

**CONVERSION OF MUNICIPAL SOLID WASTE TO
USEFUL CHEMICAL PRODUCTS**

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NOVEMBER 2004

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**SUBMITTED TO THE DEPARTMENT OF
CHEMICAL ENGINEERING, SCHOOL OF
ENGINEERING AND ENGINEERING
TECHNOLOGY, FEDERAL UNIVERSITY OF
TECHNOLOGY, MINNA. IN PARTIAL
FULFILLMENT OF THE REQUIREMENT FOR THE
AWARD OF A BACHELOR OF ENG. DEGREE IN
CHEMICAL ENGINEERING.**

NOVEMBER 2004

DECLARATION

I Okoh Adah Emmanuel do hereby solemnly declare that this project “conversion of municipal solid waste to useful chemical products” is as a result of my personal effort. It has therefore never been presented elsewhere either wholly or partially for either a degree or diploma. Also the information gotten from published work is acknowledged.

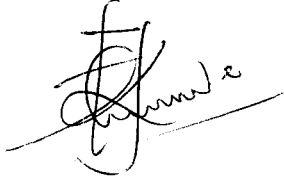


OKOH ADAH EMMANUEL

DATE

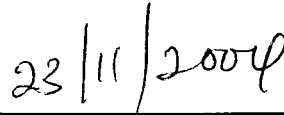
CERTIFICATION

This is to certify that this project titled “conversion of municipal solid waste to useful chemical products” was fully supervised and approved by the under listed persons on behalf of chemical engineering department for the award of the degree of Bachelor of Engineering (B.eng) in the school of Engineering and Engineering Technology..



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PROJECT SUPERVISOR



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EXTERNAL EXAMINER

DATE

DEDICATION

I dedicate this project to God Almighty and my beloved parents Mr. and Mrs. Okoh.

ACKNOWLEDGEMENTS

My most sincere gratitude goes to God Almighty for making this work possible. His love, faithfulness and mercy sustain me.

I also wish to acknowledge my parents Mr. and Mrs. O. Okoh. You are the best parents.

To my supervisor Engr. Abdulfatai Jimoh, thanks for your understanding and encouragement, and for bringing out the best in me. To my lecturers, Engr Saka, Engr Adeniyi you've all been a wonderful support. To Mrs.Eterigho I want to say a very big thank you.

To my siblings Ruth, Grace and Consolata. Thanks for your understanding, you all have been very wonderful, I love you all.

To my friends , Steve, Rakiya, Sule, Mike, Femi, Buky, Kabiru, Emma, Habiba, Olu, Manfred, Sinco, Shaguy, Okai, Kafayat, Sam, Mavis, Chigozie, Obiye. I'll miss you all.

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This work will be incomplete if I fail to mention the following families. The families of M.M Lawal, Engr. Ezekiel and Mr. Onuminya I really appreciate your assistance may God bless you all Amen.

ABSTRACT

The conversion of municipal waste into useful chemical products was analytically investigated through the effect of decomposition of solid wastes such as plastics and polyethylene. Two different samples of polyethylene (LDPE & HDPE) were subjected to heating at high temperature ranges from $28^{\circ}\text{C} - 178^{\circ}\text{C}$ and $28^{\circ}\text{C} - 198^{\circ}\text{C}$ respectively. The result obtained (Table 4.1.1 – 4.1.6) shows that using the same quantity (90g) of HDPE and LDPE samples, CO_2 gas was confirmed present at different concentration of $0.836\text{g}/\text{dm}^3$ for HDPE and $0.779\text{g}/\text{dm}^3$ for LDPE. Thus, the yield of CO_2 from HDPE is higher than that of LDPE.

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NOMENCLATURE

| | | |
|-------|---|-----------------------------|
| RDF | - | Refuse derived fuels |
| MSW | - | Municipal solid waste |
| LDPE | - | low Density polyethylene |
| HDPE | - | High Density polyethylene |
| C & D | - | Construction and demolition |
| Cl | - | Chlorine |
| S | - | Sulphur |

CHAPTER ONE

1.0 INTRODUCTION

If we look around our environment we see many unpleasant sight of waste littered all around the place, causing different kind of havoc such as blocking of drainages, air pollution etc. conversion of such wastes (especially municipal solid waste) to useful chemical products can go a long way to reduce their unpleasant sight.. Municipal solid wastes (MSW) includes waste from plant animals, food wrappers and containers haves ashes, newspapers discarded, toys rags, furniture and a variety of other items such as old tires etc. (Pavoni, 1975).

Municipal solid wastes (MSW) can be defined as residential and commercial refuse, which makes up the largest source of waste in industrialized countries.(Pavoni,1975).

Some of the major sources of waste include.

- i. Construction and demolition
- ii. Commercial and light industry
- iii. Household i.e. domestic waste

Besides, such materials can be converted into useful products by recycling and also energy can be generated. In advanced countries electricity can be generated from the burning of these so called wastes instead of leaving them, causing unnecessary nuisance along the streets of our cities.(Pavoni, 1975).

When these MSW are recycled some of the products that can be derived includes CO₂, carboxylic acid and useful energy source. This has some environmental implication but it is often seen as an attractive alternative to land filling. The derivation of energy from waste resources is however very controversial and of great significance, that is why the purpose of this research

project is of great importance to the economy of a nation (www.energy from waste.com)

The sheer quantity of packaging waste and other sources impose a load on the disposal facilities of the nation. The quantity goes up with increased standard of living in the society. If this waste can be processed, very useful agricultural, chemical and general house hold articles can be gotten from them and the bad smells and dirty sights they cause in our streets can be eliminated with a boost in the economy of our nation (Pavoni, 1975).

1.1 Aim and Objectives

The aim of this project is to convert (by burning) municipal solid waste (MSW) such as plastics and polyethylene to a useful chemical product like CO₂.

