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The Chemistry of Digestion

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THE CHEMISTRY OF DIGESTION

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PREFACE

Many high school chemistry texts present organic chemistry by covering the main topics from many different fields. Treatment in this manner tends to cover a large field, but many of the basic fundamentals are passed over lightly. It is felt that by teaching organic chemistry based on the chemistry of digestion that a more inspiring approach can be achieved.

Chemistry taught in this manner has been used in a physical science course at Eastern Illinois State College very successfully for the past five years.

This paper adapts the same approach to high school chemistry. This material was used in a chemistry course in 1954 at Pleasant Hill high school. It is felt that the results indicate its success also on the high school level.

CONTENTS

ORGANIC CHEMISTRY

What is organic chemistry?

Organic chemistry deals with the study of the properties and reactions of all compounds containing carbon. The number of these compounds is very large. More than seven hundred thousand different compounds have been isolated and new ones are produced from plant and animal products that were formerly regarded as wastes.

The human body is composed principally of organic compounds, minerals and water. Most of our foods are organic compounds. The digestion of these foods by the body involve reactions of organic compounds. To have an understanding of the chemistry of digestion it will be necessary to understand the basic principles of organic chemistry.

The properties, and the great number, of carbon compounds make it convenient to set aside organic chemistry as a separate course of study. Because of their properties, special laboratory techniques are required for handling these compounds. Almost all organic compounds are combustible, and many are very inflammable. At room temperatures, most organic compounds are very unreactive. This property enables us to use oil in preventing the rusting of metal tools. Most organic compounds, in comparison to inorganic compounds, react at a very slow speed, some requiring many hours, even with selected catalysts and high temperatures, to react.

This difference in speed of reaction arises from the fact that organic chemistry deals with molecules that are unionized or only partially ionized. This characteristic is due to the covalent bonds of most organic compounds.

What are covalent bonds?

Atoms in order to form the valence shell of an inert gas can share electrons. This results in the formation of covalent linkages or bonds. In the simplest possible instance, two hydrogen atoms can pool their lone electrons in forming the hydrogen molecule.

$$H^{\circ} + H^{\circ} \longrightarrow H{:}H$$

By sharing electrons each hydrogen atom acquires a helium shell of two and a stable molecule is formed. They are held together in a molecule through attraction for and by the shared pair of electrons.

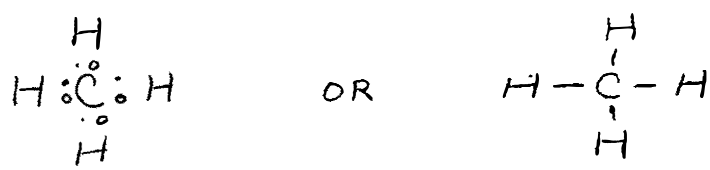
Electron sharing is of fundamental importance in organic chemistry because it is the process by which carbon regularly enters into chemical combination. The atom of carbon has four valence electrons and in almost all carbon compounds, carbon will complete its outer orbit by forming four covalent bonds.

Chapter I

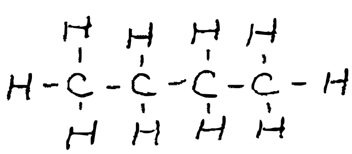
What are hydrocarbons?

The hydrocarbons are the simplest of the organic compounds. They are composed of only two elements, hydrogen and carbon. The number of hydrocarbons is very large and constitute a very important division of organic chemistry. In food chemistry they are important because they are the stepping stones from which the aldehydes, amines, alcohols, and acids are produced. All of these compounds are found in digested food.

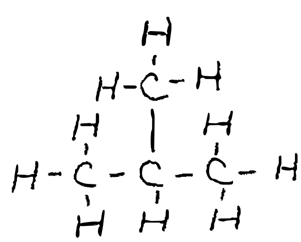
In organic chemistry the molecular formula, (CH_4), tells us absolutely nothing about the arrangement of the atoms within the molecule. It is usual to employ structural formula to illustrate organic molecules. For example in the simple hydrocarbon molecule, methane, a neutral carbon atom can share its four electrons in its outer orbit with four hydrogen atoms.



Structural formulae are also important because many of the hydrocarbons can form isomers. These are compounds that have the same number of carbon and hydrogen atoms, but instead of forming a straight chain molecule, side branches are formed. An example of this behavior can be seen by studing the straight chain and the isomer form of butane.



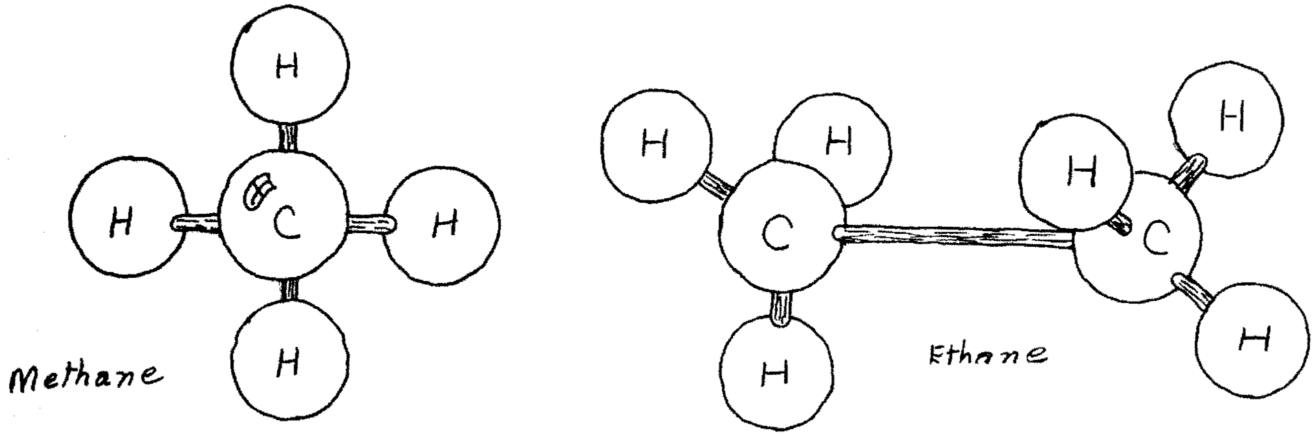
N-Butane



ISO-Butane

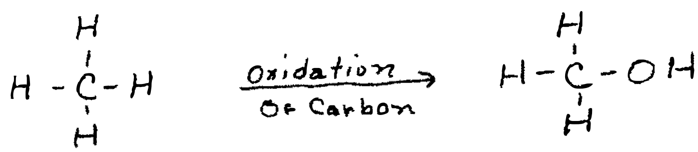
The most important source of hydrocarbons is natural gas and petroleum. Methane, ethane, propane, and butane are all found in natural gas. Other important hydrocarbons include gasoline, kerosene, lubricating oils and greases. These last hydrocarbons are all obtained by the fractional distillation of crude oil.

The concept of a definite molecular structure is fundamental in the study of the compounds of carbon. The molecule of methane is not flat, with the carbon and hydrogen atoms lying in a plane, as illustrated above. Instead, the four hydrogen atoms are so situated that the lines drawn from them to the carbon atom make equal angles in space. Molecular models are very helpful in grasping this fundamental idea of the definite structures of organic molecules. Following are illustrated the three dimensional drawings of methane and ethane.



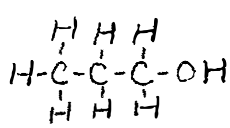
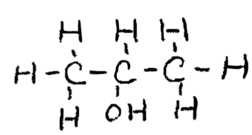
The hydroxyl derivatives of the hydrocarbons.

An important group of compounds can be obtained from the hydrocarbons by replacing one of the hydrogen atoms by another atom or group of atoms. In general, though, the hydrocarbons are relatively inert. Methane and ethane do not react with many of the common laboratory reagents. But under suitable conditions, oxidation reactions can take place. If a carbon is oxidized in a hydrocarbon, an alcohol is formed.



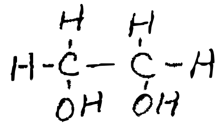
The two most common alcohols are methyl and ethyl alcohol. Methyl alcohol, commonly called wood alcohol or methanol, has many uses as a solvent of other organic compounds. It gets its name because of the similarity of its molecular structure to methane. Ethyl alcohol or ethanol, the hydroxyl derivative of ethane, is commonly called grain alcohol. It is also used as a solvent in both the home and industry.

Methane and ethane can form only one alcohol each, but the other hydrocarbons, because of longer carbon chains, can form more than one alcohol. These different forms are called isomeric forms. For example propane can form two alcohols. Generally as the number of carbon and hydrogen atoms increase, the number of isomeric alcohols will likewise increase.

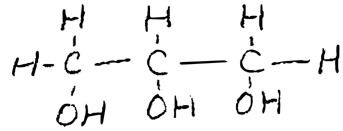
CH_3OH C_2H_5OH  

Methanol Ethanol n-Propyl Alcohol Iso-Propyl Alcohol

All the alcohols that have been discussed have only one hydroxyl group in their molecular structure. Other alcohols can be formed which contain more than one hydroxyl group. Examples of this are ethylene glycol, used as an antifreeze, and glycerol that is found in fats.



Ethylene Glycol



Glycerol

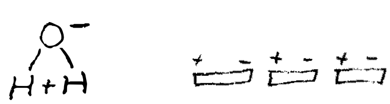
Alcohols, because of the presence of the hydroxyl group, have properties which are very similar. In alcohols, though, the hydroxyl group does not behave as the hydroxyl group found in an inorganic base. In KOH, for example, an electrovalent bond exists between the potassium and the hydroxyl group. The potassium atom releases its one valence electron completely to the oxygen of the hydroxyl group. As a result, a base will ionize in water to give a metal ion and hydroxyl ion. This can be shown by the ionization of potassium hydroxide. It is because of this ionization that a base will change red litmus paper blue and neutralize acids.

$$KOH \rightleftharpoons K^+, OH^-$$

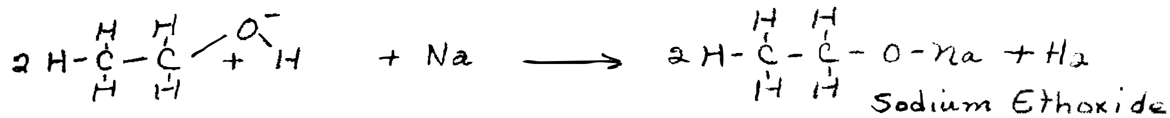
If the hydroxyl group is attached to a non-metal, an entire different set of properties result. In an acid such as nitric acid, an electrovalent bond is found between the oxygen and hydrogen. Oxygen can take hydrogen's lone electron. This will cause a positive center to be formed around hydrogen and a negative center around oxygen. As a result, hydroxyl groups attached to non-metals tend to give off hydrogen ions. This enables acids to change blue litmus paper red and to neutralize bases.

