FINAL DISSERTATION

Heat Confining Properties of Carbon Dioxide and Other Polyatomic Greenhouse Gases which Potentially Causes Global Warming

by

Nur Atiqah Bt Abd Rahman (8930)

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

JULY 2010

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CHEMICAL ENGINEERING)

Approved by,

____

(Assoc. Prof. Dr. Bambang Ariwahjoedi)

DR BAMBANG ARIWAHJOEDI
Associate Professor
Fundamental & Applied Sciences Department
Universiti Teknologi PETRONAS, PERAK

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2010

SAMPLE OF CERTIFICATION OF ORIGINALITY

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NUR ATIQAH BT ABD RAHMAN

Abstract

An experimental study was conducted to determine the most important greenhouse gas that behaves in a similar way to glass in a greenhouse effect and to study the effect of greenhouse gasses towards environment. Besides, the project also focus on the objectives to investigate the outcome of carbon dioxide (CO_2) trichlorofluoromethane (CCl_3F), and pentane ($CH_3\,(CH_2)_3CH_3$) act upon temperature of surroundings. The presence of greenhouse gasses in the environment has become a major threat to plant, animal and human life due to their effect. The projects involved experiment based. Four reflecting mirrors are prepared to fit the bases of the beakers. Carbon dioxide is introduced into one of the beaker using delivery tubes connected to the source. The temperature recorded in this beaker will rise and attain a new steady value. The investigation will be using other gas for instance trichlorofluoromethane (CCl_3F). The study also will investigate pentane (CH_3 $(CH_2)_3CH_3$) that is vapour of volatile liquids act upon temperature in beaker. The last beaker will be controlled beaker for open air (without gas). The parameters that will be controlled are the distance of photoflood light bulb from the mirror in order to find the temperature increase or decrease. The procedure will be repeated for 20 cm, and 25 cm heights.

ACKNOWLEDGEMENTS

First of all, I would like to thank God for the strength given to me in completing this project.

Next, I wish to take the opportunities to express my most gratitude to the individual that have taken the time and effort to assist me in completing the project. Without the cooperation of these individuals, no doubt I would have faced some minor complications throughout the project.

My greatest gratitude goes to the coordinator for Final Year Design Project, Dr. Khalik and my supervisor Dr. Bambang Ari-Wahjoedi. Without their guidance and patience, I would not be succeeded to continue my research up to now.

I would like to thank the Final Year Project 2 committee for arranging various seminars to provide support and knowledge in assisting me. The seminars were indeed very helpful and insightful to me. I would like to thank all lecturers from Universiti Teknologi Petronas who had given guidance throughout the period of the project especially to my Internal Examiner, Ir. Dr. A Halim Shah.

Last but not least, not to forget my family members and fellow friends who gave moral support to motivate and allowed me to pursue to greater heights in my project.

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CHAPTER 1
INTRODUCTION

Greenhouse effect and global warming are controversial issues in the present scientific and political debate. (Alexiadis, 2007) The climate of the Earth is constantly undergoing changes due to a variety of factors. These factors include, among others, changes in the Earth's orbit, changes in the Sun's intensity, changes in the ocean currents, volcanic emissions and changes in greenhouse-gas concentrations. Increased atmospheric CO2-concentration is widely being considered as the main driving factor that causes the phenomenon of global warming.(Florides & Christodoulides, 2009)

It is generally accepted that production processes should take into account environmental sustainability principles. Hence, any attempt to measure the performance of these processes should highlight, as a reference standard, those processes that combine greater amounts of desirable production with lower levels of undesirable outputs, e.g. waste generation or emissions of greenhouse gases. (Streets & Waldhoff, 1999)

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are key radioactively active greenhouse gases (GHGs) contributing to global warming (IPCC, 2001). The production and emission of these greenhouse gases have increased continuously since the pre-industrial era. (Chen, Tam, & Ye, 2010)

An inventory of biofuel combustion is used to develop estimates of the emissions of carbon-containing greenhouse gases (CO_2, CO, CH_4, and NMHC) in Asian countries. It is estimated that biofuels contributed 573 Tg-C (teragrams of carbon; 1 Tg = 10^{12} g) in 1990, about 28% of the total carbon emissions from energy use in Asia. (Streets & Waldhoff, 1999)

The presence of greenhouse gasses in the environment has become a major threat to plant, animal and human life due to their effect. The "greenhouse effect" is the heating of the earth due to the presence of greenhouse gases. It is named this way because of a similar effect produced by the glass panes of a greenhouse. Shorter-wavelength solar radiation from the sun passes through earth's atmosphere and then is absorbed by the surface of the earth, causing it to warm. Part of the absorbed energy is then reradiated back to the atmosphere as long wave infrared radiation. Little of this long wave radiation escapes back into space because the radiation cannot pass through the greenhouse gases in the atmosphere. The greenhouse gases selectively transmit the infrared waves, trapping some and allowing some to pass through into space. The greenhouse gases absorb these waves and reemits the waves downward, causing the lower atmosphere to warm. (Teitel & Tanny, 1999)

Global warming during the last decades has been a "hot" phenomenon concerning the scientific, and not only, community. According to the Intergovernmental Panel on Climate Change (IPCC) of the United Nations, it is the phenomenon, experienced in recent decades, where the average temperature of the Earth's near-surface air and oceans increases.

According to IPCC, the observed increase in globally averaged temperatures since the mid-20th century is very likely to have occurred due to the increase in anthropogenic greenhouse-gas concentrations that leads to the warming of the Earth's surface and lower atmosphere. The greenhouse effect is the phenomenon where water vapour, carbon dioxide (CO_2), methane and other atmospheric gases absorb outgoing infrared radiation resulting in the raising of the temperature. (Florides & Christodoulides, 2009)

In its turn, CO_2 is essentially blamed to be the main factor causing the greenhouse effect because it is the most important anthropogenic greenhouse gas (IPCC, 2007). The increase in global temperature has caused concern that other changes, such as the rising of sea level and the amount and pattern of precipitation, may follow, along with increases in the frequency and intensity of extreme weather events, changes in agricultural yields, glacier retreat, species extinctions, increases in the ranges of disease vectors and others. (Florides & Christodoulides, 2009)

The objectives of the project are to determine the most important greenhouse gas that behaves in a similar way to glass in a greenhouse effect and to analyze the outcome of carbon dioxide (CO_2), trichlorofluoromethane (CCl_3F) and pentane ($CH_3(CH_2)_3CH_3$) act upon temperature of surroundings.

In a greenhouse, visible light passes through glass and is absorbed by dark coloured surface inside. These heat up and radiate energy but at longer wavelength in the infrared region of the spectrum. This is absorbed by glass and so the greenhouse warms up. The greenhouse effect in the Earth's atmosphere is caused by a number of gasses that behaves in similar way to glass. They are transparent to visible light but absorb in the infrared. For this purpose, an experiment to monitor the temperature of the air in each beaker is conducted. Four beakers, each containing mirror, are placed on the bench below photoflood light bulb. The temperature of the air in each beaker is monitored by a thermometer and eventually becomes steady. Carbon dioxide gas is then led into one of the beaker via delivery tube and the temperature of this beaker is seen to rise.

In order to get acquainted with terms and subject of this dissertation, a review on global warming, greenhouse effect, carbon dioxide and chlorofluorocarbon theoretical background of effect is presented in Chapter 2. Methodology from previous experiments and studies are introduced and brief overviews of recent discoveries regarding greenhouse effect are given.

All equipments and experimental procedures used for temperature behavior and comparison are reported in Chapter 3. In order to synthesis the temperature pattern, Chapter 4 presents work in progress, results, discussion and work to be done. Finally, Section 5 summarizes recommendation and Section 6 present conclusion.

It is pointed out that there has been a debate on the accuracy of temperature reconstructions as well as on the exact impact that CO_2 has on global warming. (Florides & Christodoulides, 2009) The project will be conducted within 14weeks throughout the semester. With the simple methodology and scope of work, the project will be possible to be completed within the time frame given.

CHAPTER 2
LITERATURE REVIEW

2.1 Global Warming

There is a growing concern that human activities have increased to the level that they are 1) causing global warming, 2) allowing damaging levels of ultraviolet radiation to reach the earth's surface, 3) polluting the oceans, and 4) reducing our ability to produce enough food for the growing human population. (ELMER, 1972)

The anthropogenic CO is supposed to be responsible for the warming of the earth's atmosphere by the so-called greenhouse effect. It is feared that this warming might lead to a non-sustainable development of the earth. (Kessel, 2000) Emissions of carbon dioxide, methane, nitrogen dioxide, and chlorofluorocarbons (CFCs) have been linked to the transmission of solar radiation to the surface of the earth as well as to the transmission of terrestrial radiation to space. (ELMER, 1972)

Finally it is stressed that the understanding of the functioning of Earth's complex climate system (especially for water, solar radiation and so forth) is still poor and, hence, scientific knowledge is not at a level to give definite and precise answers for the causes of global warming. (Florides & Christodoulides, 2009)

2.2 Greenhouse Effect

The existence of the greenhouse effect was first postulated by ARRHENIUS in 1896. According to his hypothesis, specific gases in the atmosphere of the earth, in the first place water vapor, but also carbon dioxide, methane, di-nitrogen oxide, ozone, and halogenated hydrocarbons, permit the transmission of the sun's radiation (short wavelength) but not that of the long wavelength infrared radiation reflected by the surface of the earth.

Without this naturally occurring effect, the average temperature of the earth's surface would be -18°C as compared to its real value of 15°C. This natural greenhouse effect is beneficial, since it forms the basis for the great variety of plant and animal life on earth. Where it is too strong or too weak, life cannot exist. Examples exist in our planetary system: The Martian atmosphere contains too little carbon dioxide which results in a temperature of about -60°C. The atmosphere of the Venus contains too much carbon dioxide contributing to a temperature of about +430°C. (Kessel, 2000)

Besides these naturally produced greenhouse gases, there are so-called anthropogenic gases generated by human activities, in the first place carbon dioxide, but also methane and other gases. The emission of these gases by industry, traffic, power plants, home heating, and burning of tropical forests creates the so-called anthropogenic greenhouse effect. (Kessel, 2000)

Biofuel consumption is often assumed to be neutral with respect to emissions of carbonaceous greenhouse gases—that is to say, all the CO_2 emitted in the burning process is taken up in the following growing season by replacement crops and trees. However, only when the biofuel is harvested on a sustainable basis—a new tree planted for each tree cut down for fuelwood—and only when all the carbon in the fuel is converted to CO_2 can the process be considered truly carbon-neutral. While some countries are working toward sustainable harvesting, it is not the common practice in most of the developing world, and many upland areas of Asia have been severely degraded by unsustainable harvesting of fuelwood. (Streets & Waldhoff, 1999)

The GHGs included are CO_2, N_2O, and CH_4 and they are expressed as CO_2 equivalent emissions. The emissions released during extraction, processing, transport, distribution and combustion of fuels are taken into account. Besides GHGs, fuel combustion flue gases contain other polluting components such as sulphur oxides, unburned hydrocarbons, and particles. (Axelsson, Harvey, Åsblad, & Berntsson, 2003)

2.3 Carbon Dioxide

CO_2 is an odorless, invisible, and non-flammable gas. It is also safe for humans in the maximum concentrations recommended for plant growth. (Hydrofarm, 2005) An important environmental challenge during the next decades will be to reduce the impacts of global warming. Carbon dioxide (CO_2) is the main greenhouse gas, and 70-75% of all CO_2 emission is due to combustion of fossil fuels. (Hoel & Kverndokk, 1996)

