Chemistry Project

on

Natural Polymers
PREFACE

This project is about a few natural polymers. It briefs you about what a polymer is and the examples of natural as well as synthetic polymers. Then there is detailed information on structure, characteristics and uses of five natural polymers which are natural rubber, starch, ribonucleic acid (RNA), cellulose and chitosan.
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INTRODUCTION

The word "polymer" means "many parts" (from the Greek *poly*, meaning "many," and *meros*, meaning "parts"). A polymer is a large molecule (macromolecule) composed of repeating structural units called monomers, typically connected by covalent chemical bonds. While *polymer* in popular usage suggests plastic, the term actually refers to a large class of natural and synthetic materials with a wide variety of properties. Because of the extraordinary range of properties accessible in polymeric materials, they play an essential and ubiquitous role in everyday life[3], ranging from familiar synthetic plastics and elastomers to natural biopolymers such as DNA and proteins that are essential for life.

The most basic property of a polymer is the identity of its constituent monomers. A second set of properties, known as microstructure, essentially describe the arrangement of these monomers within the polymer at the scale of a single chain. These basic structural properties play a major role in determining bulk physical properties of the polymer, which describe how the polymer behaves as a continuous macroscopic material. Chemical properties, at the nano-scale, describe how the chains interact through various physical forces. At the macro-scale, they describe how the bulk polymer interacts with other chemicals and solvents.
Natural rubber was originally derived from latex, a milky colloid found in the sap of some plants. The plants would be ‘tapped’, that is, an incision made into the bark of the tree and the latex sap collected and refined into a usable rubber. The purified form of natural rubber is the chemical polyisoprene, which can also be produced synthetically. Natural rubber is used extensively in many applications and products, as is synthetic rubber.

Rubber is an example of an elastomer type polymer, where the polymer has the ability to return to its original shape after being stretched or deformed. The rubber polymer is coiled when in the resting state. The elastic properties arise from its ability to stretch the chains apart, but when the tension is released the chains snap back to the original position.

STRUCTURE

Crude rubber is primarily hydrocarbon in nature. In 1826 English chemist Michael Faraday (1791–1867) analyzed natural rubber and found it to have the empirical (simplest) formula C₅H₈, along with 2 to 4 percent protein and 1 to 4 percent acetone-soluble materials (resins, fatty acids, and sterols). In 1860 English chemist Charles Hanson Greville Williams (1829–1910) confirmed Faraday's analysis and in 1862 distilled natural rubber to obtain the pure monomer, which he named isoprene. He determined isoprene's vapor density and molecular formula, and he showed that it polymerizes to a rubbery product—an observation that led to the notion that rubber is a linear polymer of an unsaturated hydrocarbon called isoprene, proposed in 1910 by English chemist Samuel Shrowder Pickles (1878–1962).
The molecular weights of rubber molecules range from 50,000 to 3,000,000. Sixty percent of the molecules have molecular weights of greater than 1,300,000. The repeating unit in natural rubber has the cis configuration (with chain extensions on the same side of the ethylene double bond), which is essential for elasticity. If the configuration is trans (with chain extensions on opposite sides of the ethylene double bond), the polymer is either a hard plastic (naturally occurring gutta-percha, obtained from the leaves of Palaiquium, a species of sapotaceous Malaysian and East Indies trees) that was used for wire and cable coating during the nineteenth century; or a substance like gutta-percha (balata, obtained from Mimusops globosa, trees native to Panama and South America), used for modern golf ball covers.

CHARACTERISTICS

Crude rubber is a tough and an elastic solid. It becomes soft and sticky as the temperature rises. Its specific gravity is 0.915. Raw natural rubber has low tensile strength and abrasion resistant. It absorbs large quantities of water. It is insoluble in water, alcohol, acetone, dilute acids and alkalis but is soluble in ether, carbon disulphide, carbon tetrachloride, petrol and turpentine. Pure rubber is a transparent, amorphous solid, which on stretching or prolonged cooling becomes crystalline.

The most important property of natural rubber is its elasticity. When stretched, it expands and attains its original state, when released. In most elastic materials, such as metals used in springs, the elastic behavior is caused by bond distortions. When force is applied, bond lengths deviate from the (minimum energy) equilibrium and strain energy is stored electrostatically. Rubber is often assumed to behave in the same way, but it turns out this is a poor description. Rubber is a curious material because, unlike metals, strain energy is stored thermally. Also, natural rubber is so elastic that when force is applied, on natural rubber when it is on a surface similar to carpet, it may be difficult to 'pull' across the surface. It will stick.

In its relaxed state, rubber consists of long, coiled-up polymer chains that are interlinked at a few points. Between a pair of links, each monomer can rotate freely about its neighbour, thus giving each section of chain leeway to assume a large number of geometries, like a very loose rope attached to a pair of fixed points. At room temperature, rubber stores enough kinetic energy so that each section of chain oscillates chaotically, like the above piece of rope being shaken violently. The entropy model of rubber was developed in 1934 by Werner Kuhn.

When rubber is stretched, the "loose pieces of rope" are taut and thus no longer able to oscillate. Their kinetic energy is given off as excess heat. Therefore, the
entropy decreases when going from the relaxed to the stretched state, and it increases during relaxation. This change in entropy can also be explained by the fact that a tight section of chain can fold in fewer ways (W) than a loose section of chain, at a given temperature (nb. entropy is defined as $S=k\ln(W)$). Relaxation of a stretched rubber band is thus driven by an increase in entropy, and the force experienced is not electrostatic, rather it is a result of the thermal energy of the material being converted to kinetic energy. Rubber relaxation is endothermic, and for this reason the force exerted by a stretched piece of rubber increases with temperature. (Metals, for example, become softer as temperature increases). The material undergoes adiabatic cooling during contraction. This property of rubber can easily be verified by holding a stretched rubber band to your lips and relaxing it. Stretching of a rubber band is in some ways equivalent to the compression of an ideal gas, and relaxation is equivalent to its expansion. Note that a compressed gas also exhibits "elastic" properties, for instance inside an inflated car tire. The fact that stretching is equivalent to compression may seem somewhat counterintuitive, but it makes sense if rubber is viewed as a one-dimensional gas. Stretching reduces the "space" available to each section of chain.

Vulcanization of rubber creates more disulfide bonds between chains, so it shortens each free section of chain. The result is that the chains tighten more quickly for a given length of strain, thereby increasing the elastic force constant and making rubber harder and less extensible.

When cooled below the glass transition temperature, the quasi-fluid chain segments "freeze" into fixed geometries and the rubber abruptly loses its elastic properties, although the process is reversible. This is a property it shares with most elastomers. At very low temperatures, rubber is rather brittle; it will break into shards when struck or stretched. This critical temperature is the reason winter tires use a softer version of rubber than normal tires. The failing rubber o-ring seals that contributed to the cause of the Challenger disaster were thought to have cooled below their critical temperature. The disaster happened on an unusually cold day.