Alcohol does not resemble either acids nor bases in their chemical behavior. This is due to covalent bonds, the sharing of electrons, that are found in most organic compounds. Alcohols in their chemical behavior resemble water.

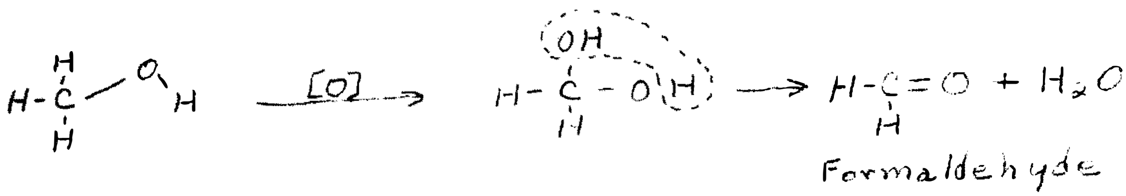
In water, the electrons are not shared equally between the oxygen and hydrogen atoms. Oxygen because of its electronegative characteristic can attract the shared electrons. By doing so a positive center is formed around the hydrogen atoms and a negative center is formed around the oxygen atom. These centers have magnet-like properties which enable water to form hydrates, to convert acid anhydrides to acids and for the association of water molecules.



Alcohol, because of its resemblence to water, can react with metals, such as sodium to form salts. A typical reaction can be shown by reacting sodium with ethyl alcohol.



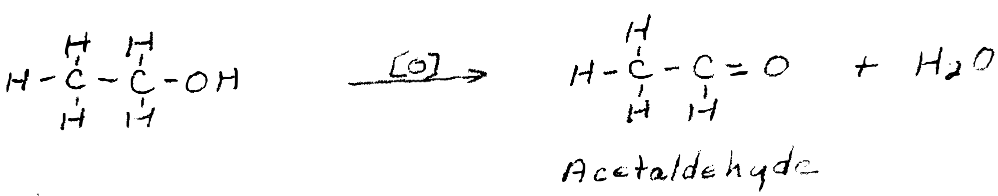
Alcohols differ from the hydrocarbons because they can be readily oxidized by solutions of chromic acid or potassium permanganate. The oxygen from $KMnO_4$ will attack the carbon-hydrogen bond, forming a carbon-hydroxyl bond. If the two hydroxyl groups are on one carbon atom, an unstable condition exists. Water can separate as shown below and an aldehyde will be formed.



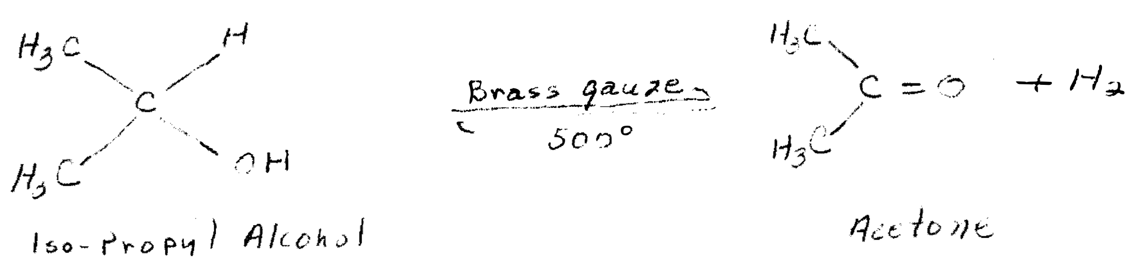
What are the aldehydes?

The aldehyde obtained from methyl alcohol is formaldehyde. It is a colorless liquid which is soluble in water and has a very sharp odor. It has many uses in industry for preparing bakelite and many other useful products. Formaldehyde is also used as a germicide, a deodorant, and as a preservative.

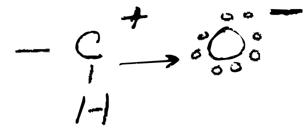
Formaldehyde is just one of the many aldehydes that can be prepared by oxidizing alcohols. If ethyl alcohol is oxidized, acetaldehyde will be formed.



Another important series of organic compounds can be formed in which one of the hydrogen atoms of an alcohol is replaced by a methyl group or a similar group. This series of compounds are called the ketones. The simplest ketone is called acetone.



The functional group of the aldehydes is the $-C=O$ group. It is the reactivity of this group that gives both the aldehydes and the ketones their chemical properties. The shift of the electrons in this group is toward the electron hungry oxygen. Because of this shift, oxygen becomes a negative center and carbon a positive center. Non-metals or negative groups can be substituted for oxygen. Because of the great number of reactions that the aldehydes can take part in, they are considered very important for the synthesis of other compounds.



An aldehyde can be further oxidized by mild oxidizing agents. Oxygen can gain possession of the electrons shared by carbon and hydrogen, and a carbon-hydroxyl bond is formed. The formation of this bond produces a new group of compounds called acids.

What are the acids?

The two most common organic acids are formic and acetic acids.

Formic Acid

Acetic Acid

Acetic acid is probably the most important of all organic acids. In the home this acid is found in vinegar. Vinegar is equal to a 4% acetic acid solution. If these acids are further oxidized, they will decompose into carbon dioxide and water.

$$H-C\overset{O}{\underset{OH}{\lessgtr}} \xrightarrow{[O]} CO_2 + H_2O$$

Formic Acid

What is the function of the digestive system?

This section is primarily to acquaint the reader with the different parts of the digestive system and to indicate the general process of digestion. The specific chemistry of the various foods and their digestion will be covered in later chapters.

Food that is taken into the mouth, and then it must pass thru the esophogus to the stomach. From the stomach the food passes into the small intestine where digestion is completed. To aid the body in the digestion of food, the digestive glands of the body produce enzymes.

The function of the digestive system is to break the large, complex water insoluble food particles up into small, water soluble particles that can be absorbed and used by the body cells.

Questions

1. What is organic chemistry?
2. What is the name of the simplest organic compound?
3. Compare the combustibility and speed of reaction of organic and inorganic compounds.
4. Why do organic compounds generally react slower than inorganic compounds?
5. What are covalent bonds?
6. Why are the hydrocarbons so important in our study of digestion?
7. What is the importance of structural formula?
8. What are isomeric forms of compounds? Give examples.
9. Ethane is the name of an alcohol, aldehyde or hydrocarbon?
11. Does an alcohol ever have more than one OH in its formula?
12. How can a alcohol be formed from methane?
13. Alcohol resembles what common compound?
14. What group of compounds are formed when an alcohol is oxidized?
15. What aldehyde is formed when ethanol is oxidized?
16. Oxidizing the aldehydes results in the formation of what compounds?
17. What is the functional group of acids?
18. Show by formula the complete oxidation of a hydrocarbon.
19. What are the most common organic acids?
20. What is the general function of the digestive system?

DIGESTION OF FATS

Why are fats important?

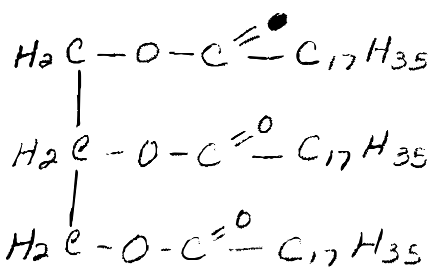
The foods we eat are composed of carbohydrates, proteins and fats. Of these three, the fats will provide more energy per gram that the others. One gram of fat will produce about 9.4 calories of heat, but the carbohydrates and proteins will produce only about 4 calories of heat per gram. The fats constitute a very important and concentrated source of energy.

Fat is a part of every living cell in both plants and animals. Our supply of fats come from eating these fat containing substances. Some of the sources include peanut oil, soy bean oil, butter, lard, cod liver oil and cocoanut oil.

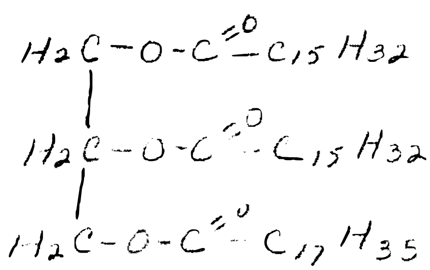
What is the composition of fats?

The fats and oils of our food are esters of fatty acids and glycerol. Esters are formed by the reaction between an organic acid and an alcohol. A simple ester that can be formed in the laboratory is ethyl acetate.

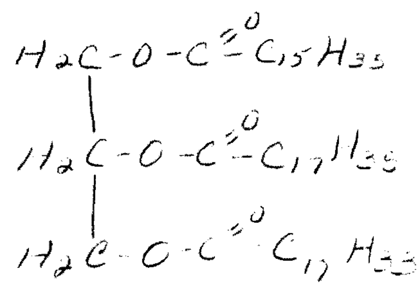
If these foods are liquid at room temperature, they are called oils; but if they are solid, they are called fats. As they occur naturally, they are mixtures of triglycerides of various fatty acids. The three fatty acids of a fat may be either all alike, two alike, or all different. The examples below will indicate the differences.



Simple

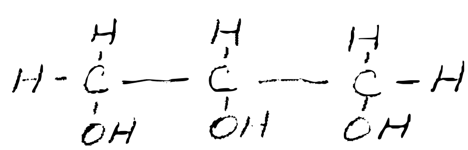


Mixed



Mixed

Glycerol is the alcohol portion of fats. It is a colorless, syrupy liquid at room temperatures, and is miscible in water. The structural formula shows it to be a derivative of the hydrocarbon propane, with a hydroxyl group on each of the carbon atoms.

