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Aluminium chloride is ionic or covalent

Why is Anhydrous Aluminum Chloride a Covalently Bonded Dimer The fast technique for identification of the chemical bond type of a substance is by identifying the nature of the component particles. When a compound is formed between a metal and a nonmetal, it generally has an ionic bond, where electrons are transferred from metal to nonmetal in accordance with the octet rule. On the other hand, when nonmetals formed a compound, they share electrons forming a covalent bond. Taking anhydrous aluminum chloride, $AlCl_3$ for instance, Aluminum is a metal and Chlorine is a nonmetal, by nature they should have formed an ionic compound. This basic concept however is not true with anhydrous aluminum chloride. Instead it has both an ionic and molecular character. In fact its ionic character is very weak such that at relatively low temperature of 180oC, it sublimes (directly changing from solid to gas phase). If the pressure is raised to just over 2 atmospheres, it melts instead at a temperature of 192C.These characteristics are indirect evidence of weak intermolecular forces between the molecules and therefore, the compound is covalent. In the vapor phase, $AlCl_3$ does not exist. In its place is a dimer (two molecules joined together), Al_2Cl_6 as shown and measured by its molecular mass. The molecular structure is formed when "one chlorine atom on each $AlCl_3$ unit donates both electrons from one of its lone pairs to form a new shared electron pair with the aluminum atom from the other unit. This completes a stable octet for the aluminum. And the two chlorines involved become bridging atoms that join the two $AlCl_3$ units into a single Al_2Cl_6 molecule. The two linking bonds are what we call co-ordinate bonds" (Christie, 2001). Once a co-ordinate bond is formed it cannot be distinguished from a normal covalent bond.Why is anhydrous aluminum chloride a covalently bonded dimer One major reason is stability. "Energy is released when the two co-ordinate bonds are formed, and so the dimer is more stable than two separate $AlCl_3$ molecules" (. Another reason is the size of the highly charged aluminum ion, Al^{3+}. The Al^{3+} ion has a large charge to size ratio. It attracts electrons so strongly that aluminium chloride is a covalent molecule. This large charge is due to higher ionic potentials caused by the inability of the d electrons to shield the nucleus very effectively. Electronegativity also is a factor of the occurrence of the covalent character. Electronegativity increases as you go across the period and, by the time you get to aluminum, there isn't enough electronegativity difference between aluminum and chlorine for there to be a simple ionic bond (Clark, 2003). These, among others explains why at room temperature solid aluminum chloride has an ionic lattice with a lot of covalent character and why its dimmers becomes coordinately, covalently bonded. Works CitedChristie, John.(2001). Re: are there coordinate ionic bonds Posted September 17 20:48:54 2001 Retrieved: December 6, 2007 at Clark, Jim. (2003). Properties of the period 3 chlorides. Retrieved: December 6, 2007 at Hello student, last class we did Chemical Laws And Its Calculations our topic for today is Chemical Bonding Of Ionic And Covalent bonds, that is, I'm going to explain how Ionic bonds are formed and also how Covalent bonds are formed, so let not waste time and get to it – Chemical Bonding Of Ionic And Covalent bonds. Chemical Bonding Of Ionic And Covalent bonds Observe the table below; The table above is called the periodic table Note : Today's topic is based on chemical combination and bonding not periodic table. In the table above, all other elements except group 8 elements try to attain the structure of a stable octet or duplet electrons (rules), although we are discussing about chemical bonding of ionic and covalent bonds today. Brief : Group 8 (rare or noble gases) are chemical unreacted because they already have 8 electrons in their outermost shell and chemical reaction is based on the concept of electron sharing. I'll explain better when we get to periodic table. Atoms of an element combine with one another in various ways and this combination are called bonding. Chemical bonding of ionic and covalent bonds There are many different types of bonding of which covalent bonding, electrovalent or ionic bonding, co-ordinate