A CHALLENGE TO THE CARBON DIOXIDE / GLOBAL WARMING CONNECTION

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One issue that seems to have been lost or avoided in the debate over the connection between atmospheric carbon dioxide (CO_2) and global warming is the miniscule mass of CO_2 that is being blamed for so many past, present and predicted natural disasters. The mass of atmospheric CO_2 is extremely small when compared to the total mass of the Earth's atmosphere and even smaller when compared to the combined masses of the land and water features on the Earth's surface as well.

The directly proportional relationship that exists between the mass of any object and its heat capacity is essentially axiomatic: all other factors being the same, the larger the mass of an object, the greater its ability to capture, store, transport and release heat. Since the concentration of CO_2 in the Earth's atmosphere is so small, the notion that it is causing global warming seems to ignore this basic truth.

It should be noted that CO_2 exists only as a gas within the the temperature extremes of the earth's atmosphere and as such, is uniformly distributed throughout the atmosphere. It cannot form layers that are capable of acting as reflective surfaces or insulating barriers. Although CO_2 can absorb heat energy from the Sun in the form of infrared radiation, the bulk of that energy is absorbed by the Earth's surface, itself, as well as by atmospheric water, oxygen and non-greenhouse gases.

The objective here is to demonstrate that the mass of CO_2 in the Earth's atmosphere is too small to absorb solar energy in quantities, sufficient to cause catastrophic global warming; and thus, to challenge those who support the connection between CO_2 and global warming to explain their theories in terms of classical science.

The arithmetic application of established physical data to classical science can be used to construct models that demonstrate the basic premise of this challenge. Each model must include a measured mass of CO_2 to capture a measured quantity of heat energy from the Sun and to transfer that heat to a measured mass of the Earth's surface.

AUTHOR'S NOTE:

The following discussion is going to involve some illustrative equations that are critical to developing this challenge. The numerical data will be presented in each equation with their applicable terms. Like terms, appearing above and below the divisor lines in each equation will be struck through with single lines to cancel each other from the final results. Having the final results of each calculation described in the proper terms is a good indication that the data were properly manipulated. Like terms in more complicated equations will be presented in like colors so as to make the arithmetic easier for the reader to follow.

The concentration of CO_2 in the Earth's atmosphere is approximately 380 parts per million (ppm) on a volume(V_{CO_2})/ volume(V_{air}) basis.

The density of CO_2 = 1.977 grams (g)/ liter (L) at sea level Standard Temperature and Pressure (STP) conditions.

The first step in developing a model to illustrate this challenge is to determine the mass of CO_2 in a measured volume of air at sea level STP conditions. 1 cubic meter of air (M^3_{air}) will be used in this model so as to simplify the arithmetic.

The volume fraction of CO_2 in air is determined as follows:

380 Liters (L_{CO2}) / 1,000,000 Liters (L_{air}) = 0.00038 L_{CO2} / L_{air}

One cubic meter ($1M^3$) = 100 centimeters (cm) X 100 cm X 100 cm = 1,000,000 cm^3:
1 cm^3 = 1 milliliter (mL).
1 L = 1,000 mL
1 M^3 = 1,000 L:
1 M^3 = 35.3 ft^3: That is larger than the inside volume of a large ($27ft^3$) family refrigerator.

The mass concentration of CO_2 in $1M^3_{air}$ at STP conditions can be established from the following calculation:

$1.977g_{CO2}$ / ~~L_{CO2}~~ X 1,000~~L_{air}~~ / M^3_{air} X 0.00038~~L_{CO2}~~/ ~~L_{air}~~ = $0.75g_{CO2}$ / M^3_{air}

Establishing a measured contact mass of material to receive all of the heat captured by CO_2 is the next step in creating these models. Water makes the ideal contact mass for this discussion because its density, specific heat capacity, fluidity and other physical characteristics are more uniform than those of the Earth's land surfaces and thus can be described more accurately through simple arithmetic. It is also critical that this contact mass should be thermally isolated from its surroundings, except where it makes contact with a measured volume of air, so as to limit all heat exchange to contact with CO_2 or with CO_2 heated air within the model's 1 M^3.