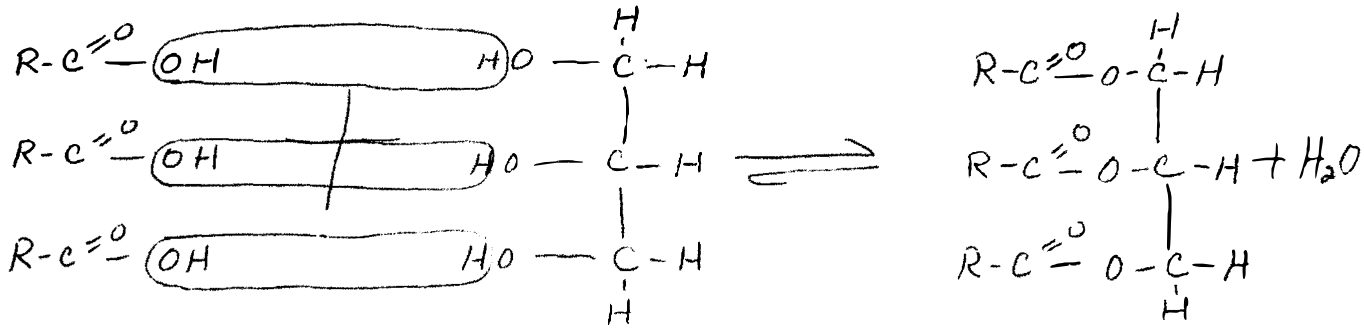


Many of the fats and oils of our foods can be formed in the laboratory by use of butyric, palmitic, oleic, and stearic acids. These all have the same functional group and therefore will have properties very much alike and similar to other organic acids.

Butyric and oleic acid are liquids at room temperature, and the other two, because of long chains of carbon atoms, are solids. In the table below is a list of the four common fatty acids and their triglycerol ester.

Butyric acid	C_3H_7COOH	Glyceryl tributyrin
Palmitic acid	$C_{15}H_{31}COOH$	Glyceryl tripalmitin
Oleic acid	$C_{17}H_{33}COOH$	Glyceryl triolein
Stearic acid	$C_{17}H_{35}COOH$	Glyceryl tristearin

By the use of the general formula for three carboxylic acids and glycerol it is possible to show how a fat and oil molecule can be formed.

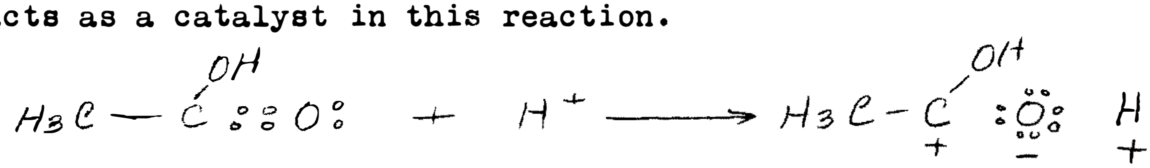


Fat or Oil Molecule

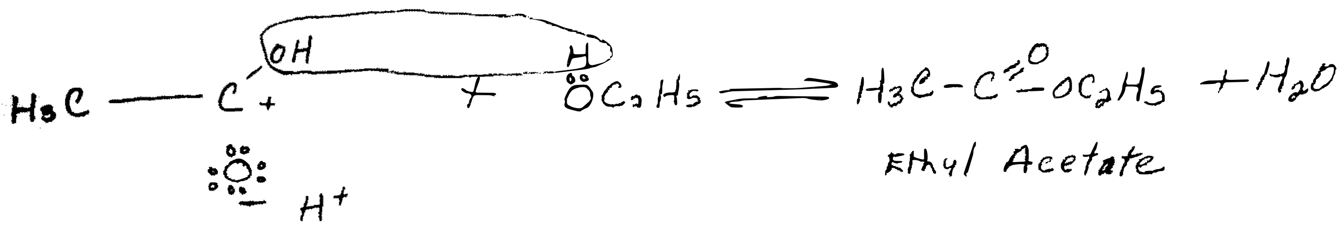
How is a ester formed?

To show how esters are probably formed, ethyl alcohol and acetic acid will be utilized. These are simpler molecules than those taking place in fat formation is a plant or animal, but the same forces will be acting in both the simple and complex ester formation.

To show how esters are formed, Lowry's explanation will be followed. If concentrated sulfuric acid is added to a mixture of ethyl alcohol and acetic acid, an ester will be formed. Evidence of its formation can be noted by a characteristic fruity odor. Sulfuric acid acts as a catalyst in this reaction.



The hydrogen from sulfuric acid will approach the relative negative oxygen of the carboxyl group of acetic acid. The pair of electrons between the carbon and oxygen atoms is attracted by the approach of hydrogen. This leaves the carbon atom more electropositive than in the usual acetic acid molecule. The electropositive carbon atom can then attract the negative region of the ethyl alcohol.



In this intermediate condition water can split off and an ester molecule is formed. The water molecule is made up of the hydroxyl group from the organic acid and a hydrogen from the alcohol. The hydrogen, attached to the organic acid, returns to the sulfate ion to form the original sulfuric acid.

The same type of reaction takes place in the synthesis of fats and oils in a plant or animal cell. But instead of just one acid and one alcohol reacting, three organic acids and one alcohol will combine to form just one ester.

What are the general properties of fats?

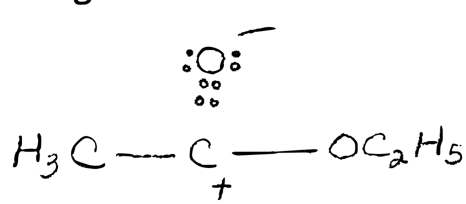
The glycerides of the lower fatty acids are slightly soluble in water, but those of the higher fatty acids are insoluble. The tri-glycerides are all soluble in hot ether, chloroform, ethyl and methyl alcohol. In the laboratory, hot ethyl alcohol is one of the best solvents for extracting fats or oils from animal or plant tissues.

The presence of color, odor and taste in the tri-glycerides found in nature is due to foreign substances either mixed or dissolved in the fat or oil. For example plant pigment is responsible for the color of butter and stored animal fat.

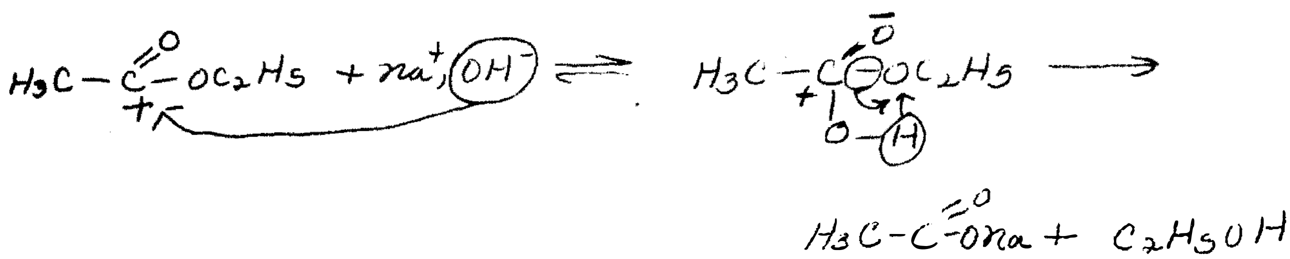
What are the chemical properties of fats and oils?

The hydrolysis of an ester, which is the reverse of esterification, will yield an alcohol and in the simple ester, such as ethyl acetate, only one acid. The two products of hydrolysis of ethyl acetate are ethyl alcohol and acetic acid. This reaction can either be catalyzed by an acid or a base. Acid hydrolysis probably proceeds in a manner similar to the reverse of esterification. In the body though, hydrolysis takes place in the alkaline medium of the small intestine.

Since fats and oils are hydrolyzed in an alkaline medium in the body, let us consider the hydrolysis of ethyl acetate in dilute sodium hydroxide. The ester molecule, contains an uneven distribution of electrons and protons, which results in two rather marked electropositive and electronegative regions.



The first step in hydrolysis is the addition of the hydroxyl group to the carbonyl carbon atom. The addition of the hydroxyl group tends to weaken the carbon-ethoxyl bond. The carbonyl carbon, by acquiring a share of the electrons of oxygen, will cause a cleavage of the C-OR bond. Sodium will be attracted to the negative oxygen and hydrogen will move to the ethoxy group. This forms ethyl alcohol and a sodium salt or soap. It is in this stage that fats can be absorbed by the blood stream.



Hydrogen can also be added to unsaturated fatty acids, that is an ester in which the CH::CH group is found. Oleic acid is an example of a unsaturated fatty acid. As hydrogen is added, the fats become more saturated and the melting point is increased. It is by the addition of hydrogen that many cooking oils can be changed to lard like products, which are more useful to the house wife. Oleo manufacturers also utilize this principle in making margarine.

How are fats and oils digested in the body?

The digestion of fats and oils in the human body takes place primarly in the small intestine. The process is mainly one of hydrolysis, similar to the basic hydrolysis of ethyl acetate. Fats are hydrolyzed to alcohol and organic acid salts. For example, glyceryl tristearin is hydrolyzed to glycerol and sodium stearate. In these primary forms the fats can be absorbed into the blood stream and utilized by the body.

In order for the fats to be used to good advantage they must be a liquid or at least soft. The human body temperature of 98.6 degrees will soften most fats. If the fats remain in a solid state, they can not be readily emulsified and may escape digestion. In the following table the melting points and the percent of several common fats and oils utilized by the body are shown.

Substance	Melting point	Percent absorbed
Stearin	60 degrees	9%
Lard	34 degrees	97%
Mutton fat	49 degrees	93%
Olive oil	0 degrees	98%

An emulsion is a colodial dispersion of a liquid in another liquid. The liquids are insoluble in each other so that a true solution is not formed. A kerosene and water emulsion, made by shaking the two liquids together, will not remain in solution but will separate into layers of water and kerosene. If an emulsifing agent is added the kerosene droplets will not separate out, but will remain dissolved in the water medium. Bile of the digestive tract is an example of an emulsifing agent. It will cause a liquid fat to form an emulsion with water. This hastens digestion because it increases the surface area of fats so they can be much easier split by enzymes.

