بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of graduate studies

Characterization and Analysis of Polypropylene Manufactured in Sudan

تشخيص وتحليل البوليبروبلين المُصنع في السودان

A thesis Submitted in Partial Fulfillment for the
Requirement of M.Sc. in chemistry

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Sep 2015

الأستهـــــلال

قال تعالى: {قَالَ رَبِّ اشْرَحْ لِي صَدْرِي (25) وَيَسِّرْ لِي
أَمْرِي (26) وَاحْلُلْ عُقْدَةً مِنْ لِسَانِي (27) يَفْقَهُوا قَوْلِي (28)}

سورة طه (25-28)

صدق الله العظيم

Dedication

To those who did not scrimp on the day of tenderness

My mother

******

To Flower my life

My father

******

To those who supported me in overcoming the obstacles

My brother and sisters

******

To complement my life

My Dear husband

******

Acknowledgements

I deeply appreciate and much thanks to my supervisor Dr**. Mohammed EL Mukhtar** for his guidance and encouragement , thanks also to Dr**. EkhlasAbd El Aziz**of theIRCC for her continuous advise.

Abstract

The objective ofthis study is to characterize and analyse threedifferent samples of polypropylene of which one was collected from Elkherat Factory (Omdurman) and two from Khartoum Petrochemical Company .The flame test of these three samples, gave a blue – yellow colour. The results of melt flow rateof these sampleswere 2.63g/20 min , 2.71g\20minand 2.99g/20 min, respectively.The results of melting point were 149 ˚C, 152 ˚c and- 160 ˚c. The results of bulk density were 0.74006g\cm^{3},0.51698g\cm^{3} and 0.92762g/cm^{3}, respectively. The results obtained for the Sudanese samples conformed with the international specifications ASTM of polymers, and therefore they could be used in different industries.

المستخلص

- تمت هذه الدراسة بغرض تشخيص وتحليل ثلاث عينات مختلفة من البولي بروبلين العينة الأولى من مصنع الخيرات (أم درمان) والثانية والثالثة من شركة الخرطوم للبتروكيميائيات(KPC) ،تمإجراء تجربة كشف اللهب للثلاث عينات وأعطت لون أزرق مصفر للعينات الثلاثة.نتائج معامل إنسياب المصهور للثلاث عينات أعطت نتائج 2.63جم/20 دقائق ،2.71 جم/20 دقائق،2.99 جم/20 دقائق على التوالي .

تم تحديد درجة الانصهار للثلاث عينات وكانت 149 ˚م، 152 ˚م، 160 ˚م على التوالي ، والكثافة الإجماليةكانت 0.74006 جم/سم^{3}، 0.51698 جم/سم^{3}، 0.92762جم/سم^{3} على التوالي .وأعطت هذه العينات نتائج تقع في المدى المنصوص عليه في مواصفة ASTM لمواصفات البوليمرات العالمية وعليهيمكن أن تستخدم كبوليمر في الصناعات المختلفة .

List of Contents

Contents	**Pages**
الاستهلال	I
Dedication	II
Acknowledgment	III
Abstract	IV
Abstract (Arabic)	V
List of contents	VI
List of figures	VIII
List of tables	VIII
Chapter One : Introduction	1
1. Introduction	2
1.1 Formation of polymer	2
1.2 Polymerization techniques	4
1.2.1 Bulk polymerization	4
1.2.2 Solution polymerization	5
1.2.3 Suspension polymerization	5
1.2.4 Emulsion polymerization	5
1.3 Thermoplastic	5
1.4 Polypropylene	6
1.4.1 Equation of reaction	11
1.4.2 mechanism of polymerization of propylene	12
1.5 Chemical and physical properties	12
1.6 Molecular masses of polymers	17
1.7 Applications of polypropylene	18
1.7.1 Flexible packaging	19
1.7.2 Rigid packaging	19
1.7.3 Automotive	19
1.7.4 Fibre	20
1.7.5 Industrial	20
1.7.6 Clothing	20
1.7.7 Medical	20
1.8 Aims	22
Chapter Two : Materials and Methods	23
2.1 Collection of samples	24
2.2 Chemicals and materials	25
2.3 Apparatus and instruments	25

2.4 Methods	26
2.4.1 Determination of melt flow rate (MFR)	26
2.4.2 Determination of bulk density	26
2.4.3 Determination of melting point	26
2.4.4 Determination of burning test	26
2.4.5 Determination of Infrared spectrum	27
Chapter Three : Results and discussion	28
3.1 Result and Discussion	29
3.1.1 Melt flow rate (MFR)	29
3.1.2 Bulk density	29
3.1.3 Melting point	30
3.1.4 Burning test	30
3.1.5 The infrared spectrum	31
3.2 Conclusion and Recommendations	34
3.3 References	35
3.4 Accessories	36

List of Figures

Contents	Pages
Figure 1 The infrared spectrum of polypropylene (KPC_1)	31
Figure 2 The infrared spectrum of polypropylene (KPC_2)	32
Figure 3 The infrared spectrum of polypropylene from Elkherat Factory	33

List of Tables

Contents	**Pages**
Table1 The result of melt flow rate for the three samples of Pp	29
Table2 The result of bulk density for the three samples of Pp	29
Table3 The result melting point for the three samples of Pp	30

Chapter One

Introduction

1. Introduction

In its simplest form a polymer (Greek, “many parts’’) is an extremely large molecule , or macromolecule , consisting of covalently linked chain of smaller molecules , called monomers (Greek, ”one parts’’). The monomer is the repeated unit of the polymer, and a typical polymer may have form hundred to hundreds of thousands of repeated units . Synthetic polymers are created by chemical reactions in the laboratory, natural polymers (or bio polymers) are created by chemical reaction within organisms . There are many types of monomers, and their chemical structures allow for the complete repertoire of inter molecular forces .(Morris,2005)

A monomer is a substance that can be converted into a polymer . In other words, it is the starting material . (singh,2014) .

Polymers are the basic of plastic and have been around for a long time. Nature made polymers such as cellulose which has existed long before man invented synthetics .Cellulose is the primary constituent of wood fibre and cotton. Other natural polymers included proteins, natural rubber, tar, and resins.

In the middle of nineteenth century man used natural polymers to form tools and weapons, but it was not until the late nineteenth century that man started modifying polymers to create plastics, which were first made by modifying natural polymeric materials.

The chemical structure and the nature of plastic materials have a significant relationship not only to the properties of the plastic but also to the ways in which it can be processed, designed, or otherwise translated into an end-product. (Hanser, 2001)

1.1 Formation of Polymer

Basically, all polymers are formed by the creation of chemical linkages between relatively small molecules or monomers to form very large molecules or polymers. The process is characterized by the simple combination of molecules without the generation of any by –products formed as a result of the combination . The molecules that combine do not decompose to produce fission products which then remain as part of the reaction debris or need to be removed from the reaction to either allow it to continue the molecule-building process or to ensure the formation of pure polymer.

In reality the addition-type process can occur in several ways. One way simply involves the external chemical activation of molecules that causes them to start combining with each other. In chain – reaction – type fashion, can occur the bonding of atoms directly within the reaction molecule. Another way for an addition polymerization to occur is through a rearrangement of atoms within both reaction molecules, but still without the net loss of any atoms from the polymer molecule.

