It's Raining… Carbon?

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Background: I have always been fascinated by the Earth's metamorphic processes. The global carbon cycle is of particular interest since it regulates the balance of CO_2 in different terrestrial sinks. Through study, I found that anthropogenic energy transformation and usage over the last 200 years have increased the amount of atmospheric CO_2, contributing to the greenhouse effect and global climate change (Michaels, 2002). I asked myself, how might balance be restored? Currently, my community is on the short-list of favorable locations for long-term radioactive waste storage. I asked myself, how can these wastes be put to good use? Recently, NASA proposed investigation of methods to harvest Martian atmosphere (95% CO_2) to refuel rockets enroute to other nearby planets (Chris Hadfield, Astronaut). I wondered what steps could be used to gather and render fuel from this abundant gas? I also wondered how such ideas could be exploited on earth to solve our own CO_2 problems and meet the Kyoto Protocol (GOC, 2003). This led me to develop my project questions and hypothesis.

I asked the **question:** Can a change in anthropogenic energy transformation practice reduce the growth of atmospheric greenhouse gases?

This lead me to my

Hypothesis: I believe that mining CO_2 from the atmosphere to make recyclable energy products can lead to a more balanced carbon cycle.

Purpose: To create an anthropogenic atmospheric energy transformation cycle that provides power to concentrate and capture CO_2 from air, utilizing alpha wave (α) decay from radioactive waste, re-energizing the CO_2 to carbon monoxide (CO) and carbon (C) combustion fuels, bringing the global carbon cycle back into balance while permitting continued anthropogenic CO_2 emissions, at the same time.

Procedure: There are five parts to the project. Part one examines the **chemical thermodynamics** of calcium oxide (lime), calcium hydroxide (slaked lime), calcium carbonate (CC), CO and C. Part two examines wind sheer **fluid dynamics** through a physical Bernoulli principle model. Part three extends the theory using a water hammer ram pump to generate misting rain, **enabling a katabatic air flow** process **driving a wind turbine** (part four). The Tesla turbine, applies Bernoulli's Theorem in transforming flow volume and velocity to mechanical rotation **for power** generation **used to chemically concentrate CO_2 in air as $CaCO_3$**, by diffusion into water, **returning CO_2 reduced air to the atmosphere**. In part five, the **regenerated pure CO_2 stream is radiolytically decomposed** with ^{241}Am,

producing a recyclable combustible fuel mixture of CO, C, He and O_2. Finally, the findings of the first five parts are evaluated via a yield calculation and a dynamic carbon cycle computer simulation, spanning 300 years.

Method: Thermodynamic calculations solved for the energy and reaction conditions required to chemically cycle CO_2 from carbonate to elemental carbon. Using the CRC Handbook (Lide, 2002), Internet information, and the Gibbs Free Energy formula (? G°=? H°-T? S°), the net heat of reaction, molar reactants and product amounts were determined and graphically compared to the free energy of dicarbon, CO_2 and carbonates, within the mineralization sequence predicted by the Miller-Urey (1959) reaction. The energetics and conditions of air to water diffusion for CO_2 to $CaCO_3$ were experimentally determined using 0.5M $Ca(OH)_2$ and 7% $NaHCO_3$(aq), followed by filtrate heating and calorimetry to cycle the CO_2 as a pure gas stream. The second procedure determined the kinetic energy capability of an induced wind-sheer physical column apparatus. A downward wind was induced by spraying water into the top cross-sectional area of a 7 meter high column, then measuring air velocity, temperature, humidity and pressure resulting at the top and bottom of the column. The experiment measures eight cross-sectional areas (0.01 to 0.1m), with two water flow rates, in three replicates, over three trials, with statistical analysis and graphs. The third procedure constructed and characterized a functional water hammer ram pump lifting water utilizing the energy of a flowing stream to create a raining mist at the top of the wind column. The physical measurements were used to construct a dynamic performance model. The fourth procedure involved the construction and fluid-dynamic performance evaluation of a Tesla air turbine. The turbine was experimentally monitored while varying the input air volume and velocity during mass lifting trials of 10 to 60 grams via a 1m string length attached to the output shaft. The results were analyzed statistically and graphically to determine the power development dynamics of the air powered turbine. In procedure five, 100% alpha emitting radioactive isotope data were evaluated to determine a suitable nuclide with desirable radiolytic CO_2 decomposition capabilities for high decay energy, long half life, high particle velocity, ionization path length, availability in large quantities as a nuclear waste and decay products which do not produce Pu. The radiolyzed product conversion rates and yields were theoretically calculated and modeled. The combustion of the radiolytic products were evaluated thermochemically, completing the cycle of CO_2 from atmosphere to an energy gas stream in terms of the overall effect upon the global carbon cycle. The final procedure was **the design and application of a computer simulation program** to model current and future atmospheric CO_2 concentration parts per million (ppm), fluxing between major carbon sinks (content in gigatonnes), as a result of metamorphic and anthropogenic CO_2 emissions, deforestation, soil tillage, and use of this new carbon sequestering method employing the alpha decay of nuclear waste converted to neutron enriched product of ^{241}Am. Applying experimental findings (above) and reliable Internet published sources (eg. the world population clock found at www.tranquileye.com), Euler's method was used to construct the 300 year integration model. Graphical output was analyzed for 36 possible global carbon cycle outcomes.