Enzymes are substances that will cause fats to undergo hydrolysis. These can not continue to catylize hydrolysis because of a slight decomposition which make them enactive. The enzyme that effects the digestion of fats is produced in the pancreas. This gland and all digestive glands are greatly influenced by the presence of food materials in the digestive organs.

The fats after they have been hydrolyzed are absorbed into the lacteals, where the glycerol and acid salts are resynthesized into fats. The lacteals carry the fats to the main artery and from there to the various parts of the body. There they are either stored or oxidized for energy.

Questions

1. Compare the calories of heat produced by fats, carbohydrates and proteins.
2. What is the difference between fats and oils?
3. Of what two things are fats composed?
4. What is the formula of glycerol?
5. Name four fatty acids.
6. Using a general formula show the probable formation of a fat.
7. What is an ester? Give an example.
8. Describe esterification using ethyl alcohol and acetic acid.
9. What is an unsaturated fatty acid? Give an example.
10. What are the general properties of fats and oils?
11. Using ethyl acetate, show the hydrolysis of that ester.
12. What effect does bile have on fats?
13. Does the body temperature of 98.6 degrees have any effect upon the digestion of fats?
14. What is an enzyme?
15. What enzyme is important for fat digestion?
16. What are the probable products of the digestion of glyceryl triolein?

DIGESTION OF CARBOHYDRATES

What is a carbohydrate?

Carbohydrates are compounds composed of carbon, hydrogen and oxygen. In a carbohydrate the ratio between the hydrogen and oxygen is 2:1, as in water. Sucrose, $C_{12}H_{22}O_{11}$, is a common example of a carbohydrate.

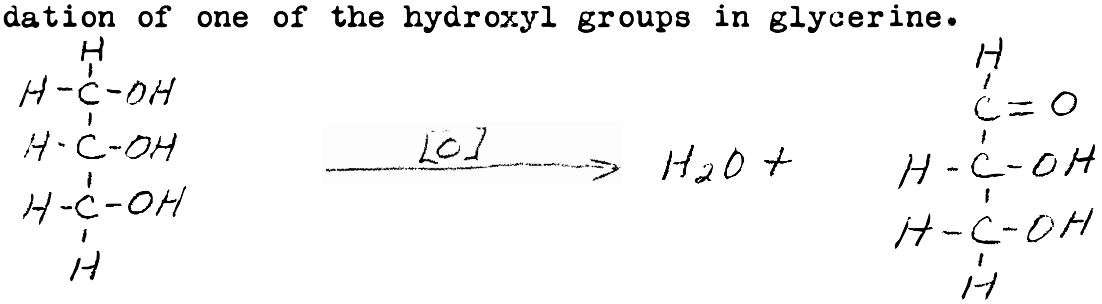
The human race consumes more carbohydrates in its food than any other kind of food. Such basic foods as rice, wheat, corn, and potatoes are predominately carbohydrate in nature. Most plants can manufacture these by a process known as photosynthesis. In this process carbon dioxide and water are combined in the presence of sunlight to form sugar. Most animals, from which man obtains much of his food protein, are either directly or indirectly dependent upon plants for food. Animals use carbohydrates not only for energy, but also in building the tissues of their body.

The two most important carbohydrates man uses as food are sucrose and starch. These must be broken down by the digestive system, into simpler carbohydrates, before they can be used by the cells of the body.

What are the simple carbohydrates?

The very simple carbohydrates that can be produced in the laboratory are not found in foods. But from the study of these, many of the important properties of the food carbohydrates can be determined. These simple carbohydrates have properties which resemble both alcohols and aldehydes. They contain a covalent bond made up of a carbon atom and an electronegative oxygen atom in a hydroxyl group. They resemble the aldehydes, by having a $>C=O$ group.

A simple carbohydrate can be prepared in the laboratory by the oxidation of one of the hydroxyl groups in glycerine.



Glycerine Glyceryl Aldehyde

Carbohydrates like the hydrocarbons, can also form isomers. The type of isomer found in hydrocarbons is due to the rearrangement of the carbon atoms in a molecule. The type of isomerism found in carbohydrates is called optical isomerism. In this type of isomerism only the atoms or groups attached to the central carbon atom is involved. The position of the hydrogen and the hydroxyl group associated with the central carbon atom is just reversed. One will be the mirror image of the other as in the case of D-glyceryl aldehyde and L-glyceryl aldehyde, shown below.

D-Glyceryl Aldehyde   L-Glyceryl Aldehyde

The simple sugars have all possible numbers of carbon atoms from two to ten. Of these sugars the only ones which are important to man are those containing six carbon atoms. These sugars are often referred to as hexoses or sometime monosaccharides. They all have the same general formula of $C_nH_{2n}O_n$, where (N) is the number of atoms.

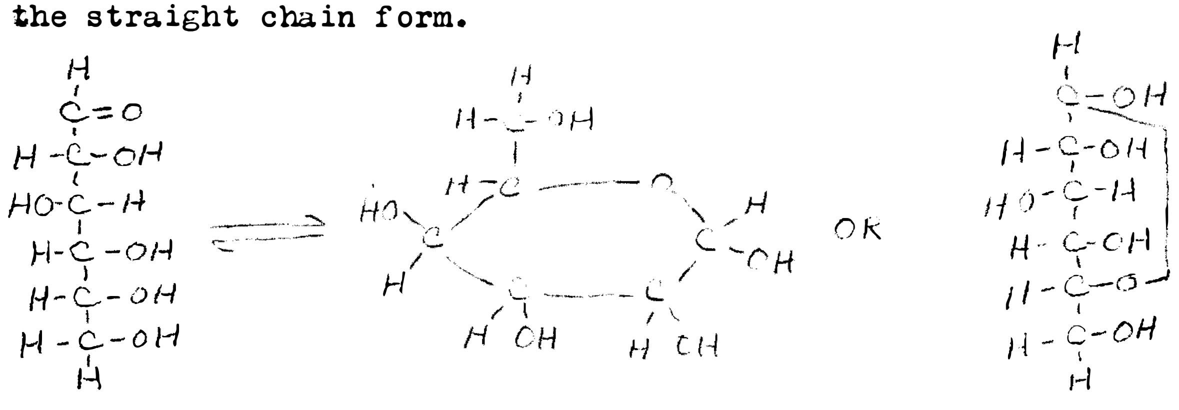
Of all the monosaccharides that are possible, only two are important in the study of digestion. These two are glucose and fructose. Both are colorless, crystalline solids. They dissolve readily in water and are thus able to diffuse through animal cell walls. Neither can be melted because they decompose (caramelize) when heated.

Where is glucose found?

Glucose is widely distributed in both plant and animal materials. It occurs in the sap of most plants and is especially abundant in the juice of grapes. For this reason it is called grape sugar. It can be manufactured in large quantities by hydrolysis of starch with steam and dilute acid. During digestion of both sucrose and starch, one of the products formed is glucose.

What is the structure of glucose?

Ordinarily glucose is shown in a straight chain form, but it can also exist in a ring form. This ring form is possible because of the free movement at the carbon to carbon bond and also the free movement of the hydrogen from one oxygen to another. When glucose is found in the ring form, it is generally in equilibrium with the straight chain form.

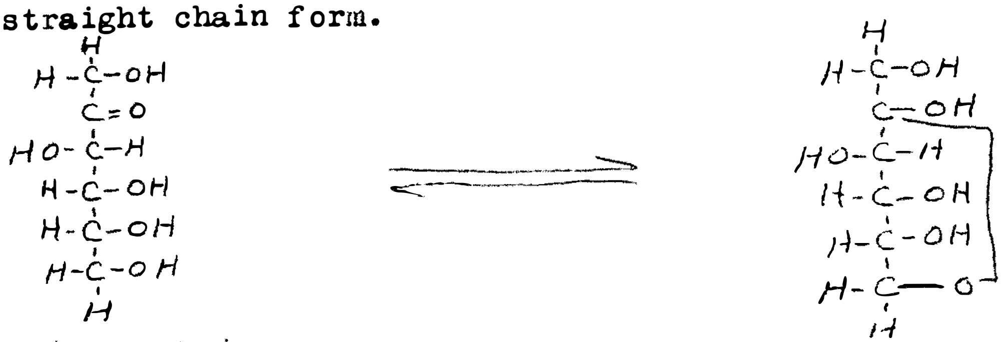


The ring form can be written in a straight chain form with a line indicating the bond between oxygen and carbon. This form is used to show the close relationship between the ring form and the straight chain form.

Glucose is also called an aldose sugar, because of the presence of an aldehyde group on the carbon atom at the end of the chain. It is because of this aldehyde group that glucose has several properties that are similar to the simple aldehydes, such as acetaldehyde. Among these properties, the most important are that it has both reducing and oxidizing powers. If glucose is oxidized it will form an acid and if reduced it will form an alcohol.

How does fructose compare with glucose?

Fructose has many of the properties of glucose, but generally it is considered less reactive. It is widely distributed in nature, it has the same general formula and it can exist in both the ring and the straight chain form.



Straight Chain Form Ring Form

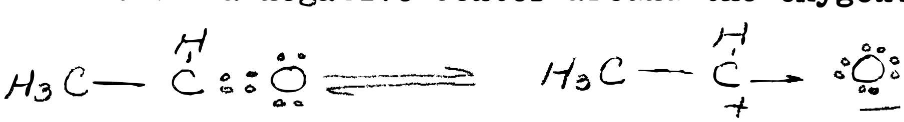
In contrast to glucose, fructose is a ketose sugar, because the $>C=O$ group is on the second carbon atom. The location of this group on the second carbon atom is typical of all ketone formations. Fructose, though, is more reactive than most of the simple ketones, such as acetone. It is the reactivity that enables fructose to reduce Fehling's solution. Fructose can be oxidized to form an acid and reduced to form an alcohol.

What are acetals?

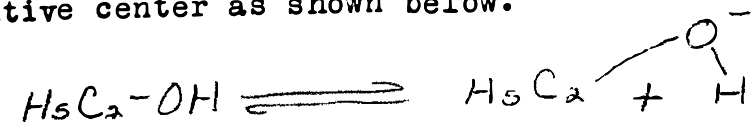
In order to understand the chemical change of large molecules when they react, it is an advantage to have a clear picture of the same behavior of simpler molecules. The characteristics of the simpler molecules are very similar to the complex molecules.