And still a third way for addition polymerization to occur is for a molecule composed of a ring of atoms to open up and connect with other ring – type molecules being opened up under the influence of the proper catalytic activators, once again with no net loss of any atoms from the polymer structure .

In another type of polymerization reaction , which has been called ''condensation'' polymerization the chemical union of two molecule can be achieved only by the splitting out of a molecule (usually small) formed by the atoms , which must be removed from the two molecules being joined to allow the coupling process or polymerization to continue. This is type of polymerization involved in the formation of some nylons, phenolics ,aminoresins , and polyester pre-polymers.

Normally the reaction by –product in a condensation type of polymerization must be immediately removed from the reaction polymer because it may either inhibit further polymerization or appear as an one desirable impurity in the finished polymer.

There is yet another method by which polymers may be formed, but it is in reality – simply a sequential combination of the previous two processes. Such a process is used in theformation of plastic such as the polyesters and the polyurethanes.

In such a polymerization, a condensation reaction usually is carried out first to form a relatively small polymer, which is then capable of undergoing further reaction by addition polymerization to form larger polymer molecules with a third ingredient. (Hanser, 2001)

1.2 polymerization Techniques

The polymerization techniques can have significant effect on the number , size and characteristic of the polymer molecules formed and thus will have a significant effect on the properties of the polymer . Thus, batches of polymer such as polystyrene , which can be made by any of the four polymerization techniques , will differ , depending on which type of polymerization method was used to make the material . (Allen,2004)

In actual practice there are many different techniques used to carry out polymerization. However, most involve one of four general methods of polymerization; the polymerization of the monomer or reaction in bulk, in suspension, and in emulsion forms. The bulk and solution methods are used for formation of both addition and condensation type polymer, where as suspension and emulsion techniques are used largely for addition polymerization.(Allen, 2004)

1.2.1 Bulk Polymerization

This type of polymerization involves the reaction of monomers or reactants among themselves without placing them in some form of extraneous media such as is done in the other types of polymerization of Initial reaction.

$$2\,CH_2{=}CH_2 + R\text{-}R \longrightarrow 2\,R\text{-}[CH_2\text{-}CH_2]-$$

Propagation reaction

$$R\text{-}[CH_2\text{-}CH_2]\text{-} + (n-1)CH_2{=}CH_2 \longrightarrow R\text{-}[CH_2\text{-}CH_2]_n\text{-}$$

Termination reaction (combination)

$$R\text{-}[CH_2\text{-}CH_2]_n\text{-} + R\text{-} \longrightarrow R\text{-}[CH_2\text{-}CH_2]_n\text{-}R$$

This rearrangement (polyurethane polymerization) reaction are the typical addition polymerization (no by – products). (Allen,2004)

1.2.2 Solution Polymerization

Solution polymerization is similar to bulk polymerization except that the solvent for the forming polymer in bulk polymerization is the monomer, where the solvent in solution polymerization is usually a chemically inert medium.

The solvents used may be complete, partial, or non-solvents for the growing polymer chain. (Allen, 2004)

1.2.3 Suspension Polymerization

Often called "pearl" polymerization, this technique is normally used only for catalyst – initiated or free radical addition polymerization. The monomer is mechanically dispersed in a liquid, usually water , which is a non – solvent for the monomer as well as for all sizes of polymer molecules that form during the reaction . (Allen, 2004)

1.2.4 Emulsion Polymerization

This technique in which addition polymerization are carried out in a water medium containing an emulsifier (soap) and a water – soluble – initiator. It is used because emulsion polymerization is much more rapid than bulk or solution polymerization at the same temperatures and produces polymer with molecular weights much greater than those obtained at the same rate in bulk polymerization. The polymerization reaction in emulsion polymerization involves the reaction to take place within a small hollow sphere composed of a film of soap molecules, called a micelle. (Allen, 2004)

1.3 THERMOPLASTIC

Plastic are generally organic high polymers and , they consist of large chain- like molecules containing carbon that are formed in a plastic state either during or after their transition from a small – molecule chemical to a solid material . The large chain – like molecules are formed by hooking together short chain molecules of chemicals (monomers) in reaction known as polymerization.

When unit of single monomer are hooked together , the resulting plastic is a homo polymer , such as polyethylene , which is made from ethylene monomer . When more than one monomer is included in the process, for example, ethylene and propylene, the resulting plastic is a copolymer.

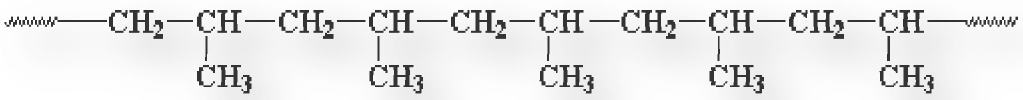
The two basic groups of plastic materials are the thermoplastic and the thermosets . Thermoplastic resins consist of long molecules, each of which may have side chains or groups that are not attached to other molecules (i,e,.,are not cross linked) .Thus , they can be repeatedly melted and solidified by heating and cooling so that any scrap generated in processing can be reused . no chemical change generally takes place while they are forming .Usually, thermo plastic polymers are supplied in the form of pellets, which often contain additives to enhance processing or to provide necessary characteristics in the finished product (e,g,.,colour, conductivity ,etc.) the temperature service range of thermoplastic is limited by their loss of physical strength and eventual melting at elevated temperatures . (Allen, 2004)

1.4 Polypropylene (PP)

This polyolefin has turned out to be the most versatile of the family, accounting for the continuing rapid increase in its use. The development of high –activity catalysts improved the yields dramatically and almost eliminated production of the a tactic form. The resulting isotactic polymer were highly stereo regular.

polypropylene can be made with different tacticities. Most polypropylene we use is isotactic. This means that all the methyl groups are on the same side of the chain, like this:

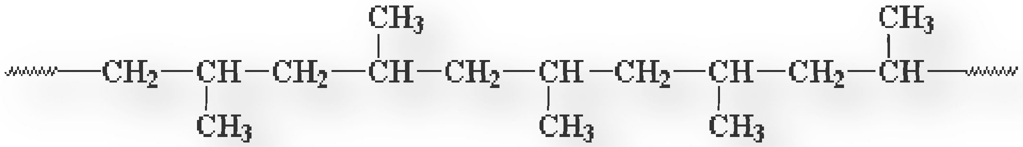
isotactic polypropylene.



$$\sim\!\!\sim CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{CH_3}{|}}{CH}-\sim\!\!\sim$$

isotactic polypropylene

But sometimes we use atactic polypropylene. atactic means that the methyl groups are placed randomly on both sides of the chain like this: Atactic polypropylene.



$$\sim\!\!\sim CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-\overset{\overset{CH_3}{|}}{CH}-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_2-\overset{\overset{CH_3}{|}}{CH}-\sim\!\!\sim$$

atactic polypropylene

However, by using special metallocene catalysts, it's believed that we can make polymers that contain blocks of isotactic polypropylene and blocks of atactic

polypropylene in the same polymer chain, This polymer is rubbery, and makes a good elastomer. This is because the isotactic blocks will form crystals by them selves. But because the isotactic blocks are joined to the atactic blocks, the little hard clumps of crystalline isotactic polypropylene are tied together by soft rubbery tethers of atactic polypropylene. To be honest, atactic polypropylene would be rubbery without help from the isotactic blocks, but it wouldn't be very strong. The hard isotactic blocks hold the rubbery isotactic material together, to give the material more strength. Most kinds of rubber have to be crosslinked to give them strength, but not polypropylene elastomers. elastomeric polypropylene, as this copolymer is called, is a kind of thermoplastic elastomer. the polypropylene that you can buy off the shelf at the store today has about 50 - 60% crystallinity, but this is too much for it to behave as an elastomer .