covalency or co-ionic bonding, hydrogen bonding, metallic bonding and van der waal's force. Let analyze covalent and ionic bonding today and probably other bonding next class. Ionic Or Electrovalent Bonding Ionic or electrovalent bonding is the type of chemical bonding between metal and non-metal and the most important principle in ionic bond is that, it's a donor-acceptor principle in which there is a complete electron transfer and the atoms formed are usually present as ions. During ionic bonding, the donor atom is usually a metal of relatively big size and the acceptor atom is usually a non-metal and relatively small size. During the bonding, an atom of a metallic element or group loses electrons from its outermost shells. The number of electrons is equal to number of its valency to attain a stable configuration and then becomes positively charged ion which is known as cations. I believed I have explained how to write a chemical configuration for elements and also discussed about auf bau principle during our class session on Atoms And Molecules Let look at the formation of sodium chloride as ionic bonding example Sodium (Na) and Chlorine (Cl) Na — e- → Na^+ The non-metallic atom gain the electron lost by the metallic atom and become negatively charged, this negatively charged ion is called acceptor or anions. Cl + e- → Cl^- Hence, Na^+ + Cl^- → NaCl The sodium chloride compound formed crystallizes as a face-cented cube. In the end face of the cube, Na^+ ion is found to occupy the center, and the four corners of the face are also occupied by Na^+ ions with four Cl^- ions spaced equally between them. During the process, the only movement or motion is vibration. When the two atoms I.e Na & Cl bonded, the solid appears to be rigid and has a negligible electrical conductivity. Note : The attraction between sodium ion and chloride ion is electrostatic attraction (please note this) Another example of electrovalent or ionic bonding is calcium chloride. Before combination (bonding), calcium has 20 proton(atomic mass) I.e 20 electrons with electronic configuration of 2,8,8,2. And chlorine has 17 proton (atomic mass) I.e 17 electrons with electronic configuration of 2,8,7. Calcium (Ca) has 2 electrons in its outermost shell and chlorine has 7 electrons in its outermost shell. That means, Calcium is looking for 6 electrons and chlorine is looking for one electron to obey octet rule. In order for bonding to take place, the two valency of calcium will be transferred to chlorine atoms so that chlorine can also obey octet rule. When this happens, the two elements becomes bonded together. Other examples of ionic bonding is calcium oxide (CaO), Potassium chloride (KCl), just have it in mind that ionic bonding occurs between metal and non-metal and make sure you note the special note below Please Note Like I said above, ionic or electrovalent bonding occurs in metals and non-metals, but not in Aluminium Chloride ($AlCl_3$), the bond between Aluminium chloride is covalent bonding not ionic or electrovalent bonding. Yes aluminum is a metal and chlorine is a non-metal, but have you also forget that aluminum is an element of semiconductor, that is under physics, let just agree in chemistry that aluminium is a semi-metal. You will know more on types of elements and groups when get to periodic table. But please note what is above, the bond between Aluminium and Chlorine to form Aluminium Chloride ($AlCl_3$) is covalent bond not ionic bond They also ask this question that, what is the bond between semiconductors? Send me a private message with your answer and explanation. Please don't ask other candidates in your group or forum, think first !!!, and also, whenever you are ask to answer a question, don't just open your browser tab and start Google searching, first go through your textbooks and lesson note. Please, it's for your own good. It's like the same reason your english teacher always tells you not to refer to dictionary as your first thought to finding the meaning of words but instead use the environment. For new candidates that doesn't know, what I meant by "send me a private message and to not ask others", just register and you will be able to add other candidates as a friends including the tutors, it's really fun, try it out and see, so let continue with today's class session – Chemical Bonding Of Ionic And Covalent bonds. So where are we? Yeah characteristics of ionic bonding. Characteristics Or Properties Of Electrovalent Or Ionic Compound (Bonding) a] Ionic or electrovalent compounds form ions in water, meaning they do not contain molecules b] Since they dissolve or dissociate in water to form ions, hence, they conduct electricity. c] Ionic or electrovalent compounds have high melting and high boiling point. d] Ionic compounds occur mainly in inorganic compounds. Hence, they do not dissolve in organic solvents such as benzene, phenymetane, ether, toluene, etc. Do you know what ether is? I can't wait for us to get to organic
