Group 12 element

Group 12 , by modern IUPAC numbering , is a group of chemical elements in the periodic table . It includes zinc (Zn) , cadmium (Cd) and mercury (Hg) . The further inclusion of copernicium (Cn) in group 12 is supported by recent experiments on individual copernicium atoms . Group 12 is also known as the volatile metals , although this can also more generally refer to any metal (which need not be in group 12) that has high volatility , such as polonium or flerovium . Formerly this group was named IIB (pronounced as " group two B " , as the " II " is a Roman numeral) by CAS and old IUPAC system .

The three group 12 elements that occur naturally are zinc , cadmium and mercury . They are all widely used in electric and electronic applications , as well as in various alloys . The first two members of the group share similar properties as they are solid metals under standard conditions . Mercury is the only metal that is a liquid at room temperature . While zinc is very important in the biochemistry of living organisms , cadmium and mercury are both highly toxic . As copernicium does not occur in nature , it has to be synthesized in the laboratory .

Physical and atomic properties

Like other groups of the periodic table , the members of group 12 show patterns in its electron configuration , especially the outermost shells , which result in trends in their chemical behavior :

Group 12 elements are all soft , diamagnetic , divalent metals . They have the lowest melting points among all transition metals . Zinc is bluish @-@ white and lustrous , though most common commercial grades of the metal have a dull finish . Zinc is also referred to in nonscientific contexts as spelter . Cadmium is soft , malleable , ductile , and with a bluish @-@ white color . Mercury is a liquid , heavy , silvery @-@ white metal . It is the only common liquid metal at ordinary temperatures , and as compared to other metals , it is a poor conductor of heat , but a fair conductor of electricity .

The table below is a summary of the key physical properties of the group 12 elements . Very little is known about copernicium , and none of its physical properties have been confirmed except for its boiling point (tentative) .

Zinc is somewhat less dense than iron and has a hexagonal crystal structure . The metal is hard and brittle at most temperatures but becomes malleable between 100 and 150 ° C. Above 210 ° C , the metal becomes brittle again and can be pulverized by beating . Zinc is a fair conductor of electricity . For a metal , zinc has relatively low melting (419 @.@ 5 ° C , 787 @.@ 1 F) and boiling points (907 ° C) . Cadmium is similar in many respects to zinc but forms complex compounds . Unlike other metals , cadmium is resistant to corrosion and as a result it is used as a protective layer when deposited on other metals . As a bulk metal , cadmium is insoluble in water and is not flammable ; however , in its powdered form it may burn and release toxic fumes . Mercury has an exceptionally low melting temperature for a d @-@ block metal . A complete explanation of this fact requires a deep excursion into quantum physics , but it can be summarized as follows : mercury has a unique electronic configuration where electrons fill up all the available 1s , 2s , 2p , 3s , 3p , 3d , 4s , 4p , 4d , 4f , 5s , 5p , 5d and 6s subshells . As such configuration strongly resists removal of an electron , mercury behaves similarly to noble gas elements , which form weak bonds and thus easily melting solids . The stability of the 6s shell is due to the presence of a filled 4f shell . An f shell poorly screens the nuclear charge that increases the attractive Coulomb interaction of the 6s shell and the nucleus (see lanthanide contraction) . The absence of a filled inner f shell is the reason for the somewhat higher melting temperature of cadmium and zinc , although both these metals still melt easily and , in addition , have unusually low boiling points . Gold has atoms with one less 6s electron than mercury . Those electrons are more easily removed and are shared between the gold atoms forming relatively strong metallic bonds .