This aim can be actualized through the realization of the following objectives:

- i. To determine the presence of CO₂ in the fumes produced from the burning of polyethylene.
- ii. To note the temperatures at which the gas/fumes starts coming outs for low and high-density polyethylene.
- iii. To determine the concentration of CO₂ produced from HDPE and LDPE.
- iv. To compare the difference between the H₂CO₃ obtained from low and high density polyethylene.

1.2 Scope of Work

This project covers only the production of CO₂ from HDPE and LDPE through burning (decomposition) using, used yoghurt containers (HDPE) and discarded polyethylene bags and pure water packs (LDPE).CO₂ produced from the samples were quantified and compared.

1.3 Justification

The importance of this project can be seen from the fact that municipal solid waste (MSW) are all over our streets and cities coursing different kind of havoc like blocking of drainages, air pollution etc. whereas, on completion of this research such waste can now be converted to more useful and profitable purposes like energy recovery and formation of different chemical products like carboxylic acid, CO₂ which are very useful in the chemical industry.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BACKGROUND

In the past, municipal waste were either left in dumps to decompose or burnt without any special attention being paid to them. As time went on, the attitude towards wastes changed better ways of waste being discarded, they were treated before being discarded to prevent release of dangerous substances. Then it was later discovered that apart from that important chemical products could be derived from them or they could be used for other things like energy generation, recycling, composting etc.(Palmer,1986).

In the present times, wastes are treated even before they are discarded, while some are even converted to useful products. For instance waste papers are recycled into tissue papers and can be used as embroidery in furniture etc. (Palmer, 1986): Recent research shows that cow dung and other solid wastes can be used to produce CO₂. polyethylene can also be used to produce CO₂ through burning, while other useful chemical product that can be obtained from wastes is carboxylic acid etc.(Palmer,1986)

Hence, this shows that the use of waste whether it is solid, liquid or gaseous waste has improved over the years and with time be better off and more important uses will be found for the waste that still lingers in our environment.(Palmer,1986).

2.2 DEFINATION OF WASTE

A waste is any solid, liquid or gaseous material that is discarded by being disposed of, burned or incinerated, or recycled. There are some exceptions for recycled materials. The waste can be a by product of a laboratory operation or

process or a commercial reagent or product that is no longer wanted or needed (Palmer, 1998).

2.3 OTHER DEFINITIONS

2.3.1 Solid Waste

Solid waste is a waste material which has served its original intended use and sometimes is discarded (Palmer,1998)

2.4 Classification of Solid Waste

By making reference to the source of waste and the institutional arrangement for waste collection and disposal, solid waste can be categorized into five types which include, municipal solid waste (MSW), construction and demolition (C&D) waste, chemical waste, special waste, and other solid waste (Palmer, 1986).

2.4.1 Municipal solid waste

Municipal solid waste can be sub-divided into;

2.4.1.1 Domestic Waste.

This refers to household waste, waste generated from daily activities in institutional premises and refuse collected from public cleaning services. A public cleansing waste includes dirt and litter collected by food, environmental and hygiene departments. (Palmer, 1986).

2.4.1.2 Commercial Waste

These are waste arising from commercial activities taking place in markets shops restaurants, hotels and offices etc.
(Palmer 1986).

2.4.1.3 Industrial Waste

These are waste form industrial activities and do not include C & D waste and chemical waste. Industries sometimes deliver their industrial waste directly to land fills for disposal. (Palmer 1986)

It should be noted that there are bulky items like furniture and domestic appliances which cannot be handled by conventional compactor type refuse collection vehicles. These items are regarded as bulky waste and are usually collected separately (Palmer, 1986).

2.4.2 Construction and Demolition(C & D) Waste

This include waste arising from any land excavation or formation, civil/building construction, site clearance, demolition activities, road works and building renovation. It also includes known types of building debris, rubble, earth, concrete timber and mixed site clearance material.(Palmer, 1986)

2.4.3 Chemical Waste

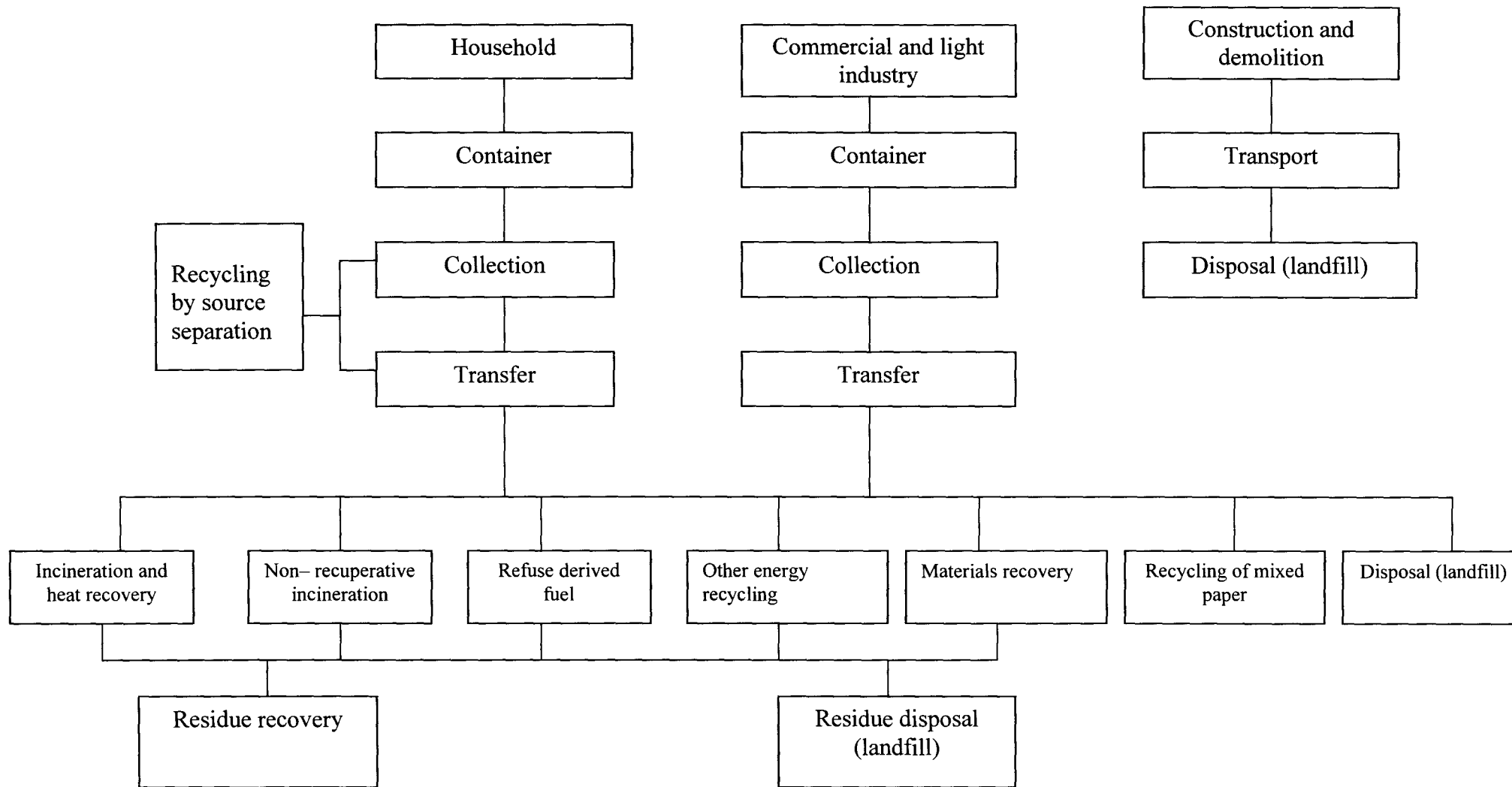
This can be any substances arising from any process or trade activity which contains chemical in such form, quantity, or concentration that can cause pollution to the environment or become a risk to health.(Palmer 1986)