chemistry. But have it in mind that esther is different from ether. Covalent Bond Covalent bonding are bonding between relatively small size elements, with the main principle of sharing electrons between atoms such that each of the atoms in the molecules has the electron arrangement of noble gases. The two main atoms (elements) involved in covalent bonding are always small. For example Chlorine (Cl) When two atoms of chlorine combine together to form chlorine gas (Cl_2), both chlorine are relatively small in size with electronic configuration of 2, 8, 7. Note : In covalent bonding, the atoms contribute one electron each to a shared-pair and molecules are produced not ions. During covalent bonding, the electron clouds overlap. the two clouds containing one electron each overlap to form a single cloud between the atoms. Other examples are: hydrogen gas (H_2), Water (H_2O), Ammonia (NH_3), Methane (CH_4), etc. Should we look at their structure? Yes, we should. Hydrogen Gas Structure Hydrogen gas (H_2) is a diatomic compound. That is, hydrogen gas contains 2 atoms. There is a single covalent bond between the atoms. Below is the formation of hydrogen gas. Methane Structure From the above image, the shared electrons are displayed towards the carbon, there are no lone pairs and the molecule is tetrahedral in shape. Brief : Shape Of Molecules a] Methane (CH_4) is tetrahedral in shape b] Water (H_2O) is bent (letter V) in shape. c] Carbon (iv) oxide (CO_2) is linear (straight) in shape. d] Ammonia (NH_3) is asymmetric in shape. Structure Of Water 1] Water (H_2O) has eight protons in the nucleus compared with one in the hydrogen nucleus 2] Water has two lone pairs of electrons. I believed I have explain what a lone pair is during our class session on atoms and molecules. 3] Water molecules are bent in shape. Structure Of Ammonia 1] Nitrogen has seven protons in the nucleus compared with one in the hydrogen nucleus. 2] Nitrogen has one lone pair of electrons. 3] Ammonia molecule is asymmetric in shape. Characteristics Or Properties Of Covalent Compounds (Bonding) a] Covalent compounds molecules does not form ions in solution, I.e they do not dissociate in water to form ions. b] Because of the characteristic above, covalent compounds do not conduct electricity, hence. They are non-electrolyte. Brief : meaning that, all compounds, substances or elements that dissociate in water to form ions conduct electricity. c] Covalent bonding occur mainly in organic compounds, meaning that, they are soluble in organic solvents for example, benzene can dissolves in camphor and carbon disulphide can dissolves in sulphur d] Covalent compounds has low melting and boiling point. Differences Between Ionic And Covalent Bond a] Ionic bonding is based on the principle of transferring of electrons while Covalent bonding is based on the principle of sharing of electrons. b] Ionic bonding occur mainly between relatively big size and small size elements while Covalent bonding occur mainly between relatively small size elements. c] Ionic bonding occur between metal and non-metal except in aluminium chloride [$AlCl_3$] while Covalent bonding occur between non-metal and non-metal. d] Ionic bonding compounds are inorganic, I.e the cannot dissolve in organic solvents such as benzene while Covalent bonding compounds are organic, I.e the can dissolve in organic solvents such as benzene. e] Ionic bonding compounds dissolves or dissociate in water to form ions, I.e they conduct electricity when dissolves in water (that why they are used as an electrolyte) while Covalent bonding compounds does not dissolves or dissociate in water to form ions but to form molecules, I.e they can or do not conduct electricity when dissolves in water (that is why they are used as non-electrolyte). f] Ionic bonding compounds have high melting and boiling points while Covalent bonding compounds have low melting and boiling points. That