34 2.70 5.91 7.31 11.8 atomic radius (pm) 87 118 136 156 156 first ionization energy (kJ/mol) 801 578 579 558 589 most common oxidation status +3 +3 +3 +3 +3 +3 +3 +3 +3 +3 +3 +3 1 ionic radius (pm)‡ −25 54 62 80 162 electron affinity (kJ/mol) −27 −42 −40 −39 −37 electronegativity 2.0 1.6 1.8 1.8 1.8 potential standard reduction (E°, V) −0.87 −1.66 −0.55 −0.34 +0.741 M3+(aq) product with O2 B2O3 Al2O3 Ga2O3 In2O3 Tl2O type amphoteric acid oxide oxide The basic product amphoteric reaction with N2 BN AlN GaN InN no reaction product with X2• BX3 Al2X6 Ga2X6 In2X6 TlX Neutral compounds of group 13 elements lack electrons, so they are generally quite strong Lewis acid. Unlike groups 1 and 2, group 13 elements showed no consistent trends in ionization energy, electron affinity, and potential reduction, while electronegativity actually increased from aluminum to thallium. Some of these anomalies, especially for the Ga, In, Tl series, can be explained by the increase in effective nuclear payload (Zeff) resulting from poor shielding of nuclear payloads by filled subshells (n−1)d10 and (n−2)f14. As a result, although the actual nuclear payload increases by 32 as we go from indium to thallium, filtering by the filled 5d and 4f subshells is so bad that Zeff increases significantly from indium to thallium. Thus the first ionization energy of thallium is actually greater than indium. Anomalies in the periodic trend between Ga, In, and Tl can be explained by an effective increase in nuclear payload due to poor shielding. Elemental boron is a very inactive semimetal; conversely, the other 13 group elements all exhibit metal properties and reactivity. Therefore we consider boron reactions and compounds separately from other elements in the group. All 13 group elements have fewer valence electrons than valence orbits, which generally results in delocalized metal bonds. With high ionization energy, low electron affinity, low electronegativity, and small size, however, boron does not form a metal lattice with delocalized valence electrons. Instead, boron forms a unique and intricate structure containing multicenter bonds, in which a pair of electrons unites three or more atoms. Image \(\PageIndex{3}\): Solid Boron Contains B12 Icosahedra. Unlike metal solids, elemental boron consists of a regular array of B12 icosahedra rather than individual boron atoms. Note that each boron atom in icosahedron B12 is connected to five other boron atoms in unit B12. (a) Allotrope boron with the simplest structure is boron α-rhombohedral, which consists of B12 octahedra in an almost cubic-covered lattice. (b) The side view of the structure indicates that the icosahedra does not pack as efficiently as the ball, making the density of the solid boron less than expected. Elemental boron forms multicenter bonds, while the other 13 group elements show metal bonds. Elemental boron base building blocks are not individual boron atoms, as is the case in metals, but rather Icosahedron B12. Since this icosahedra does not pack together very well, the solid boron structure contains a void, resulting in its low density (Image \(\PageIndex{3}\)). boron can be reacts with many nonmetal elements to provide binary compounds that have a variety of applications. For example, a carbide boron plate (B4C) can stop a 30-caliber bullet, a steel piercing, but weighs 10%–30% less than conventional armor. Other important boron compounds with nonmetal include boron nitride (BN), produced by boron heaters with excess nitrogen (Equation \(\ref{Eq22.6}\)); boron oxide (B2O3), which is formed when boron is heated with excess oxygen (Equation \(\ref{Eq22.7}\)); and boron trihalide (BX3), which is formed by an over-halogen heating boron (Equation \(\ref{Eq22.8}\)). \[\mathrm{2B(s)}+\mathrm{N_2(g)}\xrightarrow{\Delta}\mathrm{2BN(s)} \label{Eq22.6}\] \[\mathrm{4B(s)} + \mathrm{3O_2(g)}\xrightarrow{\Delta}\mathrm{2B_2O_3(s)\s)\s)?s)\s)label{Eq22.7}\] \[\mathrm{2B(s)} +\mathrm{3X_2(g)}\xrightarrow{\Delta}\mathrm{2BX_3(g)}\label{Eq22.8}\] As