**USES**

The use of rubber is widespread, ranging from household to industrial products, entering the production stream at the intermediate stage or as final products. Tires and tubes are the largest consumers of rubber. The remaining 44% are taken up by the general rubber goods (GRG) sector, which includes all products except tires and tubes.
Prehistoric uses  
The first use of rubber was by the Olmecs, who centuries later passed on the knowledge of natural latex from the *Hevea* tree in 1600 BC to the ancient Mayans. They boiled the harvested latex to make a ball for sport.

Manufacturing  
Other significant uses of rubber are door and window profiles, hoses, belts, matting, flooring and dampeners (antivibration mounts) for the automotive industry in what is known as the "under the bonnet" products. Gloves (medical, household and industrial) and toy balloons are also large consumers of rubber, although the type of rubber used is that of the concentrated latex. Significant tonnage of rubber is used as adhesives in many manufacturing industries and products, although the two most noticeable are the paper and the carpet industries. Rubber is also commonly used to make rubber bands and pencil erasers.

Textile applications  
Additionally, rubber produced as a fiber sometimes called *elastic*, has significant value for use in the textile industry because of its excellent elongation and recovery properties. For these purposes, manufactured rubber fiber is made as either an extruded round fiber or rectangular fibers that are cut into strips from extruded film. Because of its low dye acceptance, feel and appearance, the rubber fiber is either covered by yarn of another fiber or directly woven with other yarns into the fabric. In the early 1900s, for example, rubber yarns were used in foundation garments. While rubber is still used in textile manufacturing, its low tenacity limits its use in lightweight garments because latex lacks resistance to oxidizing agents and is damaged by aging, sunlight, oil, and perspiration. Seeking a way to address these shortcomings, the textile industry has turned to Neoprene (polymer form of Chloroprene), a type of synthetic rubber as well as another more commonly used elastomer fiber, spandex (also known as elastane), because of their superiority to rubber in both strength and durability.
STARCH

Starch or amylum is a carbohydrate consisting of a large number of glucose units joined together by glycosidic bonds. This polysaccharide is produced by all green plants as an energy store. It is generally deposited in the form of small granules or cells with diameters between 1-100 μm. Starch is found in seeds and in tubers or roots of the plants. It is the most important carbohydrate in the human diet and is contained in such staple foods as potatoes, wheat, maize (corn), rice, and cassava.

Pure starch is a white, tasteless and odorless powder that is insoluble in cold water or alcohol. It consists of two types of molecules: the linear and helical amylose and the branched amylopectin. Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin. Glycogen, the glucose store of animals, is a more branched version of amylopectin.

Starch is processed to produce many of the sugars in processed foods. When dissolved in warm water, it can be used as a thickening, stiffening or gluing agent, giving wheatpaste.

STRUCTURE

Starch is a polymer consisting of anhydroglucose (AHG) units. Two types of AHG polymers are usually present in starch: amylose and amylopectin [2-3, 6]. Amylose is essentially a linear polymer in which AHG units are predominantly connected through α-D-(1,4)-glucosidic bonds. The molecular weight of amylose is a function of the plant source and processing method, but usually in the range of 1.6-7 x 10^5 Da. Amylopectin is a branched polymer, containing periodic branches linked with the backbones through α-D-(1,6)-glucosidic bonds. Each branch contains about 20-30 anhydroglucose units. The molecular weight of amylopectin is higher than that of amylose and is typically 4-5 x 10^8 Da. The content of amylose and amylopectine in starch varies and largely depends on the starch source. Typically, the amylose content is between 18-28%.
Starch molecules arrange themselves in the plant in semi-crystalline granules. Each plant species has a unique starch granular size: rice starch is relatively small (about 2μm) while potato starches have larger granules (up to 100μm). Although in absolute mass only about one quarter of the starch granules in plants consist of amylose, there are about 150 times more amylose molecules than amylopectin molecules. Amylose is a much smaller molecule than amylopectin.

**CHARACTERISTICS**

Starch is insoluble in cold water, but it is very hygroscopic and binds water reversibly. Starch becomes soluble in water when heated. The granules swell and burst, the semi-crystalline structure is lost and the smaller amylose molecules start leaching out of the granule, forming a network that holds water and increasing the mixture's viscosity. This process is called starch gelatinization. During cooking the starch becomes a paste and increases further in viscosity. During cooling or prolonged storage of the paste, the semi-crystalline structure partially recovers and the starch paste thickens, expelling water. This is mainly caused by the retrogradation of the amylose. This process is responsible for the hardening of bread or staling, and for the water layer on top of a starch gel (syneresis). If starch is subjected to dry heat, it breaks down to form pyrodextrins, in a process known as dextrinization. Pyrodextrins are brown in color. This process is partially responsible for the browning of toasted bread.

The enzymes that break down or hydrolyze starch into the constituent sugars are known as amylases. Alpha-amylases are found in plants and in animals. Human saliva is rich in amylase, and the pancreas also secretes the enzyme. Individuals from populations with a high-starch diet tend to have more amylase genes than
those with low-starch diets; chimpanzees have very few amylase genes. It is possible that turning to a high-starch diet was a significant event in human evolution. Beta-amylase cuts starch into maltose units. This process is important in the digestion of starch and is also used in brewing, where the amylase from the skin of the seed grains is responsible for converting starch to maltose (Malting, Mashing).

Iodine solution is used to test for starch; a dark blue color indicates the presence of starch. The details of this reaction are not yet fully known, but it is thought that the iodine (I$_3^-$ and I$_5^-$ ions) fit inside the coils of amylose, the charge transfers between the iodine and the starch, and the energy level spacings in the resulting complex correspond to the absorption spectrum in the visible light region. The strength of the resulting blue color depends on the amount of amylose present. Waxy starches with little or no amylose present will color red.

Starch indicator solution consisting of water, starch and iodine is often used in redox titrations: in the presence of an oxidizing agent the solution turns blue, in the presence of reducing agent the blue color disappears because triiodide (I$_3^-$) ions break up into three iodide ions, disassembling the starch-iodine complex. A 0.3% w/w solution is the standard concentration for a starch indicator. It is made by adding 3 grams of soluble starch to 1 litre of heated water; the solution is cooled before use (starch-iodine complex becomes unstable at temperatures above 35 °C).

Microscopy of starch granules :- Each species of plant has a unique shape of starch granules in granular size, shape and crystallisation pattern. Under the microscope, starch grains stained with iodine illuminated from behind with polarized light show a distinctive Maltese cross effect (also known as extinction cross and birefringence).

**USES**

Maltodextrin and starch are important energy sources in baby foods because they have a low fermentability. It is estimated that 70% of the starch produced is converted into syrups for food use (Tester and Karkalas, 2002). Modified waxy maize starch is important in processed meat products where its gelling properties are useful as a binder to maintain the texture and stability of the processed product.

