Name: _____ Date: _____

Period: _____ **AP Environmental Science**

Ocean Acidification: Mini-Lab, Graphing, & Analysis

Understanding pH Chemistry

→ Read the background information about understanding pH chemistry and study the diagram on the pH handout; then, complete the task below.

Based on your understanding of the pH scale, which of the following statements are TRUE?
Check the boxes next to the statements that are true.

- ☐ A neutral pH of 7 indicates that the concentration of (H^+) ions is equal to the concentration of (OH^-) ions.
- ☐ The lower the pH, the higher the concentration of (OH^-) ions compared to the concentration of (H^+) ions.
- ☐ The pH of an unknown solution changed from pH 5 to pH 4. This means that the concentration of (H^+) ions increased by ten times.
- ☐ The lower the pH, the more acidic the solution.
- ☐ Seawater is an acid.
- ☐ The pH of seawater would become more acidic if the concentration of (H^+) ions increased.
- ☐ The pH of seawater since the Industrial Revolution has changed from 8.2 to 8.1. This means the concentration of (H^+) ions has decreased.

Experiment

The air we breathe out is 100 times more concentrated in CO_2 than our modern atmosphere. An exhaled human breath is about 3.7% CO_2 while the modern atmosphere is ~0.04% CO_2. We can use the fact that our breath is high in CO_2 to investigate what happens when CO_2 is dissolved in water.

To do this you will blow into a test tube that is partially filled with water. You will add an indicator solution that changes color with changes in pH. Then, you will determine the pH of the water by comparing the color of the water to a pH indicator color chart.

Testable Question: Does a change in dissolved CO_2 cause a change in pH?
Prediction: *Write a prediction below that describes how you think the change in dissolved CO_2 will affect the pH of the water.*

Procedure:

1. Fill a large test tube no more than ¼ full with water.
2. Add 10-15 drops of universal indicator solution.
3. Determine the pH of the water by comparing it to the *universal indicator color chart*.
4. Record the pH in the data table below.
5. Using a straw blow into the water (do not inhale or suck!)—allow it to bubble, yet not splash out of the test tube—until the color stops changing.
6. Determine the pH of the water by comparing it to the *universal indicator color chart*.
7. Add about three scoopula tips full of sodium bicarbonate to the water and stir it with a glass stirring rod.
8. Determine the pH of the water by comparing it to the *universal indicator color chart*.

	Observations	pH
Initial		
Added CO_2		
Added sodium bicarbonate		

Background Information and Analysis Questions
Refer to the background information handout to answer the questions and complete the sentences below.

1) Write a chemical equation that shows how CO_2 dissolves in ocean water, increases the concentration of hydrogen ions, and results in a decrease in the pH of ocean water.

2) The more _____ ions that float freely in seawater, the more _____ the seawater becomes.

3) What is the name of the substance that you added to the water in step-7 and what effect did it have on the pH?

4) Write a chemical equation that shows how carbonate ions can remove hydrogen ions from seawater.

5) The ability of the ocean to take up (or "sequester") hydrogen ions and prevent the pH from dropping is called its _____ _____.

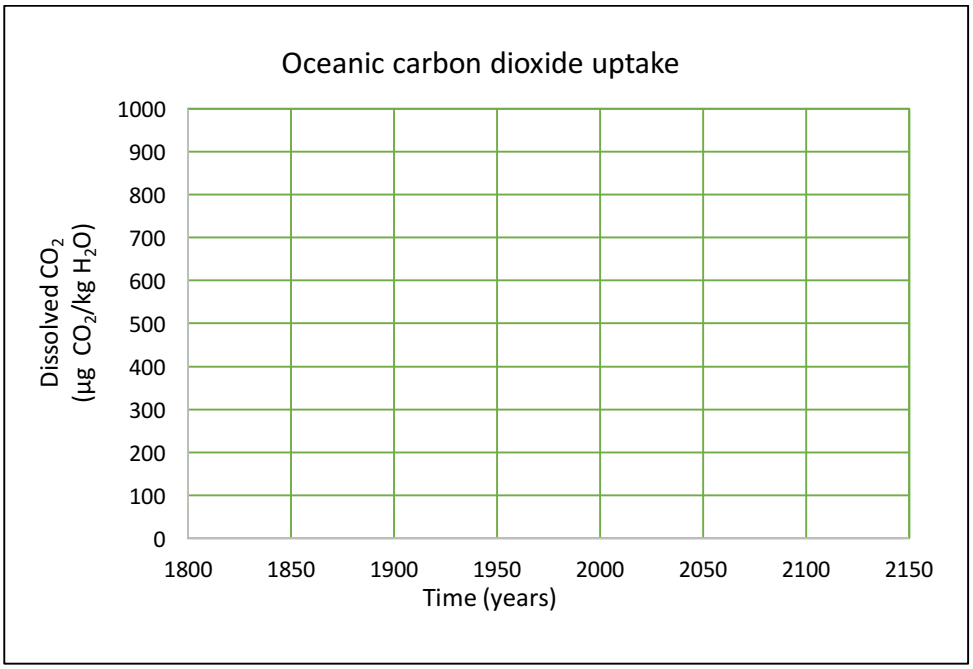
6) What is alkalinity and how is it linked to buffering capacity?