2.4.4 Special Waste

This include abattoir waste animal carcasses, asbestos, clinical waste, condemned good, livestock waste, sewage treatment and water works treatment sludge, sewage works screening and stabilized residues from chemical wastes treatment centers (Palmer, 1986)

2.4.5 Other Solid Wastes

Refers to solid wastes types not covered by the above description. these include coal, ash, dredge mud and excavated material disposed of at numerous dumps.(Palmer, 1986).



Source: - Pavoni, 1975

Fig 1 MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM

2.5 Effects of Waste

Waste like anatomical wastes, syringes, gauze, absorbents glass, cause serious health problems. Rotting of it in front of clinics, street corners are not uncommon due to which rag pickers mostly children are attached by the hepatitis virus or jaundice carrying virus. The garbage becomes breeding grounds for diseases-carry vectors such as flies, mosquitoes, rats and cockroaches, which carry pathogenic organic, causing dysentery, diarrhea, etc (Pavoni, 1975).

Waste has increased public awareness of the need to recycle and the provision of more facilities to make that possible; more bottle banks and kerb-side collection schemes operated by some local councils.

Composting is the accelerated decomposition of waste from the garden or kitchen, for example, vegetable peelings and grass cuttings. As much as 30% of household waste is suitable for composting. This can be done in individual gardens, or at a larger facility serving a whole town.

A compensation for the expenditure on its collection and transportation is the revenue it yields. Metallic wastes, metallic scraps, disposed metallic cans and wrecked automobile are reprocessed and utilized while plastic materials are melted and moulded into useful articles.

Fig 1 shows municipal and solid waste management system.

2.6 MATERIALS RECOVERY

The materials, which can be recovered from solid wastes (secondary materials), may be categorized into 2 general groups.

1. Those materials which can be directly recycled i.e directly put back into use.
2. Those materials which may require considerable amounts of processing before they can be used. The potential for reuse of a particular product or material depends to a great extent upon the use for which the product was originally

designed and manufactured. Materials may be in permanent or temporary use.

Also they may be non-recoverable. (Pavoni , 1975)

Most of the plastics, which are recycled, are processed as in house wastes. If a plastic waste is produced after the material leaves the processing or manufacturing plant, it is virtually certain that the waste will not be recycled. In essence the packaging plastic materials are not recycled but join the solid waste stream to be disposed of. Plastics are combined with paper or laminated with other plastics and sealed with steel or aluminum closures. For example a certain amount of waste occurs during the processing of plastic film, that waste produced in-house has a good chance of being reused in a film form after it has been reprocessed. (Kirk-Othmer, 1986).

However, if the film is used to make a protective package for fresh produce, the film is almost certain to find its way into a sanitary landfill or refuse incinerator.

Municipal wastes have general applicability but are not specific for direct combustion calculations; the combustion of refuse follows the physical laws as do other fossil fuels and therefore the same qualitative characteristics must be known. Trends in food processing and packaging have affected the moisture characteristics of refuse. Garbage- the vegetables and animal food waste, from the preparation and cooking and serving of food and market wastes has been greatly reduced. At one point it accounted for 65% or more of the volume of municipal refuse with an overall moisture content of 50%. Today garbage in municipal waste may average 10% or less, with a moisture content of 15% – 25%. (Kirk Othmer 1986).

Physically mined refuse contains large quantities of paper bags, crates, plastics bags (polyethylene) and similar dry combustible materials. Most attempts

to recover energy from MSW have focused upon the generation of steam. European incinerator equipped with wasted heat has utilized refuse as a source of fuel for many years. In most instances their facilities are quite sophisticated with all or part of the steam production used to generate electricity. (www. Energy form waste .com).

2.7 METHODS OF GENERATING USEFUL MATERIALS FROM MUNICIPAL SOLID WASTE.

Many different types of waste can be converted into useful products. The forest product industry makes use of wood wastes to generate heat and electricity. Similarly in many countries, agricultural wastes are a significant source of energy. The process of converting waste to energy is very dependent on the composition of the waste, and therefore it is difficult to provide a comprehensive overview of all types of wastes.(Pavoni,1975).