Zinc , cadmium and mercury form a large range of alloys . Among the zinc containing ones , brass is an alloy of zinc and copper . Other metals long known to form binary alloys with zinc are aluminium , antimony , bismuth , gold , iron , lead , mercury , silver , tin , magnesium , cobalt , nickel

, tellurium and sodium . While neither zinc nor zirconium are ferromagnetic , their alloy $ZrZn_2$ exhibits ferromagnetism below 35 K. Cadmium is used in many kinds of solder and bearing alloys , due to a low coefficient of friction and fatigue resistance . It is also found in some of the lowest @-@ melting alloys , such as Wood 's metal . Because it is a liquid , mercury dissolves other metals and the alloys that are formed are called amalgams . For example , such amalgams are known with gold , zinc , sodium , and many other metals . Because iron is an exception , iron flasks have been traditionally used to trade mercury . Other metals that do not form amalgams with mercury include tantalum , tungsten and platinum . Sodium amalgam is a common reducing agent in organic synthesis , and is also used in high @-@ pressure sodium lamps . Mercury readily combines with aluminium to form a mercury @-@ aluminium amalgam when the two pure metals come into contact . Since the amalgam reacts with air to give aluminium oxide , small amounts of mercury corrode aluminium . For this reason , mercury is not allowed aboard an aircraft under most circumstances because of the risk of it forming an amalgam with exposed aluminium parts in the aircraft .

Chemistry

Most of the chemistry has been observed only for the first three members of the group 12 . The chemistry of copernicium is not well established and therefore the rest of the section deals only with zinc , cadmium and mercury .

Periodic trends

All elements in this group are metals . The similarity of the metallic radii of cadmium and mercury is an effect of the lanthanide contraction . So , the trend in this group is unlike the trend in group 2 , the alkaline earths , where metallic radius increases smoothly from top to bottom of the group . All three metals have relatively low melting and boiling points , indicating that the metallic bond is relatively weak , with relatively little overlap between the valence band and the conduction band . Thus , zinc is close to the boundary between metallic and metalloid elements , which is usually placed between gallium and germanium , though gallium participates in semi @-@ conductors such as gallium arsenide .

Zinc and cadmium are electropositive while mercury is not . As a result , zinc and cadmium metal are good reducing agents . The elements of group 12 have an oxidation state of + 2 in which the ions have the rather stable d^{10} electronic configuration , with a full sub @-@ shell . However , mercury can easily be reduced to the + 1 oxidation state ; usually , as in the ion Hg_2^{2+} , two mercury (I) ions come together to form a metal @-@ metal bond and a diamagnetic species . Cadmium can also form species such as [Cd_2Cl_6] 4 ? in which the metal 's oxidation state is + 1 . Just as with mercury , the formation of a metal @-@ metal bond results in a diamagnetic compound in which there are no unpaired electrons ; thus , making the species very reactive . Zinc (I) is known only in the gas phase , in such compounds as linear Zn_2Cl_2 , analogous to calomel .

Classification

The elements in group 12 are usually considered to be d @-@ block elements , but not transition elements as the d @-@ shell is full . Some authors classify these elements as main @-@ group elements because the valence electrons are in ns^2 orbitals . Nevertheless , they share many characteristics with the neighboring group 11 elements on the periodic table , which are almost universally considered to be transition elements . For example , zinc shares many characteristics with the neighboring transition metal , copper . Zinc complexes merit inclusion in the Irving @-@ Williams series as zinc forms many complexes with the same stoichiometry as complexes of copper (II) , albeit with smaller stability constants . There is little similarity between cadmium and silver as compounds of silver (II) are rare and those that do exist are very strong oxidizing agents . Likewise the common oxidation state for gold is + 3 , which precludes there being much common chemistry between mercury and gold , though there are similarities between mercury (I) and gold (I) such as the formation of linear dicyano complexes , [M (CN) 2] ? . According to IUPAC 's definition of transition metal as an element whose atom has an incomplete d sub @-@ shell , or which can give rise to cations with an incomplete d sub @-@ shell , zinc and cadmium are not transition metals , while mercury is . This is because only mercury is known to have a compound where its oxidation state is higher than + 2 , in mercury (IV) fluoride . However , this classification is based on one highly atypical compound seen at non @-@ equilibrium conditions and is at odds to mercury 's more typical chemistry , and Jensen has suggested that it would be better to regard mercury as not being a transition metal .