Polypropylenes have better resistance to heat (heat distortion temperature at 66 psi : 200 – 250 ˚F) and resist more chemicals than do other thermoplastic materials of same cost . Also, polypropylenes have negligible water absorption and excellent electrical properties, and they are easy to process. In much the same way that density is important in determining the mechanical properties of polyethylenes , the stereo regularity (related to the repeated units in the stereo regular molecular chain) of a polypropylenes very often determines the characteristics of the material .

An Increase in the stereo regularity of a polypropylene will sharply increase the yield strength of the material. The hardness, stiffness and tensile strength also increase. On the other hand, as the stereo regularity decreases, elongation and impact strength increase.

The ability to carry light loads for long periods and over wide temperature ranges is one of the properties that make polypropylenes valuable in engineering applications. In fact, polypropylene often is referred to as the "living hinge" thermoplastic.

One of the limitations most often mentioned for polypropylenes is their low- temperature brittleness (-4 ˚F) . However, polypropylene copolymers have been developed with brittleness point of about -20 ˚F ,such as salt and acid solutions that are destructive to metals . They also are resistant to organic solvents and alkalis. Above 175 ˚F, polypropylene is soluble in aromatic substances such as toluene and xylene, and in chlorinated hydro carbons such as trichloroethylene .

Polypropylenes have excellent electrical resistivity (both volume and surface) and their dielectric strength is high.

The greatest commercial uses for homopolymerPP are in fibres and filaments**.** PPfibres are woven into fabrics carpets, and they are also used to produce non-woven fabrics for disposables.

PP also is made into un oriented and oriented films for packaging, which have largely replaced cellophane and glassine. HomopolymerPP is injection – moulded into caps and closures, appliance components, and auto parts.

Random co polymer PP (with up to 7% ethylene) has higher impact strength and better clarity than the homopolymer . Its heat distortion temperature is lower than that of the homopolymer, 150 to 205 ˚f under 66 psi load . These materials are used in blow – moulded containers (including oriented and multilayer bottles), injection – moulded packing, and flexible monolayer and coextruded films.

Impact copolymeres are produced in a secondary reactor. The ethylene comonomer provides a flexible component in the otherwise rigid, crystalline structure. Impact copolymers have replaced impact PPs made by blending the homopolymer with ethylene – propylene rubber.

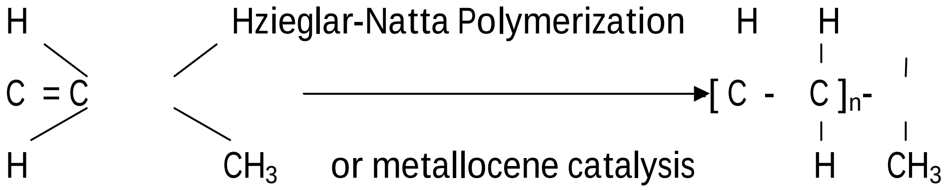
PP impact copolymers are tough, even at low temperatures, and yet retain a high percentage of the stiffness of the homopolymer. Injection moulding application include automobile battery cases, interior and exterior trim parts, house wares , and furniture . Coextruded with barrier polymer such as ethylene vinyl alcohol (EVOH), impact PP is made into multilayer sheet that is thermoformed into food packages that can withstand freezer storage and microwave cooking .

The rigidity of polypropylenes can be improved significantly by the addition of inexpensive mineral fillers. Filled PPs and even glass reinforced PPs are made into chemically bonded compounds that are truly engineering thermoplastic. (Allen,2004)

Polypropylene (PP) also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling , textiles (e.g ,ropes , thermal underwear and carpets) , stationary, plastic parts reusable containers of various types , laboratory equipment , loudspeakers , and automotive components , and polymer banknotes . An addition polymer made from the monomer propylene is rugged and un usually resistant to many chemical solvents, bases and acids. Polypropylenes offer a good balance of properties and cost unachieved by most thermoplastic. Polypropylene offers ease of processing with excellent chemical resistance and good mechanical properties. Glass fiber reinforced polypropylene has improved dimensional stability, resistance to war page, rigidity and strength. Heat deflection temperature at 264psi is increased up to 300 ˚F (150 ˚c) for 40% glass fiber reinforced polypropylene. Polypropylene coefficient of thermal expansion is cut in half with 40% glass reinforcement. Glass fiber reinforced polypropylene, when utilizing a chemical coupling agent, has significantly improved tensile and flexural strengths over regular glass reinforced polypropylene. Polypropylene with 30% chemically coupled glass reinforcement has a 180% improvement in tensile strength over the non- reinforced polypropylene and 50% improvement over conventional glass- reinforced grades. Overall, chemically – coupled polypropylene improves strength characteristics without altering the module, heat resistance, electrical properties, or handiness. Talc-filled polypropylenes have improved rigidity, hardness, and heat resistance compared to the base resin. Polypropylene (PP) is a linear hydrocarbon polymer, expressed as C_nH_{2n} .PP is manufactured from propylene –gas in presence of a catalyst such as titanium chloride . Based PP is a by – product of oil refining processes. PP, like polyethylene and polybutene (PP), is a polyolefin or saturated polymer.

Polypropylene is one of those most versatile polymers available with applications, both as a plastic and as a fibre , in virtually all of the plastics end – use markets . Structurally, it's a vinyl polymer, and is similar to polyethylene, only that on every other carbon atom in the backbone chain has a methyl group attached to it.Polypropylene can be made from the monomer propylene by Ziegler - Natta polymerization or by metallocene catalysis polymerization .(Morris,2005)

1.4.1 Equation of Reaction of propene is subjected to zieglar-Natta Polymerization or metallocene catalysis will give polypropylene



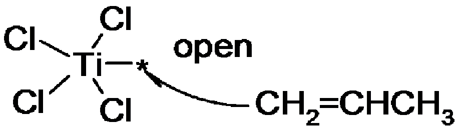
Propene **Polypropylene**

(John wiley ,1999)

1.4.2 Mechanism of polymerization of propylene

The following scheme describes the role of Zieglar –Natta catalyst in the polymerization of propylene.