The simple aldehydes and alcohols will react with each other to form acetals. As in the more complex molecules it is the presence of positive and negative centers that enable them to react. This reaction takes place first with the formation of a hemiacetal, which reacts further with a second molecule of alcohol to form an acetal. This reaction is similar to the one involved in ester formation.

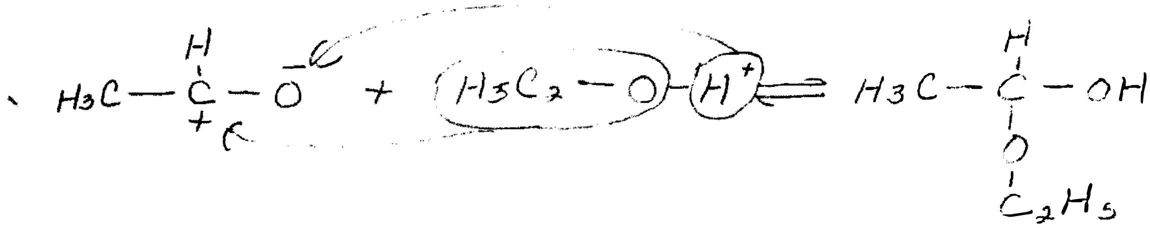
An explanation of this behavior can readily be seen by an examination of the forces which cause acetaldehyde to react with ethyl alcohol. In this reaction, the bond between the carbon and oxygen in acetaldehyde is not an even sharing of electrons. Oxygen can gain control of the shared electrons. This leaves a positive center around the carbon atom and a negative center around the oxygen.



In ethyl alcohol, as in water, the tendency is for the hydrogen to partially separate from the oxygen. This will produce a positive and negative center as shown below.

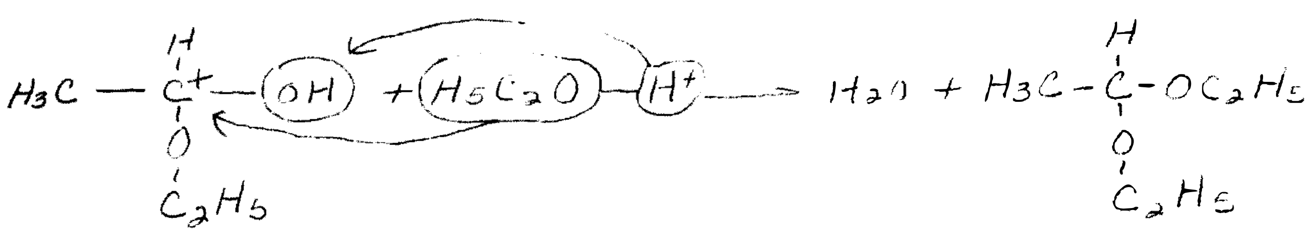


When acetaldehyde and ethyl alcohol are mixed, there is a tendency for the oxygen and the ethyl group of the alcohol to be attracted to the positive carbon of the acetaldehyde. Because of the motility of hydrogen, it is easy for it to dissociate from the ethoxy group and form a similar bond with oxygen. The result of this attraction and dissociation is an intermediate compound called a hemiacetal.



Hemiacetal

The hemiacetal will immediately react with another molecule of alcohol to form an acetal. Again it is the shift of the hydrogen from the alcohol group to the hydroxyl group of the hemiacetal to form water. By this shifting a positive center is formed around the carbon atom of the hemiacetal and this can attract the negative center of the alcohol.

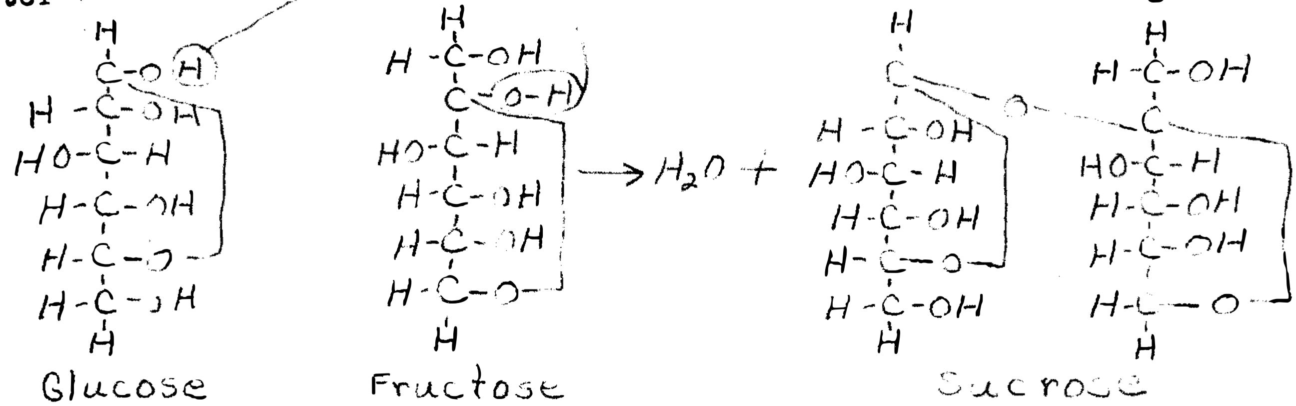


Acetal

The acetal formation is important because it can be used to describe the forces that hold glucose and fructose together in a sucrose molecule. It is this acetal formation that must be hydrolyzed during digestion of carbohydrates.

How does glucose and fructose combine to produce sucrose?

In the laboratory fructose will react with glucose under suitable conditions to produce sucrose. It is the shift in the hydrogen from one group to the hydroxyl of the other to form water, that leaves the relatively negative oxygen and two positive carbons combine to form the acetal linkage. This linkage is the force that holds glucose and fructose together in a sucrose molecule.



Where do we get our supply of sucrose?

Sucrose, a complex sugar belonging to the disaccharides, can be produced in the laboratory as indicated above. But natural sources are generally used for preparing our supply of sucrose. It is found most abundantly in sugar cane and sugar beets. Most of our supply of sugar cane is grown in Cuba, Hawaii, and Puerto Rico, but some is grown in Louisiana and Florida. Most of the sugar beets, used for the production of sucrose, are grown in our western states.

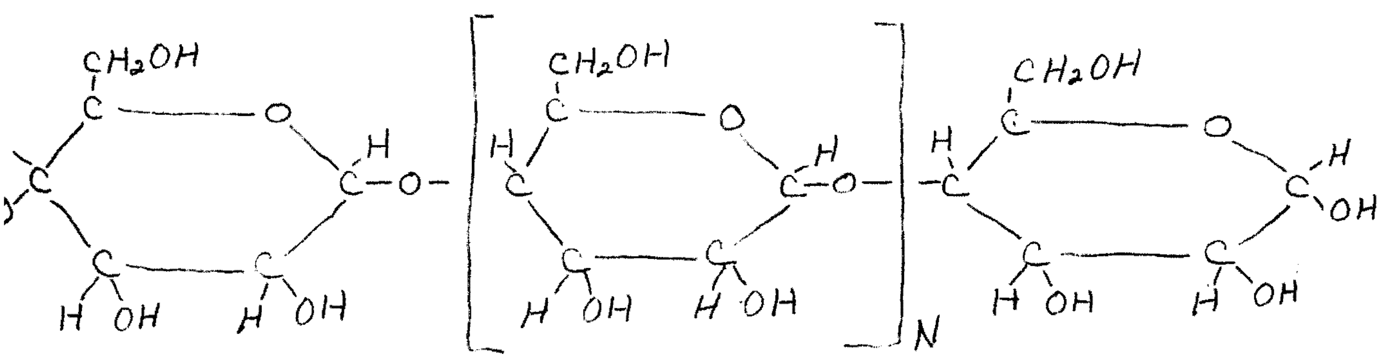
In the production of sugar the juices from both sugar cane and beets are refined by a process of evaporation, in which water is driven off and the crystaline sugar remains.

What are the starches?

Starches are the most complex of the carbohydrates and are often referred to as polysaccharides. Cereal grains and potatoes are composed principally of starch. The starch found in our food is contained in granules. Granules from different food have different shapes and sizes. By studing these granules under a microscope, it is possible to identify their source.

What is the structure of starch?

From various observations of the chemical behavior of starch the following structure is believed to represent a starch molecule.



Until recently it was believed that the starch molecule consisted of twenty four to thirty glucose units joined together as shown above.

The exact number of chains composing the starch molecule is unknown, but it is likely that the molecule contains several hundred glucose units rather than just twenty four or thirty.

What are the properties of starch?

Because of starches high molecular weight it does not give a true solution in water. It does though give colloidal dispersions. When iodine is added to a starch dispersion a deep blue color is produced. This is the basis of a very sensitive test for either starch or iodine.

In the study of carbohydrate chemistry it is often important to know if a free aldehyde group is present. This group is found in both glucose and fructose, but not in either sucrose or starch. When either of these last two carbohydrates are hydrolyzed, free aldehyde groups are formed. They will then give a positive test to Fehling's solution. The Fehling's test is designed to show the presence of a free aldehyde group. In this test blue Cu^{++} ions are reduced to Cu^{+} ions. A change in color results, which indicates the presence of a free aldehyde group.

How is starch hydrolyzed?

The commercial hydrolysis of starch is usually carried out in the presence of very dilute hydrochloric acid and steam. After the hydrolysis has proceeded to the desired stage the acid is neutralized and the solution is evaporated to give a thick syrup. Corn syrup is prepared in this way. It is composed of glucose and several other monosaccharides.

In the digestion of starch by the body, the acetal linkage is hydrolyzed by enzymes and converted into simple sugars. The end product of this digestion is always glucose.

Where does the digestion of carbohydrates take place?

All of the chemical digestive process is of one kind. The complex food stuff is broken into simpler parts by hydrolysis of the acetal linkage. This action is speeded by the presence of enzymes and an alkaline condition.

Digestion of carbohydrates begins in the mouth with the hydrolysis of starch into simple sugars. The enzyme, ptyalin found in saliva, aids in this hydrolysis. You for example can detect a sweet taste by allowing a cracker to dissolve in the mouth; indicating starch is being converted to a simple sugar. The action of ptyalin continues until it is stopped by the hydrochloric acid in the stomach. The hydrochloric acid is neutralized in the small intestine, so that the enzymes of the pancreatic gland can continue to digest carbohydrates.

