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The Role of Greenhouse Gases in Radiative Balance: A Mini-Review

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Mini-Review

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ABSTRACT

In the study of carbon dioxide, the importance of greenhouse gases for climate change is evaluated using thermodynamic data. The molar heat capacity numbers do not indicate that carbon dioxide has a greater capacity to store heat. Infrared (IR) radiation is absorbed and desorbable by greenhouse gases and this process is thought to be reversible and dynamic. It reduces solar IR radiation while also delaying Earth's re-radiation. In order to balance the radiation, greenhouse gases are essential because they act as converters of heat into infrared photons and *vice versa*. The Second Law of Thermodynamics dictates the direction of heat transfer in the atmosphere. The range of IR radiation is determined according to the gradation of air pressure in the atmosphere.

Keywords: Greenhouse gases; Carbon dioxide; Water vapour; Molar heat capacity; Radiation balance; IR absorption; IR desorption; Heat/radiation transmitters

INTRODUCTION

Earth's atmosphere keeps the globe from getting overly hot or chilly throughout the day. As a result, the lower atmosphere's climate is altered to resemble that of a Greenhouse (GH), in which life could develop. The solar energy that is radiated is filtered when it reaches the Earth's surface and is eventually released. Depending on the length of the journey and the angle of incidence, reflection and absorption decrease solar energy as it passes through the atmosphere.

With increasing wavelength, the solar energy spectrum extends from Ultraviolet (UV) through visible light to IR. Various statistics indicate that between 50 percent and 70 percent of the irradiated energy typically reaches the Earth's surface, at which point the long-wave components dominate the spectral distribution [1,2]. Water vapor, aerosols and other trace gases in the atmosphere, such as CO_2, CH_4, etc., absorb infrared radiation. Approximately 50% of the initial infrared light is absorbed by the earth.

LITERATURE REVIEW

Solar radiation is absorbed by solids and water at the Earth's surface, where it is transformed into heat and then transmitted to the molecules of the gases in the atmosphere. The Earth's surface reradiates some energy, between 15 percent and 30 percent, as infrared radiation [3]. The so-called GH gases, which include water vapor, H_2O, and the trace gases, CO_2, CH_4, N_2O, O_3 and others, are blamed for the GH effect because of their capacity to absorb IR radiation energy. A correlation between the amount of CO_2 in the atmosphere and an increase in temperature during the past 150 years is the present focus of climate research, which is based on observations of their connections in the past and their prediction into the future. As a result, the GH effect started to be extrapolated at uncertain temperatures, leading to predictions of a catastrophic climate change by the end of this century. Still, a lot of questions are unresolved.

In society and politics, two fundamental claims of recent climate research are now acknowledged as unquestionable truths:

- Climate change is attributed to an increase in the amount of CO_2 in the atmosphere. Water and water vapor have well-known properties related to heat absorption and transfer. Furthermore, ocean water plays a critical role in climate regulation [4]. The primary cause of global warming is attributed to CO_2 and in this case, human activity, even though the total amount of anthropogenic CO_2 in the atmosphere during the Industrial Revolution is estimated to be only a small portion of the 0.042 vol.% CO_2 in the atmosphere. This is because human impact has little effect on the hydrological cycle.

- There is a claim that as atmospheric CO_2 concentration rises, infrared radiation from Earth is impeded from reaching space and instead returns home. The result is a build-up of heat in the atmosphere, which raises Earth's average global surface temperature.

Using the known experimentally determined data on molar heat capacities [5], we examined the heat storage properties of CO_2 and other greenhouse gases in the atmosphere. Additionally, based on physico-chemical laws, we talked about the function of greenhouse gases in the energy exchange between solar radiation and heat emission into space.

Thermodynamic consideration of the greenhouse effect

Physically speaking, the kinetic energy, or E_{kin}, of the atmosphere's gas molecules is equal to the heat energy present in them. The greatest amount of heat energy that a gas can absorb is expressed in terms of its molar heat capacity, or Cp [6,7]. At 20°C, air (78 vol.% N_2, 21 vol.% O_2 and 1 vol.% Ar) has a molar heat capacity of 28.96 J/mol K.

Table 1. Molar heat capacities of gases.

Monoatomic: Element	**Atomic weight**	**Cp (J/mol-K)**	**spec. Cp (J/g-K)**
Helium	4	20.76	5.19
Neon	20	20.8	1.03
Argon	40	20.96	0.524
Biatomic: Compound	**Molecular weight**	**Cp (J/mol-K)**	**spec. Cp (J/g-K)**
Hydrogen (H_2)	2	28.72	14.36
Nitrogen (N_2)	28	29.1	1.04

Oxygen (O_2)	32	29.2	0.912
Nitric Oxide (NO)	30	30.27	1.009
Carbon Monoxide (CO)	28	29.43	1.051
Polyatomic: Compound	**Molecular weight**	**Cp (J/mol-K)**	**spec. Cp (J/g-K)**
Carbon Dioxide (CO_2)	44	37.2	0.846
Methane (CH_4)	16	35.4	2.21
Ammonia (NH_3)	17	35.02	1.56
Water Vapour (H_2O)	18	33.4	1.85

