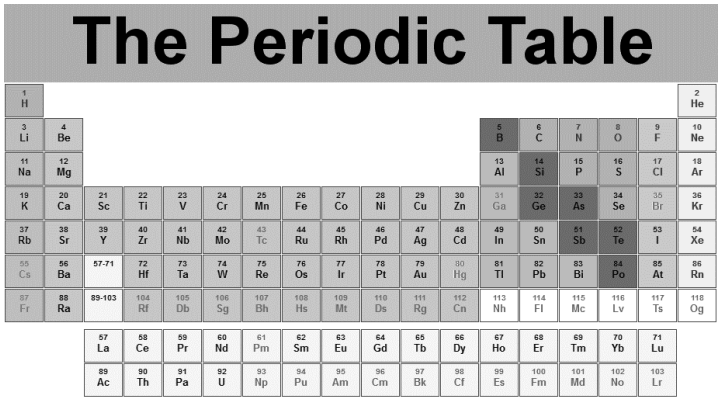
Name: _____ Period: _____ Date: _____

It's All a Balancing Act

A chemical equation contains ***reactants*** (substances that go INTO the reaction) and ***products*** (substances that come OUT of the reaction). An arrow (→) separates the two and tells us that a reaction is occurring.

To balance a chemical equation, means that the elements that make up the reactants are **equal to** the elements that make up the products. This is due to the Law of Conservation of Matter which states that nothing is created nor destroyed.



To the left is a Periodic Table which lists all known elements. It's symbol is represented by either one capital letter, or a capital and lower case letter.

A molecule is two or more elements bonded together. They usually tend to stick together unless something (like energy or a better bond) breaks them apart.

Photosynthesis and cellular respiration are two important processes that occur naturally on earth. They provide the necessary molecules for life to exist. Below we will explore how it works.

THE ELEMENTS THAT MAKE UP THE PROCESSES

1. Write down the element name to match the symbols provided below:

   C _____

   H _____

   O _____

2. The elements listed above are used to create molecules significant in the processes for both photosynthesis and cellular respiration. Write down the molecule name to match the symbols provided below:

   CO_2 _____

   H_2O _____

   O_2 _____

   $C_6H_{12}O_6$ _____

3. On the left side of the → are the chemicals going IN to a chemical reaction, on the right side of the → are the chemicals going OUT of a chemical reaction. In a chemical reaction, what does the "→" signify?

   _____

   _____

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PHOTOSYNTHESIS

$$CO_2 + H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + O_2$$

4. According to the above chemical equation, the process of photosynthesis uses _____, _____, and _____ to produce _____ and _____.

5. The chemical equation above is not balanced (remember the Law of Conservation of Matter?). To balance a chemical equation, the elements that make up the reactants must equal the elements that make up the products. So, step #1 will be to count how many elements are found on the reactant and the product side. This has been done for you below as an example.

$$CO_2 + H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + O_2$$

Reactants		Products
1	C	6
2	H	12
3	O	8

Is the above chemical equation balanced? _____ Why or why not? _____

_____

6. Step #2 is to balance the equation. Do this by changing the coefficient number to increase the number of molecules available. Note: the coefficient number applies to each element that makes up the molecule. Fill in the blanks (the coefficient number) and the resulting reactant and product numbers to show your balanced photosynthesis equation:

$$____CO_2 + ____H_2O + \text{light energy} \rightarrow ____C_6H_{12}O_6 + ____O_2$$

Reactants		Products
	C	
	H	
	O	

WHERE DO THE MOLECULES COME FROM?

7. Where is CO_2 found in our environment? _____
8. Where is H_2O found in our environment? _____
9. What could be a source of light that drives the chemical reaction to occur? _____
10. What organisms would go through this chemical process of photosynthesis? _____
11. Looking at the chemical equation, why is **CO_2** on the left of the → and why is **O_2** on the right of the →? _____

_____

12. Explain the overall purpose of photosynthesis?

CELLULAR RESPIRATION

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{chemical energy}$$

13. According to the above chemical equation, the process of cellular respiration uses _____ and _____ to produce _____, _____ and _____.

