A CHALLENGE TO THE CARBON DIOXIDE / GLOBAL WARMING CONNECTION

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PART I
SOME FUNDAMENTAL RELATIONSHIPS BETWEEN MASS AND HEAT

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 and reradiated infrared 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:

$$\frac{380 \text{ Liters } (L_{CO_2})}{1,000,000 \text{ Liters } (L_{air})} = 0.00038 \text{ } L_{CO_2} / L_{air}$$

One cubic meter ($1M^3$) = 100 centimeters (cm) X 100 cm X 100 cm = 1,000,000 cm³:
1 cm³ = 1 milliliter (mL).
1 L = 1,000 mL
1 M^3 = 1,000 L
(As a frame of reference: $1M^3$ = 35.3 ft³: That is larger than the inside volume of a large (27ft³) family refrigerator.)

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

$$\frac{1.977 g_{CO_2}}{\cancel{L_{CO_2}}} \text{ X } \frac{1,000 \cancel{L_{air}}}{M^3_{air}} \text{ X } \frac{0.00038 \cancel{L_{CO_2}}}{\cancel{L_{air}}} = 0.75 g_{CO_2} / M^3_{air}$$

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 cm² = $1M^2$

10,000 cm² X 1 cm (deep) = 10,000 cm³ = 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 definition, 1 calorie (cal) = the amount of heat required to raise the temperature of 1 g of water 1°C at sea level STP conditions.

It then follows that the specific heat capacity of water = 1 cal/ g°C 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°C.

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

$\qquad$ 1J/ g°C = 0.24 cal / g°C.

Specific heat capacity of CO_2 = 0.843 ~~J / g°C~~ X 0.24 cal / g°C = 0.202 cal/g°C

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ ~~J / g°C~~

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°C, that mass of CO_2 can trap only 0.1515 calories for each 1°C rise in its temperature.

$\qquad$ 0.75 ~~gCO2~~ X 0.202 cal = 0.1515 cal/ °C

$\qquad\qquad\qquad\qquad$ ~~gCO2~~°C

In order for that 0.75 g of CO_2 to trap and transfer 10,000 cal. to the model's contact mass of water, it would have to capture enough heat to produce the equivalent of a 66,000 °C temperature rise over time.

$\qquad$ 10,000 ~~cal~~ = 66,000 °C

$\qquad$ 0.1515 ~~cal~~/ °C

If the CO_2 in the model could achieve the accumulated effect equivalent to a 66,000 °C temperature increase at a rate of 100 °C/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°C.

$\qquad$ 66,000 ~~°C~~ X $\qquad$ 1 $\qquad\qquad$ = 27.5 days

$\qquad$ 100 ~~°C/hr~~ $\qquad$ 24 ~~hr~~/day

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.

Since the density of ice is approximately 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°C and sea level STP conditions is 79.71 cal/ g.

The heat required to melt 9,000 g of ice at 0°C = 9,000 g X 79.71 cal /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 °C rise in its temperature. To trap and transfer the 717,390 cal required to melt the model's 9,000 g of ice, its 0.75 g of CO_2 would have to capture enough heat to produce the equivalent of a 4,735,247 °C temperature rise over time.

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

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

$$\frac{4{,}735{,}247 \text{ °C}}{100 \text{ °C/hr}} \quad X \quad \frac{1}{24 \text{ hr/day}} \quad X \quad \frac{1}{365 \text{ day/yr.}} \quad = \quad 5.4 \text{ yr.}$$

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 and transfer that 5,400,000 cal, the models 0.75 g of CO_2 would have to capture enough heat to produce the equivalent of a 35,643,564 °C temperature increase over time.

$$\frac{540 \text{ cal./g X } 10{,}000}{0.1515 \text{ cal}/°C} = 35{,}643{,}564 \text{ °C}$$

Allowing the heat trapped by the CO_2 in this model to achieve an accumulated effect equivalent to this 35,643,600 °C temperature rise at a rate of 100 °C / hr., would require 40.7 years to vaporize the model's 10,000g contact mass of water.

$$\frac{35{,}643{,}564 \text{ °C}}{100 \text{ °C/hr}} \quad X \quad \frac{1}{24 \text{ hr/day}} \quad X \quad \frac{1}{365 \text{ day/yr.}} \quad = 40.7 \text{ yr.}$$

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^oC, or to change its physical state all have to be multiplied by 4.