Table 1: Physical and Chemical Properties of Carbon Dioxide

Property	**Value**
Molecular weight	44.01
Specific gravity	1.53 at 21 °C
Critical density	468 kg/m^3
Concentration in air	3703 x 10^7 ppm
Stability	High
Liquid	Pressure < 415.8 kPa
Solid	Temperature < -78 °C
Henry constant for solubility	298.15 mol/ kg bar
Water solubility	0.9 vol/vol at 20 °C

The average level of CO_2 in the atmosphere is about 300 PPM (parts per million). If the level decreases down below 200 PPM in an enclosed growing area, plant growth slows to a halt. Through the years of testing and research, the optimum enrichment level of CO_2 for plant growth has been agreed to be about 1500 PPM. This is assuming, of course, that there is plenty of bright light and a good growing system. With CO_2 enrichment, under good conditions, plant growth rates and flowering will increase 20-100%. CO_2 should be used from seedling right through harvest.(Hydrofarm, 2005)

Carbon dioxide is a naturally occurring gas, a by-product of burning fossil fuels and biomass and a result of land-use changes and other industrial processes. It is the principal anthropogenic gas that is thought to affect the Earth's radiative balance (IPCC, 2007). For this reason it is believed that there is a close correlation between CO_2 and the change of the Earth's temperature. The way this relation has been established is largely based on plotting the average temperature anomalies and the amount of CO_2 present in the atmosphere versus time. Such a demonstration is presented in Figure 1, where are plotted the annual global temperature anomalies (for the period 1850–2005, Hadley Centre, 2007) together with the historical CO_2 record data from (a) the Law Dome in Antarctica (DE08, DE08-2 and DSS ice-cores for the period 1850–1978, Etheridge et al., 1998) and (b) the atmospheric CO_2-concentrations derived from air samples collected at the South Pole, for the period 1957–2004 (Keeling and Whorf, 2005). (Florides & Christodoulides, 2009)

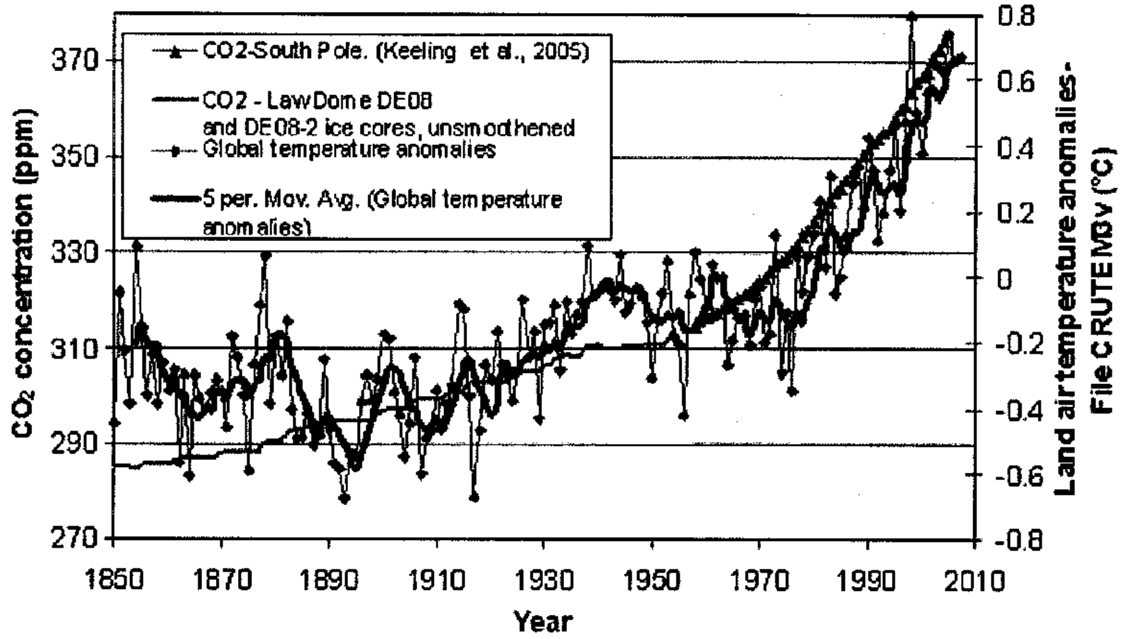

Figure 1: Annual global temperature anomalies (Hadley Centre, 2007) and CO_2 record data from (a) the Law Dome in Antarctica (DE08, DE08-2 and DSS ice-cores, Etheridge et al., 1998) and (b) the atmospheric CO_2-concentrations derived from air samples collected at the South Pole—shaded area, (Keeling and Whorf, 2005). Profiles do not follow the same trend between 1890 and 1950.

At the beginning of the Earth's history there was a great amount of CO_2 in the atmosphere. Gradually, the biological and natural processes locked a large amount of it in the rocks. Today the atmosphere of the Earth consists primarily of nitrogen (78.08%) and oxygen (20.95%). The rest 0.97% consists of the inert gas argon (0.93%) and components at trace level such as carbon dioxide (0.038%), the inert gases neon, helium and krypton, as well as hydrogen (all well under 0.002%). In addition, natural air always contains a certain amount of water vapour (0–7%). This is often neglected when giving the composition of air, although it is a very important constituent. The analogy of water vapour varies greatly with the air temperature, pressure, and humidity but typically makes up about 1% of the air (National Space Science Data Center (NSSDC), Earth Fact Sheet, 2007). The changes that occurred in the atmosphere and the surface of the Earth, related to CO_2, through the geological aeons are described below:

a) Coal deposits: The geological records show that the great coal deposits of the Earth were laid down mostly in the Carboniferous period (known as the first coal-age) about 300 Ma. Coal formation continued throughout the Permian, Triassic, Jurassic, Cretaceous, and Tertiary Periods (known collectively as the second coal-age). Coal consists mostly of carbon, which gave the name to the Carboniferous period. Coal is a member of a group of easily combustible organic sedimentary rocks composed mostly of plant remains from ancient forests. As plants and trees died, their remains formed peat deposits in swamps that were buried by sediments from rivers and lakes. With deeper and deeper burial, the heat and pressure transformed the peat to coal. A probable source of all this carbon was the atmosphere, presumably by conversion from gaseous hydrocarbons such as methane or possibly from free CO_2. The massive deposits of high-carbon rocks laid down at the end of the Paleozoic, therefore suggest a major change in the atmosphere at that time. The World Energy Council, in a Survey of Energy Resources for Coal (including Lignite), gives the recoverable reserves at the end of 2005 as 847,488 million tonnes (World Energy Council).

b) Chalk deposits: Cretaceous at the end of the Mesozoic era (65 Ma) was another period of major change. Cretaceous comes from the Latin world 'creta' (chalk) because of the 'chalky' deposits of that period. Chalk largely consists of minute skeletons of single-celled algae and isolated plates of calcite derived from their breakdown together with the remains of other planktonic organisms. The chalk deposits accumulated at the shallower parts of the ocean floors have thicknesses between 500 and 4000 m (Skelton, 2003).

c) Carbonate minerals: The carbonate mineral calcite is a chemical or biochemical calcium carbonate ($CaCO_3$) and one of the most widely distributed minerals on the Earth's surface, formed during the Cretaceous period. Limestone is a sedimentary rock also formed in the Cretaceous period, composed largely of this mineral.

Limestone often contains variable amounts of other material like silica, clay and silt in different forms within the rock. The primary source of the calcite in limestone is usually the shells of marine organisms, especially corals and molluscs. The role of atmospheric partial pressure of carbon dioxide (CO_2) on marine organisms and ecosystems still remains poorly understood but again, a possible source of the chalk and limestone could possibly be the conversion of the atmospheric CO_2.

The changes described above were enormous and affected the composition of the Earth's atmosphere greatly. As it is observed the amount of carbon left in the atmosphere is actually extremely small. Almost everything that once was in the atmosphere has since been locked in the rocks.(Florides & Christodoulides, 2009)

There appears to be some controversy on whether the population increase in the world could affect global warming that we seem to experience at the present time. For example, Robinson and Robinson (2000), Robinson et al. (2007) argue that there is absolutely no long-term effect due to the increase of the burning of fossil fuels caused by an increased population of humans. This seems to be contrary to the arguments presented by Vice President Al Gore who is warning us about the deleterious effects due to global warming caused by the burning of fossil fuels. (Lonngren & Bai, 2008)

Figure 2: Carbon Dioxide Emission

2.4 Chlorofluorocarbons

A class of synthetic chemicals those are odourless, non-toxic, non-flammable, and chemically inert. The first CFC was synthesized in 1892, but no use was found for it until the 1920s. Their stability and apparently harmless properties made CFCs popular as propellants in aerosol cans, as refrigerants in refrigerators and air conditioners, as degreasing agents, and in the manufacture of foam packaging. They are now known to be partly responsible for the destruction of the ozone layer. In 1987, an international agreement called the Montréal Protocol was established; it was one of the first global environmental treaties and it banned the use of chemicals responsible for ozone damage, such as CFCs in aerosols and refrigerants.(Helicon, 2010)

When CFCs are released into the atmosphere, they drift up slowly into the stratosphere, where, under the influence of ultraviolet radiation from the Sun, they react with ozone (O_3) to form free chlorine (Cl) atoms and molecular oxygen (O_2), thereby destroying the ozone layer which protects the Earth's surface from the Sun's harmful ultraviolet rays. The chlorine liberated during ozone breakdown can react with still more ozone, making the CFCs particularly dangerous to the environment. CFCs can remain in the atmosphere for more than a hundred years. Replacements for CFCs are being developed, and research into safe methods for destroying existing CFCs is being carried out. (Helicon, 2010)

The Kyoto Protocol (1997) regulated the emissions of six types of greenhouse gases (GHGs): CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs). Under the protocol, Japan is committed to a 6% reduction from the level of equivalent CO2 emissions in 1990 by the period between 2008 and 2012. (Hanaoka, Ishitani, Matsuhashi, & Yoshida, 2002)

The restrictions upon emissions of chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) have been omitted from the Kyoto Protocol, because CFCs and HCFCs have already been regulated as ozone depleting substances (ODSs) under the Montreal Protocol (1987). CFCs and HCFCs have effects on not only ozone depletion but also global warming. (Hanaoka et al., 2002)