For monatomic and diatomic gases, the Cp values are independent of the atomic or molar weights. The differences in the molar heat capacity of mono-atomic gases, di-atomic gases and polyatomic gases in the atmosphere were related to the molecular mobility [6]. For monoatomic gases, E_{trans} opens up the potential of translations in space. Diatomic gases are capable of using E_{rot} to rotate their molecules and E_{trans} to translate them. Due to their molecular structures, tri-atomic gas and polyatomic gas molecules like H_2O (which can make up up to 5% of the atmosphere) and trace gases like CO_2, CH_4 and others (which together make up less than 0.1% of the atmosphere's volume) can also exhibit intramolecular oscillation and deformation vibrations in addition to translation and rotation. Certain frequencies of infrared radiation cause these swingings to become excited, which turns absorbed photons of infrared radiation into heat. Thus, depending on the quantity and size of resonance frequencies, they can absorb energy, E_{swing}, within their molecular structures in addition to translational and rotational energy:

$E_{kin}=E_{trans}+E_{rot}+E_{swing}$.

When compared to the translational energy of monoatomic gases, this causes a roughly 40% increase in the heat capacities of triatomic gases. Thus, polyatomic gases-also known as GH gases-are regarded as catalysts for the greenhouse gas effect. Nevertheless, it is clear that they by no means contribute significantly to heat storage when their heat capacities are multiplied by the corresponding concentrations in the Earth's atmosphere.

Because of the high concentration of water vapor in the atmosphere, the atmospheric portion of the water cycle contributes the most to the greenhouse gas effect among the other gases. When it comes to heat storage, cooling or heating, the transformation heats of water (6.0 kJ/mol for melting and 40.7 kJ/mol for evaporation) have an infinitely larger impact.

The majority of the energy in the atmosphere is stored as translational energy, or the motion of gas molecules in space, according to the molar heat capacities of gases. Based on both molar heat capacities and atmospheric concentrations, all atmospheric gases contribute to Earth's greenhouse effect of heat retention. This indicates that the Earth's atmosphere stores heat primarily due to nitrogen, oxygen and water vapor.

The radiation equilibrium and the climate

All molecules in a gaseous environment are in contact with one another through mutual collisions and energy exchange.

Individual molecules or groups of molecules cannot behave in a static manner due to the laws of thermodynamics. According to the statistical energy distribution's Gaussian bell curve, permanent hotspot molecules are not possible.

The 2^{nd} Law of Thermodynamics specifies the direction of heat flow: Heat distributes from hot to colder molecules. The Earth's atmospheric GH exists within the troposphere. The barometric altitude formula and the equation of state for ideal gases both predict that temperature and pressure will decrease with altitude, reaching a minimum of approximately -50°C at a height of roughly 10 km.

Because of the force of gravity, molecules are unable to escape the Earth and are therefore bound to heat as kinetic energy. The exchange of energy between the earth and the universe takes place exclusively *via* electromagnetic radiation, which is not subject to the 2^{nd} Law of Thermodynamics [8].

DISCUSSION

The Earth's IR back radiation and solar IR radiation are not distinguished by the greenhouse gases. The solid Earth surface warms less as a result of their absorption of solar IR radiation. A portion of the energy emitted is reflected back to space by the Earth's surface as infrared radiation. By transforming their energy into the vibrational energy of GH gas molecules, IR photons are absorbed. As they cool down, they reemit infrared photons. One can assume that the increasing density of "absorber molecules" in the air due to barometric air density graduation inhibits the radiation from greenhouse gas molecules toward the Earth's surface.

On the other hand, the range of IR photons into direction of outer space-as the density of absorbers “decreases-should be longer than that into direction of the Earth’s surface. The effect of an increase in CO_2 concentration results in an increase of the number of absorber molecules “as well as of transmitter molecules “for both IR radiation and IR re-radiation.

It should also be possible to both generate and stop resonance oscillations in the GH gas molecules and convert them into photons by collisions with non-GH gas molecules of certain energy:

$E_{trans} \leftrightarrow E_{swing} \leftrightarrow E_{phot}$

Thus, nothing stands in the way of heat exchange between nitrogen and oxygen molecules and the universe as well. The GH gas molecules would be able to transform atmospheric heat into infrared radiation and *vice versa* in such a reversible process. Compared to the official position on climate research, this view is more convincing and more in line with the experience of gas thermodynamics than the specific role of the CO_2 molecule as an energy store.

Water vapour and CO_2, as well as other GH gases, would then act as energy transmitters and IR emitters, without which the process of energy exchange between the Earth's atmosphere and the universe and *vice versa*, cannot take place.

CONCLUSION

The primary gases that contribute to heat storage in Earth's greenhouse are nitrogen and oxygen, the building blocks of the atmosphere. Because of their ability to convert heat into infrared photons and *vice versa*, gases referred to as GH gases use their molecular vibrational degrees of freedom to act as transmitters and emitters that control the flow of energy between Earth and the universe. Even at low concentrations, they can have significant effects in a reversible exchange process. It does not seem that the radiation balance will equalize over a period of time greater than a year, or even under conditions of constant solar and planetary parameters. This can occasionally happen over millennia alone. This might cause energy buildup in the atmosphere over specific time periods. The Earth's greenhouse is working slowly and the Mankind should be prepared for regional climate changes. In this context, the novel interpretation of the role of GH gases is likely to be significant.

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