is typical of elements lying near the metal and nonmetal sorting lines , many boron compounds are amphoteric, soluble in acid or laksanat. Boron nirida is similar in many ways to carbon elements. With eight electrons, isoelectronic B–N units with C–C units, and B and N have the same average size and electronegativity as C. The most stable BN shape is similar to graphite, containing a six-member B3N3 ring arranged in layers. At high temperatures and pressures, hexagonal BN is converted to a cubic structure similar to a diamond, which is one of the hardest known substances. Boron oxide (B2O3) contains a layer of trigonal bo3 planar group (analogous to BX3) in which oxygen atoms bridge two boron atoms. It dissolves many metal and nonmetal oxides, including SiO2, to provide a variety of commercially important extravagant glasses. A small amount of CoO gives the characteristic dark blue color of cobalt blue glass. At high temperatures, boron also reacts with almost all metals to provide metal boride containing the usual three-dimensional tissue, or cluster, of boron atoms. The structures of two metal borides—ScB12 and CaB6—are displayed in The \(\PageIndex{4}\). Because metal-rich borides such as ZrB2 and TiB2 are resistant to hard and corrosion even at high temperatures, they are used in applications such as turbine blades and rocket nozzles. Figure \(\PageIndex{4}\): ScB12and CaB6 Structure, Two Boron Rich Metal Borides. (a) The ScB12 structure consists of a cluster of B12 and Sc atoms arranged in a cubic lattice centered on a face similar to NaCl, with B12units occupying the anion position and the scandium atom cation position. The B12 unit here is not icosahedra but cubooctahedra, with square faces and alternating triangles. (b) The CaB6 structure consists of an octahedral B6 cluster and calcium atoms arranged in a body-centered cubic lattice similar to CsCl, with unit B6 occupying a position calcium atom cation position. Boron hydrides were not discovered until the early 20th century, when German chemist Alfred Stock conducted a systematic investigation of boron and hydrogen binary compounds, although carbon, nitrogen, oxygen, and fluorine binary hydroxide have been known since the 18th century. Between 1912 and 1936, Stock oversaw the preparation of a series of boron-hydrogen compounds with unprecedented structures that could not be explained by a simple bond theory. All of these compounds contain multicenter bonds. The simplest example is the diborane (B2H6), which contains two hydrogen bridging atoms (part (a) in Figure \(\PageIndex{5}\). The remarkable range of polyhedral boron-hydrogen clusters is now known; one example is the B12H122−ion, which has a polyhedral structure similar to the elemental boron icosahedral B12 unit, with a single hydrogen atom attached to each boron atom. Figure \(\PageIndex{5}\): Diborane Structure (B2H6) and Aluminum Chloride (Al2Cl6). (a) The hydrogen-bridged Dimer B2H6 contains two three-middle bonds, two electrons as described for ion B2H7− in Figure 21.5. (b) Conversely, the deep bond of the Halogen-bridged Al2Cl6 dimer can be described in terms of electron pair bonding, in which chlorine atoms bound to one aluminum atom act as Lewis's base by donating a single pair of electrons to another aluminum atom, which acts as Lewis acid. Classes related to polyhedral clusters, carboran, containing CH and BH units; example shown here. Replacing carbon-bound hydrogen atoms with organic groups produces substances with new properties, some of which are currently being investigated for their use as liquid crystals and in cancer chemotherapy. Enthalpy combustion diborane (B2H6) is −2165 kJ/mol, one of the highest known values: \[B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O(l)\\\\\; H_{comb} = −2165\; kJ/mol \label{Eq 22.9}\] As a