There are four basic methods of converting MSW into useful heat and electricity. The first three methods convert organic materials into energy that would otherwise be converted into methane and carbon dioxide by natural processes any way. Because of this, energy from waste can be seen as not contributing to green house effect. Determination of the technology most appropriate for a given region depends on the local methods of collecting, processing and disposing of the MSW as well as local government regulations. (Pavoni, 1975).

The three methods are discussed below;

2.7.1. Mass Burning

MSW is made up of a variety of organic (combustible) and non – organic (non- combustible) products ranging in size and composition from dust particles to old furniture and appliances.(Pavoni,1975).

The actual composition in any location is a factor of the extent of reduction, reuse and recycling programmes and the time of the year. The moisture content of MSW is a factor of season and climate (Kirk Othmer, 1986).

Mass burning is the oldest, simplest and most popular method of recovering energy from municipal solid waste (Pavoni, 1975). In mass burning system, unrelated MSW is simply incinerated. The heat given off is converted to steam, which can pass through a turbine to produce electricity, used directly to supply heat to nearby industries and building or to produce electricity and low temperature heat suitable for space heating. Producing electricity from high temperature steam and usable heat as a by product is called “co-generation” or “combined heat and power”. This results in more efficient use of fuel. Incinerating MSW generally results in a volume reduction of 80-90% therefore reducing landfill requirements. (Pavoni, 1975).

The average energy content of a typical raw MSW is about 10,000kJ/kg. At this energy content, a typical mass burning electricity generating plant would require 45 tonnes of MSW to produce 1 megawatts (1mw = 1 million Watts) of power for 24 hours (Pavoni , 1975).

There are several types of MSW mass burn combustion systems for recovering energy from waste, including refractory and modular furnaces but water wall furnaces are the most popular at the present time. This technology is similar to the technology (furnaces) used at wall burning power plants. (Pavoni, 1975).

2.7.2 Refuse Derived Fuels (RDF).

This is as a result of processing MSW to separate the combustible fraction from the non-combustible, such as metals and glass. RDF is predominantly composed of paper, plastic, wood and kitchen or backyard wastes and has higher

energy content than untreated MSW typically in the range of 12,000 – 13,000kJ/kg. The figure will vary depending upon local paper and plastic recycling programmes. Like MSW, RDF can be burned to produce electricity and or heat. RDF processing is often combined with recovery of metals, glass and other recovery facility. At the present time RDF combustion is less than mass burning, but this may change in the future as recovery of recyclable materials and environmental concerns against incinerator emissions become important. (www. Energy facts.com)(Pavoni,1975).

One of the advantages of RDF is that it can be shredded into uniformly size particles or classified into “briqueta”. Both of these possibilities facilitate transportation and combustion. Easily handled RDF can often be burned or “co-fired” with another fuel such as a low cost additive which can reduce cost of generating heat or electricity in a variety of application. Mass burning of MSW requires specially designed boilers to handle the main composition of MSW (www. Energy facts.com).

Another advantage of burning RDF rather than raw MSW is that fewer non – combustibles such as heavy metals are incinerated. Although metals are incinerated, the high temperature of a MSW furnace causes metals to be partially ‘volatized’. Resulting in the release of toxic fumes and fly ash the composition of RDF is more uniform and well understood than that of MSW; therefore fewer combustion controls are required of RDF combustion facilities than for facilities burning untreated MSW plasma and thermal pyrolysis are technologies currently under development that can breakdown RDF to release combustible gases, which can either be burned directly to produce heat and/or electricity or condensed into oil. (Pavoni, 1975)

2.7.3 Land fill gas

A recent alternative to the two methods of deriving energy from waste through the direct combustion of the organic material is the collection of decomposition gas of landfill gas. Land fill gas is produced by the natural anaerobic (oxygen freed) decomposition of organic matter. Landfills composed of 40-60% methane (CH_4), with the remainder being largely CO_2 . Landfill gas has a gross heating value of about 70 cubic meters of landfill gas. Methane is a more effective green house gas than the CO_2 that is produced when it is burned therefore using landfill gas to produce energy has a positive impact on the green house effect. The Brock west landfill east of Toronto has received waste from about one million people for the fill gas to generate 21mW of electricity (Pavoni, 1975).

Landfill gas is naturally produced by anaerobic processes inside a land fill. Methods of collecting land fill gas depends upon the design of a particular land fill. Methane is a potentially explosive gas, so many land fills design in the past 20 years have been built with a system of pipes which is used to collect methane. Collection systems can have small diameter wells drilled and perforated plastic pipes installed to provide a collection and recovery system. Pumps are required to remove the gas and can also use gas turbines which are similar to jet engines and are generally more tolerant to impurities in the gas, finally large volumes of gas can be used to power a traditional thermal steam generating station. This set up can handle most impurities and can also mix landfill with natural gas to increase generating capacity when needed. In landfill operation the greatest difficulty presented by packaging materials is the resistance of certain materials to degradation in the soil. Aluminum, glass and plastic container are virtually indestructible and persist for decades. Even paper tends to have a long life under ground. (Kirk Othmer, 1986).

2.7.4 Pyrolysis

From the engineering point of view, pyrolysis has been widely studied in the form of low and high temperature coal carbonization, preparation of adsorbent carbon on a tonnage scale from lignite, rice hulls, nut shells and related organic matters, removed of organic insulation from wire in secondary metal plants, and partial distillation of rubber from waste tire. In these cases the equipment engineering has been developed to a high order, tonnage plants created and operated and products of the operation are disposed of at a profit. (Hatch, 1981).

Trash and waste are seldom disposed of at a profit, and therefore pyrolysis for this purpose commands few financial resources, although much publicity. (Hatch, 1981).

Pyrolysis is destructive distillation, often with carbonization in the absence of air by the application of indirect heat; often the term thermal decomposition is applied. Pyrolysis can convert trash, cellulose waste after drying, and contaminated paper into usable fuels, or it may be employed as modified incineration to produce ash, slag and ferrous metals from solid or in chemical plants moist and liquid residues. Gases generated may be useful as fuel or they maybe consume, with a gas holder added to the system, as process energy. (Hatch, 1981).