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. Moreover, convection currents that are created by the conversion of heat to kinetic energy carry water vapor and heat laden air aloft until it reaches its dew point, where the water vapor gives up its stored heat to a less dense atmosphere (and eventually space) and condenses out to form clouds, rain or snow.

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^β (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/ L̶ X 1,000 L̶ X 0.999 = 1,292 g

The literature value for the specific heat capacity of dry air is 0.240 cal/ g ^oC. The total heat capacity for the model's 1,292 g of non-greenhouse gases is 313 cal for each degree C rise in its temperature.

> 1,292 g̶ X 0.240 cal/g̶ ^oC = 310 cal/ ^oC

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^β of air have a total heat capacity that is 2,047 times that of the model's CO_2.

> $\dfrac{310 \text{ cal} / ^oC}{0.1515 \text{ cal} / ^oC}$ = 2047

This exercise demonstrates that the combined masses of non-greenhouse gases in the Earth's atmosphere can trap, store, transport and transfer 2,047 times as much heat as the total mass of its CO_2.

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 CO_2 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.

Unfortunately, too many people do not understand that solids and liquids are hundreds of times more dense than are gasses. That is to say, solids and liquids contain hundreds of times more mass per given volume than gasses do.   As shown in the preceding equations, mass is a critical factor in defining the heat related physical properties of any substance.

PART II
ILLUSTRATING THE MEANING OF 380 PPM

The fact that most people cannot conceptualize the true meaning of the fraction 380 ppm provides the underlying reason for the broad unquestioning popular acceptance of the theory of carbon dioxide induced global warming.   Exercise 1. (pages 7 and 8) is designed to give the reader a tangible evaluation of that fraction.   Table 1. (page 9) serves as an approximate connection of Exercise 1. to the real world, while illustrating the significance of a half-value curve. Fig. 1. (page 10) serves as a model that illustrates that portion of our atmosphere that is CO_2 and the portion of that CO_2 that is being blamed for global warming. Figs. 2 and 3 (pages 11 and 12) illustrate the molecular distribution of CO_2 in our atmosphere, a factor that is critical to any discussion of the resonance transport of infrared radiation from CO_2 molecule to CO_2 molecule (see Part III).

EXERCISE 1:

The true meaning of 380 ppm can be tangibly demonstrated by means of a simple number experiment.

The experimental materials:
      An 8 1/2" X 11" sheet of paper,
      A sharp pencil (or fine ball point pen)
      A 12" ruler.

Procedure:

Using the pencil and ruler, draw a line parallel to the long (11") edge of the paper from one short (8 1/2") edge to the other. Label the intersection of that line with the left edge "0 ppm". Label the intersection of that line with the right edge "1,000,000 ppm". A number line or graph depicting the interval from "0 ppm" to "1,000,000 ppm" has thus been constructed. See EXERCISE 1: FIG. 1A. Carefully fold the paper so that the "0 ppm" edge exactly overlays the "1,000,000 ppm" edge. Make a sharp crease in the paper, mark the intersection of that crease with the number line and label that mark "500,000 ppm". See EXERCISE 1: FIG. 1B. Next fold the paper so that the "0 ppm" edge touches the "500,000 ppm" mark on the number line. Make a sharp crease in the fold and mark the intersection of that crease with the number line and label it "250,000 ppm". See EXERCISE 1: FIG. 1C. Repeat this halving process by folding the paper so that the "0 ppm" edge touches the "250,000 ppm" line. Make a sharp crease in the fold, mark the intersection of that crease with the number line and label that intersection "125,000 ppm". See EXERCISE 1: FIG. 1D. Continue this halving process through "62,500 ppm", "31,125 ppm" ("32,000 ppm" for convenience), to "16,000 ppm". The folding process will become extremely difficult to continue through "8,000 ppm", "4,000 ppm", "2,000 ppm", "1,000 ppm" and "500 ppm", which will bring us to within one order of magnitude of 380 ppm. Even though the "0 ppm" to "380 ppm" interval on the number line will have to be (and could have been from the beginning) calculated, this halving process tangibly enforces the the true meaning of 380 ppm. The "0 ppm" to "380 ppm" interval on the number line can be calculated as follows:

$$\frac{(380 \ X \ 11")}{1,000,000} = 0.0042"$$

0.0042 inches very closely approximates the thickness of United States paper currency.