Materials: Thermodynamic **studies of carbonate and combustion fuel chemistry** and **CO_2 radiolytic conversion to fuel**: CRC Handbook, Microsoft Office and Explorer programs, Compaq Armada 1750 computer operating with Windows 98 (SP2), and a calculator. **Katabatic wind column experiment**: forty, 1kg size steel coffee cans, MIG welder, lamp stand, 2 pressure water misters, duct tape, bungie-cords, 1L distilled water, GIS instrument, thermometer, stopwatch, Kestrel weather station. **Tesla turbine experiment**: ¾" fir plywood, 10 x 5.25" CDs, 1 circle cutter, ½:" bit, drill press, table saw, 5/4" screws, 10 SCF 120 psi air compressor, ¼" NT input fitting, 5/8" x 10" dowel, 10' x ¼" air hose, Kestrel weather station, thermometer, air pressure gage. **CO_2 Concentration experiment**: 1L 0.5m $Ca(OH)_2$ in degassed, distilled water, 10g $NaHCO_3$, 100 ml $C2H4O_2$, electronic balance, water calorimeter, thermometer, CRC Handbook and a calculator. **Waterhammer pump study**: 200m x 1" PVC water pipe, 10' x 1" galvanized drive pipe, 2 water pressure gauges, 1" ball valve, 2 1" tees, 5 3" nipples, 1" foot valve, 1" flap valve, 1" to ½" reducer, NPT to garden hose adapter, 200m ½" garden hose, 2m 2" PVC pipe, 2" to ½" PVC reducer, ¼" nuts, ¼" threaded rod, 1" flat washer, 2.5kg weights, 12L pail, measuring tape, GIS instrument, Kestrel weather station and a stopwatch. **Dynamic simulation model:** created in Ithink computer language V5.01.