Sucrose, starch and other members of the complex sugars are hydrolyzed in the small intestine by the action of amylopsin, Sucrose is converted into water soluble glucose and fructose and starch to glucose. The digested products of carbohydrates are absorbed into the blood stream, where they are either burned for energy, or stored in some part of the body.

Questions

1. What is a carbohydrate? Give examples.
2. How can a simple carbohydrate be made in a laboratory?
3. What is an optical isomer? Give example.
4. By what two names can a carbohydrate with six carbon atoms be called?
5. Where is glucose found?
6. Write the formula of the two forms of glucose?
7. What enables both fructose and glucose to reduce Fehling's solution?
8. How are acetals formed? Write equation.
9. What is a hemiacetal?
10. How does glucose and fructose combine to produce sucrose?
11. Why are starches called polysaccharides?
12. How can starch be identified?
13. What are the properties of starch?
14. How is starch hydrolyzed?
15. How are starches digested in the human body?

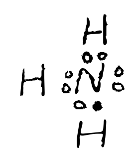
DIGESTION OF PROTEINS

What is the nature of proteins?

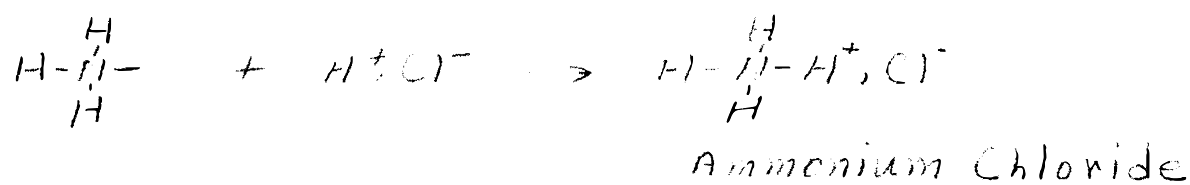
Proteins are the third class of foods. These important organic substances are found in all living things and they are the principle nitrogen containing substances of the human body. Most proteins contain about 15 to 16 percent nitrogen and this nitrogen is almost wholly in the form of a substituted amino group (NH_2). The characteristics of proteins are determined in most cases by the presence of this group. It is necessary in the study of protein digestion to know the properties of ammonia.

What are the properties of ammonia?

Ammonia is composed of one atom of nitrogen and three atoms of hydrogen. The structure of ammonia, at the right of page, indicates that reactions can take place at two points. The most important reactions of ammonia centers around the two pair of unshared electrons. The ability of ammonia to add reagents is due to these electrons.

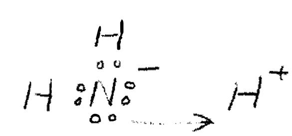


A positive ion or group because of a lack of electrons can be added at this point. In this way hydrogen may be added to form the ammonium ion (NH_4). The ammonium group becomes positive by virtue of the charge of the added hydrogen. Thus, the ammonium group can act as a positive radical. A typical example of this behavior can be shown in the reaction of ammonia with hydrochloric acid. The two substances will combine to form ammonium chloride.



Nitrogen by sharing its electrons with the hydrogen ion from the acid will become a positive center that can attract and hold the chlorine ion by electrostatic attraction. This property of ammonia is retained in all compounds containing the amino group.

The other point of reaction involves the covalent bond between nitrogen and hydrogen. Nitrogen because of its strong electronegative property can gain possession of the two pair of electrons. So that an electronegative center is formed around the nitrogen and an electropositve center around the hydrogen. Because of the weakening of this bond, hydrogen can be replaced by a positive ion or group. An example of this behavior can be found in the amine formation.



What are the amines?

Amines are often produced during the decay of nitrogenous animal and plant material. The methyl amines are found in herring brine, and part, at least, of the characteristic fish odor is due to their presence.

In the laboratory, if methyl iodide and a solution of ammonia in alcohol are heated in a sealed tube, there is obtained a mixture of all possible classes of amines. Methyl amine, the first formed is just as reactive as the ammonia. This amine will react with acids to form crystalline salts.

$$CH_3-Br + H-NH_2 \xrightarrow{\Delta} CH_3-NH_2\cdot HBr$$

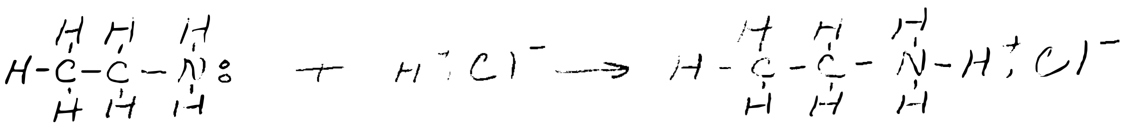
The free amines may be liberated from their salts by strong bases.

$$CH_3-NH_2\cdot HBr + NaOH \longrightarrow CH_3-NH_2 + NaI + H_2O$$

Methyl Amine

The lower members of the family of amines are gases which are very soluble in water. The amines containing three to eleven carbon atoms are liquids and those containing more than eleven carbon atoms are solid. Higher molecular weight amines are sometime added to lubricating oils to reduce acid corrosion.

The chemical properties of amines, like those of ammonia, are due to their basicity. The unshared pair of electrons on the nitrogen atom is the key to the properties of the amines. The nitrogen can donate a share in this electron pair to other atoms which are deficient. The amines have the same basic characteristic as ammonia, in that they can react with acids to form salts. The reaction of ethyl amine and hydrochloric acid will illustrate this property.

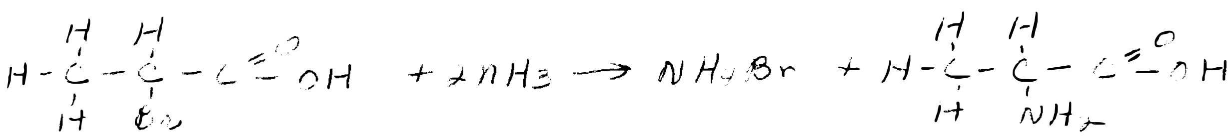


Ethyl Amine Hydrochloride

Ethyl amine by sharing its electrons with the electron poor hydrogen from the acid become an electropositive center. The amine group can attract and hold the chlorine by electrostatic attraction.

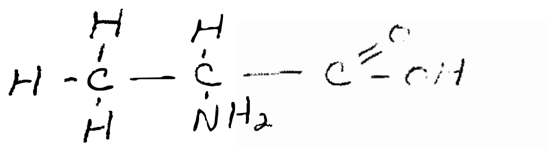
What are amino acids?

Another group of compounds known as amino acids can be prepared by replacing the halogen in a halogen acid by the amine group.

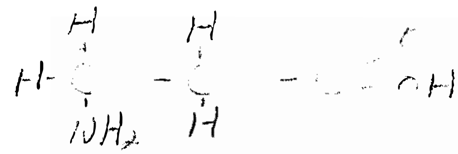


Alanine (Amino Acid)

These acids are usually classified as α, β, etc., amino acids depending upon the number of carbon atoms between the two functional groups. If the amino group is substituted for the hydrogen next to the carboxyl carbon, α-amino acid results. It is also possible to have the hydrogen from another carbon substituted, such as in the formation of β-amino acid.



α-Amino Propionic Acid



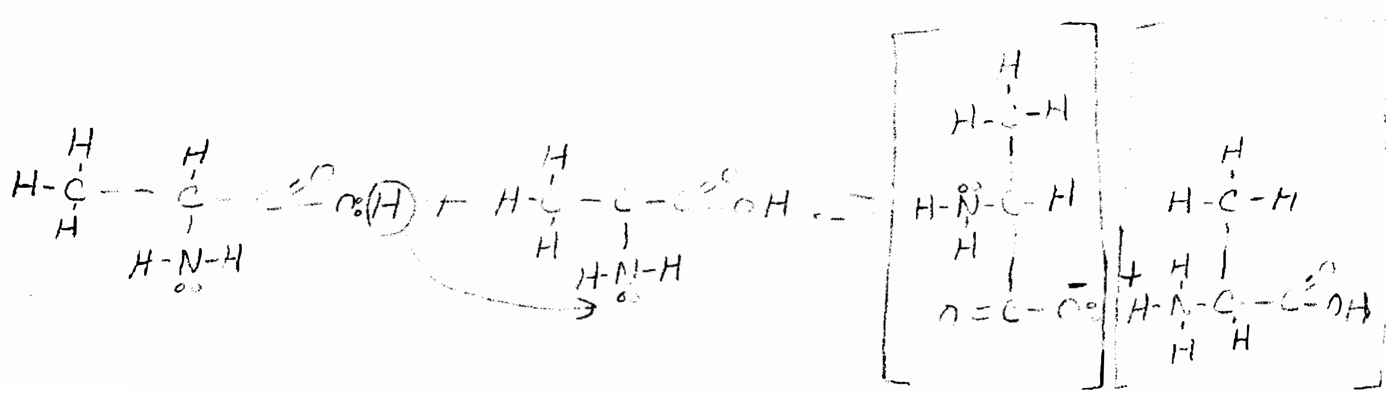
β-Amino Propionic Acid

What are the properties of -amino acids?

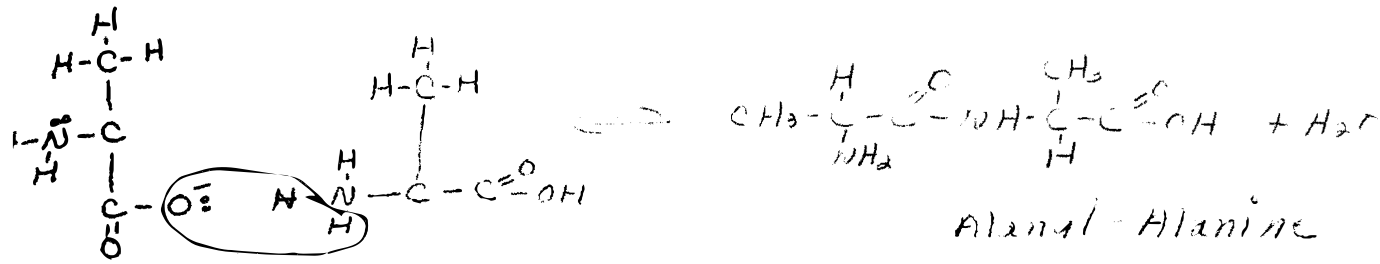
The amino acids share all the general reactions of both acids and amines, because of the presence of both groups. By means of the amino group, they can combine with acids to form salts and by the carboxyl group, they can combine with bases to form salts. Because of this behavior, the amino acids are known as amphoteric compounds.