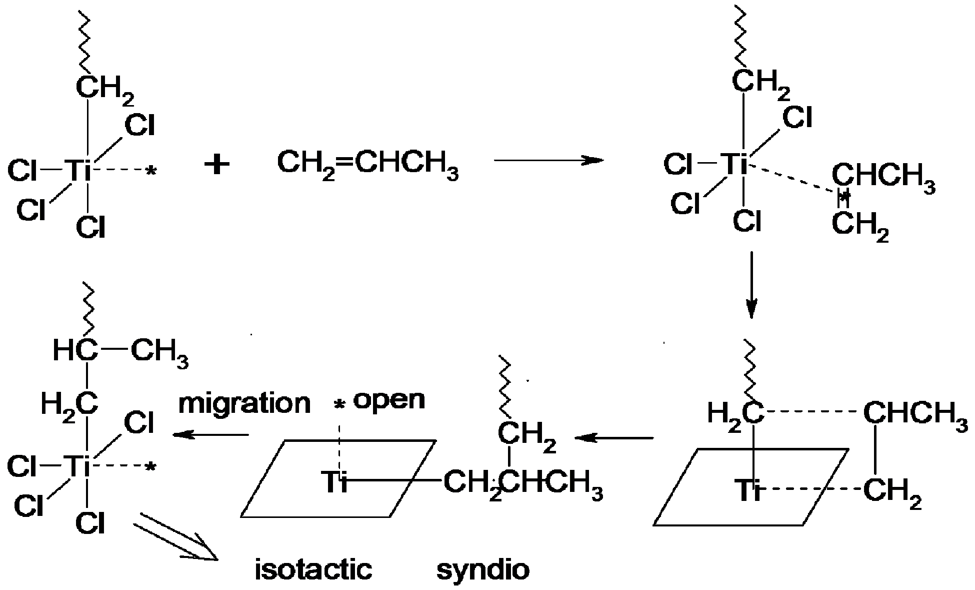
Zieglar-Natta Catalyst



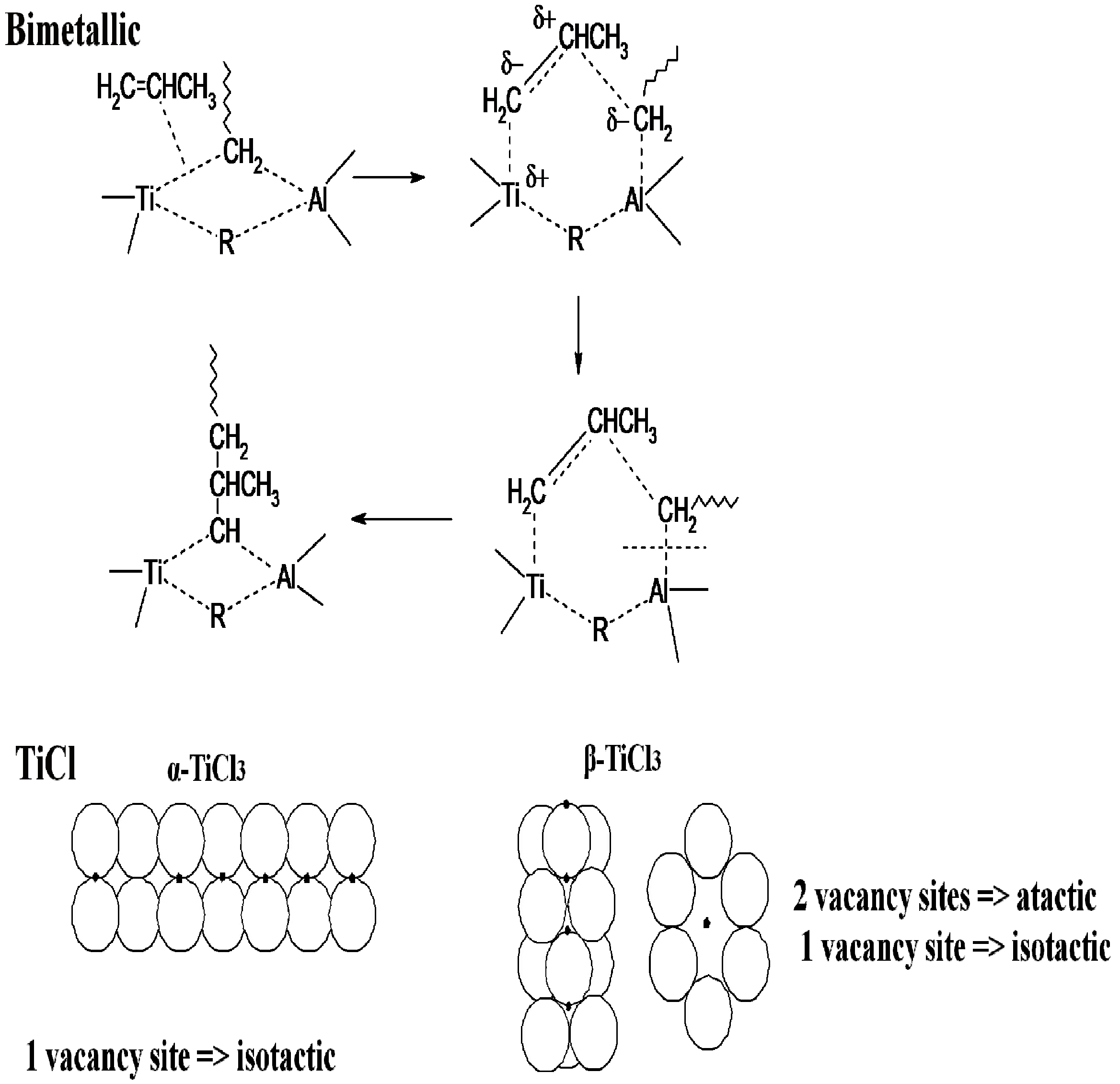
Monometallic
Bimetallic mechanism

Assumption: equal site reactivity

- Monometallic Corsee mechanism



Zieglar-Natta Catalyst



2 vacancy sites => atactic
1 vacancy site => isotactic

1 vacancy site => isotactic

(Hanser,2001)

1.5 Chemical and physical properties of polypropylene

Most commercial polypropylene is isotactic and has an intermediate level of crystallinity between that of low – density polyethylene (LDPE) ,and high density polyethylene (HDPE). Polypropylene is normally tough and flexible, especially when copolymerized with ethylene .This allows polypropylene to be used as an engineering plastic, competing with materials such as a crylonitrile butadiene styrene (ABS) .Polypropylene is reasonably economical, and can be made translucent when uncolored but is not as readily made transparent as polystyrene, acrylic, or certain other plastic .It is often opaque or colored using pigments. Polypropylene has good resistance to fatigue. The melting point of polypropylene occurs at a range, so a melting point is determined by finding the highest temperature of differential scanning calorimetry chert . Perfectly isotactic PP has a melting point of 171 ˚C (340 ˚F) .

Commercial isotactic PP has a melting point that ranges from 160 to 166 ˚C (320 to 331 ˚F) , depending on a tactic material and crystalliny. Syndiotactic PP with a crystalliny of 30% has a melting point of 130 ˚C (266 ˚F) . The melt flow rate (MFR) or melt flow index (MFI) is a measure of molecular weight of polypropylene . The measure helps to determine how easily the molten raw material will flow during processing.