The Bureau of Mines' Pittsburgh Energy research center has been studying pyrolysis in one form or another for years. Monsanto's environ-chem Systems, inc has developed and field tested a 35 ton/day pilot pyrolysis plant and guarantees that systems capable of pyrolysing up to 1500 tons/day of municipal refuse will meet all existing pollution control standards at the time of the contract is signed. (Urbanski, 1977)

Working on pyrolysis at Bu Mines started nearly half a century ago with basic studies on the carbonization of coal. Bu Mines pyrolysis unit, built in 1929, was designed to be a research tool, and features a recovery train for trapping pyrolysis products of for analysis with minor alteration the unit resources in operation today. (Urbanski, 1977).

Among the first waste material to be studied at Bu Mines was rubber in the form of shredded tires the products recovered were gas with a high Btu content, oil and a solid residue with a high heating value. Each of the products could be burned cleanly. (Urbanski, 1977)

For pilot studies, Bu Mines collected sample of municipal trash from Altoona, Pennsylvania. Altoona was chosen because glass and cans must be separated from garbage by its citizen in compliance with a local ordinance. Furthermore, the refuse is taken to a local mulch plant which shreds the trash, so it is easy to obtain reasonably representative samples (Urbanski, 1977) (Hatch, 1981),

Pyrolysis of the refuse yielded a solid residue gas and oil fractures, each with a significant thermal value. (Urbanski, 1977).

2.8 THERMOPLASTICS

Thermoplastic is a material formed by the polymerization of ethylene at low pressures. It is made principally of polyethylene, $n(\text{CH}_2-\text{CH}_2)$, and the ever increasing demand for polyethylene is partly due to the availability of the monomer ethylene from the abundant raw material, associated gas and naphtha. The ease of processing the polymer its relative low cost, its resistance to chemicals and its flexibility are also strong influence. (Urbanski, 1977).

Products made from polyethylene are numerous and ranging from building materials and electrical insulation to packing materials and sheets. It is an

inexpensive plastic and can be molded into almost any shape, extruded into fibre or filament and blown or precipitated into film or foil. Because it is more flexible and more transparent, the low density polymer is used in sheets, films and injection molding. (Urbanski, 1977)

2.8.1 Formation and types

High pressure polymerization ethylene was introduced in the 1930's, the discovery of new titanium catalyst by Karl Ziegler in 1953 opened a new era for the polymerization of ethylene at low pressures.

The two most widely used grades of polyethylene are low density polyethylene LDPE, which has branched chains and high density polyethylene, HDPE, which is predominantly linear. Low density polyethylene is produced by a free radical initiated polymerization at high pressures while high density polyethylene is produced by a low pressure process with a metallic oxide catalyst of the Ziegler type.(Urbanski, 1977).

The main difference between the two grades of poly ethylene is that LDPE is more flexible because of its lower crystallinity. This lower crystallinity is caused by the presence of branches of two or four carbon atoms along the backbone of the polymer. HDPE is more closely packed because of the absence of branches and thus the molecules become closer and less permeable to gases. (Urbanski, 1977).

The polymerization of ethylene is an exothermic reaction from which 830 calories are released for each gram of ethylene. Polyethylene decomposes at high temperature. Even in the absence of air (pyrolysis). The products are methane, carbon, and hydrogen. The following reactions occur.

Polymerization: -



Decomposition:-



Where ΔH is enthalpy

The decomposition reaction will be of interest in the course of this research work.

2.8.2 Physical and Chemical properties of Polyethylene

Probably the most important property of the polyethylene is the molecular weight and its distribution within a sample. Polyethylene is to some extent permeable to most gases. The higher density polymers are less permeable than the lower density ones. Polyethylene in general has a low degree of water absorption and is not attacked by dilute acids and alkalis, although it is attacked by concentrated acids. Its overall chemical resistance is excellent. Polyethylenes are affected by hydrocarbons of chlorinated hydrocarbons and swell/slowly in these solvents. Tensile strength of polyethylene is relatively low, but impact resistance is high. The use of polyethylene in insulation is due to excellent electrical resistance properties. (Urbanski, 1977).

TABLE 2.1 TYPICAL PROPERTIES OF POLYETHYLENE

| Polymer | Melting point °C | Density (g/cm³) | Degree of crystallinity (%) | Stiffness molecules psia 10³ |
|-----------------|-------------------------|-----------------------------------|------------------------------------|--|
| BRANCHED | | | | |
| Low density | 107 – 121 | 0.52 | 60 – 65 | 25 – 30 |
| Medium density | - | 0.935 | 75 | 60 – 65 |
| | | | | |
| LINEAR | | | | |
| High density | | | | |
| Ziegler type | 125 – 132 | 0.95 | 85 | 90 - 100 |
| Phillips type | - | 0.96 | 91 | 130 -150 |

TABLE 2.2 ENERGY EQUIVALENT VALUE AND ENTHALPY OF SOME COMMON PLASTICS

| PLASTICS | Energy Equivalent in MJ/kg | Combustion Enthalpy MJ/kg |
|------------------------------------|-----------------------------------|----------------------------------|
| Polyethylene | 69-72 | 43 |
| Polypropylene | 73 | 44 |
| Polystyrene(clear) | 80 | 40 |
| Polystyrene (high impact) | 81 | 40 |
| Polyacrylonitrile -co- | 84 | 87 |
| Butadiene- co-styrene | | |
| Poly (vinyl chloride) | 53 | 18 |
| Nylon -6,6 or -6 | 154-156 | 29 |
| Poly(ethylene terephthalate) (PET) | 84 | 31 |
| Polycarbonate | 107 | 29 |
| | | |

2.9 ENVIRONMENTAL AND HEALTH FACTORS

Two factors of principal concern are air emissions from burning solid waste or refuse derived fuel and the environmental health of workers in resources recovery plants. The overall conclusions including those from several unpublished experimental trials using RDF –coal mixtures, are that the particulate and other priority polluted emissions do not increase, either beyond legal limits, or those from coal alone until an RDF –coal weight ratio of $\leq 60/40$ is used. Exceptions may be for Cl and S; Cl can increase with increasing amounts of RDF more than coal, assuming the coal has a low Cl content, and S is likely to decrease when RDF is burned-mixed with most coals. The S content of RDF is at the lower end of concentrations determined for western sub-bituminous coals. (www.Energy facts.com.)