Conclusion:

If the whole sheet of paper represented the Earth's atmosphere, its CO_2 content would be represented by the edge of the paper.
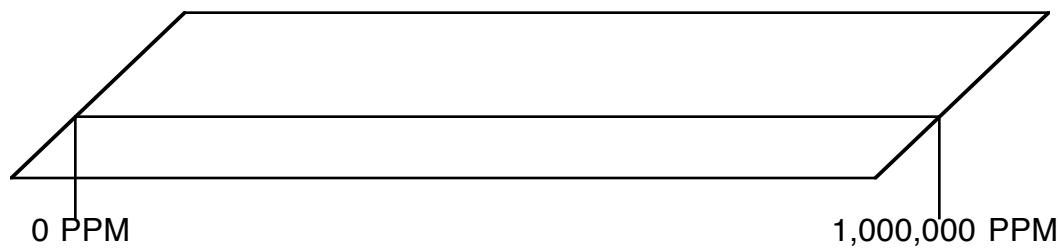
Only 25% of the CO_2 in our atmosphere is actually being blamed for causing global warming. That 25% would be represented by an interval of only 0.001" on our "0 ppm" to "1,000,000 ppm" number line or about 1/4 of the thickness of the paper and would represent that portion of the atmosphere that is being blamed causing global warming in this model.
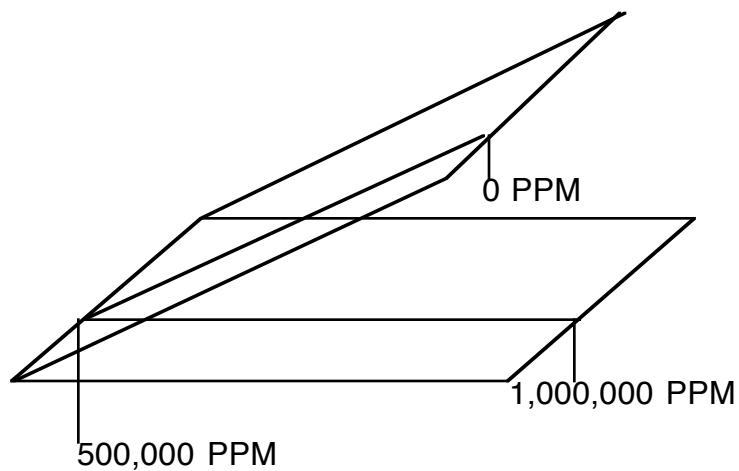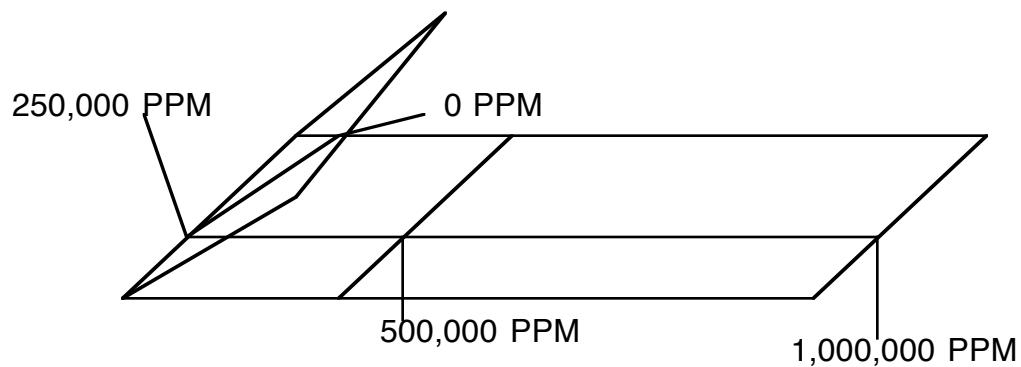
EXERCISE 1:
FIG.
1
A.