= = = Relationship with the alkaline earth metals = = =

Although group 12 lies in the d @-@ block of the modern 18 @-@ column periodic table , the d electrons of zinc , cadmium , and (almost always) mercury behave as core electrons and do not take part in bonding . This behavior is similar to that of the main @-@ group elements , but is in stark contrast to that of the neighboring group 11 elements (copper , silver , and gold) , which also have filled d @-@ subshells in their ground @-@ state electron configuration but behave chemically as transition metals . For example , the bonding in chromium (II) sulfide (CrS) involves mainly the 3d electrons ; that in iron (II) sulfide (FeS) involves both the 3d and 4s electrons ; but that of zinc sulfide (ZnS) involves only the 4s electrons and the 3d electrons behave as core electrons . Indeed , useful comparison can be made between their properties and the first two members of group 2 , beryllium and magnesium , and in earlier short @-@ form periodic table layouts , this relationship is illustrated more clearly . For instance , zinc and cadmium are similar to beryllium and magnesium in their atomic radii , ionic radii , electronegativities , and also in the structure of their binary compounds and their ability to form complex ions with many nitrogen and oxygen ligands , such as complex hydrides and amines . However , beryllium and magnesium are small atoms , unlike the heavier alkaline earth metals and like the group 12 elements (which have a greater nuclear charge but the same number of valence electrons) , and the periodic trends down group 2 from beryllium to radium (similar to that of the alkali metals) are not as smooth when going down from beryllium to mercury (which is more similar to that of the p @-@ block main groups) due to the d @-@ block and lanthanide contractions . It is also the d @-@ block and lanthanide contractions that give mercury many of its distinctive properties .

= = = Compounds = = =

All three metal ions form many tetrahedral species , such as MCl2 ?
4 . Both zinc and cadmium can also form octahedral complexes such as the aqua ions [M (H2O) 6] 2 + which are present in aqueous solutions of salts of these metals . Covalent character is achieved by using the s and possibly p orbitals . Mercury , however , rarely exceeds a coordination number of four . Coordination numbers of 2 , 3 , 5 , 7 and 8 are also known .

= = Extensions = =

Although copernicium is the heaviest known group 12 element , there has been some theoretical work regarding possible heavier group 12 elements . Although a simple extrapolation of the periodic table would put element 162 , unhexbium (Uhb) , under copernicium , relativistic Dirac @-@ Fock calculations predict that the next group 12 element after copernicium should actually be element 164 , unhexquadium (Uhq) , which is predicted to have an electron configuration of [Uuo] 5g18 6f14 7d10 8s2 8p1 / 22 . The 8s and 8p1 / 2 orbitals are predicted to be so strongly stabilized relativistically that they become core electrons and do not participate in chemical reactions , unlike the earlier group 12 elements where the s electrons behave as valence electrons . However , the 9s and 9p1 / 2 levels are expected to be readily available for hybridization and bonding , so that unhexquadium should still behave chemically like a normal transition metal . Calculations predict