Heavy metal emissions do not increase beyond levels believed to be undesirable (there are no national ambient air quality standards for most metals) when burning RDF. However, some effect depend on the volatility and melting points of the metalloid compounds released, which can lead to relative enrichment of certain metals in the emissions. Modern pollution control equipment must be used. (www. waste conversion.com).

There have been several reports of physicochemical and microbiological analysis of dusts in resource recovery plants, and most of these have been reviewed. In the studies thus cited, there were no report indication of any severe health hazards resulting from working in a resource recovery plant, provided normal hygiene precaution are taken. (Pavoni , 1975) (www. Energy facts.com)

CHAPTER THREE

3.0 METHODOLOGY

In order to carry out the conversion of municipal waste into CO₂, the used plastics and polyethylene (solid waste) had to be sorted out, washed and shredded. The shredded waste was then heated at high temperatures and the fumes that evolved were bubbled through distilled water forming a weak acid. The acid formed was titrated with NaOH as base and Phenolphthalein indicator was used.

The titration was necessary to determine the amount of CO₂ evolved for both LDPE and HDPE

3.1 Sample Collection

The samples that were used in the experiment are used yogurt containers (HDPE) and discarded polyethylene and pure water packs (LDPE). This were hand-picked from a refuse dump using hand gloves for necessary precautions.

3.2 Sample Preparation

The samples used for the analysis were used yogurt containers (high density polyethylene) (HDPE) and discarded polyethylene bags and pure water packs (low density polyethylene) (LDPE).

The sorted plastics and polyethylene was first of all washed with clean water to keep it free of dirt. The samples were then shredded to small sizes to quicken the decomposition process when heating. The reaction of the decomposition is given as:



3.3 APPARATUS AND REAGENTS

3.3.1 APPARATUS

The following apparatus were used for carrying out the experiment:

| ITEM | SIZE CAPACITY | MAKE |
|---|-----------------|-----------|
| Collection bottle | 250ml | Schott |
| U-tube | 45ml | - |
| Beaker | 1000ml | Schott |
| Retort stands and clamp | - | - |
| Metal tin | 350ml | Bournvita |
| Hot plate electric stove | 240v,80Hz,1000w | Triangle |
| Plastic connection tubes | - | - |
| Glass connection tubes | - | - |
| Pipette | 25ml | Technics |
| Burette | 25ml | Technics |
| Conical flask | 250ml | schott |
| Stoppers | - | - |
| Shredded plastics and polyethylene (yoghurt containers and polyethene bags) | 90g each | - |
| Distilled water | 200ml | - |
| Ice water | 200ml | - |