result, the U.S. military explored using boron hydrides as rocket fuel in the 1950s and 1960s. This effort was eventually abandoned due to unstable, expensive, and toxic boron hydroxide, and, most importantly, the B2O3 proved to be highly abrasive to rocket nozzles. The reaction carried out during this investigation, however, suggests that boron hydrides showed unusual reactivity. Because boron and hydrogen have almost identical electronegativity, boron hydroxide reactions are determined by small differences in the distribution of electron density in certain compounds. In general, two different types of reactions are observed: electron-rich species such as BH4− ions are reductive, while electron-deficient species such as B2H6 act as oxidants. Example \(\PageIndex{1}\) For each reaction, explain why the product is given

B2H6(g) - 3O2(g) → B2O3 (s) - 3H2O(l) BCl3(l) - 3H2O(l) → → + 3HCl(aq) \(\mathrm{2BI_3(s)}+\mathrm{3H_2(g)}\xrightarrow{\Delta}\frac{1}{6}\mathrm{B_{12}(s)}+\mathrm{6HI(g)}\) Remember: balanced chemical equations Requested: why the given product forms a Strategy: Classify the reaction type. Using periodic trends in atomic, thermodynamic, and kinetic properties, explains why reaction products are formed. Solution: Oxygen molecules are oxidants. If another reactive is a potential reductive, we hope that a redox reaction will occur. Although B2H6 contains boron in the highest oxidation state (+3), it also contains hydrogen in an oxidation state −1 (ion hydrate). Since hydride is a strong reductant, a redox reaction may occur. We hope that H− will be oxidized to H+ and O2 will be reduced to O2−, but what is the actual product? Plausible allegations are B2O3 and H2O, both stable compounds. Neither BCl3 nor water is a strong oxidant or reducant, so a redox reaction is not possible; hydrolysis reactions are more likely. Nonmetal halides are acidic and react with water to form a solution of hydrohalic acid and nonmetal oxide or hydroxide. In this case, the product containing boron is most likely to be boric acid [B(OH)3]. We usually expect boron trihalides to behave like Lewis acid. However, in this case, another reactive is the hydrogen element, which usually acts as a reducant. Iodine atoms in BI3 are in the lowest accessible oxidation state (−1), and boron is in a +3 oxidation state. As a result, we can write redox reactions in which hydrogen oxidized and boron reduced. Since boron compounds in a lower oxidation state are rare, we expect boron to be reduced to boron elements. Therefore, other products of the reaction should be HI. Exercise \(\PageIndex{1}\) Predict the product of the reaction and write a balanced chemical equation for each reaction. \(\mathrm{B_2H_6(g)}+\mathrm{H_2O(l)}\xrightarrow{\Delta}\) \(\mathrm{BBr_3(l)}+\mathrm{O_2(g)}\rightarrow\) \(\mathrm{B_2O_3(s)}+\mathrm{Ca(s)}\xrightarrow{\Delta}\) Answer \(\mathrm{B_2H_6(g)}+\mathrm{H_2O(l)}\xrightarrow {\Delta}\mathrm{2B(OH)_3(s)}+\mathrm{6H_2(g)}\) \(\mathrm{BBr_3(l)}+\mathrm{O_2(g)}\rightarrow\textrm {no reaction}\) \) \(\mathrm{6B_2O_3(s)}+18\mathrm{Ca(s)}\xrightarrow{\Delta}\mathrm{B_{12}(s)}+\mathrm{18CaO(s)}\) The fourth heavier group of 13 elements (Al, Ga, In, and Tl) reacts easily with halogens to form compounds with stoichiometry 1:3: \[2M_{(s)} + 3X_{2(s,l,g)} \rightarrow 2MX_{3(s)} \3X_{2(s,l,g)} \rightarrow 2MX_{3(s)} \s)} \3X_{2 text{ or } M_2X_6 \label{Eq10}\] Tl reaction with iodine is an exception: although the product has stoichiometry TlI3 , it is not thallium(III) iodide, but rather a compound of thallium(I) , salt Tl + of triiodide ions (I3−). This compound is formed because is not a strong enough oxidant to oxidize thallium to a +3 oxidation state. From halides, only fluorides fluorides typical behavior of ionic compounds: they have a high melting point (>950°C) and low solubility in nonpolar solvents. Conversely, trichorides, tribromides, and triiodides of