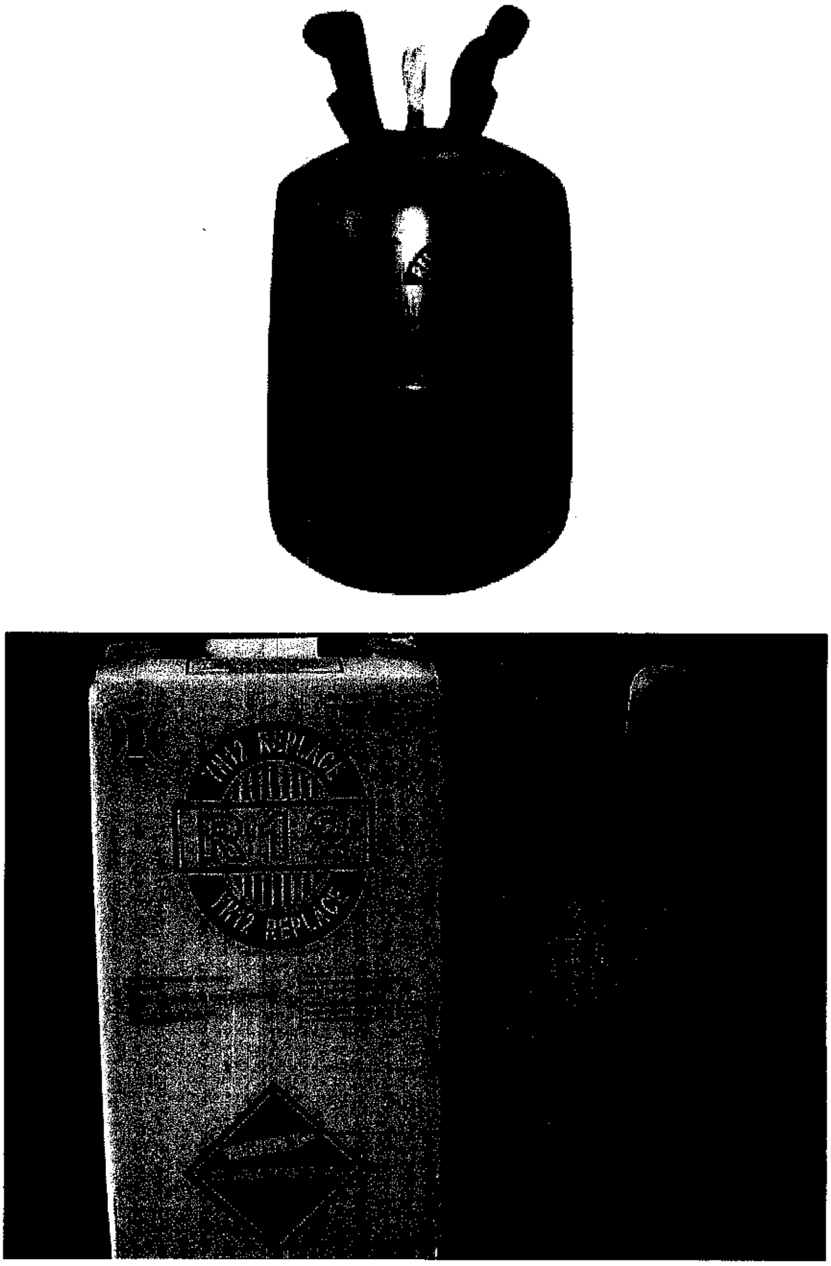

Figure 3: Example of Refrigerant 11and 12

2.5 Methodology of Previous Experiment

2.5.1 Carbon Dioxide Gas and the Greenhouse Effect

The objective of the experiment was to determine the increasing amounts of carbon dioxide in the atmosphere would cause increases in temperature. Carbon dioxide gas was obtained from dry ice which was measured by the displacement of water when the dry ice sublimated as it warmed. Increasing amounts of carbon dioxide gas were sealed in four Erlenmeyer flasks. Another two flasks, one open and one closed, contained no added carbon dioxide gas. The temperature of the air in all six flasks was recorded at thirty second intervals for fifteen minutes during exposure to sunlight.(Bryant & Greenwald, 2006)

After exposure to sunlight, the flasks with larger amounts of carbon dioxide gas had correspondingly higher temperatures when the temperatures stabilized. These temperatures were also higher than the flasks which had no added carbon dioxide. The results of the experiment supported the hypothesis that the flasks filled with larger amounts of carbon dioxide gas would produce correspondingly higher temperatures when exposed to sunlight, and would have higher temperatures than the flasks without added carbon dioxide. The results also support the theory that larger emissions of carbon dioxide could cause an increase in atmospheric temperature and therefore be a cause of global warming.(Bryant & Greenwald, 2006)

2.5.2 Greenhouse Gases

To investigate which of the most common greenhouse gases has the greater effect to the light by increasing the temperature of the earth. Materials needed are glass container, two lamps, methane, water vapor, carbon dioxide, thermometer and hose. The methane or any of the other gases (separately) are placed on the glass container. (Cassyleon, 2008)

The thermometer is stick on the container. The lamps are placed in front of the container, nut in front of the thermometer on the container. Turn on the lights. Check the temperature of the gas, inside of the container, every certain time. Note: After the water vapor is placed inside of the container, wait until the temperature goes back to normal, to turn on the lights and start checking the temperature.(Cassyleon, 2008)

Carbon dioxide and methane absorb more heat than any other greenhouse gas in the earth. Carbon Dioxide absorbs more heat than Methane, the differences between this two gases was between 66% to 90% significantly in the standard Deviation, different from air and water vapor, which overlap and demonstrated to have not much effect to heat by not increasing the temperature, but just maintaining it balance. When liquid water is evaporated to form water vapor it helps to cool the surface of the earth, and it keeps the air warm enough to support life, this was prove with the results by water vapor being lower than air. Methane and carbon dioxide had a bigger reaction to light, by absorbing the heat, and demonstrating that they do increase the temperature of earth surface significantly. Carbon dioxide has the majority of distribution on earth's atmosphere with 76% and methane with 16%. Carbon dioxide gas had more effect to heat following by methane. Carbon dioxide is an important gas because it transmits visible light but absorbs strongly in the infrared.(Cassyleon, 2008)

2.6 Methodology of Previous Study

2.6.1 Role of atmospheric CO_2 in Relation to Temperature Increase

The role of atmospheric CO_2 in relation to temperature-increase and, more generally, in relation to Earth's life through the geological aeons, based on a review-assessment of existing related studies. Moreover, using three independent sets of data (collected from ice-cores and chemistry) a specific regression analysis is performed which concludes that forecasts about the correlation between CO_2-concentration and temperature rely heavily on the choice of data used, and one cannot be positive that indeed such a correlation exists (for chemistry data) or even, if existing (for ice-cores data), whether it leads to a "severe" or a "gentle" global warming. A very recent development on the greenhouse phenomenon is a validated adiabatic model, based on laws of physics, forecasting a maximum temperature-increase of 0.01– 0.03 °C for a value doubling the present concentration of atmospheric CO_2. Through a further review of related studies and facts from disciplines like biology and geology, where CO_2-change is viewed from a different perspective, it is suggested that CO_2-change is not necessarily always a negative factor for the environment. In fact it is shown that CO_2-increase has stimulated the growth of plants, while the CO_2-change history has altered the physiology of plants. Moreover, data from palaeoclimatology show that the CO_2-content in the atmosphere is at a minimum in this geological aeon. (Florides & Christodoulides, 2009)

Meteorological stations have recorded the temperature since 1850. Today there are over 3000 stations taking records of temperatures. For marine regions sea-surface temperature (SST) measurements are taken on board merchant and some naval vessels. To overcome problems resulting from the fact that stations on land are at different elevations, and that different countries estimate average monthly temperatures using different methods and formulae, it has been established that the period 1961–90 is considered as the "zero-base" (on the grounds of available combined data).

Hence recorded temperatures are expressed as anomalies from the 0-base. Data analysed with the above method are available to the public by the Climatic Research Unit datasets, developed in conjunction with Hadley Centre of the UK Met Office (Hadley Centre, 2007). (Florides & Christodoulides, 2009)

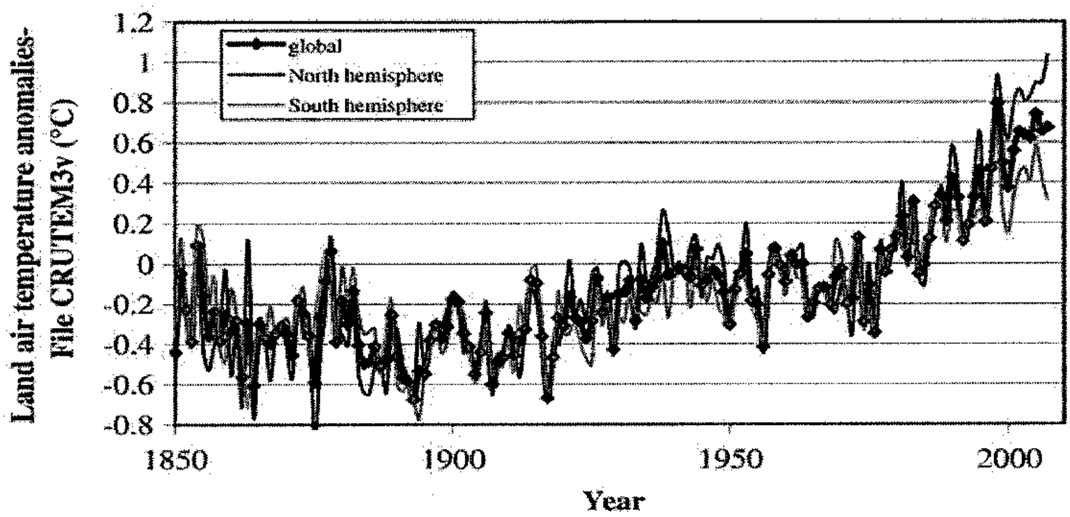

Figure 4: Land air temperature anomalies, for global, north hemisphere and south hemisphere for the period of 1850 to 2007. (File: CRUTEM3v-global variance adjusted version of CRUTEM3. Hadley Centre, 2007).

Based on available data (Hadley Centre, 2007), the land–air temperature anomalies for the global, north and south hemisphere, for the period of 1850 to 2007, are drawn in Figure 4. One can see that from the year 1850 to about 1910 the temperature gradient is essentially 0. Then there is an increase in the temperature gradient for the next 30 years. From about 1940 to 1980 the gradient is again essentially 0. Finally, there is a definite increase of about 0.6 °C in the mean global temperature since 1980. (Florides & Christodoulides, 2009)

2.6.2 Global thermodynamic model of the earth's energy balance

From the thermodynamic point of view, the earth is a closed system which exchanges only energy with its environment. The energy exchange is radiating energy in two ways: input incident solar energy and output radiating energy. Under equilibrium, incident solar energy exactly balances output radiating energy (Figure 5) and this yields the equilibrium earth's surface temperature. However, this equilibrium can be modified because either incident solar energy or outputs radiating energy are modified. Nowadays, due to human activity, GHG emissions contribute to reduce radiating emission from the earth. Let us call E the total energy of the earth at time t and dE_0 the earth's natural energy imbalance, neglecting human energy consumption, during time d_t (1 year for example) given by:

$dE_0 = E_{SE} - E_{rad}$

If positive, this energy variation, dE_0, corresponds to an excess of energy at the earth's surface (Figure 6). The earth being a closed thermodynamic system, this energy variation results in internal (dU), kinetic (dE_k) and potential (dE_{pot}) energy variations:

$dE_0 = dU + dE_k + dE_{pot}$

dE_k corresponds to the yearly variation of kinetic energy due to a climate change: it is mostly due to the increase of winds, air jets, hurricanes or cyclones although there may be a contribution coming from water flow. dE_{pot} corresponds to the variation of potential energy coming from gravitational energy due to a climate change. As is likely to be a very small contribution, neglect it in the following.

In the internal energy variation, the main contributions are due to sensible and latent heat: $dU1 = \square\,(Mc_pdT)_i + \delta M_mL_m + \delta M_vL_v$

where $\square\,(Mc_pdT)_i$ corresponds to the temperature increase of air, water, land, etc., δM_m the mass of ice melt and L_m is the latent heat of ice melting, δM_v the mass of water vaporized due to global warming and L_v is the latent heat of vaporization.

The internal energy variation is neglected due to storage or destorage of biomass due to forestation or land use change.

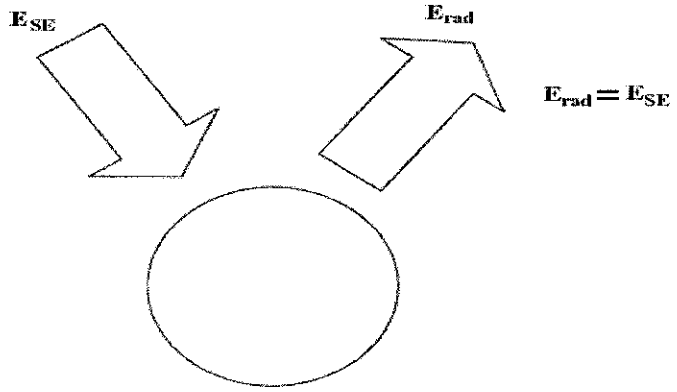

Figure 5: Pre-industrial earth's energy balance under equilibrium.