One side or surface of a M^3 is equal to 1 square meter (M^2). Making $1M^2$ the area of the contact surface between air and water and setting the depth of a contact layer of water at 1 cm, establishes the volume of that contact layer at 10,000 mL:

100 cm X 100 cm = 10,000 cm^2 = $1M^2$

10,000 cm^2 X 1 cm (deep) = 10,000 cm^3 = 10,000 mL = 10 L = 2.64 gallons

I mL of water has a mass of 1g. Thus, this contact volume contains 10,000 g of water. By comparison, If all of the 380 cm^3 of CO_2 in 1 M^3 of air at sea level STP conditions could be layered out against that same 10,000 cm^2 contact surface, its thickness would be 0.38 mm.

$$\frac{380\ \cancel{cm^3}}{10{,}000\ \cancel{cm^2}} \times 10\ mm/\cancel{cm} = 0.38\ mm = \underline{\qquad\qquad}$$ (the width of this line)

By definition, 1 calorie (cal) = the amount of heat required to raise the temperature of 1 g of water 1^oC at sea level STP conditions. It then follows that the specific heat capacity of water = 1 cal/ g^oC at STP conditions. Thus, 10,000 cal are required to raise the temperature of the thermally isolated, 10,000 g contact mass of water 1^oC.

The literature value for the specific heat capacity of CO_2 is given as 0.843 Joule / g^oC. The Joule (J) is a term applied to multiple forms of energy. Consistency in these calculations requires the conversion of J/g^oC to cal./g^oC. The conversion factor is:

1J/ g^oC = 0.24 cal / g^oC.

Specific heat capacity of CO_2 = $0.843\ \cancel{J / g^oC} \times \frac{0.24\ cal / g^oC}{\cancel{J / g^oC}} = 0.202\ cal/g^oC$

Since the model's 1 M^3 of air contains 0.75 g of CO_2 and the specific heat capacity of CO_2 = 0.202 cal/ g^oC, that mass of CO_2 can trap only 0.1515 calories for each 1^oC rise in its temperature.

$0.75\ \cancel{g_{CO_2}} \times 0.202\ cal/ \cancel{g_{CO_2}}\ ^oC = 0.1515\ cal/\ ^oC$

In order for that 0.75 g of CO2 to trap and transfer 10,000 cal to the model's contact mass of water, it would have to capture enough heat to raise its temperature to 66,000 ^oC or, more realistically, to that equivalent over time.

$$\frac{10{,}000\ \cancel{cal}}{0.1515\ \cancel{cal}/\ ^oC} = 66{,}000\ ^oC$$

If the CO_2 in the model could achieve the accumulated effect equivalent to a 66,000 ^oC temperature increase at a rate of 100 ^oC/hour (hr) and uniformly transfer that heat to the model's 10,000 g (2.64 gal.) contact mass of water, it would require 27.5 days to raise the water's temperature 1 ^oC.

$$\frac{66{,}000\ \cancel{^oC}}{100\ \cancel{^oC}/\cancel{hr}} \times \frac{1}{24\ \cancel{hr}/day} = 27.5\ days$$

Glacial melting represents another series of catastrophic events being blamed on CO_2 induced global warming. A model that brings 1 M^3 of air in contact with 10 L of ice can be constructed to examine this notion.

Ice has a density of about 0.9 g/mL.

A 10,000 mL contact volume contains 9,000 g of ice.
The heat of fusion of any solid is defined as the quantity of heat required to change that material from the solid state to the liquid state (melt) without any rise in temperature. The heat of fusion for water (ice) at 0^oC and sea level STP conditions is 79.71 cal/ g.