Papermaking is the largest non-food application for starches globally, consuming millions of metric tons annually. In a typical sheet of copy paper for instance, the
starch content may be as high as 8%. Both chemically modified and unmodified starches are used in papermaking. Together with surface sizing agent the surface starches impart additional strength to the paper web and additionally provide water hold out or “size” for superior printing properties. Starch is also used in paper coating as one of the binders for the coating formulation a mixture of pigments, binders and thickeners. Coated paper has improved smoothness, hardness, whiteness and gloss and thus improves printing characteristics.

Corrugated board adhesives are the next largest application of non-food starches globally. Starch glues are mostly based on unmodified native starches, plus some additive such as borax and caustic soda. Part of the starch is gelatinized to carry the slurry of uncooked starches and prevent sedimentation. This opaque glue is called a SteinHall adhesive

Another large non-food starch application is in the construction industry, where starch is used in the gypsum wall board manufacturing process. Chemically modified or unmodified starches are added to the stucco containing primarily gypsum. Top and bottom heavyweight sheets of paper are applied to the formulation, and the process is allowed to heat and cure to form the eventual rigid wall board. The starches act as a glue for the cured gypsum rock with the paper covering, and also provide rigidity to the board.

Clothing starch or laundry starch is a liquid that is prepared by mixing a vegetable starch in water (earlier preparations also had to be boiled), and is used in the laundering of clothes. It is used to stiffen the wide collars and ruffs of fine linen which surrounded the necks of the well-to-do. Aside from the smooth, crisp edges it gave to clothing, it served practical purposes as well. Dirt and sweat from a person's neck and wrists would stick to the starch rather than to the fibers of the clothing, and would easily wash away along with the starch. After each laundering, the starch would be reapplied. Today, the product is sold in aerosol cans for home use.

Starch is used to produce various bioplastics, synthetic polymers that are biodegradable. An example is polylactic acid. In oil exploration, starch is used to adjust the viscosity of drilling fluid, which is used to lubricate the drill head and suspend the grinding residue in petroleum extraction. Glucose from starch can be further fermented to biofuel ethanol. Hydrogen production can use starch as the raw material, using enzymes.
RIBONUCLEIC ACID (RNA)

Ribonucleic acid (RNA) is a biologically important type of molecule that consists of a long chain of nucleotide units. Each nucleotide consists of a nitrogenous base, a ribose sugar, and a phosphate. RNA is very similar to DNA, but differs in a few important structural details: in the cell, RNA is usually single-stranded, while DNA is usually double-stranded; RNA nucleotides contain ribose while DNA contains deoxyribose (a type of ribose that lacks one oxygen atom); and RNA has the base uracil rather than thymine that is present in DNA. RNA is transcribed from DNA by enzymes called RNA polymerases and is generally further processed by other enzymes. RNA is central to protein synthesis. Here, a type of RNA called messenger RNA carries information from DNA to structures called ribosomes. These ribosomes are made from proteins and ribosomal RNAs, which come together to form a molecular machine that can read messenger RNAs and translate the information they carry into proteins. There are many RNAs with other roles – in particular regulating which genes are expressed, but also as the genomes of most viruses.

STRUCTURE

Each nucleotide in RNA contains a ribose sugar, with carbons numbered 1' through 5'. A base is attached to the 1' position, generally adenine (A), cytosine (C), guanine (G) or uracil (U). Adenine and guanine are purines, cytosine and uracil are pyrimidines. A phosphate group is attached to the 3' position of one ribose and the 5' position of the next. The phosphate groups have a negative charge each at physiological pH, making RNA a charged molecule (polyanion). The bases may form hydrogen bonds between cytosine and guanine, between adenine and uracil and between guanine and uracil. However other interactions are possible, such as a group of adenine bases binding to each other in a bulge, or the GNRA tetraloop that has a guanine–adenine base-pair.\[4\]
An important structural feature of RNA that distinguishes it from DNA is the presence of a hydroxyl group at the 2' position of the ribose sugar. The presence of this functional group causes the helix to adopt the A-form geometry rather than the B-form most commonly observed in DNA. This results in a very deep and narrow major groove and a shallow and wide minor groove. A second consequence of the presence of the 2'-hydroxyl group is that in conformationally flexible regions of an RNA molecule (that is, not involved in formation of a double helix), it can chemically attack the adjacent phosphodiester bond to cleave the backbone.

RNA is transcribed with only four bases (adenine, cytosine, guanine and uracil), but there are numerous modified bases and sugars in mature RNAs. Pseudouridine (Ψ), in which the linkage between uracil and ribose is changed from a C–N bond to a C–C bond, and ribothymidine (T), are found in various places (most notably in the TΨC loop of tRNA). Another notable modified base is hypoxanthine, a deaminated adenine base whose nucleoside is called inosine (I). Inosine plays a key role in the wobble hypothesis of the genetic code. There are nearly 100 other naturally occurring modified nucleosides, of which pseudouridine and nucleosides with 2'-O-methylribose are the most common. The specific roles of many of these modifications in RNA are not fully understood. However, it is notable that in ribosomal RNA, many of the post-transcriptional modifications occur in highly functional regions, such as the peptidyl transferase center and the subunit interface, implying that they are important for normal function.

The functional form of single stranded RNA molecules, just like proteins, frequently requires a specific tertiary structure. The scaffold for this structure is provided by secondary structural elements which are hydrogen bonds within the molecule. This leads to several recognizable "domains" of secondary structure like hairpin loops, bulges and internal loops. Since RNA is charged, metal ions such as Mg$^{2+}$ are needed to stabilise many secondary and tertiary structures.

**CHARACTERISTICS AND FUNCTIONS**

RNA, which is made up of nucleic acids, has a variety of functions in a cell and is found in many organisms including plants, animals, viruses, and bacteria. Ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) differ functionally. DNA primarily serves as the storage material for genetic information. RNA can function as a carrier of genetic information, a catalyst of biochemical reactions, an adapter molecule in protein synthesis, and a structural molecule in cellular organelles.
There are five major types of RNA that are found in the cells of eukaryotes. These include heterogeneous nuclear RNA (hnRNA), messenger RNA (mRNA), transfer RNA (tRNA), ribosomal RNA (rRNA), and small nuclear RNA. Structurally, hnRNA and mRNA are both single stranded, while rRNA and tRNA form three-dimensional molecular configurations. Each type of RNA has a different role in various cellular processes. In addition to A computer-generated model of ribonucleic acid (RNA).

One of the primary functions of RNA is to facilitate the translation of DNA into protein. This process begins in the nucleus of the cell with a series of enzymatic reactions that transcribe DNA into heterogeneous nuclear RNA by complementary base pairing.

While DNA and RNA are very similar in their composition, RNA has a different roles. RNA can serve as a component of the translation machinery and catalyze chemical reactions. For example, in addition to RNA molecules such as rRNA, ribozymes are also a type of RNA that can serve catalytic functions.