0 PPM   1,000,000 PPM

B.

0 PPM

1,000,000 PPM

500,000 PPM

C.

250,000 PPM   0 PPM

500,000 PPM

1,000,000 PPM

D.

250,000 PPM   500,000 PPM
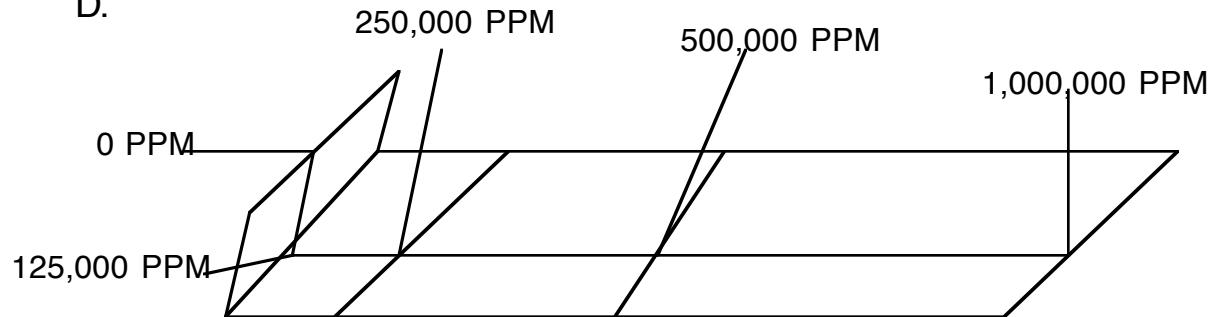
1,000,000 PPM

0 PPM

125,000 PPM

TABLE 1.

The composition of the Earth's atmosphere remains uniform from its surface to an altitude of about 110,000 feet (20.8 miles). 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.

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

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).

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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

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100 mm

100 mm

80 mm

60 mm — 1,000,000 mm^3 = 1 LITER AIR

40 mm

380 mm^3 CO$_2$
(7.24 mm)^3

20 mm

(4.56 mm)^3
95 mm^3 CO$_2$

0 mm

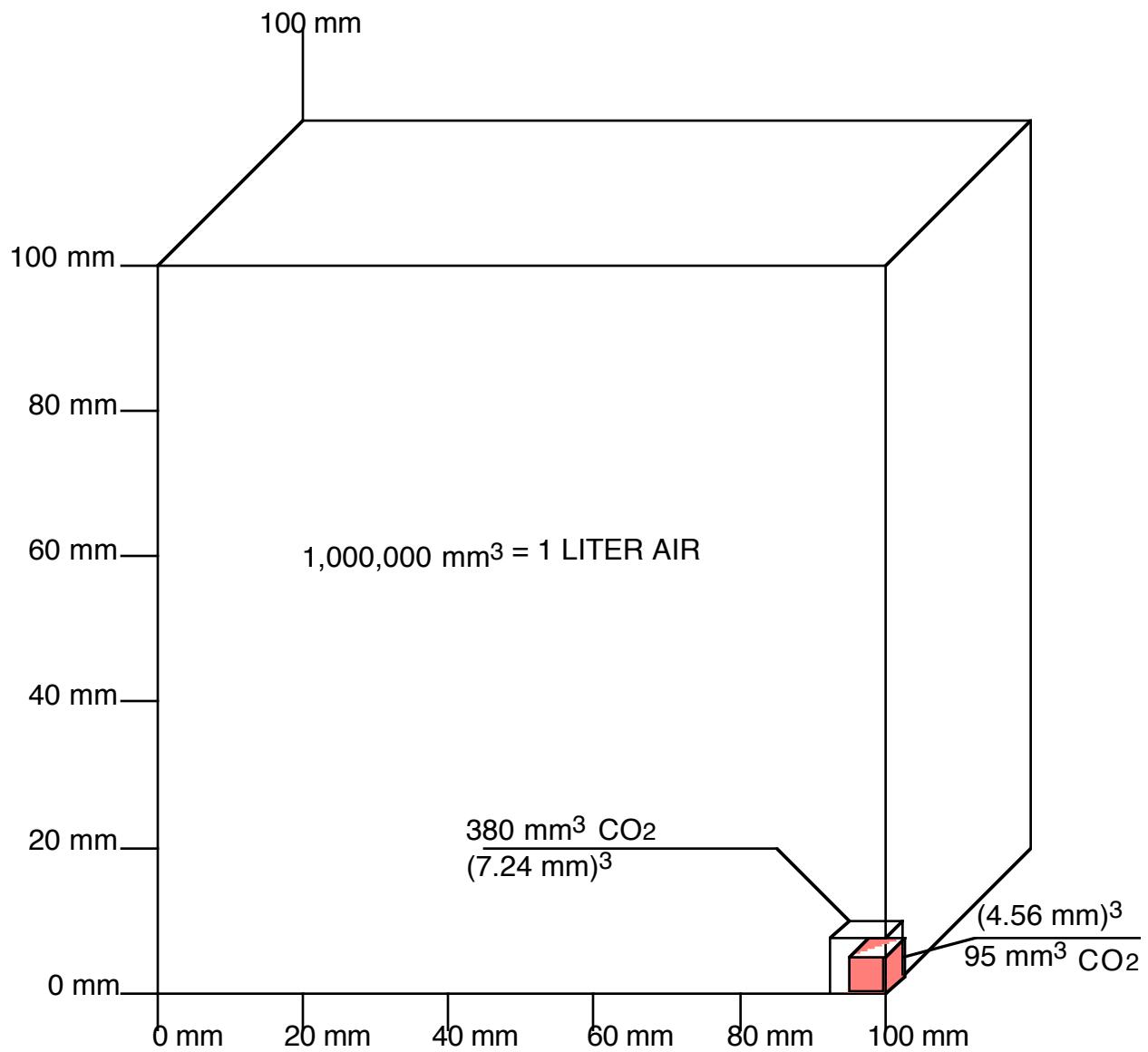0 mm   20 mm   40 mm   60 mm   80 mm   100 mm