14. Step #1, count how many elements are found on the reactant and the product side.

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{chemical energy}$$

Reactants	Products
C	
H	
O	

Is the above chemical equation balanced? _____ Why or why not? _____

_____

15. Step #2, balance the equation.

$$____C_6H_{12}O_6 + ____O_2 \rightarrow ____CO_2 + ____H_2O + \text{chemical energy}$$

Reactants	Products
C	
H	
O	

WHERE DO THE MOLECULES COME FROM?

16. Where is $C_6H_{12}O_6$ found in our environment? _____

17. Where is O_2 found in our environment? _____

18. What is the chemical energy produced in the end used for? _____

19. What organisms would go through this chemical process of cellular respiration? _____

20. Looking at the chemical equation, why is **O_2** on the left of the → and why is **CO_2** on the right of the →? _____

_____

21. Explain the overall purpose of cellular respiration?

Extension Questions

22. Cellular respiration occurs in BOTH plants and animals. Why do plants need cellular respiration?

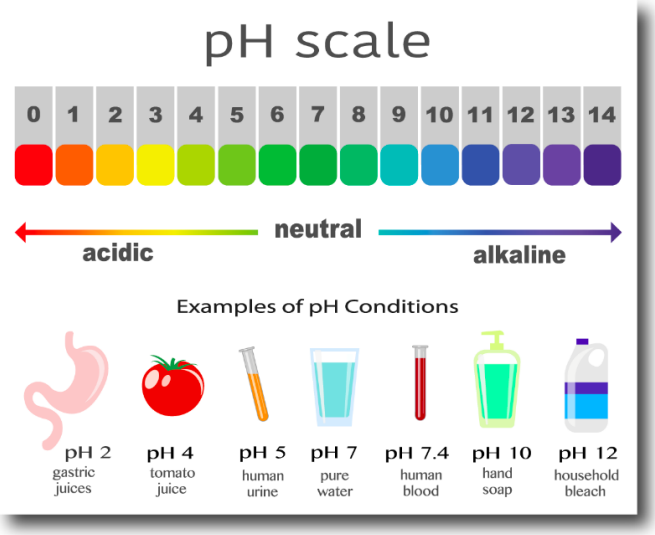
23. In the diagram below, use red arrows to show the movement of CO_2 and blue arrows for O_2.

TREE

DOG

Lab #1: How does carbon cycle between spheres?

Background Information:
In this lab, we will explore what happens to the pH of water when exposed to different substances. The water will be measured using a pH scale. A pH value is a number from 1 to 14, with 7 as the middle (neutral) point. Values below 7 indicate acidity, 1 being the most acidic. Values above 7 indicate alkalinity, 14 being the most alkaline. See the diagram (www.usgs.gov) for reference. Bromthymol blue is a solution that acts as an indicator of pH by changing colors.



Group Materials: 3 100mL glass beakers, 3 oz. paper cup, 2-clear 10 oz. plastic cups, 2 petri dish lids, 100mL graduated cylinder, grams scale, masking tape, Bromthymol blue (or other pH indicator), vinegar, baking soda, white paper towel, sharpie marker, water, drain cleaner

Individual Student Materials: PPE (goggles since vinegar is acidic; apron and gloves since Bromthymol blue can stain clothing and skin)

Procedures:
1. Place 30 mL of Bromthymol blue solution into each of the 3 100mL beakers.
2. Label one beaker “vinegar (acid)”, 2nd beaker “water (neutral)”, and 3rd beaker “drain cleaner (alkaline)”.
3. Place 30 mL of vinegar in the correctly labeled beaker. Observe any color changes.
4. Place 30 mL of water in the correctly labeled beaker. Observe any color changes.
5. Place 30 mL of drain cleaner in the correctly labeled beaker. Observe any color changes.
6. Leave these beakers on the side for reference of color.
7. Label one 10 oz. plastic cup as the “control”, the other as the “experiment”.
8. Place 60 mL of Bromthymol blue solution into each plastic cup.
9. In the 3 oz. paper cup, measure and place 2 grams of baking soda.
10. Use a piece of masking tape to tape the paper cup to the top inside of the plastic cup labeled “experiment,” so that the paper cup is NOT touching the liquid and is about 1 cm below the opening of the plastic cup.
11. Place both plastic cups onto a white paper towel (this makes it easier to see the color change).
12. Add 6 mL of vinegar to the paper cup with the baking soda. NOTE: be careful not to spill any vinegar or the mixture into the Bromthymol blue.
13. Cover both plastic cups (experiment and control) with the petri dish lid.
14. Allow about 10 minutes to pass then take observations on the Bromthymol blue liquid. What color is it? Is there any gas formation? Any solid or liquid left over in the paper cup? Compare these results of the plastic cups to the results of the beakers.
15. Write your data into the data table below.
16. Clean up lab area according to instructor. Save the liquid in the 3 beakers and “experiment” plastic cup, they will be used in lab #2.