The heat required to melt 9,000 g of ice at 0^oC = $9{,}000\ \cancel{g} \times 79.71\ cal / \cancel{g} = 717{,}390\ cal.$

As shown above, the 0.75 g mass of CO_2 in this model can trap only 0.1515 calories for each 1 ^{O}C rise in its temperature. To trap and transfer the 717,390 cal required to melt the model's 9,000 of ice, its 0.75 g of CO_2 would have to attain a temperature of 4,735,247 oC.

$$\frac{717{,}390\ \text{cal}}{0.1515\ \text{cal}/\ ^{O}C} = 4{,}735{,}247\ ^{O}C$$

If the CO_2 in this model achieved the accumulated effect equivalent to a 4,735,247 ^{O}C temperature rise at a rate of 100 ^{O}C / hour, it would take 5.4 years to melt the model's 9,000 g of ice without raising its temperature.

$$\frac{4{,}735{,}247\ ^{O}C}{100\ ^{O}C/hr} \times \frac{1}{24\ hr/day} \times \frac{1}{365\ day/yr.} = 5.4\ \text{yr.}$$

An alleged increase in extreme weather phenomena such as hurricanes and tornadoes has also been attributed to increased levels of CO_2 in the Earth's atmosphere. The energy released in these storms is derived from the change of state of water from liquid to gas and, back again, to liquid.

The heat of vaporization is defined as the heat per unit mass required to convert a liquid into a vapor (gas) without a change in temperature.

The Heat of vaporization of water is 540 cal / g.

Referring back to the model, it would require 5,400,000 cal to vaporize the thermally isolated 10,000 g contact mass of water. To trap 5,400,000 cal the models 0.75 g of CO_2 would have to attain a temperature increase of 35,643,600 ^{o}C .

$$\frac{5{,}400{,}000\ \text{cal}}{0.1515\ \text{cal}/\ ^{o}C} = 35{,}643{,}600\ ^{o}C$$

Allowing the heat trapped by the CO2 in this model to achieve an accumulated effect equivalent to this 35,643,600 ^{O}C temperature rise at a rate of 100 ^{O}C / hr., would require 40.7 years to vaporize the model's 10,000g contact mass of water.

$$\frac{35{,}643{,}600\ ^{O}C}{100\ ^{O}C/hr} \times \frac{1}{24\ hr/day} \times \frac{1}{365\ day/yr.} = 40.7\ \text{yr.}$$

It has been suggested that up until about 100 years ago, CO_2 maintained the thermal equilibrium of the Earth's atmosphere and that a 25% rise in CO_2 concentration since then has resulted in global warming. With only 25% of the total CO_2 concentration in air being responsible for global warming, CO_2 temperature changes required to warm the thermally isolated mass of water 1^{o}C, or to change its physical state all have to be multiplied by 4.

Fig. 1 (next page) illustrates, to a reasonably accurate scale, the total volume fraction (380 ppm) of CO_2 in the Earth's atmosphere and the 25% of that volume (95 ppm) that is considered to be responsible for Global Warming.

These models were developed through the arithmetic application of established physical data to classical scientific principles. They define the quantities of heat that are required to be collected by CO_2 and transferred to a fixed mass of otherwise thermally isolated water or ice and raise its temperature or change its phase. Thus, they pose a challenge to the inferred connection between catastrophic global warming and the over emphasized 25% increase in the very small mass of CO_2 in the atmosphere. A large fraction of a small number is a smaller number.

Water, which has 505 times the density and 5 times the specific heat capacity of CO_2 is a much larger heat sink than CO_2. The fact that water can exist in all three states of matter within the temperature range of the Earth's atmosphere gives it the ability to trap, store, transport and release large amounts of heat and gives it the ability to layer out in the atmosphere to form reflective surfaces and insulating barriers.