Certain viruses contain RNA as their primary genetic material. Viruses bind to a specific protein or receptor on the surface of the cell that it is going to infect. RNA, the virus's genetic material, is injected into the cell. The viral RNA associates with the ribosomes that belong to the cell it is infecting. In a sense, viruses hijack the host's molecular machinery, using the cells transcriptional abilities for its own purpose, to produce viral proteins. The viral proteins then form new viruses. Viral RNA can also form replication complexes where it can copy itself. This copied RNA then gets packaged into the newly created viruses that can cause the cell to lyse, or break open, and these released viruses can infect other cells.

RNA interference (RNAi) is a system within living cells that helps to control which genes are active and how active they are. Two types of small RNA molecules – microRNA (miRNA) and small interfering RNA (siRNA) – are central to RNA interference. RNAs are the direct products of genes, and these small RNAs can bind to specific other RNAs and either increase or decrease their activity, for example by preventing a messenger RNA from producing a protein. RNA interference has an important role in defending cells against parasitic genes – viruses and transposons – but also in directing development as well as gene expression in general.

The RNAi pathway is found in many eukaryotes including animals and is initiated by the enzyme Dicer, which cleaves long double-stranded RNA (dsRNA) molecules into short fragments of ~20 nucleotides. One of the two strands of each fragment, known as the guide strand, is then incorporated into the RNA-induced
silencing complex (RISC). The most well-studied outcome is post-transcriptional gene silencing, which occurs when the guide strand base pairs with a complementary sequence of a messenger RNA molecule and induces cleavage by Argonaute, the catalytic component of the RISC complex. This process is known to spread systemically throughout the organism despite initially limited molar concentrations of siRNA.

The selective and robust effect of RNAi on gene expression makes it a valuable research tool, both in cell culture and in living organisms because synthetic dsRNA introduced into cells can induce suppression of specific genes of interest. RNAi may also be used for large-scale screens that systematically shut down each gene in the cell, which can help identify the components necessary for a particular cellular process or an event such as cell division. Exploitation of the pathway is also a promising tool in biotechnology and medicine.
CELLULOSE

Cellulose is an organic compound with the formula \((C_6H_{10}O_5)_n\), a polysaccharide consisting of a linear chain of several hundred to over ten thousand \(\beta(1\rightarrow4)\) linked D-glucose units. Cellulose is the structural component of the primary cell wall of green plants, many forms of algae and the oomycetes. Some species of bacteria secrete it to form biofilms. Cellulose is the most common organic compound on Earth. About 33 percent of all plant matter is cellulose (the cellulose content of cotton is 90 percent and that of wood is 40-50 percent).

The acetal linkage is beta which makes it different from starch. This peculiar difference in acetal linkages results in a major difference in digestibility in humans. Humans are unable to digest cellulose because the appropriate enzymes to breakdown the beta acetal linkages are lacking. Undigestible cellulose is the fiber which aids in the smooth working of the intestinal tract. Animals such as cows, horses, sheep, goats, and termites have symbiotic bacteria in the intestinal tract. These symbiotic bacteria possess the necessary enzymes to digest cellulose in the GI tract. They have the required enzymes for the breakdown or hydrolysis of the cellulose; the animals do not, not even termites, have the correct enzymes. No vertebrate can digest cellulose directly.

STRUCTURE

Cellulose is derived from D-glucose units, which condense through \(\beta(1\rightarrow4)\)-glycosidic bonds. This linkage motif contrasts with that for \(\alpha(1\rightarrow4)\)-glycosidic bonds present in starch, glycogen, and other carbohydrates. Cellulose is a straight chain polymer: unlike starch, no coiling or branching occurs, and the molecule adopts an extended and rather stiff rod-like conformation, aided by the equatorial conformation of the glucose residues. The multiple hydroxyl groups on the glucose from one chain form hydrogen bonds with oxygen molecules on the same or on a neighbor chain, holding the chains firmly together side-by-side and forming microfibrils with high tensile strength. This strength is important in cell walls, where the microfibrils are meshed into a carbohydrate matrix, conferring rigidity to plant cells.

Several different crystalline structures of cellulose are known, corresponding to the location of hydrogen bonds between and within strands. Natural cellulose is cellulose I, with structures \(I_\alpha\) and \(I_\beta\). Cellulose produced by bacteria and algae is enriched in \(I_\alpha\) while cellulose of higher plants consists mainly of \(I_\beta\). Cellulose in
regenerated cellulose fibers is cellulose II. The conversion of cellulose I to cellulose II is not reversible, suggesting that cellulose I is metastable and cellulose II is stable. With various chemical treatments it is possible to produce the structures cellulose III and cellulose IV.

![Cellulose](image)

**CHARACTERISTICS**

Cellulose has no taste, is odourless, is hydrophilic, is insoluble in water and most organic solvents, is chiral and is biodegradable. It can be broken down chemically into its glucose units by treating it with concentrated acids at high temperature. Cellulose is soluble in cupriethylenediamine (CED), cadmiumethylenediamine (Cadoxen), N-methylmorpholine N-oxide and lithium chloride / dimethylformamide\(^{[14]}\). This is used in the production of regenerated celluloses (as viscose and cellophane) from dissolving pulp.

Compared to starch, cellulose is also much more crystalline. Whereas starch undergoes a crystalline to amorphous transition when heated beyond 60-70 °C in water (as in cooking), cellulose requires a temperature of 320 °C and pressure of 25 MPa to become amorphous in water.

Many properties of cellulose depend on its chain length or degree of polymerization, the number of glucose units that make up one polymer molecule. Cellulose from wood pulp has typical chain lengths between 300 and 1700 units; cotton and other plant fibers as well as bacterial celluloses have chain lengths ranging from 800 to 10,000 units. Molecules with very small chain length resulting from the breakdown of cellulose are known as cellodextrins; in contrast to long-chain cellulose, cellodextrins are typically soluble in water and organic solvents. Plant-derived cellulose is usually contaminated with hemicellulose, lignin, pectin and other substances, while microbial cellulose is quite pure, has a much higher water content, and consists of long chains.
USES

The applications of cellulose to the necessities of human life, infinitely varied in kind as they are colossal in magnitude, depend upon two groups of qualities or properties, (1) structural, (2) chemical. The manufactures of vegetable textiles and of paper are based upon the fibrous forms of the naturally occurring cellulosics, together with such structural qualities as are expressed in the terms strength, elasticity, specific gravity. As regards chemical properties, those which come into play are chiefly the negative quality of resistance to chemical change; this is obviously a primary factor of value in enabling fabrics to withstand wear and tear, contact with atmospheric oxygen and water, and such chemical treatments as laundring; positive chemical properties are brought into play in the auxiliary processes of dyeing, printing, and the treatment and preparation in connexion with these. Staple textiles of this group are cotton, flax, hemp and jute; other fibres are used in rope-making and brush-making industries. These subjects are treated in special articles under their own headings and in the article Fibres.