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.

FIG 2.

The numeric representation of 380 ppm equals the fraction: 380/1,000,000. Dividing both the numerator and denominator by 100 gives an equivalent fraction: 3.8/10,000 or 3.8 parts per 10,000. Rounding off 3.8 to its next higher integer gives the fraction: 4/10,000. The field below, which is 100 units X 100 units contains 10,000 square units. Making this field 1 unit thick would give it volume of 10,000 cubic units. The 4 red dots (o), one cubic unit each, in that volume illustrate a concentration of 4 parts in 10,000, which approximates the molecular distribution of CO_2 in the Earth's atmosphere.
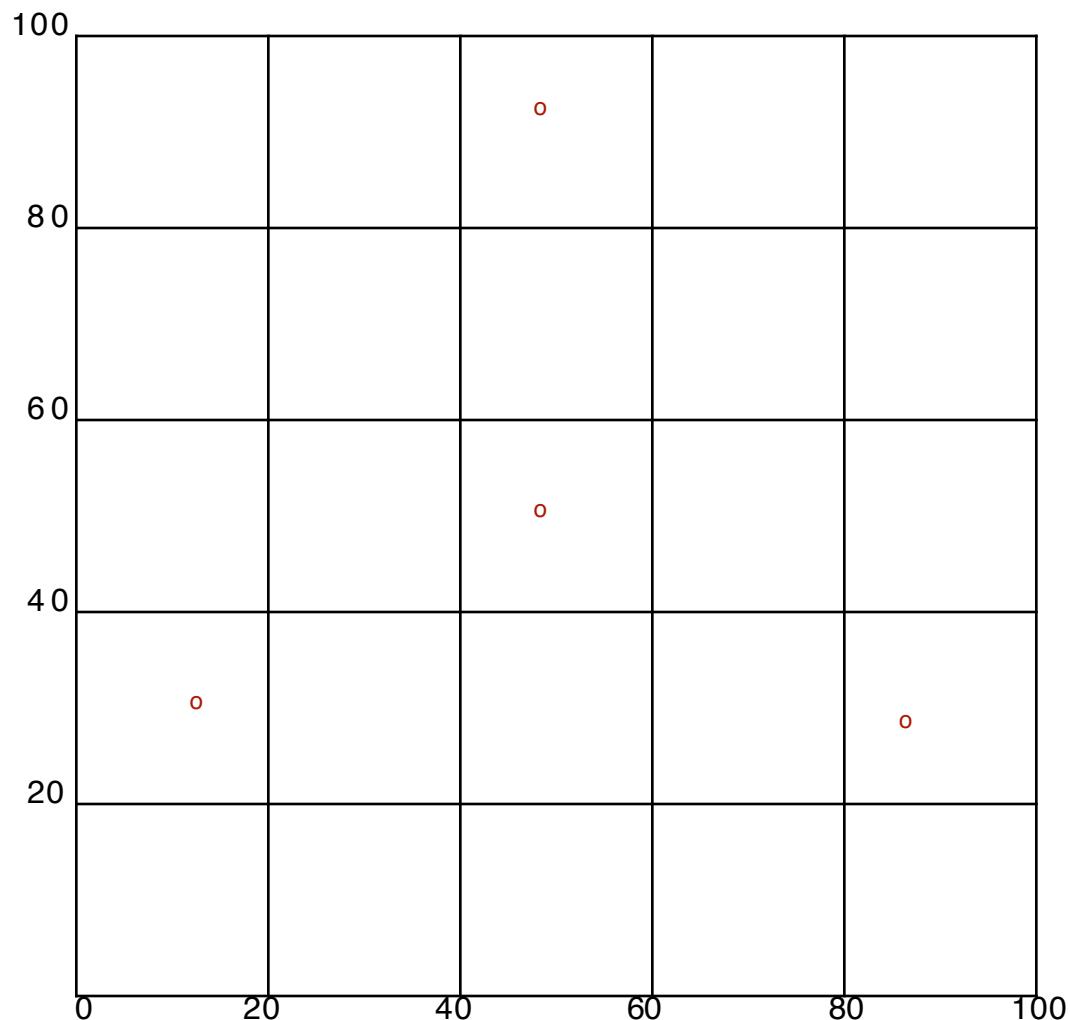
FIG 3.