all on chemical bonding of ionic and covalent bonds. Next Topic : Co-ordinate Or Co-ionic And Metallic Bonding Feel free to ask our tutors any question Chemical Bonding Of Ionic And Covalent bonds via the comment box or use our ask question page and we will be happy to answer your question and take the session again if necessary, your comment notifications is a motivation to us, so don't forget to write something. Our Contact Page or will you like to know more About Our Tutors, while browsing this website we believed that you have read and agree to our privacy policy and disclaimer and also don't forget that there is love in sharing, so don't forget to share. This page discusses the structures of the chlorides of the Period 3 elements (sodium to sulfur), their physical properties and their reactions with water. Chlorine and argon are omitted—chlorine because it is meaningless to talk about "chlorine chloride", and argon because it is inert and does not form a chloride. The chlorides of interest are given in the table below: NaCl $MgCl_2$ $AlCl_3$ $SiCl_4$ PCl_5 S_2Cl_2 PCl_3 Sulfur forms three chlorides, but S_2Cl_2 is most common. Aluminum chloride also exists under some conditions as a dimer, Al_2Cl_6. The structures: Sodium chloride and magnesium chloride are ionic and consist of large ionic lattices at room temperature. Aluminum chloride and phosphorus(V) chloride are more complicated. They change their structures from ionic to covalent as their solids transition to liquids or vapors. This is discussed in greater detail below. The other chlorides are simple covalent molecules. Melting and boiling points: Sodium and magnesium chlorides are solids with high melting and boiling points because of the large amount of heat which is needed to break the strong ionic attractions. The rest are liquids or low melting point solids. Leaving aside the aluminum chloride and phosphorus(V) chloride cases where the situation is quite complicated, the attractions in the others will be much weaker intermolecular forces such as van der Waals dispersion forces. These vary depending on the size and shape of the molecule, but will always be far weaker than ionic bonds. Electrical conductivity: Sodium and magnesium chlorides are ionic and so will undergo electrolysis when they are molten. Electricity is carried by the movement of the ions and their discharge at the electrodes (not electrons). In the aluminum chloride and phosphorus(V) chloride cases, the solid does not conduct electricity because the ions aren't free to move. In the liquid (where it exists - both of these sublime at ordinary pressures), they have converted into a covalent form, and so don't conduct either. The rest of the chlorides do not conduct electricity either solid or molten because they don't have any ions or any mobile electrons. Reactions with water: As an approximation, the simple ionic chlorides (sodium and magnesium chloride) just dissolve in water. Although other chlorides all react with water in a variety of ways described below for each individual chloride. The reaction with water is known as hydrolysis. Sodium chloride is an ionic compound consisting of a giant array of sodium and chloride ions. A small representative portion of a sodium chloride lattice looks like this: This is normally drawn in an exploded form as: The strong attractions between the positive and negative ions require a large amount of heat energy to break, so sodium chloride has high melting and boiling points. The compound does not conduct electricity in the solid state because it has no mobile electrons, and the ions are constrained by the crystal lattice. However, when it melts it undergoes electrolysis. Sodium chloride dissolves in water to give a neutral solution. Like sodium chloride, magnesium chloride also forms an ionic solid, but with a more complicated crystal structure of the ions to accommodate twice as many chloride ions as magnesium ions. As with sodium chloride, large amounts of heat energy are needed to overcome the attractions between the ions (because of the high lattice enthalpy of the compound), so the melting and boiling points are also high. Solid magnesium chloride is a non-conductor of electricity because the ions are constrained. However, upon melting, the compound undergoes electrolysis. Magnesium chloride dissolves in water to give a slightly acidic solution (with a pH of approximately 6). When magnesium ions are solvated