The paper trade has required to seek new sources of cellulose, in consequence of the enormous expansion of the uses of paper. As a development of the paper industry we must mention the manufacture of paper textiles, based upon the production of pulp yarns. Paper pulps are worked into flat strips, which are then rolled into cylindrical form, and by a final twisting process a yarn is produced sufficiently strong to be employed in weaving.

What we may call the special cellulose industries depend upon specific chemical properties of cellulose, partly intrinsic, partly belonging to the derivatives such as the esters. Thus the cellulose nitrates are the bases of our modern high explosives, as well as those now used for military purposes.

The industries in celluloid, xylonite, &c., also depend upon the nitric esters of cellulose, and the plastic state which they assume when treated with solvent liquids, such as alcohol, amyl acetate, camphor and other auxiliaries, in which state they can be readily moulded and fashioned at will. They have taken an important place as structural materials both in useful and artistic applications.

The acetates of cellulose have recently been perfected, and are used in coating fine wires for electrical purposes especially in instrument-making; this use depends upon their electrical properties of high insulation and low inductive capacity.

Of special importance are the more recent developments in the production of artificial fibres of all dimensions, by spinning or drawing the solutions of cellulose or derivatives. Three such processes are in course of evolution. (1) The first is
based on the nitrates of cellulose which are dissolved in ether-alcohol, and spun through fine glass jets into air or water, the unit threads being afterwards twisted together to constitute the thread used for weaving. (2) The cupro-ammonium solution of cellulose is similarly employed, the solution being spun or drawn into a strong acid bath which instantly regenerates cellulose hydrate in continuous length. (3) Still more recently the "viscose" solution of cellulose, i.e. of the cellulose xanthogenic acid, has been perfected for the production of artificial silk or lustra-cellulose; the alkaline solution of the cellulose derivative being drawn either into concentrated ammonium salt solutions or into acid baths. The viscose solution of cellulose is also used for a number of industrial effects in connection with paper-sizing, paper-coating, textile finishes, and the production of book cloth and leather cloth, and, solidified in solid masses, is used in preparing structural solids which can be moulded, turned and fashioned.
Terms chitin and chitosan describe a continuum of copolymers of N-acetyl-D-glucosamine and D-glucosamine residues, the two being distinguished by insolubility or solubility in dilute aqueous acid solutions. Their properties are frequently dependent on the relative proportions of N-acetyl-D-glucosamine and D-glucosamine residues, as are their biodegradability and their biological role.

STRUCTURE

Chitosan is a linear polysaccharide composed of randomly distributed β-(1-4)-linked D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit).

CHARACTERISTICS

Chitosan is characterised by either the degree of acetylation (DA), which corresponds to the N-acetylamine groups, or the degree of deacetylation DDA (DDA=100-DA), D-glucosamine groups. The degree of acetylation has an influence on all the physicochemical properties, (molecular weight, viscosity, solubility, etc…) so, it is one of the most important parameters.

Chitosan in the form of free amine is insoluble in water to pH near neutrality, in concentrated acids with the exception of sulphuric acid, the bases and organic solvents. Their acid base properties allow easy dissolution. Therefore, chitosan is soluble in dilute HCl, HBr, HI, HNO₃, and HClO₄. Chitosan is also slightly soluble in dilute H₃PO₄ but is insoluble in dilute H₂SO₄ at room temperature, although chitosan sulphate dissolves in water on heating and reforms on cooling. In fact, chitosan is soluble in diluted acids on account of a protonation of free amine groups.
USES

In agriculture, chitosan is used primarily as a natural seed treatment and plant growth enhancer, and as an ecologically friendly biopesticide substance that boosts the innate ability of plants to defend themselves against fungal infections. The biocontrol mode of action of chitosan elicits natural innate defense responses within plant to resist against insects, pathogens, and soil borne diseases when applied to foliage or the soil. Chitosan increases photosynthesis, promotes and enhances plant growth, stimulates nutrient uptake, increases germination and sprouting, and boosts plant vigor. Agricultural applications of chitosan can reduce environmental stress due to drought and soil deficiencies, strengthen seed vitality, improve stand quality, increase yields, and reduce fruit decay of vegetables, fruits and citrus crops (see photo right). Horticultural applications of chitosan increases blooms, extends the life of cut flowers and Christmas trees.

Chitosan can also be used in water processing engineering as a part of a filtration process. Chitosan causes the fine sediment particles to bind together and is subsequently removed with the sediment during sand filtration. Chitosan also removes phosphorus, heavy minerals, and oils from the water. Chitosan is an important additive in the filtration process. Sand filtration apparently can remove up to 50% of the turbidity alone while the chitosan with sand filtration removes up to 99% turbidity. Chitosan has been used to precipitate caseins from bovine milk and cheese making. Chitosan is also useful in other filtration situations, where one may need to remove suspended particles from a liquid. Chitosan, in combination with bentonite, gelatin, silica gel, isinglass, or other fining agents is used to clarify wine, mead, and beer. Added late in the brewing process, chitosan improves flocculation, and removes yeast cells, fruit particles, and other detritus that cause hazy wine. Chitosan combined with colloidal silica is becoming a popular fining agent for white wines, because chitosan does not require acidic tannins (found primarily in red wines) to flocculate with.\[28\]

Scientists have recently developed a polyurethane coating that heals its own scratches when exposed to sunlight, offering the promise of scratch-free cars and other products. The self-healing coating uses chitosan incorporated into traditional polymer materials, such as those used in coatings on cars to protect paint. When a scratch damages the chemical structure, the chitosan responds to ultraviolet light by forming chemical chains that begin bonding with other materials in the substance, eventually smoothing the scratch. The process can take less than an hour.
Chitosan's properties allow it to rapidly clot blood. Chitosan hemostatic products reduce blood loss in comparison to gauze dressings and increase patient survival. Chitosan is frequently sold in tablet form at health stores as a "fat binder": It is supposed to have the capability to interact with lipids (fat) from the digestive system and limit their absorption in the body. Therefore, chitosan can be an effective complement to help lose weight during diet period or to stabilise ones weight.
Chemistry Project

To study the quantity of casein present in different samples of milk

Submitted as per the requirement of All India Senior School Certificate Examination of Central Board of Secondary Education, 2011.