Response of the earth's surface to energy imbalance (Figure 6), the energy balance of the closed thermodynamic system submitted to the earth's energy imbalance is given by

$$dE_0 = E_{SE} - E_{rad}$$

$$= \square\ (Mc_pdT)_i + \delta M_mL_m + \delta M_vL_v + dE_k + dE_{pot}$$

In the absence of variation of the potential energy, we get

$$E_{SE} - E_{rad} = \square\ (Mc_pdT)_i + \delta M_mL_m + \delta M_vL_v + dE_k$$

$$= dU_l + dE_k$$

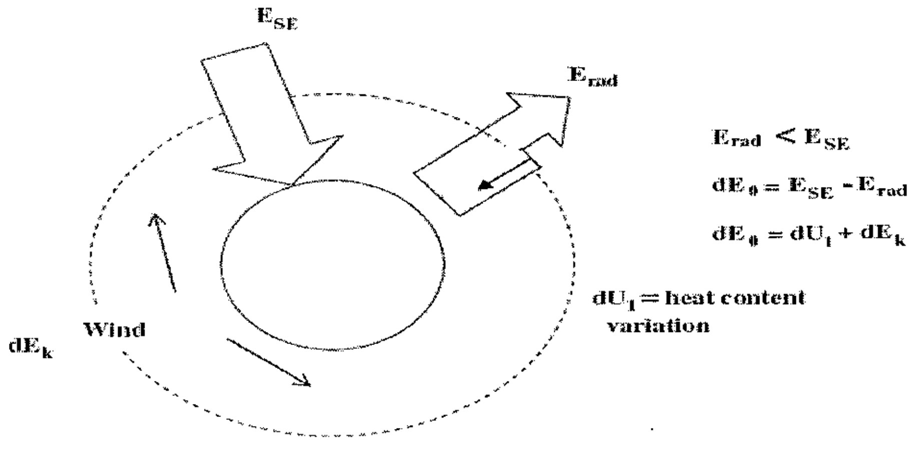

Figure 6: Earth's energy imbalance due to the greenhouse effect induced by human activity.

CHAPTER 3
METHODOLOGY

The experiment will be conducted based on the method introduced by Classic Chemistry Demonstrations, Copyright © The Royal Society of Chemistry 1995. The following is the method of experimentation that will be used in collecting the data for this project.

3.1 Descriptive

Four beakers will be used, each containing a reflecting mirror, are placed on the bench below a photoflood light bulb. The temperature of the air in each beaker is monitored by a thermometer and eventually becomes steady. Carbon dioxide (CO_2) gas is then led into one of the beaker via delivery tube and the temperature of this beaker is seen to rise. The same procedure will be repeated by using other gas such as, trichlorofluoromethane (CCl_3F). Other volatile vapor will be used such as pentane (CH_3 $(CH_2)_3CH_3$). A control beaker with open air (without gas) shows the ambient temperature to be compared.

3.2 Apparatus and Chemicals

Table 2: Apparatus

APPARATUS	AMOUNT
250 cm^3Beaker	4
Aluminum Foil	1 Roll
275 Watt Photoflood Light Bulb and Plain Bulb Holder	4
Thermometer	4
Reflecting Mirror	4
Pipette	1
Retort Stand	2
Carbon Dioxide Regulator Manipulator	1

Table 3: Chemicals

CHEMICALS	AMOUNT
Carbon Dioxide (purchased from Malaysia Oxygen Berhad)	Cylinder
Pentane (purchased from R7M Marketing, Essex, U.K)	25ml
CFC 12 (CCl_2F_2) (purchased from Benua Asia Sdn. Bhd)	Small cylinder

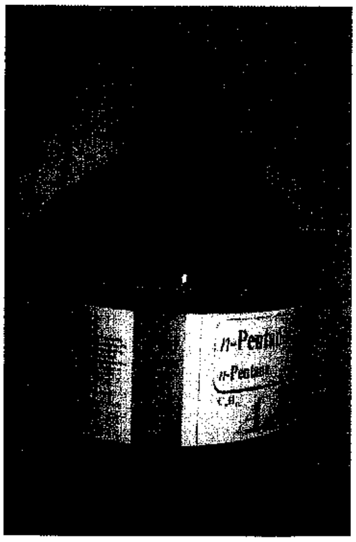

Figure 7: n-Pentane

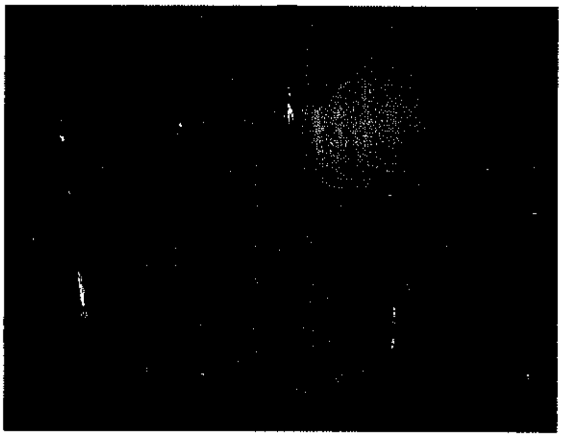

Figure 8: Apparatus

3.3 Equipments Setup

The project examines the effect of carbon dioxide and other polyatomic molecules gas that act as greenhouse gasses towards temperature. The projects involved experiment based. In the first part of the project, four reflecting mirrors are prepared to fit the bases of the beakers. These mirrors are to absorb and re-radiate radiant energy and they stimulate the Earth's surface. The beakers are placed side by side on the bench with the reflecting mirrors inside and the photoflood light bulb and its holder are placed about 15 cm above. All of the beakers should be wrapped equally from inside with aluminum foil and illuminated equally when the bulb is switched on. A thermometer is clamped with its bulb about 2 cm above the reflecting mirror inside each beaker. These thermometers should be chosen so that they read the same temperature in the same surroundings.

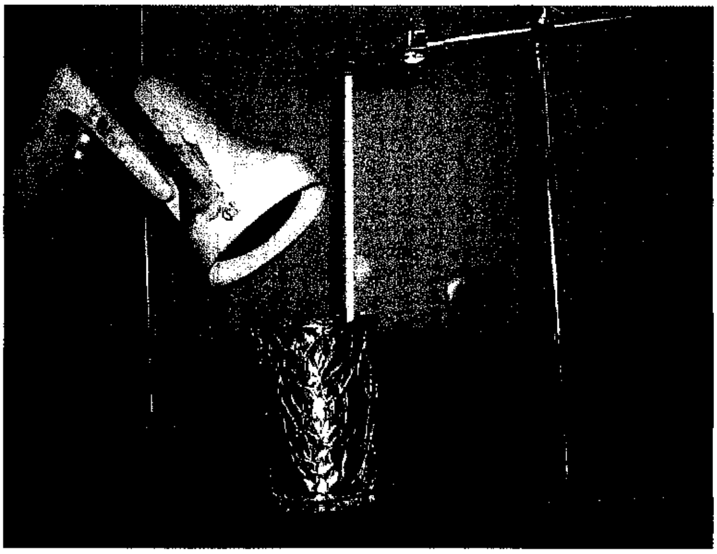

Figure 9: Equipments Setup

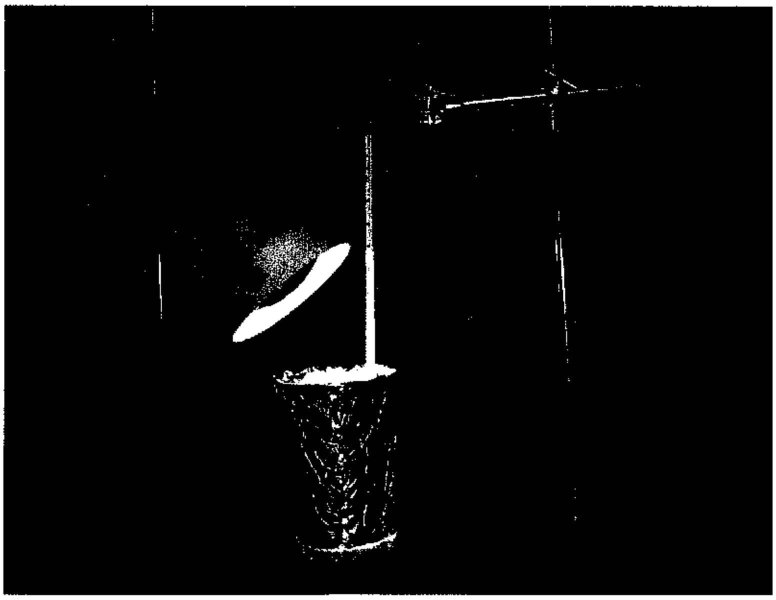

Figure 10: Demonstration of Experiment

3.4 Gas Regulator Manipulative Procedures

The easiest way to raise the CO_2 level is by the compressed CO_2 gas method with a tank. The size comes in 25kg from Malaysia Oxygen Berhad. The characteristic of the gas are asphyxiating in high concentration, no odor, heavier than gas and gas liquefied under pressure.

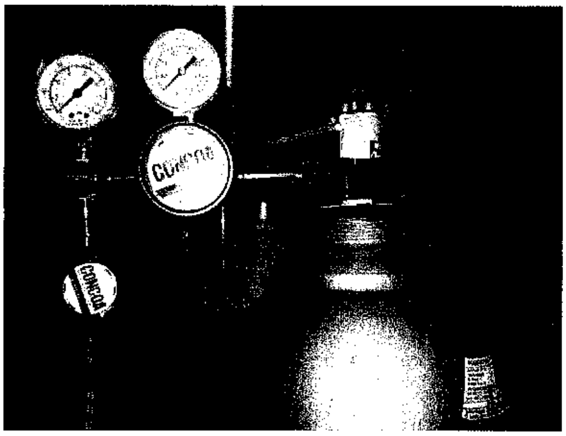

Figure 11: Carbon Dioxide Tank and Regulator

3.4.1 Setting Up Your System

It is important before attaching the regulator to the CO_2 tank, slowly open the tank valve wide open for 3-5 seconds to blow out any sediment that may be in the tank valve. Reclose the valve tightly. Whenever you are opening the tank valve, do it extremely slowly to avoid damaging the inner seals in the regulator. Make sure the washer is seated evenly in the regulator valve. Then attach regulator assembly to tank. Do not open the tank valve yet. Insert the shorter extension tube into the plastic fitting on the back of the flowmeter. Take the other end of the extension tube and insert it onto the "T" fitting as shown.(Hydrofarm, 2005)

3.4.2 Distribution Ring

The distribution ring is designed to be suspended above the plants in a circular pattern. First screw the eyelets in according to the diagram. Then thread the tubing through them in a circular pattern over your growing area. Connect the return end to the other side of the "T" fitting. CO_2 is heavier than air and will spread downward from the distribution points. Make sure the distribution tubing is secured and does not interfere with your lighting or light movement systems.(Hydrofarm, 2005)

3.4.3 Adjusting The Regulator

Once the system is securely attached and set up, your regulator can be adjusted. Plug your solenoid cord into the timer and rotate the dial until the tabs are in an "ON" position. Very, very slowly open the tank valve until it is fully open. Now, using a screwdriver and a crescent wrench adjust the pressure so it reads 1 bar. Tighten the locknut. Unplug the solenoid valve. (Hydrofarm, 2005)

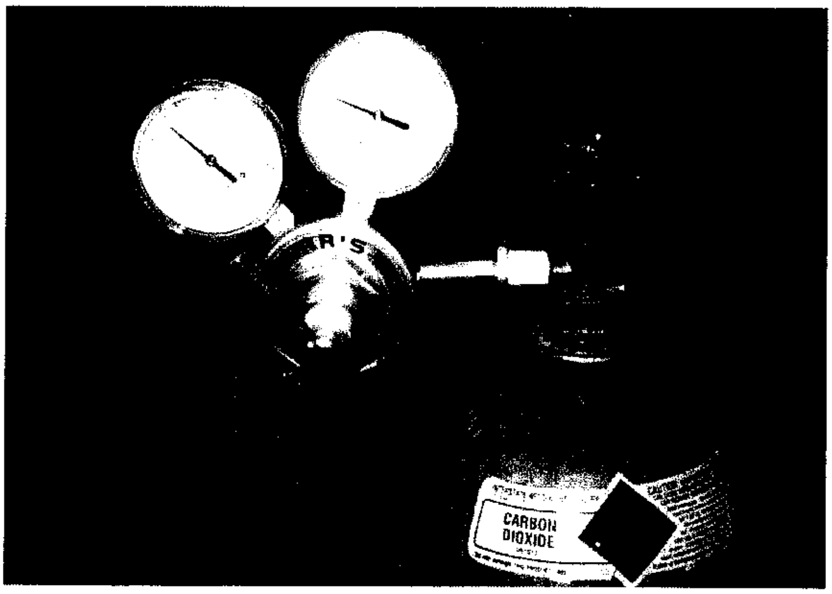

Figure 12: Gas Manipulative Regulator Procedure

3.5 Demonstration of Experiment

In the second part of the project, the lights are switched on and wait until the thermometers have reached steady state readings (these will be about 45°C depending on the distance of the bulb). If these are not the same, the lamp is moved until they do give identical readings.