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Lab #1 Group Members Names: _____

Date: _____

Data:

	OBSERVATIONS BEFORE EXPERIMENT	OBSERVATIONS AFTER EXPERIMENT	pH (Acidic, Neutral, or Alkaline)
Vinegar			
Water			
Drain Cleaner			
Control			
Experiment			

Discussion Questions:

1. What was the purpose of the Control? What did it show?

2. When vinegar (CH_3COOH) is mixed with baking soda ($NaHCO_3$), a chemical reaction occurs to form sodium acetate (CH_3COONa), carbon dioxide (CO_2), and water (H_2O). The sodium acetate and water combine to form an aqueous solution. Based on your observations what happened with the carbon dioxide in the paper cup?

3. Based on your observations what happened with the Bromthymol Blue liquid in the "experiment" plastic cup after the 10 minutes?

4. When carbon dioxide (CO_2) is combined with water (H_2O), another chemical reaction occurs to form carbonic acid ($H2CO_3$). This acid breaks down further within the water and releases its hydrogen ions (H^+) which decreases the pH of water. Use this information to explain and diagram what happened within the paper cup and the "experiment" plastic cup, that made you conclude the pH of the Experiment is acidic, neutral, or alkaline.

5. How does this experiment relate to one way carbon cycles between the spheres?

Cycling of Carbon Diagram

Carbon is found within all living things. It can also be found within the ocean, the atmosphere, and the soil. Carbon cycles continuously as one of the major biogeochemical cycles. We already learned some of the ways carbon cycles: through photosynthesis, respiration and diffusion (between air and water). Processes that release carbon to the atmosphere are called **carbon sources**, while processes that absorb it from the atmosphere are called **carbon sinks.**

Work in a small group of 3 and use the picture cut-outs to diagram how the cycling of carbon occurs and identify the carbon sources and sinks in our world. Your completed diagram will help you to answer the discussion questions.

1. Diagram the cycling of carbon

Step 1: Obtain a set of laminated pictures and labels from your teacher.

Step 2: Match the pictures with the correct labels. HINT: there may be more than one picture per label.

Step 3: Write in the correct balanced chemical equation for the photosynthesis label, as well as the cellular respiration label. Use whiteboard markers.

Step 4: Organize the pictures + labels on a large laminated sheet of paper (14'x18'). Arrange them so the carbon is able to flow and cycle through all the pieces. Use a little scotch tape to place pictures, this will be so they are moveable. Place the title piece on the top and write in an appropriate one, use whiteboard markers.

Step 5: Consult will all members of your group and be sure everyone agrees with the arrangement.

Step 6: Use whiteboard markers to draw in arrows to show the flow of carbon.

Step 7: Peer share your diagram with a neighboring group who is done. Share and explain the flow of carbon in the diagram and the reason or method of flow. For example: The carbon in the atmosphere gets taken in by the plants in the form of carbon dioxide through the process of photosynthesis. When the plants die, they decompose and some of the carbon gets sequestered back into the Earth or become sediment within the ocean…

Step 8: Now that you have shared, come back to your own group and consult with all your members. Be sure everyone agrees with the arrangement and understands the flow and labeling.

Step 9: Using two different colored whiteboard markers, circle where your group thinks are the carbon sinks and the carbon sources. Carbon sinks can be circled red and carbon sources circled in blue.

Step 10: A class discussion will take place with your teacher. Label and take notes on your diagram with whiteboard markers.

2. Fill in the quantitative model and answer the discussion questions with your group.

Group Members Names: _____

Date: _____

Carbon Stores and Fluxes – Quantitative Model

Use the estimates of carbon stores and changes to complete the table and model.

1. Rank the spheres by the amount of carbon stored, with 1 being the most carbon.
2. Calculate the current carbon stored where there have been changes due to industrialization. Numbers are measured in Petagrams of Carbon.
3. Put the updated data in the model.
4. The lines indicate annual flows between spheres. Black lines are natural processes, red lines are human caused. Draw arrow heads to indicate the direction of the flows.