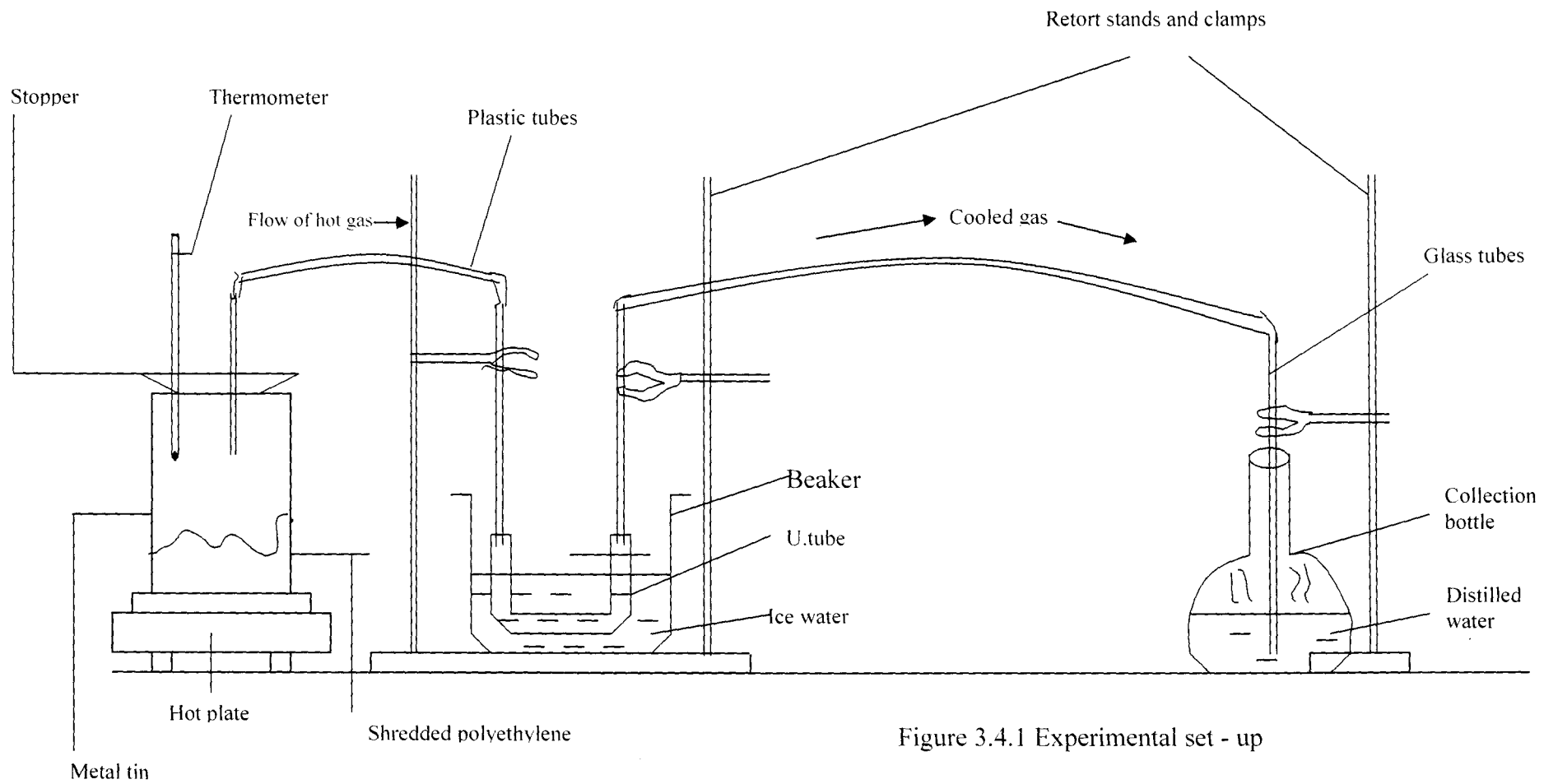


Figure 3.4.1 Experimental set - up

3.3.2 Reagents

The following reagents were used to ascertain the presence of CO₂ gas and its concentration respectively.

- Caustic Soda (NaOH) (0.33125mole/dm³).
- Phenolphthalein indicator.
- Lime water (Ca (OH)₂).

3.4 Experimental Procedure

After the pre-treatment, the samples were placed in the heating metal tin. It was then heated on the hot plate to achieve decomposition of the samples.

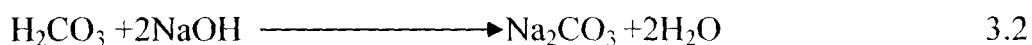
Gas/fumes evolve from the samples as heat is being applied. The gas/fumes evolved flows through the connection tubes into the cold trap (U-tube submerged in ice water –Fig 3.4.1). At this point, condensation took place and a yellow liquid was recovered. The non-condensable gas/fumes flowed into the collection bottle, which contains distilled water. The gas bubbles through the distilled water for some time and then a weak acid was formed.

The equation of the reactions is given as :



The weak acid was then titrated against NaOH to ascertain its concentration.

The neutralization reaction is:



CO₂ was tested for by bubbling the gas obtained through Lime water. After Some time the lime water turned milky in appearance showing the presence of CO₂. The reaction is shown in the equation below:



CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS.

At the end of the experiment the following results were obtained as shown in table

4.1.1 to 4.1.6

4.1.1 Low Density Polyethylene (LDPE).

When LPDE was subjected to heating the following observation was made:

| TEMPERATURE (°C) | OBSERVATION |
|-----------------------------|---|
| 28.00 (Ambient temperature) | Heating commenced |
| 40.00 | Droplets began to appear on the glass tube connected to the heating tin. |
| 59.00 | Evolution of white fumes began from the heating tin. |
| 62.00 | The gas (fumes) began to arrive in the u-tube. |
| 75.00 | Bubbling began in the distilled water in the collection bottle. |
| 77.00 | The evolution of the gas became rapid for about 5 minutes. |
| 130.00 | The evolution of the gas became greatly reduced |
| 142.00 | The temperature on the thermometer appeared to stand still with sparing evolution of the gas for 2 minutes. |
| 138.00 | A temperature drop was observed on the thermometer for about 3 minutes and picked up again. |
| 145.00 | The evolution further increased with a deep yellow condensation being formed for about 4 minutes. |
| 147.00 | The evolution further increased with a deep yellow condensate being formed in |

| | |
|--------|--|
| | the u-tube (cold trap) |
| 178.00 | The experiment was stopped when there were no more changes . |

4.1.2 High Density Polyethylene (HDPE)

When HDPE was subjected to heating the following observations were made

| TEMPERATURE (°C) | OBSERVATION |
|-----------------------------|---|
| 28.00 (Ambient temperature) | Heating commenced |
| 62.00 | White fumes were noticed in the glass tube |
| 70.00 | The white fumes began to arrive in the u-tube |
| 72.00 | The fumes began to flow through the tubes submerged in the distilled water in the collection bottle |
| 130.00 | The evolution of the gas appeared to reduce quite considerably |
| 146.00 | The evolution of the gas picked up |
| 160.00 | The evolution became more rapid |
| 163.00 | There was a decline in the evolution of the gas |
| 165.00 | An even more rapid evolution of the gas was observed for about 3 minutes |
| 170.00 | A temperature drop was observed for about 2 minutes. |
| 172.00 | The evolution stopped and the temperature appeared to stand still for about 3 minutes. |
| 175.00 | The temperature picked up and there was a rapid evolution of gas as (white fumes) and condensation of a yellow liquid started in the u-tube |
| 198.00 | The experiment was stopped because there was no other noticeable changes. |

Table 4.1.3 Titration Results for LDPE

| Burette reading | 1 st titration (cm) | 2 nd titration (cm ³) |
|---------------------|--------------------------------|--|
| Final | 111 | 109 |
| Initial | 0 | 0 |
| Volume of acid used | 111 | 109 |

Table 4.1.4 Amount of CO₂ Obtained for LDPE.

| Quantity of raw materials used (g) | Concentration of acid formed (mol/dm ³) | Mass concentration of acid formed (g/dm ³) | Amount of CO ₂ evolved (g/dm ³) |
|------------------------------------|---|--|--|
| 90 | 0.0179 | 1.1098 | 0.77923 |

Table 4.1.5 Titration results for HDPE.

| Burette reading | 1 st titration (cm) | 2 nd titration (cm ³) |
|---------------------|--------------------------------|--|
| Final | 116 | 105 |
| Initial | 0 | 0 |
| Volume of acid used | 116 | 105 |