In the third part of the project, the lamp is switched on and the readings are taken from all thermometers every second for seven minutes to show that they become steady. Now, carbon dioxide is introduced into one of the beaker using delivery tubes connected to the source, but taking care that the tube does not shade the thermometer from the light. The carbon dioxide is leaved flowing slowly to keep the beaker full of carbon dioxide with flow rate of $5cm^3/s$ and make up losses by diffusion. The temperature recorded in this beaker will rise and attain a new steady value of about 8°C above that in the control beaker. The flow is stopped and the temperature will drop again as carbon dioxide diffuses out of the beaker. The whole cycle will take about 7 minutes.

The same procedure will be repeated by using other gas for instance trichlorofluoromethane (CCl_3F). The cycle also will be repeated by pentane ($CH_3(CH_2)_3CH_3$) that is vapour of volatile liquids. About 1 cm^3 of liquid can be added to the beaker using a dropping pipette. The temperature will be rise several degree as the liquid evaporates and drop again as the vapour diffuses out of the beaker. The last beaker will be controlled beaker for open air (without gas).

The parameters that will be controlled are the height of photoflood light bulb from the mirror in order to find the temperature increase or decrease. The procedure will be repeated for 20 cm and 25 cm heights.

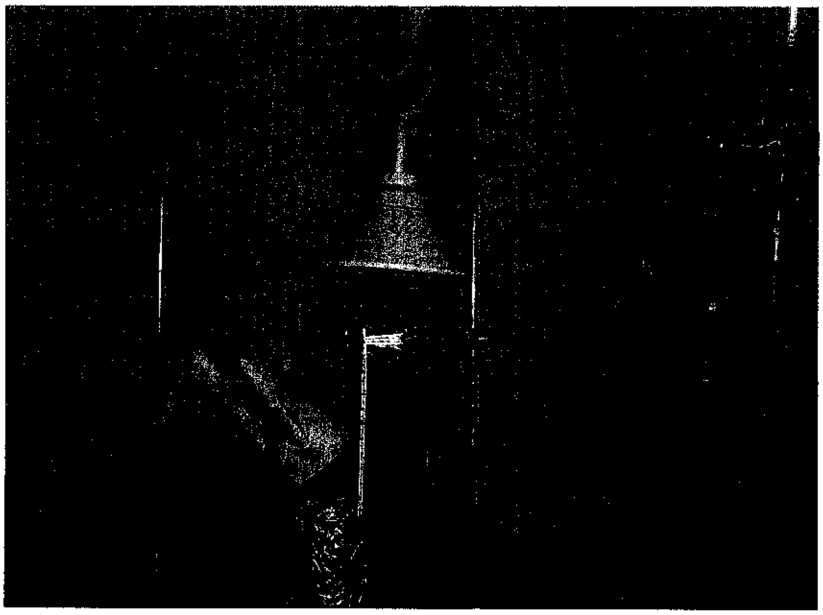

Figure 13: Experiment using CO_2 Gas

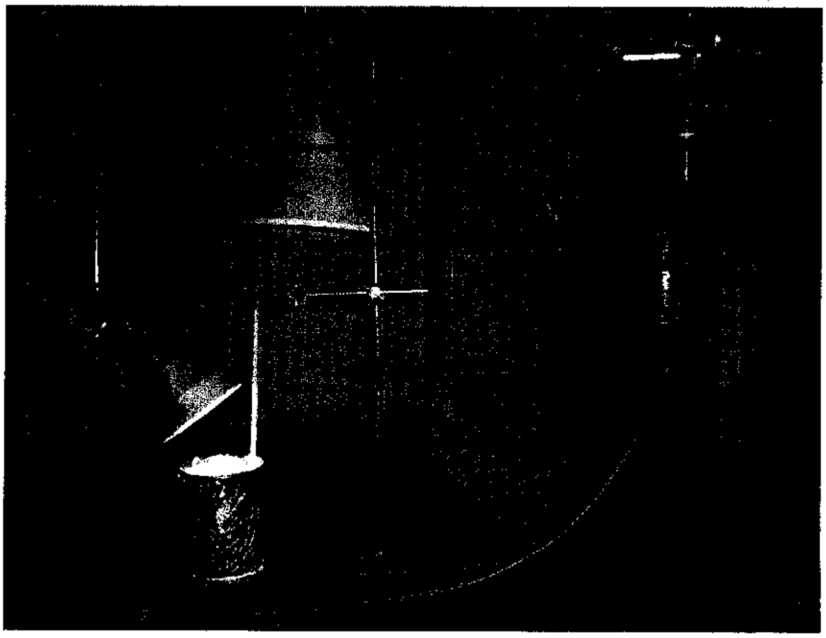

Figure 14: Demonstration of Experiment using CO_2 Gas

CHAPTER 4

WORK IN PROGRESS AND WORK IN PLAN

4.1 Work in Progress

The prototype of greenhouse has been developed by using beaker wrapped equally from inside with aluminum foil. This will help the radiation from photoflood light bulb illuminated equally. The weights of all beakers are measured to ensure all are same. This will avoid any heat capacity different between each beaker and effect the amount of radiation absorbed by the beaker .The reflecting mirrors are prepared to fit the bases of the beakers. These mirrors are to absorb and re-radiate radiant energy and they stimulate the Earth's surface. The photoflood light bulb and its holder are placed about 15 cm above. A thermometer is clamped with its bulb about 2 cm above the reflecting mirror inside each beaker. These thermometers should be chosen so that they read the same temperature in the same surroundings. Temperature distribution is one of the elements that have been examined.

The project examines the effect of carbon dioxide and other polyatomic molecules gas that act as greenhouse gasses towards temperature. The projects involved experiment based. When carbon dioxide is introduced into one of the beaker using delivery tubes connected to the source, the carbon dioxide is leaved flowing slowly to keep the beaker full of carbon dioxide and make up losses by diffusion. When the beaker is full of carbon dioxide, the concentration of carbon dioxide is assume to be one (100%). The flow is non-steady state as the data collected will be vary according to time and the whole cycle will take about 7 minutes.

4.2 Results

From the data recorded, three types of graph have been analysis as below:

1) Temperature vs. time (effect of different distance between photoflood light bulb and surface of beaker)
2) Temperature vs. time (effect of different component of greenhouse gases)
3) Temperature vs. distance (effect of varying temperature)

4.2.1 Graph of Temperature vs. Time (effect of different distance between photoflood light bulb and surface of beaker)

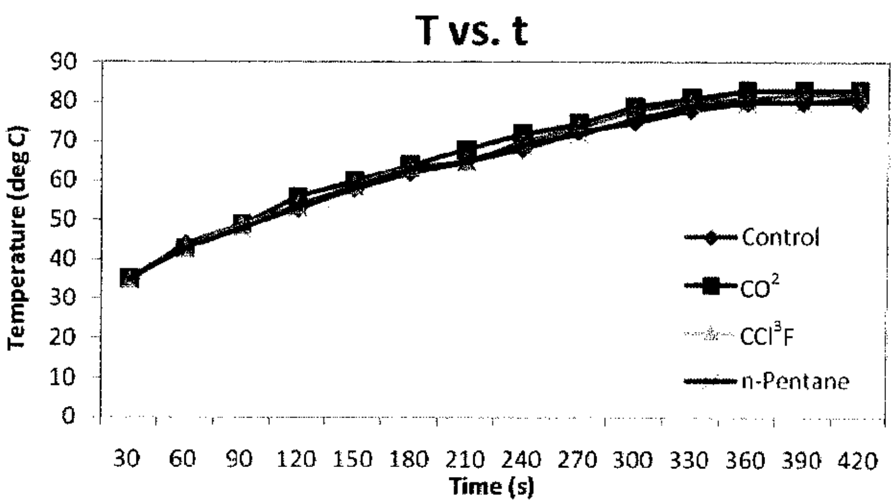

Figure 15: Temperature vs. Time Graph for Height = 15 cm

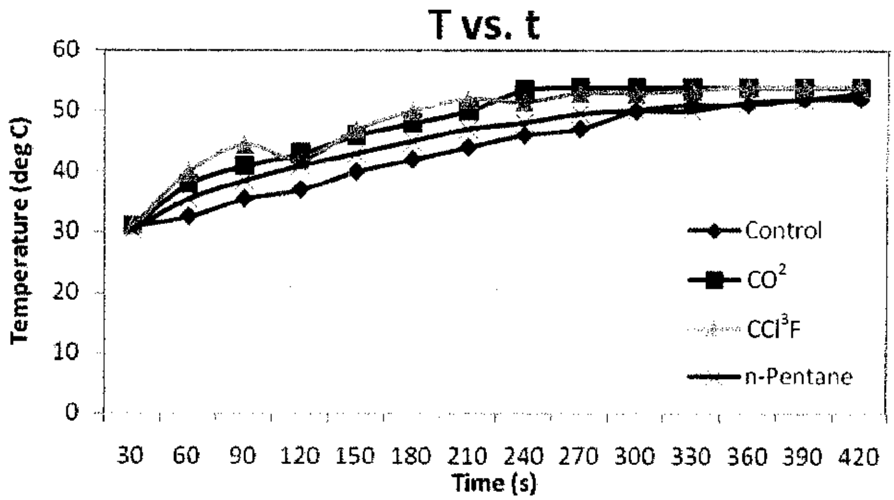

Figure 16: Temperature vs. Time Graph for Height = 20 cm

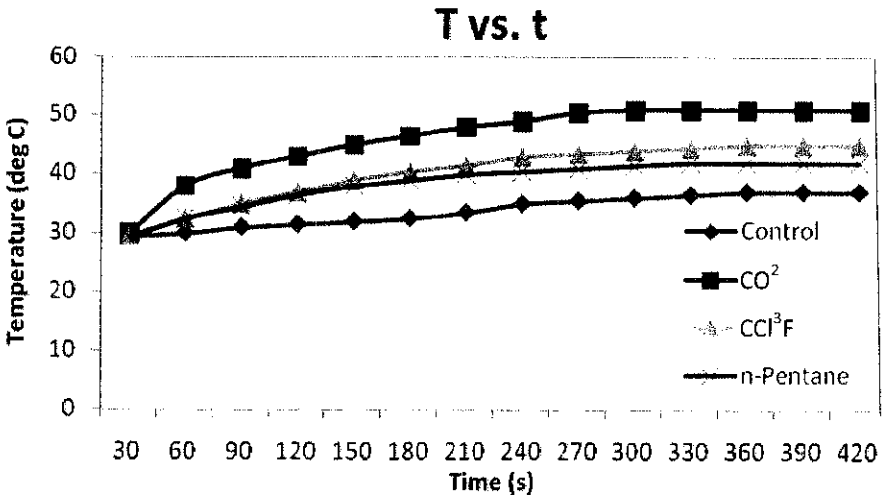

Figure 17: Temperature vs. Time Graph for Height = 25 cm

4.2.2 Temperature vs. time

(effect of different component of greenhouse gases)