Rank	Sphere		Pre-industrial	Change	Current
	Atmosphere		589	+ 240	
	Biosphere	vegetation	450-650	-30	
		soil	1,500-2,400		
	Geosphere	Fossil fuel reserves*	1,002-1,940	-365	
		Ocean floor sediment	1,750		
		Sedimentary rocks	66,000,000-100,000,000		
	Hydrosphere	Ocean water	38,000	+155	

*Fossil fuel reserves are limited to resources that have been discovered and are possible to extract.

Data: Ciais et al. 2013. IPPC Fifth Assessment Report. https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/TBI_co2_and_the_carbon_cycle.pdf

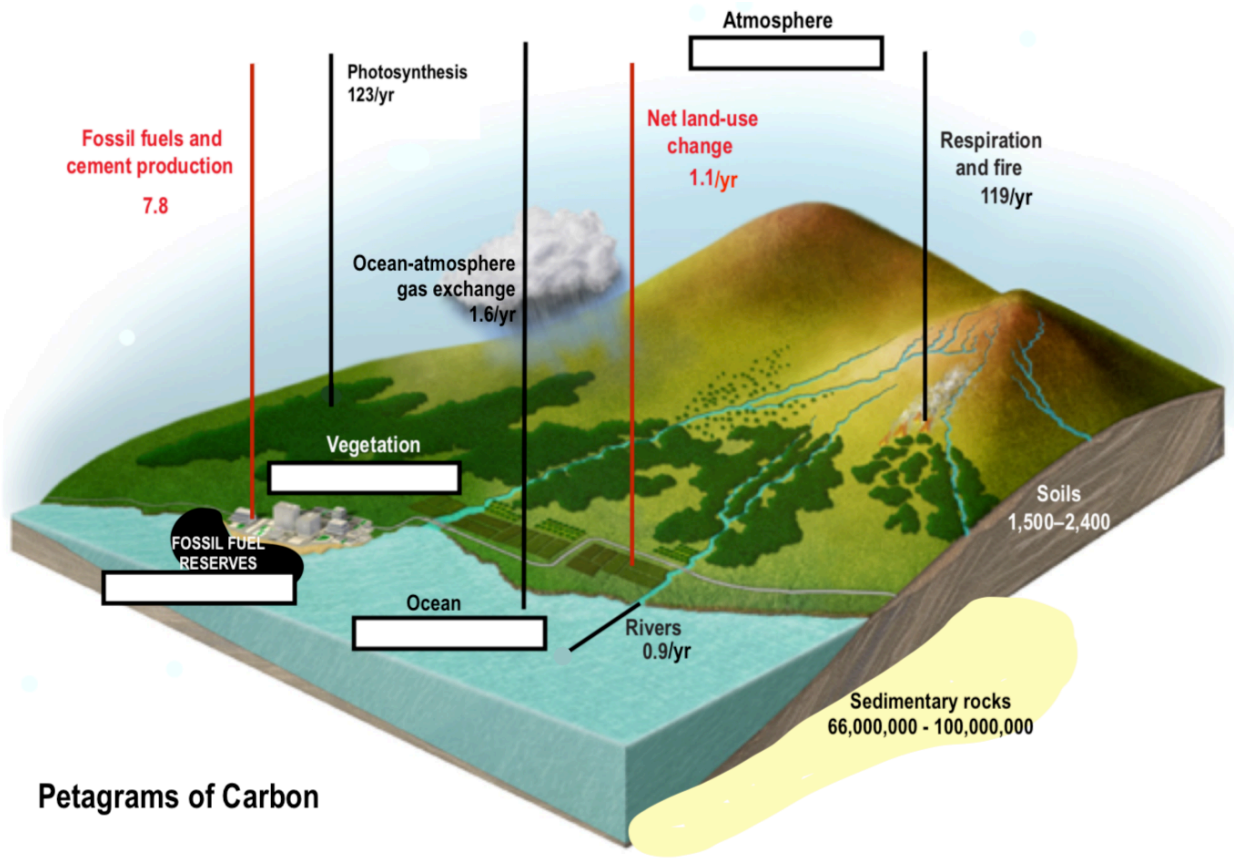

Image adapted from Selmants, et al. 2017, U.S. Geological Survey Professional Paper 1834.