The catastrophic impact of CO_2 on the Earth's atmosphere, and its surface as well, is being blamed on the 25% increase in its concentration over the past 100 years. From the discussion associated with FIG 2., it can be seen that 25% of the total concentration of CO_2 in the atmosphere amounts to 1 part in 10,000, which can be illustrated by the one red dot (1 cubic unit) in this field of 10,000 cubic units.
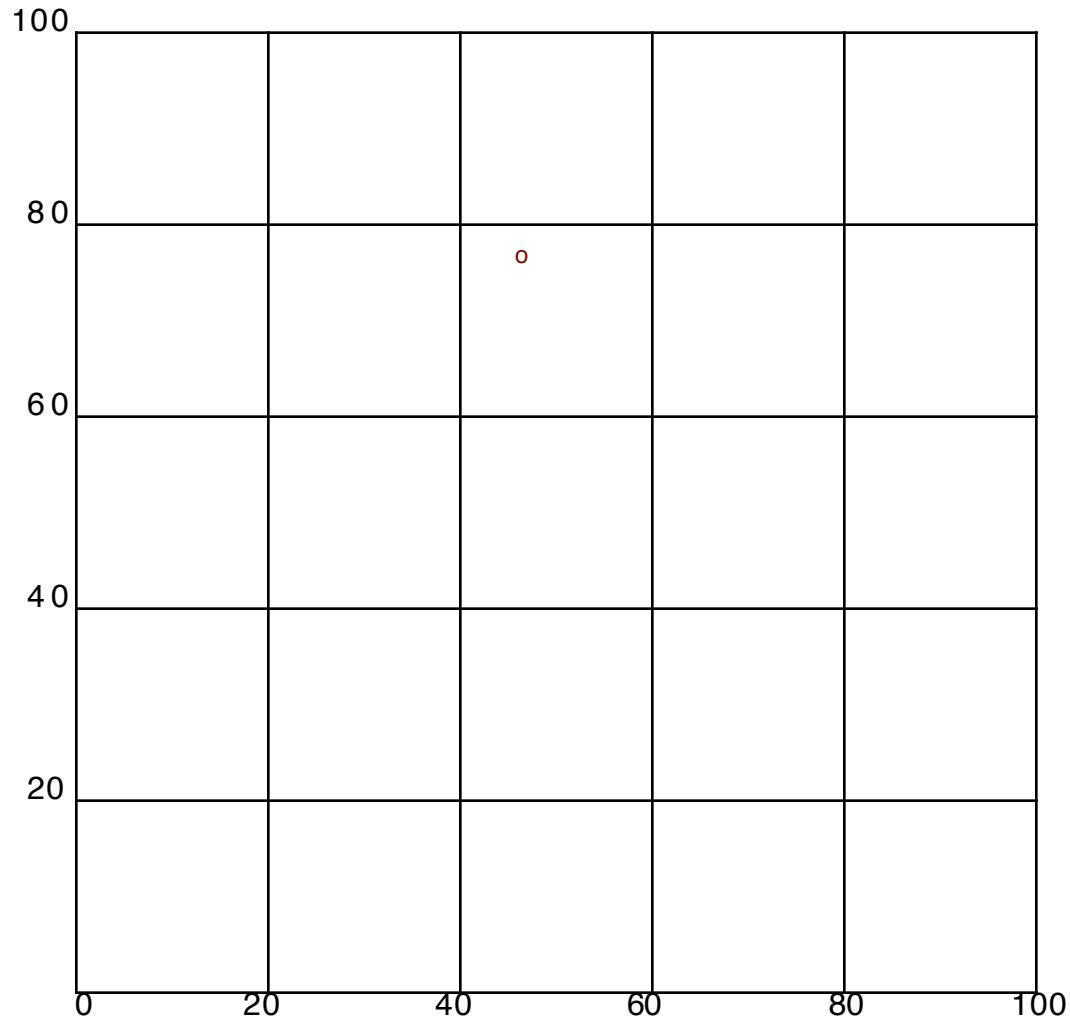
PART III
CHARACTERISTICS OF RADIANT (HEAT) ENERGY