Table 4.1.6 Amount of CO₂ Obtained for HDPE

| Quantity of raw materials used (g) | Concentration of acid formed (mol/dm ³) | Mass concentration of acid formed (g/dm ³) | Amount of CO ₂ evolved (g/dm ³) |
|------------------------------------|---|--|--|
| 90 | 0.019 | 1.178 | 0.836 |

4.2 DISCUSSION OF RESULTS

After the sample of HDPE and LDPE were subjected to decomposition through heating, the result obtained from the analysis were shown in table 4.1.1. to 4.1.6

Table 4.1.1 and 4.1.2 shows the observations made during the decomposition of HDPE and LDPE. In both cases, it was observed that there was evolution of gas/fumes at different temperatures. Evolution of gas commenced at 59^oc for LDPE and at 62^oc for HDPE. Differential in temperature could be attributed to the straight chain in the HDPE as against branched chain in the LDPE (Urbanski, 1977). The gas that bubbled through the distilled water in the collection bottle formed a weak acid, which was then subjected to titration to determine the presence and concentration of CO₂ formed.

Table 4.1.4 and 4.1.6 shows the quantity of CO₂ obtained at the end of the titration analysis. It was observed that about 0.77923 g/dm³ of CO₂ was produced from 90g of LDPE while 0.836g/dm³ of CO₂ was produced from HDPE using the same quantity of 90g. Although the quantity of CO₂ produced in both cases were expected to be greater than the values obtained but this could be attributed to the small quantity of oxygen supplied in the bench scale experiment resulting. Incomplete combustion, which in turn affected the yield of CO₂ produced (Cheremissonof, 1978).

LDPE is a branched chain polymer, with lower melting point when compared to HDPE, which is a straight chain polymer that requires much quantity of energy to break the bonds. However, the quantity of CO₂ obtained from HDPE (0.836 g/dm³) is a little higher than that of LDPE 0.7792 g/dm³.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSION

The following conclusion was made at the end of the experimental analysis.

- i. It has been established that there was CO₂ present in the gas fumes evolved during the decomposition of the samples HDPE and LDPE.
- ii. The yield of CO₂ from HDPE was found to be 0.836g/dm³ as against 0.77923 g/dm³ from LDPE. Thus the yield of CO₂ from HDPE is greater than that of LDPE the same quantity (90g) of the two samples were used.
- iii. It has also been established that the decomposition of LDPE is easier than that of HDPE due to the branched chains in the former as against the straight chains in the latter.
- iv. Finally it can be concluded that municipal solid waste (polyethylene and plastics) is a good source of chemical feed in the form of CO₂ which is of diverse use in the industrial sector.

5.2 RECOMMENDATION

The following recommendations can be made to improve the quality and quantity of gas produced;

- i. The heating element should be situated in the kiln and the kiln in turn lagged to conserve heat and reduce losses.
- ii. Due to incomplete combustion, the yield of the CO₂ may be minimized. To minimize its yield, a catalyst and better air supply can be used to aid complete/better combustion.
- iii. The introduction of more effective means of analysis (computerization) would greatly enhance the research, reduce time wastage and give more precise/accurate results.

iv. The yellow liquid condensate formed in the cold traps of the LDPE and HDPE should be tested for the following functional groups;

- alcohol
- ammine
- alkenes
- alkane
- aldehyde
- Ketone
- Ester
- Amide

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APPENDIX

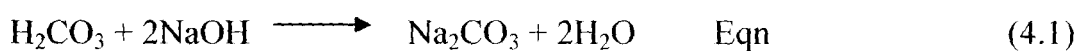
1. Calculation for the amount of CO₂ from LDPE.

first titration result = 111 cm³, second titration result = 109 cm³

The average volume of acid used for LDPE will be.

$$\frac{111 + 109}{2} = 110 \text{ cm}^3$$

To calculate the molar concentration of the H₂CO₃ we take into consideration the neutralization reaction



Using the formula

$$\frac{C_A V_A}{C_B V_B} = \frac{n_A}{n_B} \quad \text{Eqn} \quad (4.2)$$

Where

C_A is concentration of the acid

n_A = volume of the acid

C_B = concentration of the base

V_B = volume of the base

n_B = number of moles of the base

Substituting into the equation above,

$$\frac{C_A \times 110}{13 \times 0.33125} = \frac{1}{2}$$

$$C_A = 0.0179 \text{ mole/dm}^3$$

$$\text{Molar mass of the H}_2\text{CO}_3 = 1(2) + \text{R} + 16(3)$$

$$= 62 \text{ g per mole}$$

$$\text{Mass concentration of H}_2\text{CO}_3 = \text{Concentration (moldm}^3) \times \text{molar mass}$$

$$= 0.0179 \times 62 = 1.1098 \text{g/dm}^3$$

Molar mass of $\text{CO}_2 = 12 + 2(16)$

$$= 44 \text{g per mole}$$

$$\frac{44 \times 1.098 \text{g/dm}^3}{62}$$

$$= 0.77923 \text{g/dm}^3$$

This is the amount of carbon (iv) oxide evolved from the burning of the low-density polyethylene (LDPE)

2. Calculation for the amount of CO_2 from HDPE

First titration result = 116cm^3 , second titration result = 115cm^3

The average volume of acid used for HDPE will be;

$$\frac{116 + 115}{2} = 115.5 \text{cm}^3$$

To calculate the molar concentration of the H_2CO_3 , equation (4.2) will be used

$$\frac{C_A \times 115.5}{13 \times 0.33125} = \frac{1}{2}$$

$$\text{Therefore } C_A = 0.019 \text{ mole/dm}^3$$

Molar mass of the $\text{H}_2\text{CO}_3 = 62 \text{g per mole}$

$$\text{Mass concentration of } \text{H}_2\text{CO}_3 = 0.019 \times 62 = 1.178 \text{g/dm}^3$$

The amount of CO_2 evolved is evaluated as

$$\frac{44 \times 1.178}{62} = 0.836 \text{g/dm}^3$$

This is the amount of CO_2 evolved from burning high-density polyethylene (HDPE)