Results: Carbonate synthesis thermodynamic analysis gave the total energy of formation, product chemistry and stoichiometry. Converting atmospheric CO_2 into $CaCO_3$, results in freeing 735 kJ/mole in energy! Converting CO_2 into CO requires 257 kJ/mole of input energy. Combusting carbon fuels to form CO_2 releases 5.98 kJ/mole of carbon oxidized. Thus, converting carbon dioxide to a carbonate follows the Urey reaction, creating a stable sink for excess atmospheric carbon while at the same time transforming energy to do other work. As an effective industrial process, the reaction requires the use of aqueous $Ca(OH)_2$, obtained by water slaking CaO and removing the 109.43 kJ/mole heat of reaction. Adding CO_2 to $Ca(OH)_2$ precipitates as $CaCO_3$ plus 96.53 kJ/mole. Exposing $CaCO_3$ to the heat of 178.71 kJ/mole releases a pure CO_2 gas stream, regenerating CaO for further CO_2 sequestering recycles. Therefore, in a closed energy loop, the net heat of reaction required to capture the CO_2 from air to regenerate a concentrated pure CO_2 stream ((96.53 + 109.43) - 178.71) = 27.25 kJ/mole. Since the CO_2 is in air, a favorable air to water diffusion condition must be created which provides for high gas flow volumes to enable the air to water transition, water for solution and adequate removal of the heat of reaction. Achieving these conditions implies that an equivalent amount of fuel combustion can be added back into the atmosphere with no net increase in the CO_2 concentration, assuming the sequestered CO_2 can be rendered into some other environmentally benign product or state. However, if the pure CO_2 product of the $CaCO_3$ recycle were to be upgraded to a fuel such as CO, then CO_2 need not be sequestered, merely recycled. One way of accomplishing this would be to radiolytically decompose the pure CO_2 to CO, C and O2. Procedure 5 calculations show that 1 mole ^{241}Am makes use of the five orders of magnitude greater alpha particle decay ionization flux energy (as compared to Gibbs Free Bonding Energy) to convert 1 mole of pure CO_2 to a combustible mixture of CO, C, He and O_2 every 79 hours. Increasing the flux rate by adding more Am could further reduce this time. Further, the same 241AM mole can convert 47,980 CO_2 moles over one half life of 432 years before continuing that function as ^{237}Np.Using 55 tonnes of Am would allow the recycling of 26 Gt of CO_2 per year. The physical measurement scaling from Procedures 2 to 4 show that a wind column 400m wide and 1200m tall would process 13 km^3/day at a 10 m/s flow, matching the $CaCO_3$ recycle and ^{241}Am radiolytic conversion capability, providing 89 megaWatt hours/day of turbine energy for use in other industrial processes.

Conclusions: A literature review provided values necessary to calculate the impact of a radiolytic CO_2 recycle in global carbon sequestration. World fossil fuel combustion, cement and fertilizer manufacture produces 22 Gt/y of CO_2 while terrestrial photosynthesis currently binds 390 Gt/y of atmospheric carbon (Alpert, 1993). Applying mathematical calculation to the experimental results shows how 26 Gt/y of carbon can be removed by a net concentration and radiolytic conversion of 13 km^3/day containing 372 ppm CO_2. The associated katabatic wind column process and CO_2 to $CaCO_3$ to C and CO a decay recycle provides a net 89 MWh of energy for other anthropogenic uses or fuel replacement. Therefore, an atmospheric CO_2 decrease of 2.2 ppm/y results, accounting for 100% of the world's ten year Kyoto commitment, relieving global warming and deleterious climate effects. Using the dynamic simulation where the katabatic wind-carbonate concentration-radiolytic fuel cycle is integrated within industrial processes, the global carbon cycle and atmospheric CO_2 levels can quickly be brought to balance, even with continued use of fossil fuels. My project has several interlinking **applications**. Using the recycling methods described forms a new 4 Gt/y

Therefore, my hypothesis is correct. Mining CO_2 from the atmosphere, to make recyclable energy products leads to a more balanced carbon cycle. Two costly, worthless waste products become valuable feed stocks to fuel world wide growth. Simply raining atmospheric carbon will prove to be the black gold of the 21st century.

carbon sink which also sequesters 55t of radioactive waste. Therefore, the Kyoto Protocol can be implemented without impeding fossil fuel use, allowing slow change out of old for new energy infrastructure, without degrading standards of living or third world development. As an opportunity for the City of Timmins, the storage of nuclear waste as ^{241}Am facilitates atmospheric mining of CO_2, electricity generation, and fossil fuel equivalents to support revitalizing secondary industry, with world wide significance. Truly, the wind column represents one way of terraforming our planet by making it rain carbon using a new energy paradigm for the 21st century.

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