The melt flow index (MFI) or (MFR) melt flow rate is a measure of the ease of flow of the melt of thermoplastic polymer . It is defined as the mass of polymer, in grams, flowing in ten minutes through a capillary of a specific diameter and length by a pressure applied via prescribed alternative gravimetric weights for alternative prescribed temperatures . polymer processors usually correlate the value of MFI with the polymer grade that they have to choose for different processes, and most often this value is not accompanied by the units, because it is taken for granted to be g/20 min . similarly, the test load conditions of MFI measurement is normally expressed in kilograms rather than any other units . The method is described in the similar standards ASTM D 1238 an ISO 1133 .

Melt flow rate is an indirect measure of molecular weight, with high melt flow rate corresponding to low molecular weight. At the same time, melt flow rate is measure of the ability of the material’s melt to flow under pressure. Melt flow rate is inversely proportional to viscosity of the melt at the conditions of the test, though it should be borne in mind that viscosity for any such material depends on the applied force. Ratios between tow melt flow rate values for one material at a different gravimetric weights are often used as a measure for the broadness of the molecular weight distribution .

Melt flow rate is very commonly used for polyolefin's, polyethylene being measured at 190 ˚C and polypropylene at 230 ˚C. The plastics engineer should choose a material with a melt index high enough that the molten polymer van be easily formed into the article intended , but low enough that the mechanical strength of the final article will be sufficient for its use . (ISO,2011)

The relationship between MFI and temperature can be used to obtain the activation energies developed from MFI values has advantage of simplicity and easy availability. The concept of obtaining activation energy from MFI can be extended to copolymers as well wherein there exists an anomalous temperature dependence of melt viscosity leading to the existence of two distinct values of activation energies for each copolymer.(shenoy,1988)

Polypropylene with higher MFR will flow to fill the plastic mould more easily during the injection or blow – molding production process. As the melt flow increases, however, some physical properties, like impact strength, will decrease. There are three general types or polypropylene homopolymer, random copolymer, and block copolymer the comonomer is typically used with ethylene.Etlylene - propylene rubber added to polypropylene homopolymer increases its low temperature homopolymer impact strength .Randomly polymerized ethylene monomer added to polypropylene homopolymer decreases the polymer crystalliny , lowers the melting point and makes the polymer more transparent .(Sato , Hidek and Ogawa , Hiroyuki , 2009) (Sato et al .,2009)

At the time of writing several companies are developing metallocene catalyst systems for use with polypropylene and these are expected to become important by the of the decade.

The system has a high activity and a high polymerization rate and the level of isotacticity can be controlled by varying the component ratios

Structure and Properties of Polypropylen.

Polypropylene is a linear hydrocarbon polymer containing little or no unsaturation. It is therefore not surprising that polypropylene and polyethylene have many similarities in their properties, particularly in their swelling and solution behavior and in their electrical properties. In spite of the many similarities the presence of a methyl group attached to alternate carbon atoms on the chain backbone can alter the properties of the polymer in a number of ways. For example it can cause a slight stiffening of the chain and it can interfere with the molecular symmetry. the first effect leads to an increase in the crystalline melting point where as the interference with molecular symmetry would tend to depress it. In the case of the most regular polypropylenes the net effect is a melting point some 50°C higher than that of the most regular polyethylene. The methyl side groups can also influence some aspects of chemical behavior. for example the tertiary carbon atom provides a site for oxidation so that the polymer is less stable than polyethylene to the influence of oxygen. In addition, thermal and high-energy treatment leads to chain scission rather than cross-linking. the most significant influence of the methyl group is that it can lead to products of different tacticity, ranging from completely isotactic and syndiotactic structures to atactic molecules .the isotactic form is the most regular since the methyl groups are all disposed on one side of the molecule. Such molecules can not crystallize in a planar zigzag form as do those of polyethylene because of the steric hindrance of the methyl groups but crystallize in a helix, with three molecules being required for one turn of the helix. both right-hand and left-hand helices occur but both forms can fit into the same crystal structure. theatactic polymer is an amorphous somewhat rubbery material of little value, the isotactic polymer is stiff, highly crystalline and with a high melting point. within the range of commercial polymers, the greater the amount of isotactic material the greater the crystallinity and hence the greater the softening point, stiffness, tensile strength, modulus and hardness. the influence of molecular weight on the bulk properties of polypropylene is often opposite to that experienced with most other well-known polymers. Although an increase in molecular weight leads to an increase in melt viscosity and impact strength, in accord with most other polymers, it also leads to a lower yield strength, lower hardness, lower stiffness and softening point. this effect is believed to be due to the fact that high molecular weight polymer does not crystallize so easily as lower molecular weight material and it is the differences in the degree of crystallization which affect the bulk properties. It may also be mentioned that an increase in molecular weight leads to a reduction in brittle point Published data on commercial polypropylenes indicate that their molecular weights are in the range Mn, = 38 000-60000 and Mw, = 220000-700000, with values of Mw , / Mn , from about 5.6 to 11.9. These averages are somewhat higher than those encountered normally with polyethylene and may help to explain the difference in molecular weight dependence. It is in fact the case that the very high molecular weight polyethylenes also have some difficulty in crystallizing and they too have lower tensile strength and stiffness than more conventional polymers of lower molecular weight. only a limited amount of information is available concerning the effects of molecular weight distribution. there is, however, evidence that the narrower the distribution the more newtonian are the melt flow properties. It has been noted that with polymers of molecular weights suitable for moulding and extrusion. polymers of wide distribution are stiffer and more brittle than those with a Mw / Mn, ratio of about 2. the morphological structure of polypropylene is rather complex and at least four different types of spherulite have been observed. The properties of the polymer will depend on the size and type of crystal structure formed and this will in turn be dependent on the relative rates of nucleation to crystal growth. the ratio of these two rates can be controlled by varying the rate of cooling and by the incorporation of nucleating agents. in general the smaller the crystal structures the greater the transparency and flex resistance and the less the rigidity and heat resistance. One unfortunate characteristic property of polypropylene is the dominating transition point which occurs at about 0°C with the result that the polymer becomes brittle as this temperature is approached. even at room temperature the impact strength of some grades leaves something to be desired. products of improved strength and lower brittle points may be obtained by block copolymerization of propylene with small amounts (4-15%) of ethylene. Such materials are widely used (known variously as polyallomers or just as propylene copolymers) and are often preferred to the homopolymer in injection moulding and bottle blowing applications. Further variations in the properties of polyethylene may be achieved by incorporating additives.(ASTM,2007)

1.6 Molecular masses of polymers

Polymerization reactions, both synthetic and natural, can lead to high - molecular mass compounds. The reaction chain, however, is broken by some termination process that usually occurs in around manner with respect to the size to which the polymer has already grown.

It follows that polymers have arange of molecular masses and that any data for the size or mass of the molecules of a polymer must represent some sort of average value. It will be seen that attempts to deduce molecular masses of polymers lead to number – average and mass – average molecular masses.

The number average **Mn** is defined as the mass of sample divided by the total number of moles **n** in the sample. Any measurement that leads to the number of particles or molecules present in a given mass of sample will allow the calculation of number – average molecule mass .