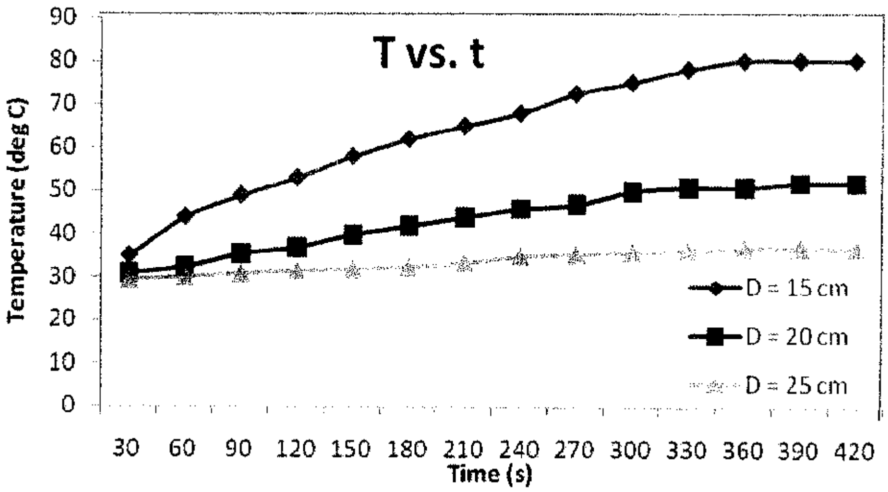

Figure 18: Temperature vs. Time Graph for Control Beaker

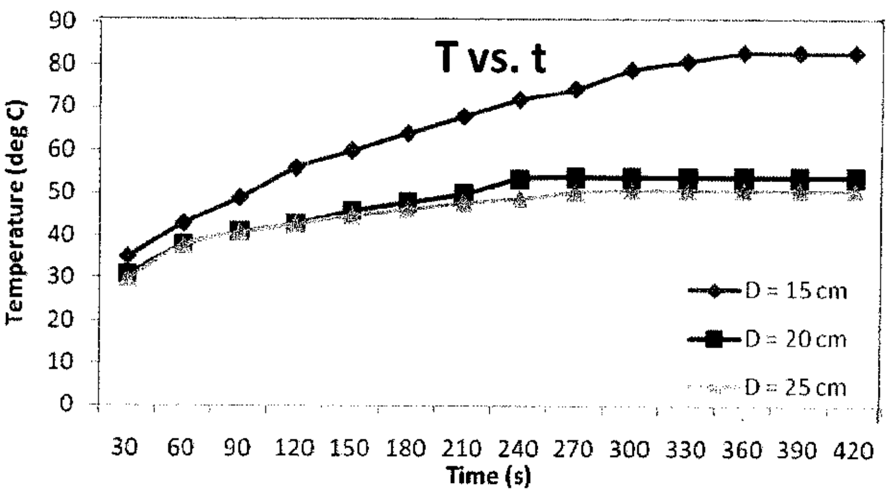

Figure 19: Temperature vs. Time Graph for CO_2

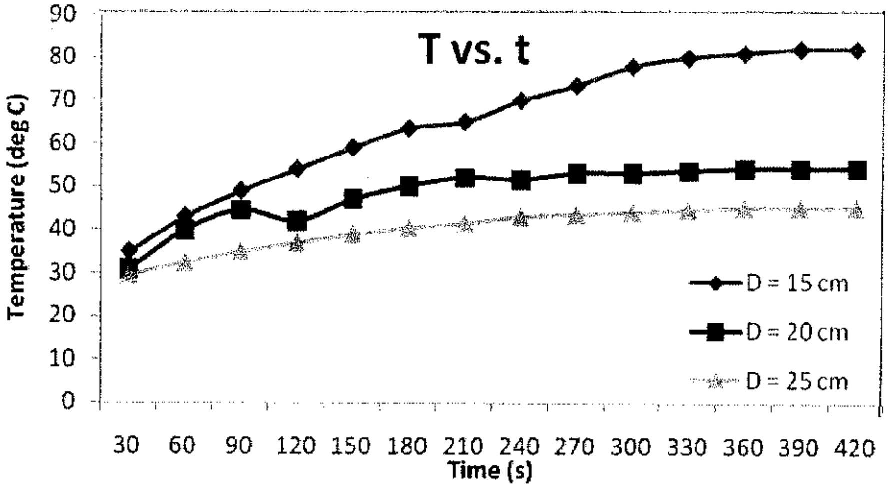

Figure 20: Temperature vs. Time Graph for CCl_3F

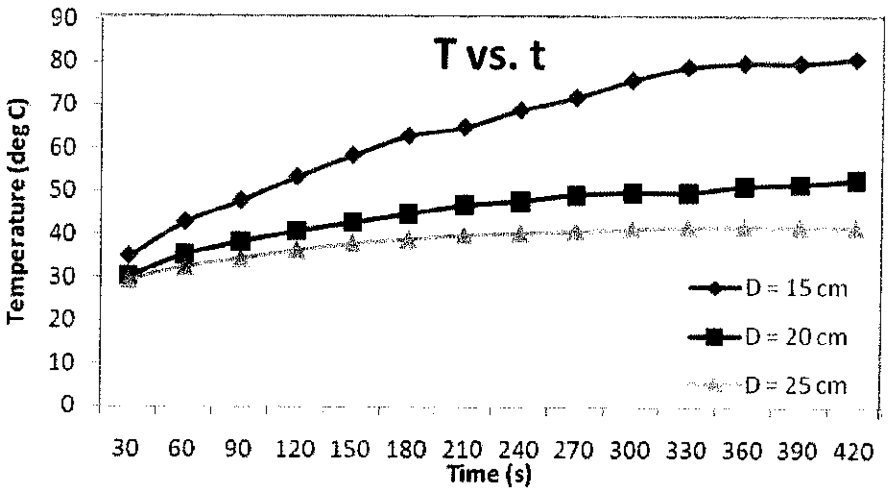

Figure 21: Temperature vs. Time Graph for n-Pentane

4.2.3 Temperature vs. distance (effect of varying temperature)

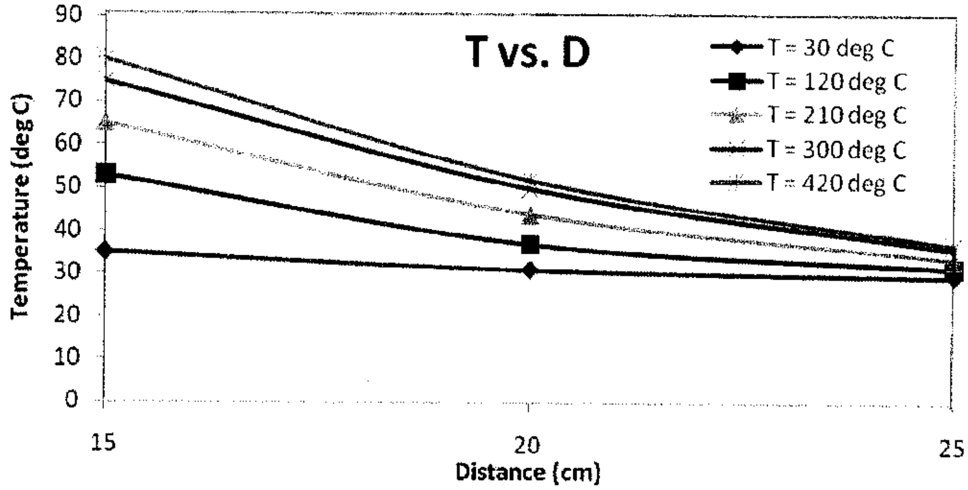

Figure 22: Temperature vs. Distance Graph for Control Beaker

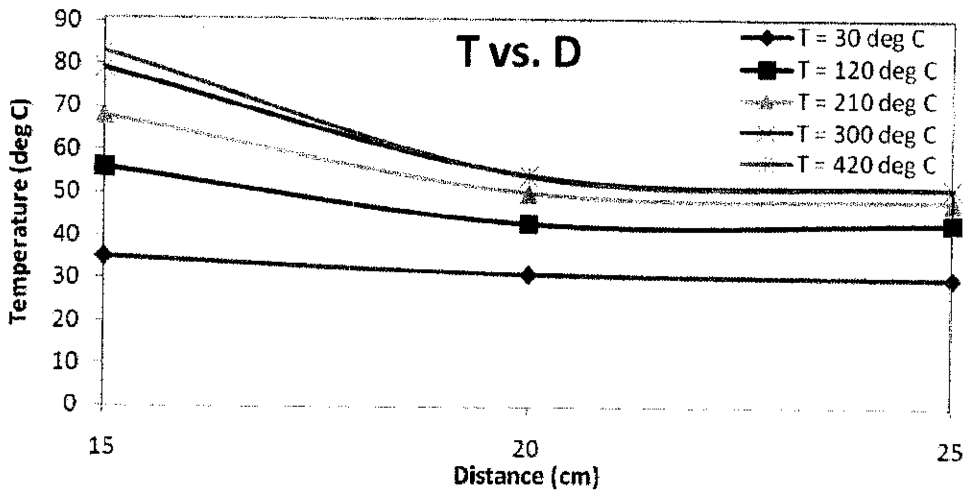

Figure 23: Temperature vs. Distance Graph for CO_2

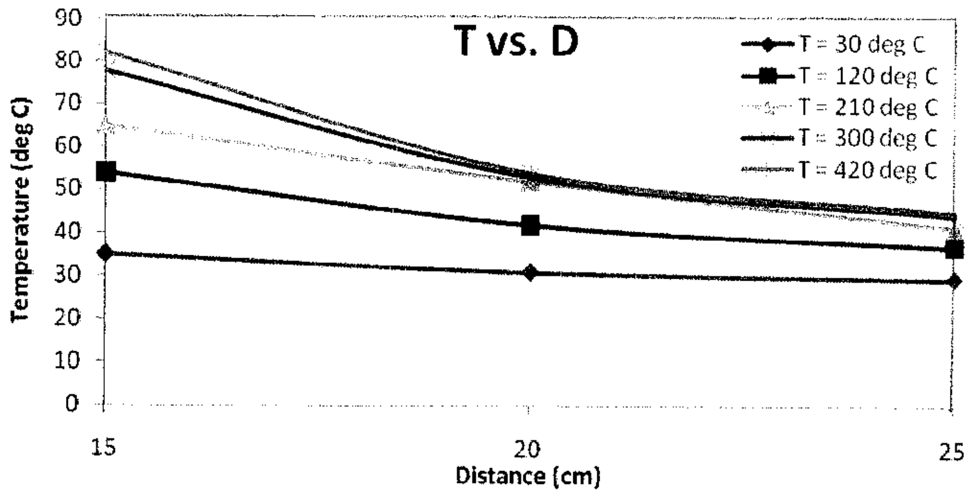

Figure 24: Temperature vs. Distance Graph for CCl_3F

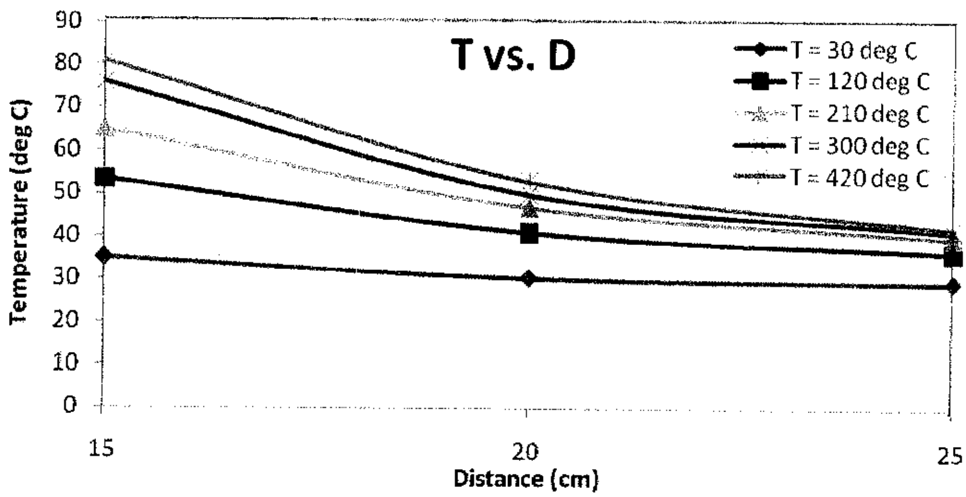

Figure 25: Temperature vs. Distance Graph for n-Pentane

4.2.4 Discussion

Based on Temperature vs. Time Graph, parameter that varies in this experiment is the distance between the bulb and the surface of the beaker. After exposure to bulb, the result shows that the decrease distance led to higher intensity of the light and will greatly increase the temperature inside the beaker. If the intensity of the light is less different between each gas, the heating of the gas become significant. In this case, we can conclude carbon dioxide is the worst greenhouse gas. Second worst gas is trichlorofluoromethane (CCl_3F) and less greenhouse effect is n-pentane. Control beaker has the lowest temperature readings.

For distance 15 cm, each beaker shows greatly higher temperature compare to distance 20 cm and 25 cm. After exposure to photoflood light bulb, the beaker with carbon dioxide gas had correspondingly higher temperatures when the temperatures stabilized. The trends for the increasing temperature follow from control beaker, beaker filled with n-Pentane, beaker filled with trichlorofluoromethane and lastly beaker filled with carbon dioxide. The results also support the theory that larger emissions of carbon dioxide could cause an increase in atmospheric temperature and therefore be a cause of global warming.

Based on Temperature vs. Time Graph, parameter that varies in this experiment is the type of gas used for distance 15 cm, 20 cm and 25 cm. All four graphs show same trend for control and greenhouse gases. There is no significant different trend between the gases. The highest temperature is approximately to $90^{0}C$. It is very dangerous for human being to be exposed to infrared directly.

Based on Temperature vs. Distance Graph, parameter that varies in this experiment is type of gas used in the beaker. From the smallest to largest time, heating of the atmosphere inside the temperature is occurred. Fast or slow heating is depending on the interval of the graph. From all four graphs, the same trends show where at 15 cm, fast heating is occurred. However, control beaker is less affected by the heating process at 25 cm followed by n-Pentane, trichlorofluoromethane and carbon dioxide. At 25 cm, carbon dioxide is the most affected as the curve of the graph is expanded very wide relatively short time compare to other three beakers. Carbon dioxide behaves similar at 20 cm and 25 cm. Trichlorofluoromethane, n-pentane and control beaker behave differently at 20 cm and 25 cm.

For all four graphs, the curve of graphs tends to converge but carbon dioxide graph tend to level off, only at early it converge. For carbon dioxide gas, at other longer distance, the heat up rate is at same extent. Carbon dioxide absorbs more heat than any other greenhouse gas in the earth. Carbon Dioxide absorbs more heat than trichlorofluoromethane and n-Pentane. Carbon dioxide had a bigger reaction to light, by absorbing the heat, and demonstrating that increase the temperature of earth surface significantly. Carbon dioxide gas had more effect to heat following by trichlorofluoromethane and n-Pentane.