Cycling of Carbon – Discussion Questions

Answer as a group, using your diagram and your quantitative model to help with your answers.

1. Name the carbon sink(s) in your diagram.

2. Name the carbon source(s) in your diagram.

3. Which carbon sink has sequestered additional carbon since the industrial revolution?

4. How does carbon get to be sequestered in the carbon sink you identified in question #3?

5. Explain how a carbon sink is able to become a carbon source. Provide an example of the process.

6. Humans have greatly impacted the carbon cycle. Name examples of human made carbon sources.

7. Explain how human made carbon sources disrupted the carbon cycle.

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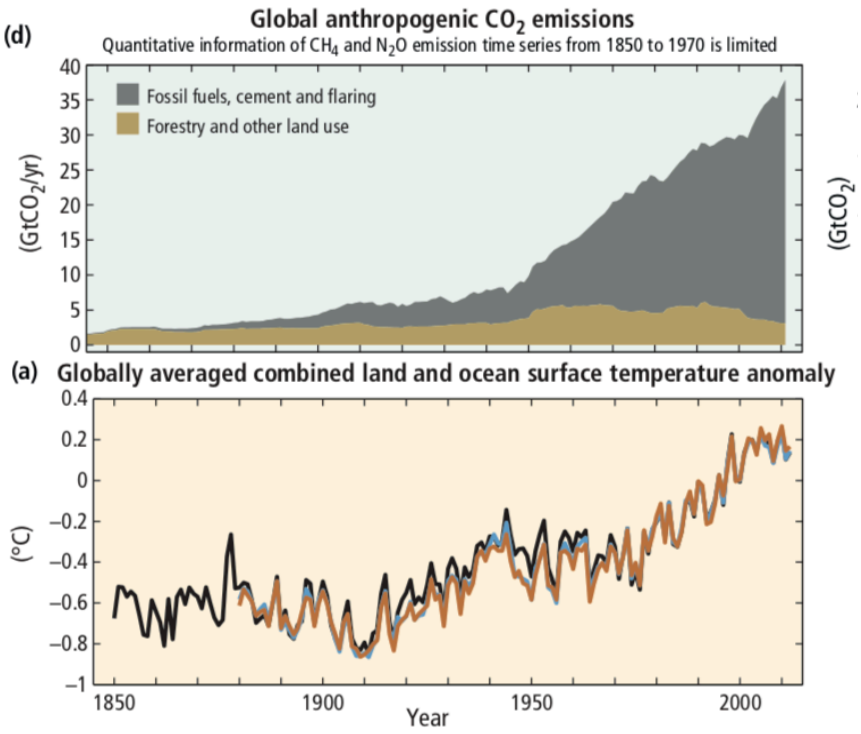
8. What happens when the carbon in our atmosphere increases?

Carbon gases trap heat from the sun. Otherwise the Earth would be as cold as outer space. Look at the graphs. The first one shows human emissions of carbon to the atmosphere. The second one shows average global temperatures. What do you wonder from the patterns you see?



IPPC. Climate Change 2014 Synthesis Report

9. Think back on what you observed in Lab #1. What happens when carbon increases in our oceans?

10. What are ways we can help restore the balance of the carbon cycle?

Lab #2: How does a change in the carbon cycle affect marine ecosystems?

Background Information: Based on Lab #1, it was discovered that carbon dioxide within the atmosphere can mix with water to form carbonic acid which releases hydrogen ions as it breaks down further to make carbonate ions. All those released hydrogen ions are what decreases the pH value and makes the water acidic. This is a natural process, but will increasing concentrations of carbon dioxide in our oceans affect marine ecosystems?