If the sample can be considered as being made up of fractions consisting of n_1 mole of molecular mass M_1 ,$n_2$mole of molecular mass M_2 , and so forth, then

$$\mathbf{Mn} = \frac{n_1 M_1 + n_2 M_2 + \cdots}{n_1 + n_2 + n_3 + \cdots} = \frac{\sum_i \; n_i M_i}{\sum_i n_i}$$

In other experiments each particle makes a contribution to the measured result according to its molecular mass. The average molecular mass deduced from such measurements is therefore more dependent on the number of heavier molecules than it is in experiment's depending simple appropriate average for such determinations is the mass average defined as for

an appreciable distribution of molecular sizes in a polymer sample , the two molecular masses Mn and Mw will be appreciably different . (Barrow, 1979).

1.7 Applications of polypropylene

Polypropylene can be manufactured to a high degree of purity to be used for the semiconductor industry. It's resistance to bacterial growth makes it suitable to be used in medical equipment. Polypropylene is used in most of our nonwoven fabrics such as rope used in a variety of industries, including fishing and agriculture .**Pp** can be used for flexible packaging applications (e.g.yogurt containers , syrup bottles , straws, etc), contraction sector (e.g. drainage pipes, pumps,etc.), automotive sector ,etc, buckets,bowls,crates,toys,medicalcomponents,washing ,machine drums,battery cases , bottle caps. Elestomer modified for bumpers , etc. tale filled for additional stiffness at elevated temperatures – jug kettles , etc.

1.7.1 Flexible packaging

PP is one of the leading materials used for film extrusion. PP film is available either as cast film or Bi – axially orientated PP (BOPP). The food and confectioneries sector is the largest of the film markets with usages ranging from confectioneries to crisps and biscuits. Rigid packaging subdivides into a multitude of packaging applications from caps and closures to pallets and crates.

1.7.2 Rigid packaging

Reusable and collapsible / stackable crates are a great application for PP, providing ease to transport (both full and empty) and allow simple, safe and efficient storage of products and are ideal for just – in – time (JIT) storage solutions. As a consequence, supermarkets are beginning to revert to use and similar products are finding application in the automotive supply chain.

Caps and closures manufactured of PP have benefited from growth in bottle market, particularly for mineral water containment and that of edible oil.

1.7.3 Automotive

In the automotive sector PP is utilized as a monomaterial solution for automotive interiors. The monomaterial dashboard is becoming increasingly a achievable, PP film cushioning, film skins, bumpers, cladding, and exterior trim are also available manufactured from polypropylene. Polypropylene developed for such applications provides low coefficient of linear thermal expansion and specific gravity, high chemical resistance and good weather ability, process ability and impact / stiffness balance . Improvements with colour-at-the -press and pre colouredPP have also reduced or eliminated the need for painting is some applications.

1.7.4 Fibre

PPfibre Is utilized in a host of applications including tape, strapping , bulk continuous filament , staple fibres , spun bound, and continuous filament .

1.7.5 Industrial

PP is used to manufacture arrange of sheet, pipe , compounding and returnable transport packaging (RTP) , with the exception of RTP where injection moulding is used , extrusion dominates the conversion process used for these products. Some PP is utilized by the construction sector, most notable domestic drainage pipes.

1.7.6 Clothing

Polypropylene is a major polymer used in nonwovens , with over 50% used for diapers or sanitary products where it is treated to absorb water (hydrophobic), rather than naturally repelling water (hydrophilic), polypropyler or 'polypro' has been used for the fabrication of cold – weather base layers such as long sleeve shirts or long underwear . Polypropylene is also used in warm – weather clothing, which transports sweat away from the skin.

More recently, polyester has replaced polypropylene in these applications in the U.S. military clothes. Although polypropylene clothes are not easily flammable, they can melt, which may result in severe burns if the wearer is involved in an explosing or fire of any kind. Polypropylene undergarments are known for retaining body odors which are then difficult to remove. The current generation of polyester does not have this disadvantage .

1.7.7 Medical

Polypropylene has been used in hernia and pelvic organ pro lapse repair operations to protect the body from new hernias in the same location.A small patch of the material is placed over the spot of the hernia, below the skin, and is painless and rarely, if ever, reject by the body. However, a polypropylene mesh will erode the tissue surrounding it over the uncertain period from days to years. therefore , the polypropylene mesh medical kits for certain applications in pelvic organ pro lapse , specifically when introduced in close proximity to the vaginal wall due to a continued increase in number of mesh – driven tissue erosions reported by patients over the past few years .(sinn,1995)

1.8 Aims

The objectives of this research work are :

(1) Characterization and analysis of polymer (polypropylene) manufactured in Sudan.

(2) Determination of the chemical and physical properties of polypropylene.

Chapter Two

Materials and Methods

2.1 Collection of samples

Three samples of polypropylene were collected randomly from:

1) Khartoum Petrochemical Company (KPC),(2 samples).

2) Elkherat Factory in Omdurman, one samples.

These samples were kept in dry cleaned plastic containers which were carefully closed.

2.2 Chemicals and materials

- Polymer of polypropylene.

- Distilled water.

2.3 Apparatus and instruments

1. Dyniscodevise.

2. Electrothermal (melting point apparatus) .

3. Infraredspectrophotomery(IR) .

4. Oven.

5. Balance .

6. Measuring Cylinder .

7. Pipettes .

8. Beakers.

9. Glass rod.

10. Crucible.

2.4 Methods

2.4.1Determination of Melt Flow Rate (MFR) or Melt Flow Index (MFI)

Porcelain Crucible six grams of sample powder or granules were weighed accurately in the cup .which was dried in an oven for ten minutes, this method contain all necessary parameters. When the barrel temperature reach the test temperature, 230 ˚C.Samples/were added into barrel in small amounts with pressing the piston stick and weighte into samples and started the test pressed test piston stick downward to reject out additional melted polypropylene when elapsed time reaches 120-300 seconds. Started cutting after 420 seconds. The pieces were weighed and calculated the results. Cleaned the inside wall of barrel with cotton patches to cleaned.

The equation of $(MFR) = m*600/t$

Where the m = mass of cutting, t = time, 600 = factor.

2.4.2 Determination of Bulk density

A volume of water measured in a measuring cylinder, then a little amount of sample was added to the cylinder, the volume of the sample was calculated by measuring cylinder then the bulk density of the sample was calculated as the equation below

Bulk density =weight of sample /volum of sample

2.4.3 Determination of Melting point

The melting point was measured by the electrothermal devise for the powder samples.

2.4.4 Burning test

Small amount of sample was taken by spatula and then heated in a bunsen burner flame.

2.4.5 Determination of Infrared spectrum

The spectral analysis was carried out using FTIR spectrophotometer obtained from SHIMADZU in KBr pellets.

Chapter Three

Results and Discussion

3.1 Resultsand Discussion

3.1.1 Melt flow rate (MFR) for samples

Test condition cutting interval (t), 20

Test temperature, ˚c 230

Load, Kg 2.16

The results of melt flow rates for the three samples of PPare shown in Table 1.