from the solid lattice, there is enough attraction between the 2+ ions and the water molecules to form coordinate (dative covalent) bonds between the magnesium ions and lone pairs on surrounding water molecules. Hexaaquamagnesium complex ions are formed, $[Mg(H_2O)_6]^{2+}$, as follows: $MgCl_{2 (s)} + 6H_2O \rightarrow [Mg(H_2O)_6]^{2+}_{(aq)} + 2Cl^-_{(aq)}$ Many complex ions are acidic, the degree of acidity depending on the attraction between the electrons in the water molecules and the metal at the center of the ion. The hydrogen atoms carry less electron density in this state, and are thus more easily removed by a base. For magnesium, the amount of distortion is quite small, and only a small proportion of the hydrogen atoms are removed, in this case by water molecules in the solution: $[Mg(H_2O)_6]^{2+} + H_2O_{(l)} \rightleftharpoons [Mg(H_2O)_5(OH)^{2+}]^+ +H_3O^+_{(aq)}$ The hydronium ions make the solution acidic. Few are formed (the equilibrium lies well to the left) because the solution is only weakly acidic. The previous equation can be simplified as follows: $[Mg(H_2O)^6]^{2+}_{(aq)} \rightleftharpoons [Mg(H_2O)_5(OH)]^+_{(aq)} + H^+_{(aq)}$ It is essential to include the state symbols if the equation is written this way. Electronegativity increases across the period; aluminum and chlorine do not differ enough in electronegativity to form a simple ionic bond. The structure of aluminum chloride changes with temperature. At room temperature, the aluminum is 6-coordinated (i.e. each aluminum is surrounded by 6 chlorine atoms). The structure is an ionic lattice, but it has a lot of covalent character. At atmospheric pressure, aluminum chloride sublimes at about 180°C. If the pressure is increased to just over 2 atmospheres, it melts instead at a temperature of 192°C. Both of these temperatures are far below the expected range for an ionic compound. They suggest comparatively weak attractions between molecules instead of strong attractions between ions. This is because the coordination of the aluminum changes at these temperatures. It becomes 4-coordinated—each aluminum is surrounded by 4 chlorine atoms rather than 6. The original lattice converts into an Al_2Cl_6 arrangement of molecules. The structure is shown below: In the conversion, all ionic character is lost, causing the aluminum chloride to vaporize or melt (depending on the pressure). These dimers and simple $AlCl_3$ molecules exist in equilibrium. As the temperature increases further, the position of equilibrium shifts more and more to the right of the following system: $Al_2Cl_6 \rightleftharpoons 2AlCl_3$ At room temperature, solid aluminum chloride has an ionic lattice with significant of covalent character. At temperatures around 180 - 190°C (depending on the pressure), aluminum chloride coverts to its molecular form, Al_2Cl_6. This causes it to melt or vaporize due to comparatively weak intermolecular attractions. As the temperature increases further, more $AlCl_3$ molecules are formed. Solid aluminum chloride does not conduct electricity at room temperature because the ions are not free to move. Molten aluminum chloride (only possible at increased pressures) is also nonconductive, because it has lost its ionic character. Aluminum chloride reacts dramatically with water. A drop of water placed onto solid aluminum chloride produces steamy clouds of hydrogen chloride gas. Solid aluminum chloride in an excess of water still splutters, but instead an acidic solution is formed. A solution of aluminum chloride of ordinary concentrations (around 1 mol dm^{-3}, for example) has a pH around 2-3. More concentrated solutions have a lower pH. The aluminum chloride reacts with the water rather than simply dissolving in it. In the first instance, hexaaquaaluminum complex ions and chloride ions are formed: $AlCl_3 (s) + 6H_2O (l) \rightarrow [Al(H_2O)_6]^{3+} (aq) + 3Cl^- (aq)$ This is very similar to the magnesium chloride equation given above—the only difference is the charge on the ion. The greater charge attracts electrons in the water molecules quite strongly toward the aluminum, making the hydrogen atoms more positive and therefore easier to remove from the ion. Hence, this ion is much more acidic than in the corresponding magnesium case. The acid-base equilibria for this reaction lie further to the right than those for magnesium, and so the solution formed is more acidic—more hydronium ions are formed, as shown: $[Al(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H_3O^+$ or, more simply: $[Al(H_2O)_6]^{3+} (aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} (aq) + H^+$ If there is little water present, hydrogen chloride gas is produced. Because of the heat produced in the reaction and the concentration of the solution formed, hydrogen ions and chloride ions in the mixture combine together as hydrogen chloride (HCl) molecules and are given off as a gas. In a large excess of water, the temperature is never high enough for this to happen; the ions remain solvated. Silicon tetrachloride is a simple no-messing-about covalent chloride. There isn't enough electronegativity difference between the silicon and the chlorine for the two to form ionic bonds. Silicon tetrachloride is a colorless liquid at room temperature which fumes in moist air. The only attractions between the molecules are van der Waals dispersion forces. It doesn't conduct electricity because of the lack of ions or mobile electrons. It fumes in moist air because it reacts with water in the air to produce hydrogen chloride. If you add water to silicon tetrachloride, there is a violent reaction to produce silicon dioxide and fumes of hydrogen chloride. In a large excess of water, the hydrogen chloride will, of course, dissolve to give a strongly acidic solution containing hydrochloric acid. $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ There are two phosphorus chlorides: phosphorus(III) chloride, PCl_3, and phosphorus(V) chloride, PCl_5. This simple covalent chloride exists as a fuming liquid at room temperature because there are only van der Waals dispersion forces and dipole-dipole attractions between the molecules. The liquid does not conduct electricity because of the lack of ions or mobile electrons. Phosphorus(III) chloride reacts violently with water to generate phosphorous acid, H_3PO_3, and hydrogen chloride fumes (or a solution containing hydrochloric acid in excess of water): $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$ Phosphorus(V) chloride is structurally more complicated than phosphorus(III) chloride. At room temperature, it forms a white solid which sublimes at 163°C. Increasing the temperature beyond its sublimation point dissociates (divides reversibly) more the phosphorus(V) chloride into phosphorus(III) chloride and chlorine: $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ Phosphorus(V) chloride is an ionic solid. The formation of the ions involves two molecules of PCl_5. A chloride ion transfers from one of the original molecules to the other, leaving a positive ion, $[PCl_4]^+$, and a negative ion, $[PCl_6]^-$. At 163°C, the phosphorus(V) chloride converts to a molecular form containing PCl_5 molecules. Because only van der Waals dispersion forces exist between these molecules, the species vaporizes. Solid phosphorus(V) chloride does not conduct electricity. Phosphorus(V) chloride reacts violently with water, producing hydrogen chloride fumes. As with the other covalent chlorides, if there is enough water present, these dissolve to give a hydrochloric acid solution. The reaction happens in two stages. The first takes place in cold water; phosphorus oxychloride, $POCl_3$, is produced along with HCl: $PCl_5 + 4H_2O \rightarrow POCl_3 + 2HCl$ As the solution is brought to a boil, the phosphorus(V) chloride reacts further to give phosphoric(V) acid and more HCl. Phosphoric(V) acid is also known as phosphoric acid or as orthophosphoric acid: $POCl_3 + 3H_2O \rightarrow H_3PO_4 + 3HCl$ Combining these equations gives the overall reaction in boiling water: $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ Disulfur dichloride is one of three sulfur chlorides and is the species formed when chlorine reacts with hot sulfur. Disulfur dichloride is an orange, unpleasant-smelling covalent liquid. Its rather unusual structure is given below: The molecule's conformation indicates its possible intermolecular interactions: There is no plane of symmetry in the molecule; therefore, it has an overall permanent dipole. In liquid state, the molecule experiences van der Waals dispersion forces and dipole-dipole attractions. There are no ions in disulfur dichloride and no mobile electrons, making it nonconductive. Disulfur dichloride reacts slowly with water to produce a complex mixture of hydrochloric acid, sulfur, hydrogen sulfide and various sulfur-containing acids and anions. Jim Clark (Chemguide.co.uk)