aluminum, gallium, and indium, as well as TlCl3 and TlBr3, are more valen in character and form halogen-bridged dimers (part (b) in the \(\PageIndex{4}\)). Although this dimer structure is similar to a diborane (B2H6), bonds can be explained in terms of electron pair bonds rather than delocalized electron deficiency bonds found in diborane. Menjembankan halide is a bad electron pair donor, so the group of 13 trihalides is a potent Lewis acid that reacts with Lewis's base, such as amines, to form lewis-base acid adduct: \[Al_2Cl_{6(soln)} + 2(CH_3)_3N_{(soln)} \rightarrow 2(CH_3)_3N:_3N:_3N_ {(soln)} \rightarrow 2(CH_3)_3N:AlCl_ _3N <3> <7>{3(soln)} \label{Eq11}\] In water , halides group 13 metal trellis to produce metal hydroxide (\[M(OH)_3\)) : \[MX_{3(s)} + 3H_2O_{(l)} \rightarrow M(OH)_{3(s)} + 3HX_{(aq)} \label{Eq12}\] In related reactions, Al2(SO4)3 is used to clarify drinking water with hydrated Al(OH)3 rainfall. Heavier metal halides (In and Tl) are less reactive with water due to the lower charging to radius ratio. Instead of forming hydroxide, they dissolve to form hydrated metal complex ions: [M(H2O)6]3+. Of the group of 13 halides, only fluorides behave as typical ionic compounds. Like boron (Equation \(\ref{Eq22.7}\)), all the heavier 13 group elements react with excess oxygen at high temperatures to provide trivalent oxide (M2O3), although Tl2O3 is unstable: \[\mathrm{4M (s)}+\mathrm{3O_2(g)}\xrightarrow{\Delta}\mathrm{2M_2O_3(s)} \label{Eq13}\] Aluminum oxide (Al2O3), also known as alumina, is hard, high melting point, Chemical inert insulators are used as ceramics and as abrasive in sandpaper and toothpaste. Replacing a small number of Al3+ ions in crystal alumina with cr3+ ions forms ruby gemstones, while replacing Al3+ with a mixture of Fe2+, Fe3+, and Ti4+ produces blue sapphires. The gallium oxide compound MgGa2O4 gives a brilliant green light that is familiar to anyone who has ever operated an xerographic photocopier. All oxides are soluble in diluted acids, but Al2O3 and Ga2O3 are amphoteric, which is consistent with their location along the diagonal lines of the periodic table, also dissolves in a concentrated aqueous base to form a solution containing M(OH)4−ions. Group 13 trihalides are potent Lewis acids that react with Lewis's base to form Lewis's acid-base adduct. Aluminum, gallium, and indium also reacted with another group of 16 elements (chalcogens) to form chalcogenides with stoichiometry M2Y3. However, due to Tl(III) strong oxidants to form stable compounds with electron-rich anions such as S2−, Se2−, and Te2−, thallium only forms thallium (I) (I) with stoichiometry Tl2Y. Only aluminum, such as boron, reacts directly with N2 (at very high temperatures) to provide the AlN, which is used in transistors and microwave devices as a nontoxic heat sink due to its thermal stability; GaN and InN can be set up using other methods. All metals, again except Tl, also react with heavier groups of 15 elements (pnicogens) to form so-called III-V compounds, such as GaAs. These are semiconductors, whose electronic properties, such as their band gaps, differ from those that can be achieved using pure or doped group 14 elements. For example, gallium nitrogen and phosphorus-doped arsenide (GaAs1−x−yPxNy) are used in calculator displays and digital watches. All 13 groups of oxides dissolve in diluted acid, but Al2O3 and Ga2O3 are amphoteric. Unlike boron, the heavier group of 13 elements did not react directly with hydrogen. Only aluminum and gallium hydroxide are known, but they must be prepared indirectly; AlH3 is an insoluble polymer solid that is rapidly decomposed by water, while GaH3 is unstable at room temperature. Boron has a relatively limited tendency to form complexes, but aluminum, gallium, indium, and, to some extent, thallium form many complexes. Some of the simplest are hydrated metal ions [M(H2O)63+], the relatively strong Brønsted-Lowry acid