Group Materials: 5 250mL glass beakers, graduated cylinder, masking tape, sharpie marker, distilled water, local ocean water, lab #1 liquids, sea shells (similar shape and size; e.g. from a mussel or cockle or sea urchin; bought or collected from the beach), pH strips or digital pH meter, grams scale, paper towel

Individual Student Materials: PPE (goggles since vinegar is acidic)

Procedures:

1. Obtain the 5 250mL glass beakers and label them using the tape and marker: vinegar, water, drain cleaner, ocean water, lab #1 experiment liquid
2. Measure and place 50 mL of the correct liquid in each respective beaker. NOTE: the amount of liquid depends on the size of the shell. Be sure the shell is completely submersed in the liquid, so may want to test out beforehand. But all 4 beakers should have the same amount of liquid.
3. Use pH strips or pH meter to measure the pH level of each liquid. Record the results in the data table.
4. Obtain 5 (similar in size and shape) shells. Measure the mass for each shell on a grams scale. Record the results in the data table.
5. Place the shell in the correctly labeled beaker with the liquid. Observe what happens to the shells for about a minute. Record your observations in the data table.
6. Leave the beakers on the side of the classroom where it will not get disturbed, for about 2 days.
7. After 2 days, take some time to observe and compare the shells and liquids in the different beakers. Record your observations in the data table.
8. Carefully remove the shell from one beaker and dry it on a paper towel.
9. Measure the number of grams for the shell on a grams scale. Record the results in the data table.
10. Repeat step 8 and 9 for the other 4 shells.
11. Clean up your lab area according to your instructor.

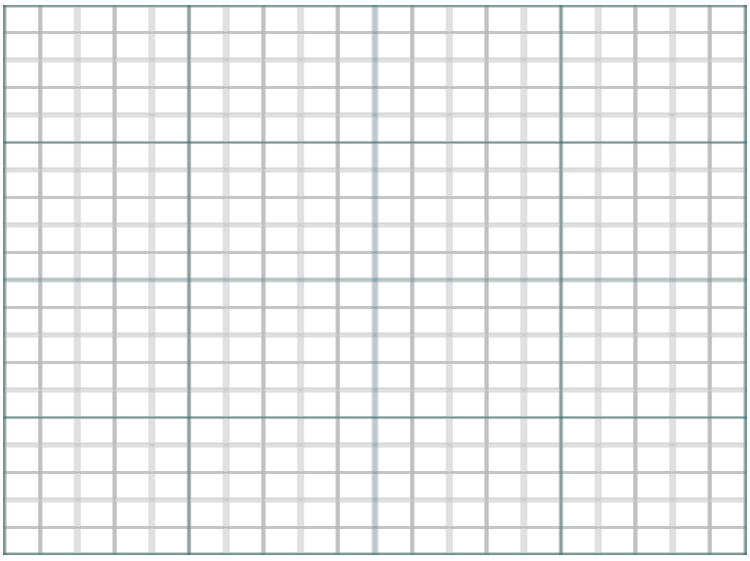
Lab #2 Group Members Names: _____

Date: _____

Data:

	pH value	Before - Shell mass (g)	Before Observations	After Observations	After – Shell mass (g)	Difference in Shell mass (g)
VINEGAR						
WATER						
DRAIN CLEANER						
OCEAN WATER						
LAB #1 EXPERIMENT LIQUID						

Line Graph: pH vs. Difference in Shell Mass (g)



Discussion Questions:

1. List the liquids in order from most acidic to least.

2. Based on your data, which shell was observed to have the most change? Explain.

3. Was there a control experiment within this lab? Why or why not?

4. Based on your graph, does it show a trend based on pH and shell mass? Explain.

5. What was the pH of the ocean water? Is this acidic, neutral or basic?

6. Based on your data and observations, what happened to the shell in ocean water after 2 days? Why do you think this occurred?

7. Remember, from lab #1, how an increase in carbon dioxide in our atmosphere can be taken into our oceans causing its pH to decrease and become more acidic. If this is the case, then based on your graph, predict the pH level that is the threshold for affecting sea shells. Explain how you came up with your answer.

Group Names_____

Date_____

LOCAL SOLUTIONS TO SAVE OUR OCEANS!

1. What factors are affecting the stability of biodiversity in the oceans? Indicate what causes what.

2. Propose 3 solutions that could be implemented on your island to protect biodiversity in the oceans from ocean acidification. For each solution, state its scientific basis.

1)

2)

3)

Get more input.

- Look at more information and data provided by your teacher.
- Consider the specific areas of focus your teacher asks you to choose between.
- Refine one of your previous solutions or create a new one.

3. Our chosen local solution is:

Get teacher approval before going further.

TEACHER APPROVAL SIGNATURE: _____

4. **List the criteria you will use in your design.** Criteria are the outcomes you will achieve. (For quantitative data use Table 1 on the preceding page.)

Which human activities will you reduce or change and by what measurable quantity? What measureable impacts will your solution have?