Guided by:
Department of Chemistry

Submitted by:
Roll No:-
CERTIFICATE

This is to certify that the Project Work entitled “To study the quantity of casein present in different samples of milk” has been carried out successfully by student name in partial fulfillment of the requirement for the award of All India Senior Secondary School Certificate Examination, Central Board of Secondary Education is record of my supervision under work carried out during the academic year

(Teacher name)
HOD
ACKNOWLEDGEMENT

I express my deep sense of gratitude to my guide, Teacher Name, Head of Chemistry Department, for her kind guidance, sympathetic supervision, authentic suggestion and encouragement during the Project Work

Class XII
Section-A(Science)
INTRODUCTION

Milk is a complete diet as it contains proteins, carbohydrates, fats, minerals, vitamins and water. The average composition of milk from different sources is given below:

<table>
<thead>
<tr>
<th>SOURCE OF MILK</th>
<th>WATER (%)</th>
<th>MINERALS (%)</th>
<th>PROTEINS (%)</th>
<th>FATS (%)</th>
<th>CARBOHYDRATES (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>87.1</td>
<td>0.7</td>
<td>3.4</td>
<td>3.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Human</td>
<td>87.4</td>
<td>0.2</td>
<td>1.4</td>
<td>4.0</td>
<td>4.9</td>
</tr>
<tr>
<td>Goat</td>
<td>87</td>
<td>0.7</td>
<td>3.3</td>
<td>4.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Sheep</td>
<td>82.6</td>
<td>0.9</td>
<td>5.5</td>
<td>6.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Casein (from Latin Caseus “cheese”) is the most predominant phosphoprotein found in milk and cheese. When coagulated with rennet, casein is sometimes called Paracasein. British terminology, on the other hand, uses the term caseinogen for the uncoagulated protein and casein for coagulated protein. As it exists in milk, it is a salt of calcium.

Casein is not coagulated by heat. It is precipitated by acids and by rennet enzymes, a proteolytic enzyme typically obtained from the stomachs of calves. The enzyme trypsin can hydrolyze off a phosphate-containing peptone.

Casein consists of a fairly high number of praline peptides, which do not interact. There are also no disulphide bridges. As a result, it has relatively little secondary structure or tertiary structure. Because of this, it cannot denature. It is relatively hydrophobic, making it poorly soluble in water. It is found in milk as a suspension of particles called casein micelles which show some resemblance with surfactant-type micelles in a sense that the hydrophilic parts reside at the surface. The caseins in the micelles are held together by calcium ions and hydrophobic interactions. These micelles have negative charge and on adding acid to milk the negative charges are neutralized.

\[
\text{Ca}^{2+} - \text{Caesinate} + 2\text{CH}_3\text{COOH(aq)} \rightarrow \text{Casein}^+ (\text{CH}_3\text{COO})_2\text{Ca(aq)}
\]

The isoelectric point of casein is 4.7. The purified protein is water insoluble. While it is also insoluble in neutral salt solutions, it is readily dispersible in dilute alkalis and in salt solutions such as sodium oxalate and sodium acetate.
**Applications**

In addition to being consumed in milk, casein is used in the manufacture of adhesives, binders, protective coatings, plastics (such as for knife handles and knitting needles), fabrics, food additives, and many other products. It is commonly used by bodybuilders as a slow-digestive source of amino acids as opposed to the fast-digesting whey protein, and also as an extremely high source of glutamine (post workout). Another reason it is used in bodybuilding, is because of its anti-catabolic effect, meaning that casein consumption inhibits protein breakdown in the body. Casein is frequently found in otherwise nondairy cheese substitutes to improve consistency especially when melted.
OBJECTIVE OF PROJECT

To study the quantity of casein present in different samples of milk.
OBJECTIVE OF THE PROJECT:

To study the quantity of casein present in different samples of milk.

REQUIREMENTS:
1. Beakers[250ml]
2. Filter Paper
3. Glass Rod
4. Weight Box
5. Filtration flask
6. Buchner flask
7. Water Pump
8. Test tubes
9. Porcelain dish
10. Burner
11. Different samples of Milk
12. 1% Acetic acid solution
13. Saturated ammonium sulphate solution

THEORY:

Natural Milk is an opaque white fluid secreted by the mammary glands of female mammals. The main constituents of natural milk are Protein, Carbohydrate, Mineral, Vitamins, Fats and Water and are a complete balanced diet. Fresh milk is sweetish in taste. However, when it is kept for long time at a temperature of 5 degree, it becomes sour because of bacteria present in air. These bacteria convert lactose of milk into lactic acid which is sour in taste. In acidic condition, casein of milk starts separating out as a precipitate. When the acidity in milk is sufficient and temperature is around 36 degree, it forms semi-solid mass called curd.
**PROCEDURE:**

1. A clean dry beaker was taken. 20 ml of cow’s milk was added along with 20 ml of ammonium sulphate with slow stirring. Fat along with casein is precipitated out.

2. The solution was filtered and the precipitate was transferred into another beaker. 30 ml of water was added to the precipitates. Only casein dissolved in water forming a milky solution leaving fat undissolved.

3. The milky solution was heated to about 40°C and 1% acetic acid solution was added when the casein precipitated.

4. The precipitate was filtered, washed with water and was allowed to dry.

5. The solid dry mass was weighed in a previously weighed watch glass.

6. The above experiment was repeated for other samples of milk.

**OBSERVATIONS:**

The volume of milk taken in each case = 20 ml

<table>
<thead>
<tr>
<th>NAME OF MILK</th>
<th>WEIGHT OF CASEIN (in grams)</th>
<th>% of CASEIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>COW MILK</td>
<td>0.21</td>
<td>1.095%</td>
</tr>
<tr>
<td>BUFFALO MILK</td>
<td>0.35</td>
<td>1.825%</td>
</tr>
<tr>
<td>GOAT MILK</td>
<td>0.47</td>
<td>2.451%</td>
</tr>
</tbody>
</table>

**CONCLUSION:**

Different Samples of milk contain different percentage of casein.
BIBLIOGRAPHY

1. Comprehensive Practical Chemistry by Dr. N.K. Verma.
2. Internet Database
CHEMISTRY
INVESTIGATORY
PROJECT

TO DETERMINE THE AMOUNT OF CASEIN PRESENT IN DIFFERENT SAMPLES OF MILK

NAME :
CLASS : XII
ROLL NO :
SCHOOL NAME :
This is to certify that ____________ has satisfactorily completed the course of CHEMISTRY INVESTIGATORY PROJECT prescribed by the CBSE under the AISSCE course in the laboratory of this school in the year of 2007-2008.

Date:

Signature of the Teacher
CHEMISTRY
INVESTIGATORY
PROJECT

Name of the candidate : 
Examination center :
I would like to sincerely and profusely thank ___________ for the valuable guidance, advice and for giving useful suggestions and relevant ideas that facilitate an easy and early completion of this project.