that can lose protons to form M(H2O)5(OH)2+ ions: \[[M(H_2O)_6]^{3+}_{(aq)} \rightarrow M(H_2O)_6]^{3+}_{(aq)} \rightarrow M(<1>)_5(OH)^{2+}_{(aq)} + H^+_{(aq)} \label{Eq14}\] Group 13 metal ions also form a stable complex with species containing two or more negatively charged groups , like oxalate ions. The stability of the complex increased as the number of coordination groups provided by ligands increased. Example \(\PageIndex{2}\) For each reaction, explain why the given product is formed. \(\mathrm{2Al(s)} + \mathrm{Fe_2O_3(s)}\xrightarrow{\Delta}\mathrm{2Fe(l)} + \mathrm{Al_2O_3((s)}\) \(\mathrm{2Ga(s)} + \mathrm{6H_2O(l)}+ \mathrm{2OH^-(aq)}\xrightarrow{\Delta}\mathrm{3H_2(g)} + \mathrm{2Ga(OH)^-_4(aq)}\) \(\mathrm{In_2Cl_6(s)}\xrightarrow{{\mathrm{H_2O(l)}}\mathrm{2In^{3+}(aq)}+\mathrm{6Cl^-(aq)}\) Remembering: balanced chemical equation Requested : why the given product forms a Strategy: Classify the type of reaction. Using periodic trends in atomic, thermodynamic, and kinetic properties, explains why reaction products are formed. Solution: Aluminum is a strong active and reductive metal, and Fe2O3 contains Fe(III), a potential oxidant. Therefore a redox reaction is possible, resulting in metallic Fe and Al2O3. Since Al is the main group element located above Fe, which is a transition element, it should be a more active metal than Fe. As such should proceed to the right. In fact, it is a termite reaction, which is so powerful that it produces liquid Fe and can be used for welding. Gallium is located just below the aluminum in the periodic and amphoteric tables, so it will dissolve in acid or base to produce hydrogen gas. Since gallium is similar to aluminum in many of its properties, we predict that gallium will dissolve on a strong base. The metal character of the group 13 element increases with an increase in the number of atoms. Therefore indium trichloride should behave like a typical metal halide, soluble in water to form a hydrated cation. Exercise \(\PageIndex{2}\) Predict the product of the reaction and write a balanced chemical equation for each reaction. LiH + Al2Cl6(soln)→ Al2O3(s) + OH−(aq)→ Al.s) + N2(g) \(\xrightarrow{\Delta}\) Ga2Cl6(soln) + Cl−(soln)→ Answer 8LiH + Al2Cl6(soln)→2LiAlH4(soln) + 6LiCl(s) Al2O3) + 2OH−(aq) + 3H2O(l) → 2Al(OH)4−(aq) 2Al(s) + N2(g) \(\xrightarrow{\Delta }\) 2AlN(s) Ga2Cl6(soln) + 2Cl−(soln) → 2GaCl4−(soln) Compound groups of 13 elements with oxygen in a stable thermodination. Many of the anomalous properties of group 13 elements can be explained by zeff's increase moving down the group. Isolation of groups of 13 elements requires a large amount of energy because the group compounds 13 elements with thermodinationally stable oxygen. Boron behaves chemically like a nonmetal, whereas heavier congeners exhibit metal behavior. Many of the inconsistencies observed in the properties of group 13 elements can be explained by zeff enhancements emerging from poor nuclear payload shields with filled subshells (n−1)d10 and (n−2)f14. Instead of forming a metal lattice with relocated valence electrons, boron forms unique aggregates containing multicenter bonds, including metal borides, in which borons are bound to other boron atoms to form three-dimensional networks or clusters with ordinary geometric structures. All neutral compounds from the group of 13 elements lack electrons and behave like Lewis acid. Trivalent halides of heavier elements form halogen-bridged dimers that contain electron pair bonds, rather than electron deficiency bonds that delocalize the characteristics of the diborane. Their oxides dissolve in diluted acid, despite aluminum oxide and amphoteric bile. None of the 13 group elements react directly to hydrogen, and the stability of the hidrides prepared by other routes decreases as we descend the group. Unlike boron, heavier group 13 elements form a large number of complexes in a +3 oxidation state. Country.