5. **List the constraints you will consider when planning your design.** These might include things like monetary costs, availability of resources, human power or transportation needs that will be impacted, the impact on biodiversity, or other environmental impacts. You can add to the list later as you learn more about your solution.

The constraints we will consider.

The constraints we will consider.

6. **Read the relevant resource materials provided and do outside research if needed.** Once you have learned more about existing technologies, costs and initiatives under way, come back together as a group to discuss and make decisions.

7. **Decide on your time frame.** You may have part of your solution take place in the short term with known costs and technologies, and other parts of your solution take place in the longer term with more uncertain costs and technologies. You can make up reasonable assumptions, just state what they are.

8. Decide on your location/s. Will your solution target the whole State, your whole island, or just one area on your island? Make sure the solution you pick matches the resources and potential of the location you pick.

9. **Decide on the components of your solution (actions). Document the components and describe, with quantities where appropriate, how each meets your criteria and constraints.** For example: If you are working on Electric Power, how many MW are you trying to produce? With what technology? In what location? What is the timeframe? How many million metric tons of CO2 will be avoided? What money or other resources will it require? What will the impact be on biodiversity? Are there other environmental impacts?

10. Evaluate your solution. How are human needs met compared to the way they are being met now? What are costs compared to current costs? What negative environmental impacts were avoided? What positive environmental impacts were created? Is your solution reliable and safe?

11. Share your solutions within your class. Pair up with another group and share your solution. 5 minutes to present, 5 minutes for comments and questions. Then switch turns.

12. **Refine the design – write down your ideas here**. Did you learn anything from the solutions of other groups that you can use to improve your own design? Can any solutions proposed different groups be combined better meet the criteria or minimize constraints?

Table 1.

STATE & ISLAND LEVEL million metric tons of CO_2 equivalent ($mmtCO_2eq$)							
	State	**Oahu**	**Hawaii**	**Kauai**	**Maui**	**Molokai**	**Lanai**
Population[1]	1,361,790	953,207	186,738	66,921	144,444	7,345	3,135
Land area (acres)[1]	4,034,560	382,080	2,577,920	353,280	465,280	166,400	89,600
FLUX - Annual emissions minus annual sequestration							
Electric power[2]	10.18	6.77	0.77	0.35	0.78	0.05	0.02
Transport[2]	9.79	9.25	1.28	0.54	1.38	0.09	0.04
Food[3]*	3.49	2.44	0.48	0.17	0.37	0.02	0.01
Stuff[3]*	4.02	2.90	0.47	0.18	0.41	0.02	0.01
Waste[2]	0.78	0.72	0.14	0.07	0.13	0.01	0
Land use							
Livestock, ag, forest fires[2]	1.05	0.09	0.48	0.1	0.13	0.01	0.1
Grassland[4]	0.81	0.02	0.66	0.03	0.06	0.01	0.02
Urban trees[2]	-0.4	-0.4	no data	no data	no data	no data	no data
Shrubland[4]	-0.96	-0.07	-0.57	-0.08	-0.08	-0.11	-0.04
Forest[4]	-1.96	-0.23	-1.11	-0.23	-0.25	-0.08	-0.05
TOTAL NET EMISSIONS / YR	**26.8**	**21.49**	**2.59**	**1.13**	**2.93**	**0.02**	**0.11**
Long term carbon storage							
Forest[4]	143.79	19.03	92.63	0.03	21.25	6.77	4.09
Shrubland[4]	22.31	1.84	14.67	0.01	2.05	2.78	0.97
Grassland[4]	51.97	1.48	44.16	0.01	4.31	0.78	1.22
Soil / other land[4]	5.70	0.02	5.34	0.00	0.29	0.03	0.01
TOTAL STORED	**223.77**	**22.36**	**156.80**	**0.05**	**27.91**	**10.35**	**6.30**

*Mostly imported.

Sources

1 - https://energy.hawaii.gov/wp-content/uploads/2011/10/ghg-inventory-20081.pdf

2 - ICF International for DBEDt December 31 2008 (2007 for all island level data) https://health.hawaii.gov/cab/files/2019/02/2015-Inventory_Final-Report_January-2019-004-1.pdf (2015 for State level data only)

3 - coolclimate calculator, UC Berkeley

4 - CAH USGS study 2017