I also express my deep gratitude to __________________ (lab assistant), who was instrumental in this regards by providing the required laboratory facilities, which also helped in easy completion of this project.
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<td>13</td>
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<td>15</td>
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</table>
AIM

to determine the amount of
CAESIN
Present in different samples of
MILK
Casein is the main protein constituent of milk. Casein constitutes about 80% of the total protein in cow’s milk and about 3% of its weight. Casein group of protein precipitated when the milk is slightly acidified. Casein dissolves slightly in water, extensively in alkalies or strong acids. Casein is a complete protein meaning that it contains all of the essential amino acids, which the body can not manufacture on its own. When dried, it is a white, amorphous powder without taste and odour. Casein is a mixed phosphoprotein and occurs in milk as calcium salt (calcium caseinate) in the form of micelle. The micelle has negative charge. When an acid is added to milk the negative charge is neutralized and the neutral protein gets precipitate. Addition of 10% aqueous solution of Acetic acid to milk causes precipitation in casein.
Calcium caseinate +Acetic acid $\rightarrow$ casein (s) +Calcium acetate (aq)

The $\text{pH}$ of the fresh milk is 6-7 and its isoelectric $\text{pH} = 4.7$. At the isoelectric $\text{pH}$, the solubility of the protein is minimum therefore casein gets precipitated if the $\text{pH}$ falls to 4.7. On standing the $\text{pH}$ of the milk falls due to production of lactic acid by fermentation of lactose. When $\text{pH}$ reaches $4.5 - 4.7$, the casein gets precipitated.
**THEORY**

Milk contains about 3-4% of casein which is suspended in water in colloidal form. It can be separated by precipitated in a weekly acidic medium and filtration. The solid obtained is dried and its weight is noted.
REQUIREMENTS

(A) Apparatus
- 250ml beakers
- Funnel, glass rod
- Porcelain dish
- Chemical balances
- Test tubes
- Filtration flask
- Burner

(B) Chemicals
- Different samples of milk
- 1% of acetic acid solution
- Saturated ammonium sulphate solution
**PROCEDURE**

- **Take a clean dry beaker.** Put into 20ml of cow’s milk and 20ml of saturated ammonium sulphate solution slowly and with stirring. Fat along with CASEIN will precipitate out.

- **Filter the solution and transfer the precipitates in another beaker.** Add about 30ml of water to the precipitates. Only CASEIN dissolves in water forming milky solution leaving fat undissolved.

- **Heat the milky to about 40 C and add 1% of acetic acid solution drop wise where casein gets precipitated.**
- Filter the precipitate, and wash with water and let the precipitate dry.

- Weigh the dry solid mass in a previously weighed watch glass.

- Repeat the experiment with other samples of milk.
<table>
<thead>
<tr>
<th>SL.NO</th>
<th>NAME OF MILK</th>
<th>WEIGHT OF CASEIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cow milk</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Buffalo milk</td>
<td></td>
</tr>
</tbody>
</table>
"Different samples of milk contain different amount of casein."
TOPIC: Study of Diffusion of solids in Liquids

BY
CLASS
ROLL No.: 
INDEX

1. Aim
2. Introduction
3. Objective
4. Experiment 1
5. Experiment 2
6. Experiment 3
7. Result
AIM

Study of Diffusion of solids in liquids
When substances are brought in contact with each other they intermix, this property is known as *Diffusion*. This property of diffusion takes place very rapidly in case of gases and to a lesser extent in case of liquids, whereas solids do not show this process of diffusion with each other. But what we can observe in case of solids is that the diffusion of solids in liquids takes place at a very slow rate.

If a solid is kept in contact with an excess of solvent in which it is soluble, some portion of the solid gets dissolved. We know that this process is known as *dissolution* of a solid in liquid and this process has taken place due to the diffusion of solid particles into liquid.

Molecules of solute are in constant random motion due to the collision between molecules of solute and that of the solvent.
Rate of diffusion depends upon:-

1. *Temperature*: As temperature increases, the kinetic energy of the particles increases so the speed of particles also increases which thus increases the rate of diffusion.

2. *Size of the particle*: As the size of particle increase rate of diffusion decreases.

3. *Mass of the particle*: As the mass of the particle increases the rate of diffusion decreases.
EXPERIMENT 1

To study diffusion when copper sulphate is brought in contact with water (liquid)

REQUIREMENTS
   Copper sulphate crystals, 100ml beaker.

PROCEDURE
   1. Take about 2b of copper sulphate crystals in 100ml beaker.
   2. Add about 50ml of water and allow it to stand for few minutes.
   3. Note the development of blue colour in water.
   4. Allow to stand further till it is observed that all copper sulphate disappears.
   5. Note the blue colour change in water.

CONCLUSION
   When solids such as copper sulphate, potassium permanganate are brought in contact with liquids such as water, intermixing of substances, i.e. diffusion takes place.
EXPERIMENT 2

To study the effect of temperature on the rate of diffusion of solids in liquids

REQUIREMENTS
Copper sulphate crystals, 200ml beaker, watch glass, wire gauge, burner, tripod stand, thermometer and stop watch.

PROCEDURE
1. Take 5g of copper sulphate each in three beakers.
2. Pour 100ml of distilled water slowly in one of the beakers.
3. Cover this beaker with a watch glass.
4. Pour 100ml of cold water in a second beaker slowly.
5. Place a third beaker containing 100ml of water on a tripod stand for heating.
6. Observe the diffusion process which begins in all the beakers.
7. Record of copper sulphate the time taken for the dissolution of copper sulphate in all the three cases.
OBSERVATIONS

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Temperature of water</th>
<th>Time Taken in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>25 °C</td>
<td>15 Min.</td>
</tr>
<tr>
<td>2.</td>
<td>10 °C</td>
<td>20 Min.</td>
</tr>
<tr>
<td>3.</td>
<td>70 °C</td>
<td>10 Min.</td>
</tr>
</tbody>
</table>

CONCLUSION

The Rate of diffusion of copper sulphate in water is in the order of *Beaker 3 > Beaker 1 > Beaker 2*. Thus, the rate of diffusion varies directly with temperature.
EXPERIMENT 3

To study the effect of size of particles on the rate of diffusion of solids in liquids

REQUIREMENTS
  Graduated 100ml measuring cylinders, copper sulphate crystals of different sizes, stop watch

PROCEDURE
  1. Add 50ml of water to each of the three cylinders.
  2. Take 5g each of big size, medium size, small size crystals of copper sulphate and add them separately in three cylinders.
  3. Allow to stand for sometime.
  4. Note the time taken for blue colour to reach any fixed mark in each of the cylinders and note the observations.
OBSERVATION

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Crystal size</th>
<th>Time Taken in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Big</td>
<td>20 Min.</td>
</tr>
<tr>
<td>2.</td>
<td>Medium</td>
<td>15 Min.</td>
</tr>
<tr>
<td>3.</td>
<td>Small</td>
<td>10 Min.</td>
</tr>
</tbody>
</table>

CONCLUSION

Small particles undergo diffusion more quickly than bigger particles.
1. When solids such as copper sulphate, potassium permanganate are brought in contact with liquid such as water, intermixing of the substances, i.e. diffusion takes place.

