Properties of alcohols and ethers

Alcohols are organic compounds in which a hydrogen atom of an aliftic carbon is replaced by a hydroxyl group. Thus, an alcohol molecule consists of two parts; one containing the alkyl group and the other containing functional hydroxyl group. They have a sweet smell. They have a unique set of physical and chemical properties. The physical and chemical properties of alcohols are mainly due to the presence of the hydroxyl group. Recommended videos Some prominent physical and chemical properties of alcohol are given below. Physical properties of alcohol 1. The Boiling Point of Alcohols generally have higher boiling points compared to other hydrocarbons that have equal molecular masses. This is due to the presence of intermolecular hydrogen binding between hydroxyl groups of alcohol molecules. In general, the boiling point of alcohols increases with an increase in the number of carbon atoms in the alias carbon chain. On the other hand, the boiling point decreases with an increase in the branching in the alphatic carbon chains that van der Waals forces decrease with a decrease in the surface. Thus, primary alcohols have a higher boiling point. Solubility of Alcohols The solubility of alcohol in water is governed by the present hydroxyl group. The hydroxyl group in alcohol is involved in the formation of intermolecular hydrogen binding. Thus, hydrogen bonds are formed between water and alcohol molecules that make alcohol soluble in water. However, the alkyl group attached to the hydroxyl group is of a hydrophobic nature. Thus, the solubility of alcohol decreases with the increase in the size of the alkyl group. 3. The acidity of alcoholic alcohols reacts with active metals such as sodium, potassium, etc. to form the corresponding alkoxide. These reactions of alcohol indicate their acidic nature. The acidic nature of alcohol is due to the polarity of –OH bond. The acidity of alcohol decreases when a group of electron donation joins the hydroxyl group as the density of electrons in the oxygen atom increases. Therefore, primary alcohols are generally more acidic than secondary and tertiary alcohols. Due to the presence of unshared electrons in the oxygen atom, alcohols act as bronsted bases as well. The chemical properties of alcoholic alcohols present a wide range of spontaneous chemical reactions due to the neckline of the C-O bond and the O-H link. Some prominent chemical reactions of alcohols are: 1. Oxidation of alcohol alcohol are subjected to oxidation in the presence of an oxidizing agent to produce aldehydes and ketones that after oxidation give carboxylic acids. Alcohols: Physical and chemical properties 2. Dehydration of alcohol After treatment with protic acids, alcohols undergo dehydration (removal of a water molecule) to form alkenes. Alcohol Dehydration For detailed on the physical and chemical properties of alcohols, download Byju's- The Learning App. The graph below shows the boiling points of the following alcohols with up to 4 carbon atoms: These boiling points are compared to those of the equivalent Alkanes (methane to butane) with the same number of carbon atoms. Note that: The boiling point of an alcohol is always significantly higher than that of the analogous alcane. Boiling points of alcohol increase as the number of carbon atoms increases. The patterns at the boiling point reflect the patterns in the intermolecular attractions. The union of hydrogen occurs between molecules in which a hydrogen atom binds to a heavily electron element: fluoride, oxygen or nitrogen. In the case of alcohols, hydrogen bonds occur between partially positive hydrogen atoms and solitary pairs in oxygen atoms of other molecules. Hydrogen atoms are slightly positive because binding electrons are pulled towards very electronegative oxygen atoms. In Alkanes, the only intermolecular forces are the dispersal forces of van der Waals. Hydrogen bonds are much stronger than these, and therefore more energy is needed to separate molecules from alcohol than to separate Alcan molecules. This is the main reason for higher boiling points in alcohols. Boiling points of alcohols: Hydrogen binding is not the only experience of intermolecular force alcohols. There are also van der Waals dispersal forces and dipole-dipole interactions. Hydrogen binding and dipol interactions are much the same for all alcohols, but dispersal forces increase as alcohols get older. These attractions get stronger as the molecules