The mechanism exploited by CO_2 induced global warming models is related to specific vibrational frequencies of the carbon-oxygen bond that can resonate with those same frequencies within the infrared region of the electromagnetic spectrum; thus absorbing that energy and reradiating it to and from other CO_2 molecules within the Earth's atmosphere. However, two important facts have to be considered in connection with this notion. First of all, infrared light (radiant heat) appears within the low energy region of the electromagnetic spectrum. Secondly, all radiant energy (E) varies indirectly as the square of the distance (D) from its source ($E = 1/D^2$). Interpreting FIG. 2 (page 11) on a molecular scale, illustrates that this weak (infrared) radiant energy will be significantly diffused as it moves among the widely separated molecules of CO_2 in our atmosphere. Nitrogen, oxygen and argon, which make up 99.9% (999,000 ppm) of our atmosphere and thus occupy much of the space surrounding its CO_2 molecules, can directly absorb that diffused radiant heat in proportion to their individual masses and specific heat capacities. This resonance form of energy transfer among CO_2 molecules is more efficient on Venus where the atmosphere is 98% (980,000 ppm) CO_2 and where the atmosphere is much more dense than Earth's is. There are more molecules of CO_2 in the atmosphere of Venus and they are closer together than they are within the is Earth's atmosphere. These two factors lead to a more efficient resonance transfer of infrared energy among CO2 molecules on Venus than on Earth.

PART IV
CONCLUSIONS

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 physical properties of any substance or object that involve the capture, storage, transport and transfer of (heat) energy are mass dependent and the notion that 25% of the CO_2 in our atmosphere can cause the melting of glaciers and the warming of oceans implies that an infinite amount of energy can be stuffed into a finite mass. The challenge, expressed here, requires the proponents of CO_2 induced global warming to reconcile their models with classical scientific principles and established physical data. Any response must define, explain, illustrate, and, most importantly, quantify the physical properties of CO_2 that conclusively establish this miniscule component of our atmosphere as a greenhouse gas, capable of heating the relatively huge mass of the Earth's land and water features to catastrophic proportions.

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GENERAL NOTES:

1. The scientific principles presented in this paper can be verified by referring to any of the of the on-line encyclopedias such as ABOUT.COM, ASK.COM and/or WIKIPEDIA
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.

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