Fourier transform infrared (FTIR) spectrometry provides an excellent tool for quantitative analysis of solid, liquid and gaseous samples.(Armenta, Garrigues, & de la Guardia, 2008) Fourier transform infrared spectroscopy (FTIR) is a technique which is used to obtain an infrared spectrum of absorption, emission, photoconductivity or Raman scattering of a solid, liquid or gas. An FTIR spectrometer simultaneously collects spectral data in a wide spectral range. This confers a significant advantage over a dispersive spectrometer which measures intensity over a narrow range of wavelengths at a time. Table below show Fourier Transformed Infrared Spectrometry Correlation Chart:

Table8: Summary of Correlation Chart

Infrared Functional Groups			
Group	**Vibration**	Type	**Range**
C-O to C-C	Stretch	Anti-symmetrically coupled	1°: 1050± 25 2°: 1125± 25 3°: 1150± 50
C=O	Stretch	C=O	3420
		C=O	1727
		Conjugated	3400
	Stretch	Conjugated	1715
		Antisymmetric	1755± 15

Based on the FTIR frequency in Fourier Transform Infrared Spectometry Corellation Chart, the approximate value that coincides with direct infrared is carbon dioxide. Carbon dioxide has the structure where double bond C=O is stronger and has approximately same frequency with the photoflood light bulb. Trichlorofluoromethane is less strong and less absorbing the infrared. The rotational spectrum for the lowest vibrational mode for CCl3F has been measured in the 0.1 to 1.5THz frequency range. N-pentane is visible in infrared.

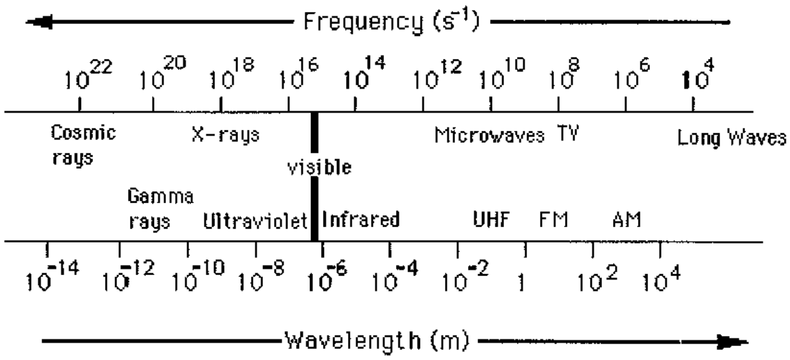

Figure 26: Electromagnetic Spectrum

A portion of the electromagnetic spectrum is shown in Figure 26, along with the names associated with various regions of the electromagnetic spectrum. Our eyes can detect only a very limited range of wavelengths, the visible spectrum between about 300 and 800 nm. Atoms and molecules can absorb electromagnetic radiation, but only at certain energies (wavelengths). The diagram in Figure 27 illustrates the relationships between different energy levels within a molecule. The three groups of lines correspond to different electronic configurations. The lowest energy, most stable electron configuration is the *ground state* electron configuration. Certain energies in the visible and ultraviolet regions of the spectrum can cause electrons to be excited into higher energy orbital; some of the possible absorption transitions are indicated by the vertical arrows. Very energetic photons (ultraviolet to x-ray region of the spectrum) may cause an electron to be ejected from the molecule (ionization).

Photons in the infrared region of the spectrum have much less energy than photons in the visible or ultraviolet regions of the electromagnetic spectrum. They can excite *vibrations* in molecules. There are many possible vibrational levels within each electronic state. Transitions between the vibrational levels are indicated by the vertical arrows on the left side of the diagram. Microwave radiation is even less energetic than infrared radiation. It cannot excite electrons in molecules, nor can it excite vibrations; it can only cause molecules to *rotate*. Microwave ovens are tuned to the frequency that causes molecules of water to rotate, and the ensuing friction causes heating of water-containing substances. Figure 28 illustrates these three types of molecular responses to radiation.

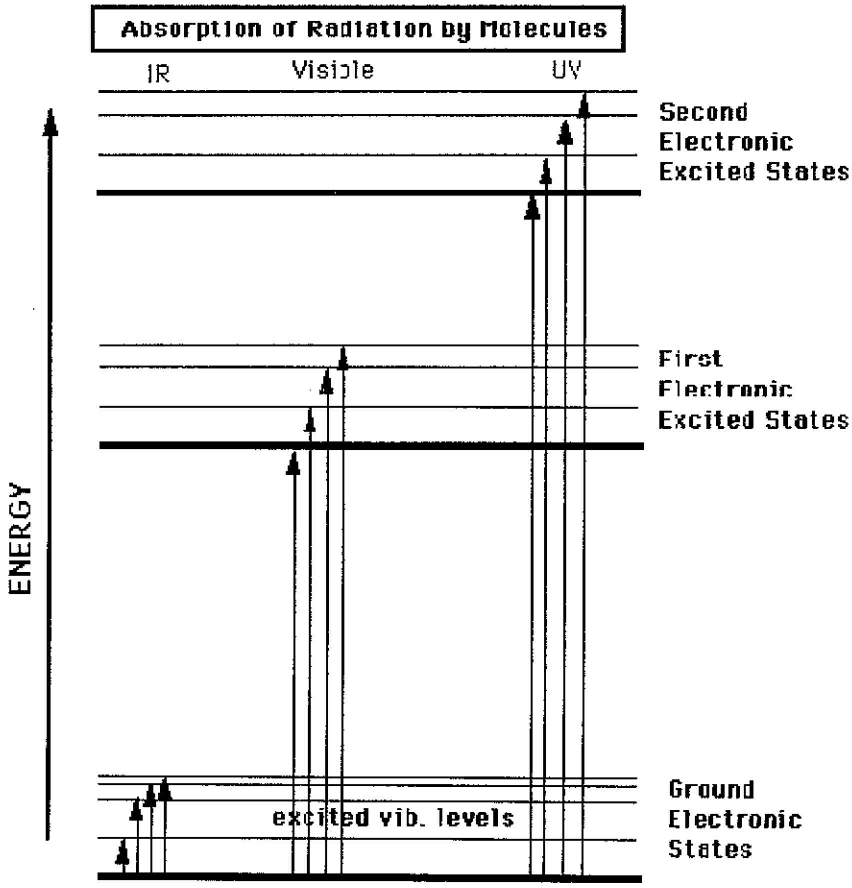

Figure27: Energy Levels in Molecules

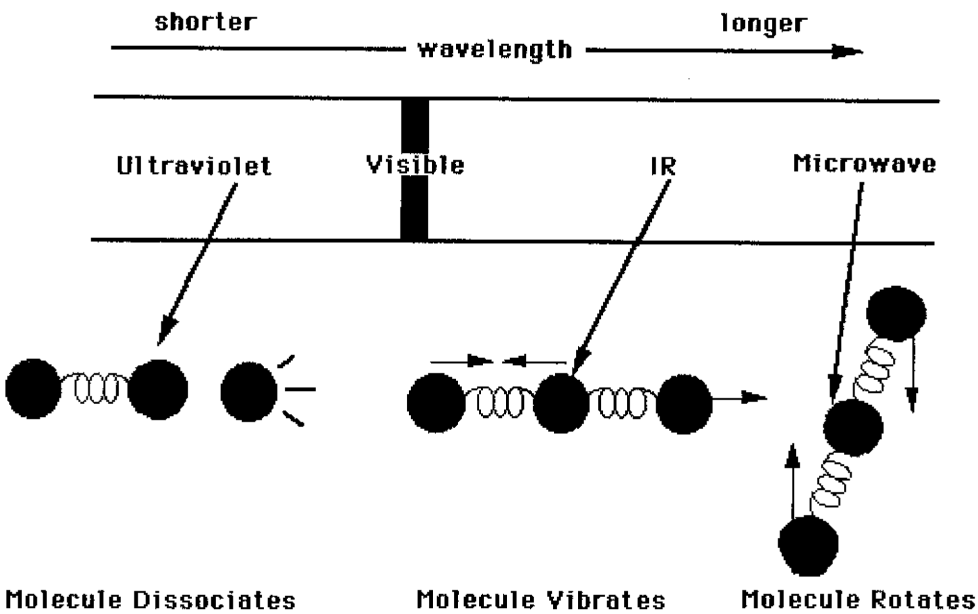

Figure 28: Molecular Response to Radiation

The stronger the bond, the more energy will be required to excite the stretching vibration. This is seen in organic compounds where stretches for triple bonds such as C≡C and C≡N occur at higher frequencies than stretches for double bonds (C=C, C=N, C=O), which are in turn at higher frequencies than single bonds (C-C, C-N, C-H, O-H, or N-H). The heavier an atom will led the lower the frequencies for vibrations that involve that atom. The characteristic regions for common infrared stretching and bending vibrations are given in Figure 29. (Altan, 2006)