get longer and have more electrons. This increases the sizes of the temporary dipoles formed. That's why boiling points increase as the number of carbon atoms in chains increases. More energy is needed to overcome dispersal forces, and therefore boiling points increase. Comparison between alkanes and alcohols: Even without any hydrogen binding or dipol interactions, the boiling point of alcohol would be higher than the corresponding alkanes with the same number of carbon atoms. Compare ethanol and ethanol: ethanol is a longer molecule, and the oxygen atom carries an extra 8 electrons. Both increase the size of van der Waals dispersal forces, and then boiling point. A more accurate measure of the effect of hydrogen binding at boiling point would be a comparison of ethanol with propan instead of ethanol. The lengths of the two molecules are more similar, and the number of electrons is exactly the same. Small alcohols are completely soluble in water; mixing the two in any proportion generates a single solution. However, solubility decreases as the length of the hydrocarbon chain increases in alcohol. At four carbon atoms and beyond, the decrease in it is noticeable; a two-layers substance can appear in a test tube when the two mix. Consider ethanol as a typical small alcohol. In both pure water and pure ethanol, the main intermolecular attractions are hydrogen hydrogen To mix the two, hydrogen bonds between water molecules and hydrogen bonds between ethanol molecules must be broken. Energy is required for both processes. However, when molecules mix, new hydrogen bonds are formed between water molecules and ethanol molecules. The energy released when these new hydrogen bonds are formed roughly offsets the energy needed to break the original interactions. In addition, there is an increase in system disorder, an increase in entropy. This is another factor when deciding whether chemical processes occur. Think of a hypothetical situation involving 5-carbon alcohol molecules. Hydrocarbon chains are forced between water molecules, breaking hydrogen bonds between these water molecules. The -OH ends of alcohol molecules can form new hydrogen bonds with water molecules, but the hydrocarbon tail does not form hydrogen bonds. This means that many of the original hydrogen links that are broken are never replaced by new ones. Instead of these original hydrogen bonds are simply van der Waals forces of dispersion between water and hydrocarbons tails. These attractions are much weaker, and can't provide enough energy to compensate for broken hydrogen bonds. Even allowing the increase of the disorder, the process becomes less feasible. As the length of alcohol increases, this situation becomes more pronounced, and therefore solubility decreases. Ether molecules have no hydrogen atom in the oxygen atom (i.e. no oh group). Therefore, there is no intermolecular binding of hydrogen between ether molecules, and ethers, therefore, have quite low boiling points for a given molar mass. In fact, ethers have boiling points roughly the same as those of comparable molar dough alkanes and much lower than those of the corresponding alcohols (Table 14.4 Comparison of boiling points in Alcanes, Alcohols and Ethers). Table 14.4 Comparison of boiling points of alcanes, alcohols and condensed ethers Structural formula name molar mass boiling point (°C) Intermolecular union of hydrogen in pure liquid? PROPANE CH3CH2CH3 44 –42 no CH3OCH3 dimetile ether 46 –25 no CH3CH2OH thylic alcohol 46 78 yes CH3CH2CH2CH2CH3 pentane 46 – 25 no CH3CH2OH thylic alcohol 46 78 yes CH3CH2CH2CH2CH3 pentane 46 46 78 yes CH3CH2CH2CH2CH3 pentane 46 78 yes CH3CH2CH2CH2CH3 pentane 46 72 36 no CH3CH2OCH2CH3 eryl ether 74 35 no CH3CH2CH2CH2OH butyl alcohol 74 117 Yes ether molecules do have an oxygen atom , however, and participate in the union of hydrogen with water molecules. Consequently, an ether has about the same solubility in water as the alcohol that is isomeric with it. For example, dimethyl ether and ethanol (both with molecular formula C2H6O) are completely water soluble, while the ether dimetil and 1-butanol C4H10O) are barely water soluble (8 g/100 mL of water). Collaborators Jim Clark (Chemguide.co.uk) Physical properties: Solubility in waterAlcohols are water soluble. This is due to the hydroxyl group in alcohol that is able to form hydrogen bonds with water molecules. Alcohols with a smaller chain of hydrocarbons very soluble. As the length of the hydrocarbon chain