Name: ___________________________ Date: ____________ Hour: ________

A Poker Chip Model of Global Carbon Pools and Fluxes

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1. What is a pool or reservoir?

2. For each pool listed below, list primary form(s) of carbon. If possible, describe the forms of carbon both at the macro (visible) and micro (atomic-molecular) scale. For example, living plants would represent the macroscopic visible scale, which store of their carbon in cellulose molecules inside their cell walls, which represents the atomic-molecular scale.

Global Carbon Pool	Primary forms of carbon
Vegetation	
Soils	
Fossil fuel reserves	
Atmosphere	
Upper ocean and marine life and deep ocean	
Sedimentary rock	

Word bank – may use words more than once(optional):

calcium carbonate ($CaCO_3$) *shale* *bicarbonate (H_2CO_3)* *coal*
plankton *methane (CH_4)* *natural gas* *carbon dioxide (CO_2)*
cellulose *crude oil* *limestone* *organic matter* *decomposing plants*
plants

3. What is a Gigatonne (Gt)? Global carbon pools and fluxes are huge! They are typically measured in Gigatonnes. A gigatonne is one billion metric tons! A metric ton (tonne) is 1000 kilograms or ~2200 pounds (a little more than a ton). For reference, a large bull or a small car might weigh 1000 kg. So a Gt is approximately the mass of a billion large bulls or small cars. The average mass of a 13 year old is 100 pounds or 45 kilograms. How many 13 year olds are in a tonne?

4. Model the carbon pool sizes: To create a scale model of the amount of carbon stored in each pool, stack poker chips and/or construct paper columns representing the amount of carbon in each location as instructed by your teacher.

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5. <u>Discussion questions</u>: Does anything surprise you about the amount of carbon stores in each location? Is the drawing to scale? Where is most of the carbon stored?

6. <u>Carbon fluxes.</u> The arrows on the diagram show how carbon moves between carbon pools. These fluxes represent processes that transform and move carbon between pools. For each arrow, discuss what processes (biological and chemical) are causing the flux. You can choose from the options listed below. Write the process or processes next to each arrow. Put an * next to fluxes that are associated with human activity. For example, human agriculture affects the rate of carbon dioxide release from the soil.

   a. Photosynthesis
   b. Respiration
   c. Combustion
   d. Erosion/weathering
   e. Diffusion
   f. Ocean mixing and sedimentation
   g. Volcanism

7. <u>Label the carbon flux rates</u>: Flux rate describes the rate at which carbon moves between pools through a variety of natural process and human activities. At the global scale, flux rates are measured in gigatonnes per year (Gt/yr). Write the flux rates provided next to each arrow.

8. <u>Discussion questions</u>: What patterns do you see with the flux rates? Are the numbers between pools balanced? How does the size of the flux compare with the size of the pools? Note: these numbers include fluxes caused by human activity.

9. <u>Dynamic equilibrium and net fluxes</u>:

   A. Some pairs of pools have arrows in both directions connecting them meaning that carbon moves both directions between those pools. If exactly the same amount of carbon moves both directions between two pools, the fluxes have no effect on the size of the pools. There is no net flux. Model the net fluxes by looking first at the fluxes between the atmosphere and the ocean. Use poker chips (100 Gt/yr), pennies or bingo chips (1 Gt/yr) or paper columns to model the two fluxes. What is the net effect of these two fluxes – how do they affect the size of the atmospheric and oceanic pools?

   B. The net flux is the difference between two opposing fluxes. Calculate and then model with pennies or bingo chips (1 Gt/yr) the net fluxes between pairs of pools.

10. <u>Interpreting Net Fluxes</u>: Look at the net flux rates between vegetation and atmosphere, atmosphere and ocean, upper and deep ocean. Where is the carbon moving? What does the net flux tell you about the balance between carbon transforming processes?

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11. Calculate net flux into atmosphere: Carbon in the atmosphere (CO_2 and CH_4) is particularly important, because it contributes to the greenhouse effect. Increased level of these gases lead to global warming. Look at the fluxes going in and out of the atmosphere every year. How does the number of fluxes into the atmosphere compare to the number leaving? Why is this? Give three examples of human activity associated with the flux from sedimentary rocks to the atmosphere.

12. Implications for climate change: How much additional carbon is added to the atmosphere every year? (Hint: This requires subtracting all of the fluxes leaving the atmosphere (a, d) from those entering (b, e, h, i).) Represent the net flux of carbon into the atmosphere with pennies or bingo chips. Which arrows and what processes are moving carbon into the atmosphere? Which is the biggest net flux into the atmosphere? What is the long-term effect of the net flux of carbon?

13. Reducing atmospheric carbon levels: How much would we have to reduce fossil fuel use in order to see atmospheric CO_2 levels fall (assuming all other fluxes stay the same)?

14. Brainstorm and model climate change mitigation strategies: Referring to your diagram, come up with 2 strategies that could reduce the net flux of carbon into the atmosphere. Model one of the strategies on your diagram by either adding or moving bingo chips. Some strategies might require drawing new arrows. Be prepared to explain your model.

15. Biofuels: Biofuels are fuels for vehicles such as ethanol made from plant material. Use your model to decide whether or not substituting biofuels in for some fossil fuels would help slow the increase in atmospheric carbon dioxide.

Assessment

16. Some people argue that because the flux of carbon dioxide into the atmosphere from fossil fuels is small (7.8 gigatonnes/yr) compared to the influxes from oceans (78.4 gigatonnes) and vegetation (119.8 gigatonnes/yr), we don’t have to worry about our use of fossil fuels. Do you agree with this position? Explain your reasoning.

Extension questions:

17. Using the yearly flux rate into the atmosphere, calculate how much additional carbon should be in the atmosphere pool in 100 years.

18. Move the poker chips from one pool to another to represent the movement of carbon into the atmosphere over 100 years.

19. Model and explain what a “carbon neutral” global system would look like.