Nitrogen (N_2), oxygen (O_2) and Argon (Ar), together, make up 99.9% (999,000 ppm) of the Earth's atmosphere on a V_{gas}/ V_{air} basis and are not considered to be "greenhouse gases". The basic premise of this discussion requires a comparison of the combined masses of these non-greenhouse gases to the mass of CO_2. The literature value for the density of air at sea level STP conditions is given as 1.2928 g/ L. Thus, the model's 1 M_3 (1,000L) of air has a mass of 1,293 g and the combined masses of N_2,O_2 and Ar make up 99.9% of that mass or 1,292 g.

$$1.293\ g/\cancel{L}\ \times\ 1{,}000\ \cancel{L}\ \times\ 0.999\ =\ 1{,}292\ g$$

The literature value for the specific heat capacity of dry air is 0.242 cal/ g ^{o}C. The total heat capacity for the model's 1,292 g of non-greenhouse gases is 313 cal for each degree C rise in temperature.

$$1{,}292\ \cancel{g}\ \times\ 0.242\ cal/\cancel{g}\ ^{o}C\ =\ 313\ cal/\ ^{o}C$$

It was previously shown that the total heat capacity for the model's CO_2 is 0.1515 cal for each degree C rise in its temperature. The non-greenhouse gases in the model's 1 M^3 of air have a total heat capacity that is 2,066 times that of the model's CO_2.

$$\frac{313\ \cancel{cal/\ ^{o}C}}{0.1515\ \cancel{cal/\ ^{o}C}}\ =\ 2066$$

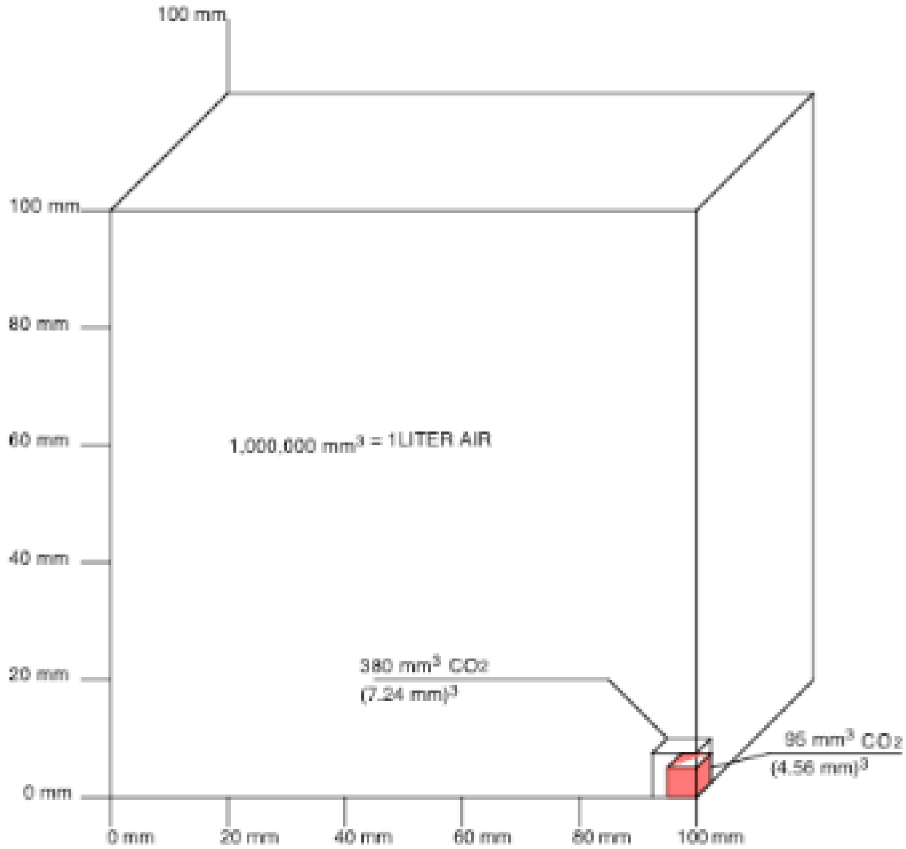

FIG 1: VOLUME OF CO_2 (95 mm^3)CAUSING GLOBAL WARMING / LITER OF AIR

VS. TOTAL VOLUME OF CO2 (380 mm^3) / LITER OF AIR.