increases, the solubility of water decreases. With four carbon in the hydrocarbon chain and higher, the decrease in solubility becomes visible as the mixture forms two immiscible layers of liquid. The reason solubility decreases as the length of the hydrocarbon chain increases is because more energy is required to overcome hydrogen bonds between alcohol molecules as molecules are more closely packed as size and mass increases. In the image above, the partially negative oxygen atom of the ethanol molecule forms a hydrogen bond with the partially positive hydrogen atom in the water molecule. Boiling point This graph shows the comparison of methane boiling points with methanol, ethanol with ethanol, propane with propane, and butane with butanol. From the graph we can see that the boiling point of an alcohol is always much higher than the boiling point of the corresponding alcanes with the same chain of hydrocarbons. The boiling point of alcohols also increases as the length of the hydrocarbon chain increases. The reason alcohols have a higher boiling point than alkanes is because the intermolecular forces of alcohols are hydrogen bonds, unlike alkans with van der Waals forces as their intermolecular forces. The following image shows ethanol molecules with a hydrogen link. Alcohols are converted from liquid to solid at room temperature and pressure (rtp) as the length of the hydrocarbon chain increases in alcohol. The boiling points of the first 11 alcohols are as follows: The factors affecting boiling/melting alcohols are not only hydrogen bonds, but also van der Waals dispersion forces and dipole-dipole interactions. Hydrogen bonds and dipol interactions will remain relatively the same throughout the alcohol series. Van der Waals dispersal forces increase as the length of the hydrocarbon chain increases. This is due to the increase in the number of electrons in the molecules, which in turn increases the strength and size of the temporarily induced dipol-dipol attraction. Therefore, more energy is required to overcome intermolecular forces, resulting in increased boiling/melting points. ViscosityViscosity is owned by a fluid that resists force tending to cause fluid to flow. The viscosity of alcohols increases as the size of molecules increases. This is because the strength of intermolecular forces increases, keeping the molecules more firmly in place. PolarityAmide > Acid > Alcohol > Ketone ~ Aldehyde > Amine > Ester > Ether > AlkaneAmide is the most polar while alkane is the least. Alcohol ranks third in terms of polarity due to their hydrogen binding capabilities and the presence of an oxygen atom in an alcohol molecule. Carboxylic acids are more polar than alcohols because there are two oxygen atoms present in a carboxylic acid molecule. Flammability Alcohol inflammation decreases as the size and mass of the Increases. Combustion breaks down the covalent bonds of molecules, so as the size and mass of molecules increases, there are more covalent bonds to break down to burn this alcohol. Therefore, more energy is required to break the bonds, therefore, the flammability of alcohol decreases as the size and mass of molecules increases. Chemical properties: CombustionAlcohols burns in oxygen to produce carbon dioxide and water. Alcohols burn cleanly and easily, and do not produce sutge. It is becoming increasingly difficult to burn alcohols as the molecules get bigger. The general molecular equation of the reaction is: CnH2n+1OH + (1.5n)O2 → (n+1)H2O + nCO2e.g. ethanol combustion: C2H5OH(l) + 3 O2 (g) → 2 CO2 (g) + 3 H2O (g); (ΔHc = −1371 kJ/mol) Dehydration - alcohol in alkeneDehydration of alcohols is done by heating with concentrated sulphuric acid, which acts as the dehydrating agent, at 180 °C. This reaction uses alcohol to produce corresponding alkenes and water as a byproduct. Dehydration of ethanol: Oxidation - alcohol to carboxylic acidAlcohols can be oxidized in carboxylic acids. for example, ethanol oxidation: C2H5OH + [O] → CH3COOH + H2O oxidation can be done by using oxidizing agents such as acidified potassium dicromat (VI), acidified potassium manganate (VII)...... or atmospheric oxygen. Ethanol, if left exposed to the air, can oxidize and become ethanol acid. An example is the wine that becomes sour, since the alcohol content, which is ethanol, is oxidized by atmospheric oxygen. SterilizationAlcohols can react with carboxylic acid to form esters. More of this will be explained under the formation of ester esters