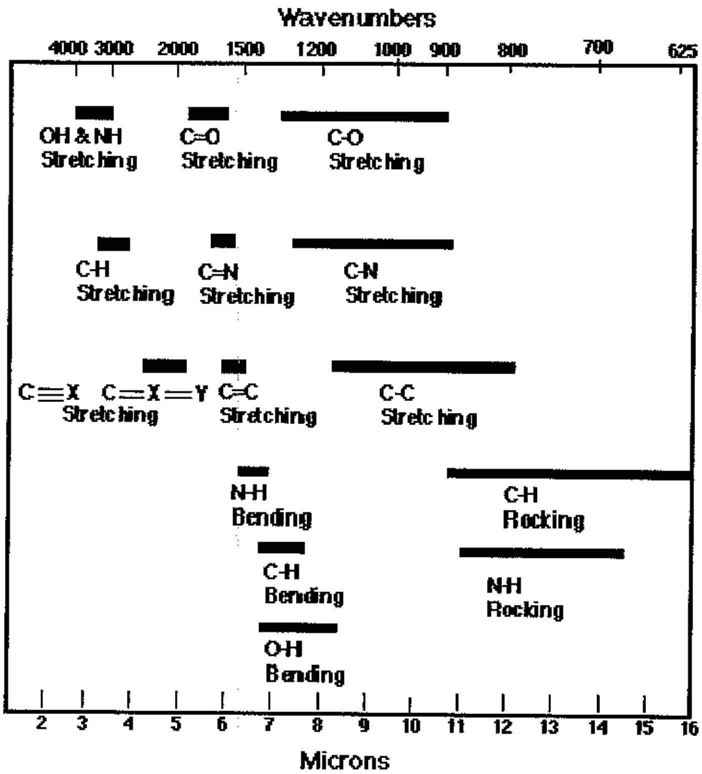

Figure29: Chart of Characteristic Vibration

4.3 Work in Plan

Table 7: Timeline of Proposed Activity, Milestone and Deadline.

Week	Activity
6	• Experiment using carbon dioxide, CO_2
9	• Experiment using trichlorofluoromethane (CCl_3F)
10	• Experiment using pentane ($CH_3(CH_2)_3CH_3$)
11	• Temperature comparison and analysis • Submission of Progress Report 2 (Final Draft) • Prepared for Pre-EDX, Poster Exhibition and Progress Reporting
12-14	• Prepared for Final Report and Oral Presentation
18-19	• Oral Presentation FYPII

CHAPTER 5
RECOMMENDATION

5.1 Future Implementation on the Project

5.1.1 Examine Other Greenhouse Gasses such as Methane, Nitrous Oxide and Refrigerant-134 towards Atmosphere Temperature

The emission of greenhouse gasses for instance Methane, Nitrous Oxide and current refrigerant use in automobile, Refrigenrant-134 can be investigate the effect towards temperature. The research is essential to estimate future global warming temperature.The main sources of greenhouse gases due to human activity are:

1. Burning of fossil fuels and deforestation leading to higher carbon dioxide concentrations. Land use change (mainly deforestation in the tropics) account for up to one third of total anthropogenic CO_2 emissions.
2. Livestock enteric fermentation and manure management, paddy rice farming, land use and wetland changes, pipeline losses, and covered vented landfill emissions leading to higher methane atmospheric concentrations. Many of the newer style fully vented septic systems that enhance and target the fermentation process also are sources of atmospheric methane.
3. Use of chlorofluorocarbons (CFCs) in refrigeration systems, and use of CFCs and halons in fire suppression systems and manufacturing processes.
4. Agricultural activities, including the use of fertilizers, that lead to higher nitrous oxide (N_2O) concentrations

5.1.2 Greenhouse Effect as Renewable Energy

Climate change induced by global warming is a result of an excess of energy at the earth's surface due to the greenhouse effect. But a new energy management can reverse the situation taking advantage of the greenhouse effect to produce renewable energy. In fact, both the renewable energy and the energy consumed which are not dissipated into heat are subtracted from the excess of energy produced by the greenhouse effect and contribute to mitigate climate change. This opens perspectives to harness the greenhouse effect. Should all the primary energy be renewable energy and should part of the energy production not dissipated into heat, the present earth's energy imbalance should be beneficial and should serve to produce renewable energy. (Meunier, 2007)

5.1.3 Low Carbon Electricity Generation

The changes in particle air pollution emissions and consequent effects on health that is likely to result from greenhouse-gas mitigation measures in the electricity generation sector in the European Union (EU), China, and India. The effect in 2030 of policies that aim to reduce total carbon dioxide (CO_2) emissions by 50% by 2050 globally compared with the effect of emissions in 1990. Three models are used: the POLES model, which identifies the distribution of production modes that give the desired CO_2 reductions and associated costs; the GAINS model, which estimates fine particulate matter with aerodynamic diameter 2·5 µm or less ($PM_{2\cdot5}$) concentrations; and a model to estimate the effect of $PM_{2\cdot5}$ on mortality on the basis of the WHO's Comparative Risk Assessment methods. (Markandya et al., 2009)

Changes in modes of production of electricity to reduce CO_2 emissions would, in all regions, reduce $PM_{2\cdot5}$ and deaths caused by it, with the greatest effect in India and the smallest in the EU. Health benefits greatly offset costs of greenhouse-gas mitigation, especially in India where pollution is high and costs of mitigation are low.

The estimation is approximations but suggest clear health gains (co-benefits) through decarbonising electricity production, and provide additional information about the extent of such gains.(Markandya et al., 2009) The opportunities for energy cost savings and emission reductions are very dependent on the existing design of the process and the energy system. (Axelsson et al., 2003)

5.1.4 Rules and Regulations

On October 5, 2009, President Obama released Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance (EO 13514), which, in addition to strengthening energy efficiency and environmental performance requirements set forth by the Energy Independence and Security Act (EISA), the Energy Policy Act of 2005, and Executive Order 13423, requires that all Federal agencies establish and report a comprehensive inventory of absolute greenhouse gas (GHG) emissions and set targets for reducing their GHG emissions (Federal Register, 2009). In response to EO 13514, Federal agencies are working with the Federal Energy Management Program (FEMP) and the World Resources Institute (WRI) to develop consistent GHG accounting protocols for the public sector. This Public Sector Standard is modeled after a corporate GHG protocol developed by WRI and the World Business Council for Sustainable Development's (WBCSD) - The Greenhouse Gas Protocol: Corporate Accounting and Reporting Standard (WRI, 2009; WRI/WBCSD, 2004) - and will help to ensure that Federal agencies prepare GHG inventories that are consistent, accurate, and transparent. (Steuer,)

CHAPTER 5
CONCLUSION

Earth is a dynamic planet with a continuous variation of its climate. The present study has indicated that in their turn the atmosphere, the lithosphere and the biosphere of the Earth change constantly through complex mechanisms affecting the climate. Many of these changes are unpredictable, enormous and sometimes sudden. It is certain that such natural climate-changes—both cooling and warming—will occur again and again in the future. Studying the climate record indicates that the 20th-century changes fall well within frequently seen past natural variations. It is our view that, there is not yet sufficient let alone rigorous evidence that anthropogenic CO2-increase is indeed the main factor contributing towards the global warming of the 20th-century. (Florides & Christodoulides, 2009)

The earth's energy balance without climate change is achievable in the presence of radiative forcing and high energy consumption. Using renewable energy, high energy consumption due to the development of emerging countries could be achieved at the expense of the earth's present energy imbalance. This is exactly the reverse situation of what happens presently when energy consumption produces an earth's energy imbalance responsible for climate change. Moreover, it is also pointed out that the earth's total energy imbalance may be dissipated not only as sensible or latent heat (global warming) but also as kinetic energy (winds, cyclones). (Meunier, 2007)

As conclusion, the trends for the increasing temperature follow from control beaker, beaker filled with n-Pentane, beaker filled with trichlorofluoromethane and lastly beaker filled with carbon dioxide. After exposure to bulb, the result shows that the intensity of the light will greatly increase the temperature inside the beaker. For distance 15 cm, each beaker shows greatly higher temperature compare to distance 20 cm and 25 cm. Carbon Dioxide absorbs more heat than trichlorofluoromethane and n-Pentane.

Carbon dioxide gives the most effect towards global warming. Eventhough trichlorofluoromethane is not the worst, trichlorofluoromethane can effect ozone depletion. N-pentane is just one type of hydrocarbon molecule.

APPENDIX A

Gantt chart for the Second Semester of 2-Semester Final Year Project:

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	18/19	20
1	Project Work Continue								Mid Semester Break									
2	Submission of Progress Report 1																	
3	Project Work Continue																	
4	Submission of Progress Report 2																	
5	Pre-EDX, Poster Exhibition																	
6	EDX																	
7	Submission of Final Report (Softbound)																	
8	Final Oral Presentation																	
9	Submission of Hardbound copies																	

MilestoneProcess

APPENDIX B

The experiments have been conducted by varying the distance between photoflood light bulb and its holder 15 cm, 20 cm and 25 cm above. Two types of gases (CO^2 and CCl^3F), a volatile liquid (n-Pentane) and control beaker were used to record the differences temperature distribution according to time. Data recorded are as below:

Table 4: Distance = 15 cm

	Control	CO^2	CCl^3F	n-Pentane
Time (s)	T (°C)	T (°C)	T (°C)	T (°C)
30	35	35	35	35
60	44	43	43	43
90	49	49	49	48
120	53	56	54	53.5
150	58	60	59	58.5
180	62	64	63.5	63
210	65	68	65	65
240	68	72	70	69
270	72.5	74.5	73.5	72
300	75	79	78	76
330	78	81	80	79
360	80	83	81	80
390	80	83	82	80
420	80	83	82	81

Table 5: Distance = 20 cm

	Control	CO^2	CCl^3F	n-Pentane
Time (s)	T (°C)	T (°C)	T (°C)	T (°C)
30	31	31	31	30.5
60	32.5	38	40	35.5
90	35.5	41	44.5	38.5
120	37	43	42	41
150	40	46	47	43
180	42	48	50	45
210	44	50	52	47
240	46	53.5	51.5	48
270	47	54	53	49.5
300	50	54	53	50
330	51	54	53.5	50
360	51	54	54	51.5
390	52	54	54	52
420	52	54	54	53

Table 6: Distance = 25 cm

	Control	CO^2	CCl^3F	n-Pentane
Time (s)	T (°C)	T (°C)	T (°C)	T (°C)
30	29.5	30	29.5	29.5
60	30	38	32.5	32.5
90	31	41	35	34.5
120	31.5	43	37	36.5
150	32	45	39	38
180	32.5	46.5	40.5	39
210	33.5	48	41.5	40
240	35	49	43	40.5
270	35.5	50.5	43.5	41
300	36	51	44	41.5
330	36.5	51	44.5	42
360	37	51	45	42
390	37	51	45	42
420	37	51	45	42

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