When an amino acid is dissolved in water there is a dissociation of the hydrogen ion from the carboxyl group, leaving the remainder of the molecule electronegative. The amino group of the same molecule can share its electrons with this ionized hydrogen. This gives the amino group a positive charge. This salt forming property is an important characteristic of these compounds.

Salt formation is also possible between two amino acid molecules. For example two molecules of alanine can combine to form a salt.



If the resulting salt is carefully heated with a low flame, it is possible to remove water from the salt formation.



The carboxyl group of one molecule of amino acid will unite with the amino group of the neighboring molecule, with the separation of water and the formation of a peptide link. Bonds between amino acids, such as in alanyl-alanine, are often referred to as peptide linkages. Alanyl-alanine, since it is made up of two molecules of amino acid, is a dipeptide. The reaction, just described, may be continued with the resulting formation of tripeptides, tetrapeptides, and polypeptides.

The proteins which make up our foods are polypeptides, and the number of molecules of amino acid entering into the formation of one molecule of protein usually ranges from three hundred to one thousand. In some instances, however, the number of amino acids may even exceed one hundred thousand.

What kind of amino acids are found in proteins?

Some thirty different amino acids have been isolated from the different animal and plant proteins. Probably more will be found, since several have been isolated only recently.

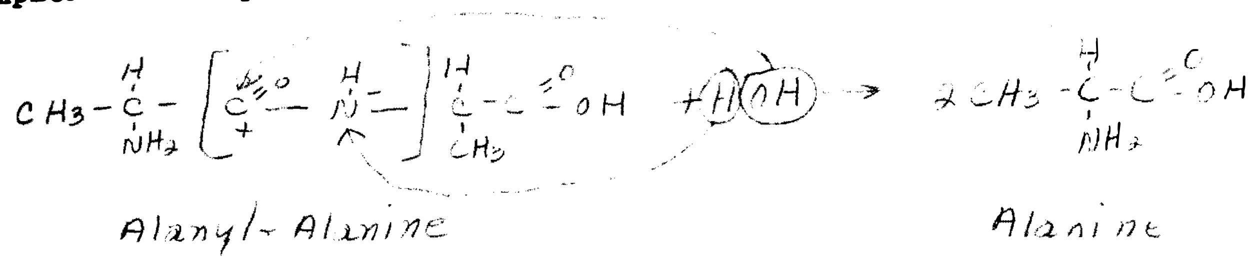
It may seem surprising at first that the existing proteins can be made from so small a number of amino acids. Each kind of animal and plant have proteins peculiar to it and each kind of cell and tissue in each of these have its own proteins, even in the same body. Blood test indicate that the proteins of members of the same family are specifically different.

By combining only thirty amino acids in different order or amounts, or by leaving one or more out, an almost infinite number of proteins are possible. The amino acids, then are the building blocks from which the proteins found in the body are built.

When a protein is digested, the peptide linkages are hydrolyzed so that the orginal amino acids are formed. It has been found that dietary proteins can be replaced by mixtures of pure amino acids. Only nine of the known thirty amino acids are necessary to support growth in man. If any one of these nine amino acids, which are commonly referred to as the essential acids, are absent from the diet, man would fail to grow and may even die. Since only nine of the amino acids are essential to growth, it means the human body must be able to synthesize the other twenty one acids. It is only nine amino acids that the human body can not synthesize from the other acids.

How are proteins digested?

The proteins are closely related to the amino acids since these acids are the principle end products obtained by digestion of proteins. The decompostion of the protein molecule is a gradual process in which the large molecule of protein is coverted into products of successively lower molecular weight. By repeated hydrolysis of the peptide links the end product of amino acid is obtained. The process is just the reverse of protein formation and can be readily explained by using the simple protein, alanyl-alanine. The forces involved in the hydrolysis of this protein are very similar to those of the more complex nature proteins.



The hydrolysis can take place in an acid medium, as in the stomach, or an alkaline medium as in the small intestine. In both cases the hydroxyl group can be attracted and become attached to the positive carbon atom of the peptide link. By this association the peptide link is broken, leaving a negative center at the NH group. This is neutralized by combining with hydrogen. Two molecules of alanine are formed by the hydrolysis of alanyl-alanine.

What are the tests for proteins?

Because of the different chemical make up of the proteins, they can be identified in the laboratory by various chemical tests. Many color reactions are characteristic of proteins and can be used in testing for their presence. The Biuret test is one the most common examples of this type of test. A positive Biuret test gives a violet color.

Other tests include the Xanthoproteic test. It involves the reaction of nitric acid to give a yellow color. The protein tyrosine found in the skin will react in this manner to give a positive test. Millon's reagent causes proteins to precipitate and a red color to develop. The amino acid, tyrosine will give a positive test, and because it is so widely distributed in proteins, it is a good test for the presence of proteins.

Where does the digestion of proteins take place?

The two different organs in which proteins are digested are the stomach and the small intestine. The stomach contains the enzyme pepsin which speeds up the hydrolysis of certain proteins. Those that are not hydrolyzed by pepsin are acted upon by the two enzymes found in the small intestine. Due to the combination action of erpsin and trypsin, proteins are completely broken down into simple amino acids. These amino acids are now ready for absorption into the blood stream. The human body cells will then convert these amino acids into the many proteins that are needed in the body for growth and life.

Questions

1. What groups characterize all proteins?
2. What is the amino group?
3. Reactions of ammonia take place at what two points?
4. How are the amines formed?
5. What are the physical and chemical properties of the amines?
6. How are amino acids formed?
7. What is the simplest amino acid?
8. What is the difference between α-amino acid and β-amino acid?
9. How is it possible for an amino acid to form a salt?
10. Show the possible salt formation between two amino acid molecules.
11. What is the formula of a simple protein?
12. How many molecules of amino acid are necessary to form a food protein?
13. Why are the essential amino acids so important to man?
14. Show the probable hydrolysis of a protein.
15. What is the Xanthoproteic test for proteins?
16. What is the linkage between amino acids called?

PROPERTIES OF ALCOHOLS

Apparatus. Test tubes; 100 milliliter beaker; glass rod; copper wire; cork; Bunsen burner; evaporating dish.

Materials. Methanol, ethanol, iso-propanol, butanol, and amyl alcohol; sulfuric acid; sodium hydroxide; solution of iodine in KI; sugar; gasoline; cotton seed oil; acetic acid.

1. ODOR. Pour about 1 ml of the following alcohols in separate test tubes and note with care their odors: methyl, ethyl, iso-propyl, butyl and amyl alcohol.

   Describe their odors.

2. INFLAMMABILITY. Pour a few milliliters of methyl alcohol in an evaporating dish and ignite it. Observe the color of the flame and the ease of ignition. Repeat using ethyl, iso-propyl, butyl and amyl alcohol.

   Results.

3. IODOFORM. (A test for ethanol) Pour about 2 ml of ethyl alcohol in a small beaker. Then add about 1 ml of sodium hydroxide solution. Add a solution of iodine in KI until a faint yellow color persists. Warm in a beaker of water to 60°,

and leave undisturbed for about 10 minutes. Note the odor of the new product and the appearance of the precipitate.

Odor of the iodoform. ______________________________

Nature of precipitate. ______________________________

4. SOLVENT ACTION. Pour about 2 ml of ethyl alcohol in 4 separate test tubes. Add about 2 drops of gasoline to one test tube; about 0.1 gm of NaCl to the second; 2 drops of cotton seed oil to a third; and to the fourth add 0.1 gm of sugar.

Results.

5. ESTERIFICATION. Pour 2 ml of ethanol in a pyrex test tube. Add 2 ml of acetic acid and to the acid cautiously add 20 drops of concentrated sulfuric acid. Warm the mixture gently over a small flame, then pour into 50 to 75 ml of cold water. Stir and note odor.

Odor.

Write an equation for the reaction.

6. OXIDATION OF METHANOL. Pour 1 ml of methyl alcohol into a pyrex test tube. Add 2 ml of water to the test tube and mix thoroughly. Prepare a copper wire spiral by wrapping the wire tightly around a pencil. Attach the wire to a cork, and using it as a holder, heat the copper wire to red heat. (This will change the copper to copper oxide). After cooling slightly plunge the spiral into the water and methyl alcohol in the test tube. Repeat until the odor of formaldehyde can be detected in the test tube.

Describe the odor.

Write an equation of the reaction.

ACETIC ACID: VINEGAR

Apparatus. Evaporating dish; burette; beaker; graduated cylinder.

Materials. Phenolphthalein solution; litmus paper; acetic acid; vinegar; normal solution of sodium hydroxide.

1. PROPERTIES OF ACETIC ACID. Pour about 5 ml of acetic acid into a small beaker. Test acetic acid with litmus paper. Add about 60 ml of water to the acid and taste one drop after thoroughly mixing.

Odor.

Reaction to litmus paper.

Taste.

Add to the dilute acid 3 or 4 drops of phenolphthalein solution and then add, drop by drop, the normal sodium hydroxide solution until neutral.

Write the equation for the reaction.

Carefully evaporate the solution to dryness in an evaporating dish. The solid is sodium acetate.

What are the properties of sodium acetate?

2. SOLIDS IN VINEGAR. Weigh an evaporating dish and record the weight in the table below. Add 25 ml of vinegar to the evaporating dish. Evaporate to complete dryness and again weigh. Record the weights in the table below.

Weight of evaporating dish - - - - - - - - - - - - - - - - - -	________g
Weight of evaporating dish and residue - - - - - - - - - - -	________g
Weight of residue (difference between 1 and 2) - - - - - - -	________g
Weight of solids in 100 ml of vinegar (calculate) - - - -	________g

SUGARS

Apparatus. Test tubes; beakers; stirring rod; Bunsen burner.