Table 1 : Melt flow rate for the three samples of PP

No	Sample of KPC$_{(1)}$	Sample of KPC$_{(2)}$	Sample of Elkherat factory
Extrudate weight (m) , g	0.0871 0.0872 0.0890	0.0896 0.0899 0.0916	0.0984 0.0996 0.1005
(MFR) Result g/20min	2.63	2.71	2.99

The equation of MFR = 600.m/t

The results of Melt flow rate (MFR) (2.63,2.71,2.99)g/20min .This results are on specification range (2-4 g/20min).

3.1.2 Bulk Density

The results of bulk density for the three samples of Pp shown in Table2

Table 2. Flow of the result bulk density for three samples of Pp

No	The weight of sample	The volume of water before addition sample	The volume of water after addition of sample	The volume of sample	Bulk density
KPC$_{(1)}$	7.9186	60	70.7	10.70	0.74006
KPC$_{(2)}$	5.4283	40	50.5	10.50	0.51698
Elkherat	9.2762	30	40	10.00	0.92762

The result of bulk density (0.74006,0.51698,0.92762) g/cm^3 of PP samples respectively.

3.1.3 Melting point

The results of melting point for three samples of Pp are shown in the Table3.

Table 3. The results for three samples of Pp

The melting point of sample $KPC_{(1)}$	149 ˚C
The melting point of sample $KPC_{(2)}$	152 ˚C
The melting point of Elkherat	160 ˚C

The result of melting point (149,152,160) ˚C are will in specification range of polypropylene (130-171) ˚C .

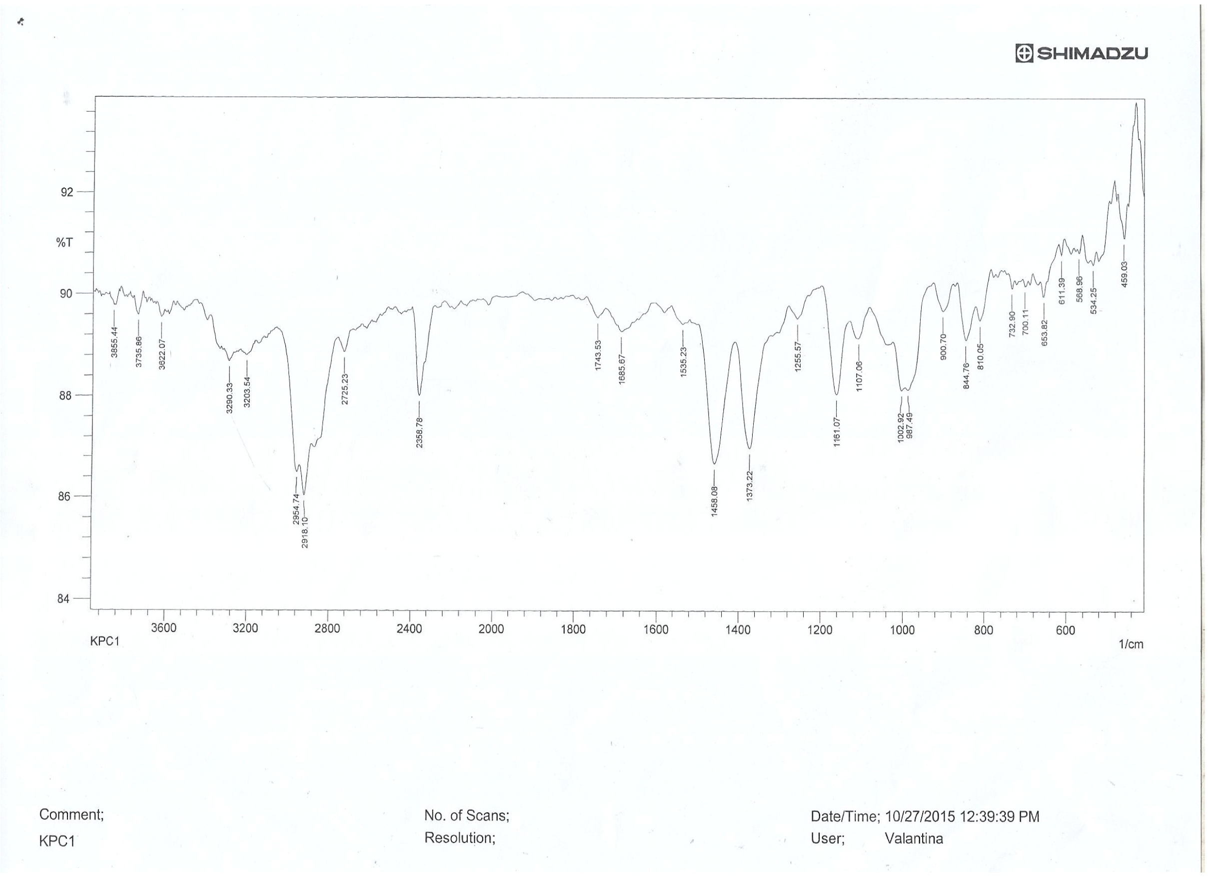
3.1.4 Burning test

In burning test it gave yellowish – blue calour for the three samples .

The results of a burning test is a typical of results of specification sample of PP ASTM.

3.1.5 The infrared spectrum of polypropylene

Figure1 shows the infrared spectrum of polypropylene of Khartoum petrochemical company (KPC_1)



Comment;
KPC1

No. of Scans;
Resolution;

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User; Valantina

Figure1 infrared spectrum of polypropylene of (KPC_1)

In the spectrum of Infrared spectrum (IR) of the three samples, 2954and 2918 cm $^{-1}$ stretching vibration of Sp^3 C-H a absorption peaks always occur at frequencies less than 3000 cm^{-1} .

- 1458 cm^{-1} me for CH_2 methylene groups bending vibration .

- 1373 cm^{-1} for CH_3 groups bending vibration.

- 732cm^{-1} for CH_2 bending (rocking) motion associated with long chain occurs usually at (720 cm^{-1}) .

Figure2 shows the infrared spectrum of polypropylene of Khartoum petrochemical company (KPC_2)