This exercise demonstrates that the combined masses of non-greenhouse gases in the Earth's atmosphere can trap, store, transport and transfer 2,066 times as much heat as the total mass of its CO_2.

The composition of the Earth's atmosphere remains uniform from its surface to an altitude of about 110,000 feet. The density of the atmosphere diminishes with increasing altitude in agreement with a half value curve where the half value layers are about 18,000 ft. thick. Thus, 1/ 2 of the atmosphere exists below 18,000 ft., 75% below 36,000 ft., 87.5 % below 54,000 ft, 93.75 % below 72,000, 96.8% below 90,000 ft and 98.45% below 108,000 ft. The concentration of CO_2 in the atmosphere is uniform throughout this volume and remains at 380 ppm on a V_{CO2}/ V_{air} basis. If the CO_2 in the first 18,000 ft. (1/2 of the atmosphere) of air were to layer out against the Earth's surface at sea level STP conditions, it would be about 3.42 ft. thick.

$$18{,}000 \text{ ft} \times 0.00038 \times 0.5 = 3.42 \text{ ft}$$

A similar CO_2 layer from each succeeding 18,000 ft of altitude would diminish by 1/2. Combining all of these CO_2 layers at the Earth's surface at sea level STP conditions would amount to a CO_2 layer that is approximately 6.73 ft thick (measurements were made in 18,000 ft blocks rather than calculating the area under the 1/2 value curve). See table 1 below.

ALTITUDE IN FT	VOL. % OF ATMOSPHERE	VOL. FRACTION. OF ATMOSPHERE	VOL. FRACTION. OF CO_2	EQUIVALENT LAYER OF CO_2
0 TO 18000	50	0.5	0.00038	3.42 FT
18000 T0 36000	25	0.25	0.00038	1.71 FT
36000 TO 54000	12.5	0.125	0.00038	0.85 FT
54000 TO 72000	6.25	0.0625	0.00038	0.43 FT
72000 TO 90000	3.13	0.0313	0.00038	0.21 FT
90000 TO 108000	1.57	0.0157	0.00038	0.11 FT
TOTALS	98.45	0.9845		6.73 FT

Table 1. Estimated volumes of air and CO_2 taken in 18,000 ft. blocks and converted to sea level STP conditions .

The Earth's water features (about 71 % of its surface) provide for a heat sink, capable of trapping, storing, transporting and releasing huge quantities of heat. The mass of water on the Earth's surface far exceeds the mass of CO2 in its atmosphere. Add to that, the heat exchange that occurs when water changes phases and one cannot ignore water's role in regulating global temperatures. Water is also a CO_2 sink, capable of trapping, storing, transporting and releasing huge quantities of CO_2 . The solubility of CO_2 in water (0.759 L_{CO2}/ L_{water} at sea level STP conditions) decreases with an increase in water temperature. As water is heated by the Sun, it not only heats the atmosphere but also releases CO_2 into it. One could infer that concomitant changes in the atmosphere's temperature and CO_2 concentration are the result of the Earth's water features being heated by the Sun.

This discussion illustrates how the connection between global warming and the tiny mass of CO_2 in the Earth's atmosphere has been exaggerated. The challenge, expressed here, simply asks the proponents of CO_2 induced global warming to reconcile their theories with classical scientific principles and established physical data.

ACKNOWLEDGMENT

I want to thank my former colleague and longtime friend, Roy C. Tulee for proofreading this paper. His efforts led to the clarification of some areas of confusing verbiage.

GENERAL NOTES:

1. The scientific principles presented in this paper are so basic as to have been part of any (my) high school science curriculum and / or obtained from on-line encyclopedias such as ABOUT.COM and *ASK.COM.*

2. Physical data and conversion factors were obtained from *POCKET REF, SECOND EDITION*, Thomas J. Glover, Sequoia Publishing, Inc. and *HANDBOOK OF CHEMISTRY AND PHYSICS,* The Chemical Rubber Co.