Materials. Fehling's solutions A and B; corn sirup; sucrose; honey; candy; saturated solution of sodium carbonate; molasses; litmus paper; hydrochloric acid; sulfuric acid.

1. COMPOSITION OF SUCROSE. Put about 5 g of sucrose in an old test tube. Heat the test tube and its contents very gently.

Results.

Then heat the test tube to a high temperature. Describe what is left in the bottom of the tube after it has been heated.

What are the three elements that constitute sucrose?

2. FEHLING'S TEST OF SUGARS. Pour into a test tube about 1 ml each of solutions A and B. After thoroughly mixing, the resulting solution should have a deep-blue color. Heat the solution nearly to boiling and then add one or two drops of corn sirup. Continue the heating for a few moments. The copper sulfate in the solution is reduced to cuprous oxide by the aldehyde group of fructose. Cuprous oxide should separate and form a red or yellow solid. Dissolve samples of candy, honey, molasses and sucrose in a small amount of water and test for the presence of the aldehyde group.

Results.

Preparation of Fehling's Solution. Solution A: dissolve 3.5 g of pure copper sulfate crystals in 100 cc of water; Solution B: dissolve 17 g of sodium potassium tartrate crystals (Rochelle salt) in 15 ml of warm water and add to a solution of 5 g of solid sodium hydroxide in 15 ml of water. Cool, and dilute to a volume of 100 ml. The solutions should be kept separately and not mixed until time for use, since the mixed solution deteriorates on standing.

Dissolve about 0.5 g of sucrose in 5 ml of water in a test tube and add 3 or 4 drops of hydrochloric acid. Place the test tube and its contents in a beaker of boiling water and leave it there for about five minutes; then pour the solution into a small beaker, cool the solution and neutralize the acid present by adding a concentrated solution of sodium carbonate until the resulting mixture is just alkaline (test with red litmus paper). Test the resulting solution with Fehling's solution as before.

Results.

To a concentrated sucrose solution add a little concentrated sulfuric acid, and heat gently. (Sulfuric acid is a dehydrating agent).

Results.

CELLULOSE AND STARCH

Apparatus. Test tubes; beaker; stirring rod; Bunsen burner; funnel.

Materials. Iodine solution; flour; starch; piece of bread; potato; sodium carbonate; hydrochloric acid; litmus paper; starch solution; Fehling's solution; filter paper; wood splint; sulfuric acid; ammonia; nitric acid.

1. COMPOSITION OF STARCH AND CELLULOSE. Place about 1 gram of starch and a wood splint in separate test tubes. To each add about 2 ml of concentrated sulfuric acid and allow to stand for about 10 minutes.

   Results.

   What are the three elements that compose carbohydrates, wood and starch;

2. PREPARATION OF PARCHMENT PAPER. Dip a thin strip of filter paper into a cold solution of sulfuric acid (two vols. of acid to one vol. of water) and after exactly fifteen seconds transfer the paper to a beaker filled with cold water. Place the paper in a very dilute aqueous ammonia solution. Wash out the ammonia with pure water and allow to dry. The result should be parchment paper. Try writing on the paper with ink.

   How has the filter paper been changed?

3. PREPARATION OF CELLULOSE NITRATE. Mix carefully in a 250 ml beaker exactly 10 ml of water, 68 ml of concentrated sulfuric acid and 30 ml of concentrated nitric acid. Cool the solution to 30^{0} and place about one gram of absorbent cotton. Stir constantly and maintain the temperature at 30 degrees for twenty minutes. At the end of this time remove the cotton from the solution and place in a beaker of water. Finally wash with warm water until the washings do not show an acid reaction to litmus paper. Squeeze as dry as possible and spread out to dry in the air. After it has dried, hold a small piece by means of tongs and place in the flame of a Bunsen burner.

   Results.

4. FEHLING'S TEST OF STARCH. Try the action of starch solution on Fehling's solution, as in the experiment on sugars.

Results.

5. IODINE TEST FOR STARCH. Prepare a starch solution by mixing one gram of starch with 15 ml of cold water and stir until a uniform suspension is obtained. Pour this suspension slowly with stirring into 135 ml of boiling water and continue to boil for a few minutes. To 10 ml of this resulting solution add 6 drops of iodine solution. The iodine solution is prepared in the following way; dissolve one gram of iodine crystals and two grams of potassium iodide in 8 ml of water.

Test different foods such as bread, potatoes, oats, and butter in the same manner. To do this boil about 5 g of the food with 100 ml of water. Filter and cool, then test with the iodine solution.

Results.

FATS AND OILS

Apparatus. Test tubes; beakers; stirring rod; evaporating dish; Bunsen burner; funnel; filter paper; watch glass; glass plate.

Materials. Cocoanut oil; cotton seed oil; peanut oil; corn oil; linseed oil; carbon tetrachloride; bromine in carbon tetrachloride; lard; NaOH; ethanol; HCl; cheese; milk; piece of white writing paper.

1. SAPONIFICATION OF COCOANUT OIL. Add 25 ml of denatured ethanol to 7 g of cocoanut oil in an evaporating dish. To the resulting mixture add 2 g of sodium hydroxide dissolved in 4 ml of water. Heat the evaporating dish and its contents in a water bath maintained at 70 to 85 degrees. Care is necessary to keep the alcoholic solution from boiling over and from catching on fire. If the mixture does catch on fire cover with a glass plate.

When solution of the cocoanut oil takes place remove the evaporating dish from the water bath. Place a few drops of the solution on a watch glass and acidify with conc. HCl. A fatty acid percipitate should form.

Write an equation which describes the reaction.

Add the remainder of the alcoholic solution of cocoanut oil to 25 ml of water in a 199 ml beaker. Boil off the alcohol with a small flame, stirring the mixture constantly with a stirring rod until the odor of alcohol can no longer be detected. Add water to the beaker from time to time to maintain the volume of solution.

Cool the solution and add NaCl until the solution is saturated. Soap should precipitate and can be separated by filtration. Wash two or three times with water to remove the excess chemicals.

Test the ability of your soap to form suds. Describe the results.

Due to incomplete saponification of the oil, your soap may be oily or it may be too strongly alkaline.

Write an equation for the saponification of cocoanut oil.

2. SOLUBILITY OF FATS AND OILS. Test the solubility of typical fats and oils in water, alcohol, and carbon tetrachloride. Place a few drops of peanut oil in a clean test tube and add about 1 ml of water. Repeat using alcohol and then carbon tetrachloride. Test the solubility of another fat or oil in the same solvents.

Results.

Place a drop of one of the various oils, such as cotton seed oil, corn oil or linseed oil on a piece of white writing paper. Note the appearance of the resulting spots when they are held in front of a light. Heat the paper slightly to see if the spots will disappear.

Results.

Test for fats, by this method, using cheese and milk.

Results.

3. TEST FOR UNSATURATION. Place 1 ml of corn oil and 5 ml of carbon tetrachloride in a test tube. Then add bromine in carbon tetrachloride until a yellow color caused by an excess of bromine remains after shaking.

Repeat using cotton seed oil, peanut oil and linseed oil. Arrange these oils according to the amount of bromine solution which reacts with them. (a large amount indicates a great degree of unsaturation.)

Results.

PROTEIN DIGESTION

Apparatus. Test tubes; 400 ml beaker; two pieces of 5 mm glass tubing; Bunsen burner; thermometer.

Materials. White of an egg; pepsin solution; citric acid; hydrochloric acid; sodium carbonate solution; wax pencil.

1. CONDITION FOR PROTEIN DIGESTION. Prepare coagulated egg-white by filling two 6 cm lengths of 5 mm glass tubing with the white of an egg. Place the glass tubes in boiling water and leave until the egg is coagulated. Then cut the glass tubing and coagulated egg into three 2 cm lengths.

Number six clean test tubes at the top from one to six with a wax penceil. Into each add a 2 cm piece of coagulated egg-white and 5 ml of water. Then add to each test tube the reagents as indicated below.

Test tube number one. five ml of pepsin solution.

Test tube number two. five ml of 0.1 N hydrochloric acid.

Test tube number three. 2.5 ml of 0.2 N hydrochloric acid and 2.5 ml of pepsin solution.

Test tube number four. 2.5 ml of 0.2 N citric acid and 215 ml of pepsin solution.

Test tube number five. 2.5 ml of 1% sodium carbonate solution and 2.5 ml of pepsin solution.

Test tube number six. 2.5 ml of 0.2 N hydrochloric acid and 2.5 ml of pepsin solution. Before addition of the pepsin solution to test tube number six, bring the pepsin solution to a boil.

Mix the contents of each test tube thoroughly and place in a water bath, maintained at 40 degrees, at the same time. Note the time that is required for the disappearance of the coagulated egg-white in each case.

Results.

Conditions for proteins digestion.

Chemistry Final Test

1. What is organic chemistry?

2. Where are organic compounds found?

3. Why do organic compounds react slower than inorganic?

4. Of what importance are the hydrocarbons in the study of digestion?

5. What are the general formula of the following organic compounds?

   a. Acid ________________

   b. Alcohol ________________

   c. Aldehyde ________________

   d. Hydrocarbon ________________

6. What are the steps for the complete oxidation of methane?

7. Show the resemblance between alcohol and water.

8. What is the function of the digestive system?

9. What is the functional group of a organic acid?

10. Which of the three kinds of foods provide man with the most concentrated source of energy?

11. The alcohol portion of a fat molecule is glycerine; what is the formula of glycerine?

12. What are the four carboxylic acids that were discussed in the chapter on digestion of fats?

13. Explain Lowry's theory of esterification using ethanol and acetic acid.

14. The reverse of esterification (this occurs during digestion) is called?

15. When fats are digested they always form ____________________ and three molecules of a ____

16. What are optical isomers?

17. What are the structural formula of glucose and fructose?

18. Show the mechanism for the hydrolysis of sucrose.

19. Why was a study of ammonia made in the protein chapter? ________

____

____

20. Show how two molecules of alanine can react to form a protein-like molecule containing the peptide linkage.

21. Why are only nine amino acids listed as essential? ____________

____

____

22. Why does maltose, glucose, and fructose show a positive test to Fehlings solution, but sucrose does not?

23. What is the difference between an α -amino acid and an β- amino acid?

24. Why can a molecule of amino acid form a salt with itself?

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