that the 7d electrons of unhexquadium should participate very readily in chemical reactions , so that unhexquadium should be able to show stable + 6 and + 4 oxidation states in addition to the normal + 2 state in aqueous solutions with strong ligands . Unhexquadium should thus be able to form compounds like Uhq (CO) 4 , Uhq (PF3) 4 (both tetrahedral) , and Uhq (CN) 2 ?
2 (linear) , which is very different behavior from that of lead , which unhexquadium would be a heavier homologue of if not for relativistic effects . Nevertheless , the divalent state would be the main one in aqueous solution , and unhexquadium (II) should behave more similarly to lead than unhexquadium (IV) and unhexquadium (VI) .
Unhexquadium should be a soft metal like mercury , and metallic unhexquadium should have a high melting point as it is predicted to bond covalently . It is also expected to be a soft Lewis acid and have Ahrlands softness parameter close to 4 eV . It should also have some similarities to ununoctium as well as to the other group 12 elements . Unhexquadium should be at most moderately reactive , having a first ionization energy that should be around 685 kJ / mol , comparable to that of molybdenum . Due to the lanthanide , actinide , and superactinide contractions , unhexquadium should have a metallic radius of only 158 pm , very close to that of the much lighter magnesium , despite its being expected to have an atomic weight of around 474 u , about 19 @.@ 5 times as much as that of magnesium . This small radius and high weight cause it to be expected to have an extremely high density of around 46 g · cm ? 3 , over twice that of osmium , currently the most dense element known , at 22 @.@ 61 g · cm ? 3 ; unhexquadium should be the second most dense element in the first 9 periods of the periodic table , with only its neighbour unhextrium (element 163) being more dense (at 47 g · cm ? 3) . Metallic unhexquadium should be quite stable , as the 8s and 8p1 / 2 electrons are very deeply buried in the electron core and only the 7d electrons are available for bonding . Metallic unhexquadium should have a very large cohesive energy due to its covalent bonds , most probably resulting in a high melting point .
Theoretical interest in the chemistry of unhexquadium is largely motivated by theoretical predictions that it , especially the isotope 482Uhq (with 164 protons and 318 neutrons) , would be at the center of a hypothetical second island of stability (the first being centered around 306Ubb , with 122 protons and 184 neutrons) .

= = History = =

The elements of group 12 have been found throughout history , being used since ancient times to being discovered in laboratories . The group itself has not acquired a trivial name , but it has been called group IIB in the past .

= = = Zinc = = =

Zinc has been found being used in impure forms in ancient times as well as in alloys such as brass that have been found to be over 2000 years old . Zinc was distinctly recognized as a metal under the designation of Fasada in the medical Lexicon ascribed to the Hindu king Madanapala and written about the year 1374 . The metal was also of use to alchemists . The name of the metal was first documented in the 16th century , and is probably derived from the German zinke for the needle @-@ like appearance of metallic crystals .
The isolation of metallic zinc in the West may have been achieved independently by several people in the 17th century . German chemist Andreas Marggraf is usually given credit for discovering pure metallic zinc in a 1746 experiment by heating a mixture of calamine and charcoal in a closed vessel without copper to obtain a metal . Experiments on frogs by the Italian doctor Luigi Galvani in 1780 with brass paved the way for the discovery of electrical batteries , galvanization and cathodic protection . In 1880 , Galvani 's friend , Alessandro Volta , invented the Voltaic pile . The biological importance of zinc was not discovered until 1940 when carbonic anhydrase , an enzyme that scrubs carbon dioxide from blood , was shown to have zinc in its active site .

= = = Cadmium = = =

In 1817 , cadmium was discovered in Germany as an impurity in zinc carbonate minerals (calamine) by Friedrich Stromeyer and Karl Samuel Leberecht Hermann . It was named after the Latin cadmia for " calamine " , a cadmium @-@ bearing mixture of minerals , which was in turn named after the Greek mythological character , ?????? Cadmus , the founder of Thebes . Stromeyer eventually isolated cadmium metal by roasting and reduction of the sulfide .
In 1927 , the International Conference on Weights and Measures redefined the meter in terms of a red cadmium spectral line (1 m = 1 @,@ 553 @,@ 164 @.@ 13 wavelengths) . This definition has since been changed (see krypton) . At the same time , the International Prototype Meter was used as standard for the length of a meter until 1960 , when at the General Conference on Weights and Measures the meter was defined in terms of the orange @-@ red emission line in the electromagnetic spectrum of the krypton @-@ 86 atom in vacuum .

= = = Mercury = = =

Mercury has been found in Egyptian tombs which have been dated back to 1500 BC , where mercury was used in cosmetics . It was also used by the ancient Chinese who believed it would improve and prolong health . By 500 BC mercury was used to make amalgams (Medieval Latin amalgama , " alloy of mercury ") with other metals . Alchemists thought of mercury as the First Matter from which all metals were formed . They believed that different metals could be produced by varying the quality and quantity of sulfur contained within the mercury . The purest of these was gold , and mercury was called for in attempts at the transmutation of base (or impure) metals into gold , which was the goal of many alchemists .