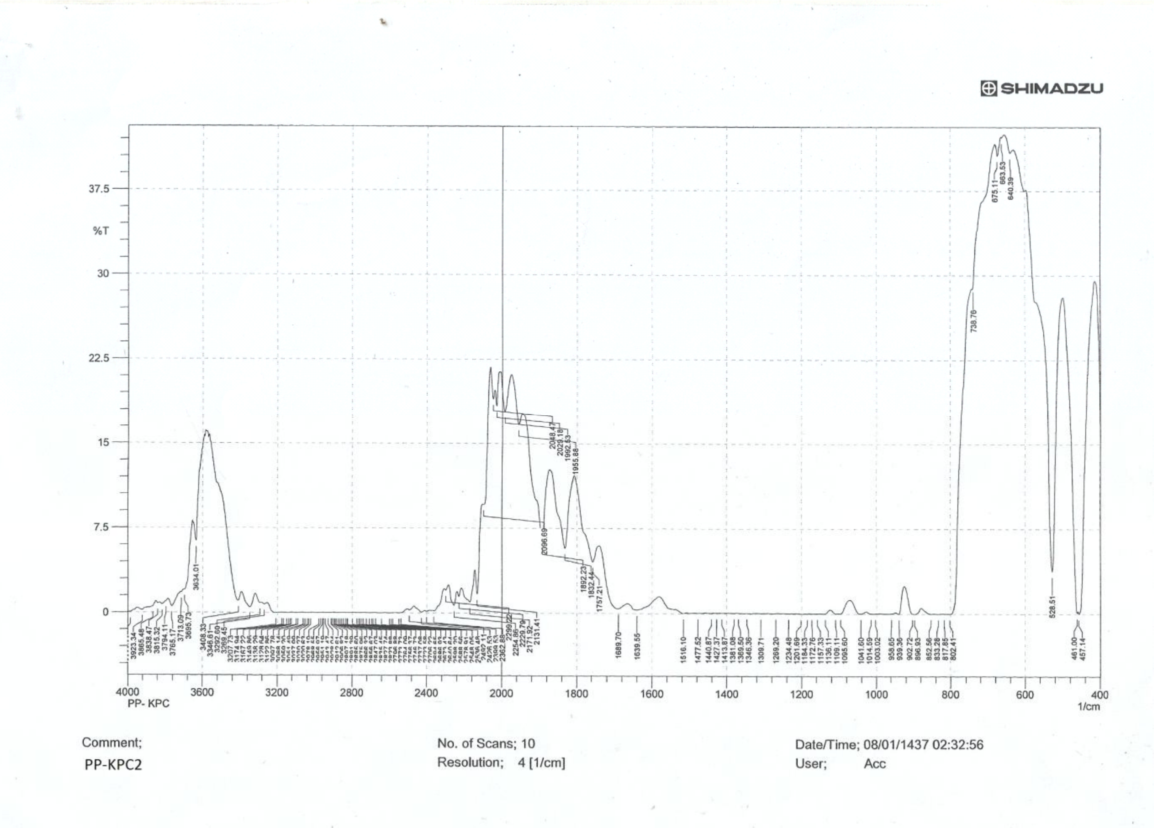


Figure2infrared spectrum of polypropylene of (KPC_2)

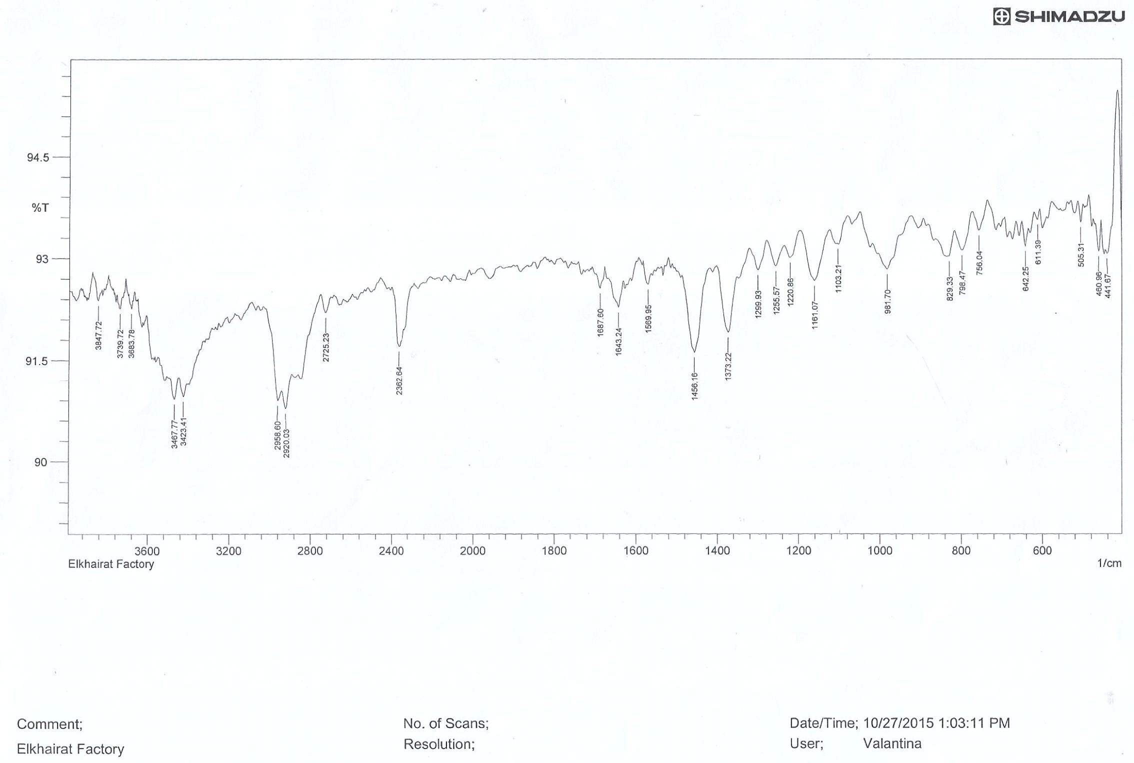
In the spectrum of Infrared spectrum (IR) of the three samples, 2954and 2918 cm $^{-1}$ stretching vibration of Sp^3 C-H a absorption peaks always occur at frequencies less than 3000 cm^{-1} .

- 1458 cm^{-1} me for CH_2 methylene groups bending vibration .

- 1373 cm^{-1} for CH_3 groups bending vibration.

- 732cm^{-1} for CH_2 bending (rocking) motion associated with long chain occurs usually at (720 cm^{-1}) .

Figure3 shows the infrared spectrum of polypropylene of Elkhairat factory



Comment;
Elkhairat Factory

No. of Scans;
Resolution;

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Figure3 Infrared spectrum of polypropylene of Elkhairat factory.

In the spectrum of Infrared spectrum (IR) of the three samples, 2954and 2918 cm $^{-1}$ stretching vibration of Sp^3 C-H a absorption peaks always occur at frequencies less than 3000 cm^{-1} .

- 1458 cm^{-1} me for CH_2 methylene groups bending vibration .

- 1373 cm^{-1} for CH_3 groups bending vibration.

- 732cm^{-1} for CH_2 bending (rocking) motion associated with long chain occurs usually at (720 cm^{-1}).

Since no two molecules of a different structure have actuality the same Infrared absorption pattern (Infrared spectrum) thus the IR spectrum can be used for molecules as a finger print. Ascend and more important use of IR spectrum is to determine structural information about a molecule.

3.2 Conclusion and Recommendations

All results which were obtained through this research confirm and comply with the standard range of properties of polypropylene.

Due to the obtained results of the three samples, polypropylene can be used in several fields such as; medicine , laboratories equipments and home furniture , ...etc . In addition side effects on the environment and human healthare low and can be easily controlled by simple and cheap means.

Further research work is needed to study other chemical and physical parameters :

1) Characterization of polypropylene (Pp) using X-ray methods, thermal methods , UV and XRD(X-ray diffraction).
2) Application of polypropylene in building , clothing , medical and several industries .

3.3 References

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3.4 Accessories :

Dynisco devise

Electrothermal (melting point apparatus)