2. The rate of diffusion varies directly with temperature.

3. Small particles undergo diffusion more quickly than bigger particles.
It is hereby certify that the original and genuine research work has been carried out to investigate about the project matter and the related data preparation has been completed and satisfactory by Student name regarding the project preparation.
ACKNOWLEDGEMENTS

I would like to thank my chemistry teacher [Teacher Name] for her guidance and support. I would also like to thank my Principal [Principal Name] and my parents for their encouragement. I would also like to thank my classmate [Classmate Name] for [Encouragement].

Student Name
Aluminium because of its low density, high tensile strength and resistance to corrosion is widely used for the manufacture of aeroplanes, automobiles, furniture and even for aluminium cans. Being a good conductor of electricity it is used for the transmission of electricity. Aluminium is also used for making utensils.

The recycling of aluminium cans and other aluminium products is a very positive contribution to saving our natural resources. Most of the recycled aluminium is melted and recast into other aluminium metal products or used in the production of various aluminium compounds, the most common of which are the alums.

Alums are double sulphates having the general formula: 

$$X_2SO_4 \cdot M_2(SO_4)_3 \cdot 24H_2O$$
Some important alums and their names are given below:

\[
K_2SO_4.Al_2(SO_4)3.24H_2O \text{ - Potash Alum}
\]

\[
Na_2SO_4.Al_2(SO_4)3.24H_2O \text{ - Soda Alum}
\]

\[
K_2SO_4.Cr_2(SO_4)3.24H_2O \text{ - Chrome Alum}
\]

\[
(NH)_2SO_4.Fe_2(SO_4)3.24H_2O \text{ - Ferric Alum}
\]

Potash alum is used in papermaking, in fire extinguishers, in food stuffs, and in purification of water.

Soda alum is used in baking powders and chrome alum is used in tanning leather and water proofing fabrics.
In addition to these primary uses, alum is also used as:

- **An astringent**: A substance or preparation that draws together or constricts body tissues and is effective in stopping the flow of blood or other secretions. Alum has also been used by conventional hairdressers for treating shaving cuts.

- **A mordant**: Substances used in dyeing to fix certain dyes on cloth. Either the mordant or a colloidal produced by the mordant adheres to the fiber, attracting and fixing the colloidal mordant dye. The insoluble, colored precipitate that is formed is called a lake. Alum is a basic mordant used for fixing acid dyes.

- **For the removal of phosphate from natural and waste waters**: The aluminium ion combines with the orthophosphate around pH 6 to form the solid aluminium hydroxyphosphate which is precipitated.

- **For fireproofing fabrics.**
Aim

Prepare potash alum from aluminium scrap.
Apparatus

- 250 ml flask
- Funnel
- Beaker
- Scrap aluminium or cola can
- Potassium hydroxide solution (KOH)
- 6 M Sulphuric Acid (H₂SO₄)
- Water Bath
- Ethanol
Theory

Aluminum metal is treated with hot aqueous KOH solution. Aluminium dissolves as potassium aluminate, KAl(OH)$_4$, salt.

Potassium aluminate solution on treatment with dil. Sulfuric acid first gives precipitate Al(OH)$_3$, which dissolves on addition of small excess of H$_2$SO$_4$ and heating.

$2\text{Al}(s) + 2\text{KOH}(aq) + 6\text{H}_2\text{O}(l) \rightarrow 2\text{KAl(OH)}_4(aq) + 3\text{H}_2$

The resulting solution is concentrated to near saturation and cooled. On cooling crystals of potash alum crystallize out.

$2\text{KOH}(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow 2\text{Al(OH)}_3(s) + \text{K}_2\text{SO}_4(aq) + 2\text{H}_2\text{O}(l)$

$2\text{Al(OH)}_3(s) + 3\text{H}_2\text{SO}_4(aq) \rightarrow \text{Al}_2(\text{SO}_4)_3(aq) + 6\text{H}_2\text{O}(l)$

The resultant solution is concentrated to near saturation and cooled. On cooling crystals of potash alum crystallize out.

$\text{K}_2\text{SO}_4(aq) + \text{Al}_2(\text{SO}_4)_3(aq) + 24\text{H}_2\text{O}(l) \rightarrow \text{K}_2\text{SO}_4.\text{Al}_2(\text{SO}_4)_3. 24\text{H}_2\text{O}(s)$
Reactions

\[ 2\text{Al}_\text{s} + 2\text{KOH}_{\text{aq}} + 6\text{H}_2\text{O}_{\text{l}} \rightarrow 2\text{KAl(OH)}_4(\text{aq}) + 3\text{H}_2 \]

\[ \text{K}_2\text{SO}_4(\text{aq}) + \text{Al}_2(\text{SO}_4)_3(\text{aq}) + 24\text{H}_2\text{O}_{\text{l}} \rightarrow \text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}_{\text{s}} \]

\[ 2\text{Al(OH)}_3(\text{s}) + 3\text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Al}_2(\text{SO}_4)_3(\text{aq}) + 6\text{H}_2\text{O}_{\text{l}} \]

\[ 2\text{KOH}_{\text{aq}} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{Al(OH)}_3(\text{s}) + \text{K}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O}_{\text{l}} \]

\[ \text{K}_2\text{SO}_4(\text{aq}) + \text{Al}_2(\text{SO}_4)_3(\text{aq}) + 24\text{H}_2\text{O}_{\text{l}} \rightarrow \text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}_{\text{s}} \]
Procedure

- Clean a small piece of scrap aluminium with steel wool and cut it into very small pieces. Aluminium foil may be taken instead of scrap aluminium.

- Put the small pieces of scrap aluminium or aluminium foil (about 1.00g) into a conical flask and add about 50 ml of 4 M KOH solution to dissolve the aluminium.

- The flask may be heated gently in order to facilitate dissolution. Since during this step hydrogen gas is evolved this step must be done in a well ventilated area.

- Continue heating until all of the aluminium reacts.

- Filter the solution to remove any insoluble impurities and reduce the volume to about 25 ml by heating. Allow the filtrate to cool. Now add slowly 6 M H\textsubscript{2}SO\textsubscript{4} until insoluble Al(OH)\textsubscript{3} just forms in the solution.
- Gently heat the mixture until the Al(OH)₃ precipitate dissolves.

- Cool the resulting solution in an ice bath for about 30 minutes whereby alum crystals should separate out. For better results, the solution may be left overnight for crystallization to continue.

- In case crystals do not form, the solution may be further concentrated and proceed as above.

- Filter the crystals from the solution using vacuum pump, wash the crystals with 50/50 ethanol-water mixture.

- Continue applying vacuum until the crystals appear dry.

- Determine the mass of alum crystals.
Observations

Mass of aluminium metal = __________g

Mass of potash alum = __________g

Theoretical yield of potash alum = __________g

Percent yield = __________%
Result

Potash alum was prepared from aluminium scrap.
Bibliography

- Wikipedia