7) Describe how alkaline compounds, like bicarbonate and carbonate ions, are added to the oceans. How does the rate of this process compare to the rate at which CO_2 is being added to the oceans? What is the net result?

The data below shows historic and project levels of oceanic carbon uptake.

Instructions: Plot the the data from the data table on the graph below. Then, draw a smooth curve that shows the trend in the data. Additionally, add labels to the graph as described below.

Time (years)	Dissolved CO_2 (μg CO_2/kg H_2O)
1850	400
1900	415
1950	445
2000	505
2050	685
2100	900



Graph labels:

Time (years)	Dissolved CO_2 (μg CO_2/kg H_2O)	**Labels**
1850	400	Add an arrow pointing to the line with the label "1850 (pH=8.16)"
2009	550	Add an arrow pointing to the line with the label "2009 (pH=8.10)"
2100	900	Add an arrow pointing to the line with the label "2100 (pH=7.85)"

Analysis Questions

8) Calculate the percent change in dissolved CO_2 concentrations in seawater, in μg CO_2/kg H_2O, between 1850 and 2009.

9) Explain why the movement of carbon dioxide into the sea has been increasing since 1850.

10) What is the relationship between dissolved CO_2 in ocean water and the pH of ocean water?

Background Information and Analysis Questions

Refer to the background information handout to answer the questions and complete the sentences below.

11) Give five examples of marine organisms that need calcium carbonate ($CaCO_3$) to form shells and other essential structures.

12) The more _____ ions free-floating in seawater from CO_2 absorption and uptake, the more _____ ions react with hydrogen ions to form _____.

13) This means that the amount of _____ ions in the seawater will _____.

14) What happens to the amount of carbonate ions in seawater as the amount of hydrogen ions increases?

15) The more _____ ions in seawater, the easier it is form organisms to make their _____ + _____ shells, through a process called _____.

16) What is the essential ingredient for shell calcification?

17) The decrease in _____ ions from ocean acidification lowers the _____ _____ and makes it harder for organisms to make shells.

18) What is aragonite and why is it important?

19) Write a chemical equation that shows calcium carbonate formation.

20) Explain the following:
    a. $\Omega_{aragonite}$ 1.0

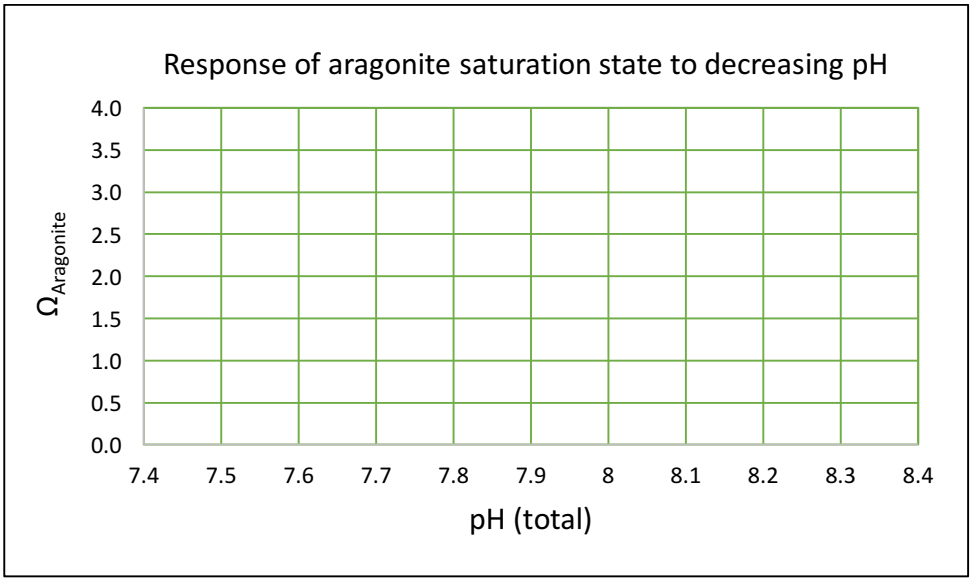
    b. $\Omega_{aragonite}$ >1.0

    c. $\Omega_{aragonite}$ <1.0

21) What happens to the $\Omega_{aragonite}$ value as carbon dioxide dissolves into seawater from the atmosphere and the acidity of the surface seawater increases.

The data below shows trends in aragonite ($CaCO_3$) saturation state, pH, and dissolved CO_2 in ocean water.
Instructions: Plot the the data from the data table on the graph below. Then, draw a smooth curve that shows the trend in the data. Additionally, add labels to the graph as described below.

pH (total)	Ω Aragonite
7.5	0.75
7.6	0.85
7.7	1.1
7.8	1.3
7.9	1.6
8	2
8.1	2.4
8.2	3
8.3	3.5



Graph labels:

pH (total)	Ω Aragonite	**Labels**
8.0	2.0	Add an arrow pointing to the line with the label "Chronic effects"
7.8	1.3	Add an arrow pointing to the line with the label "Acute effects"
7.5	0.75	Add an arrow pointing to the line with the label "1,600 µatm" This shows the carbon dioxide levels in partial pressure (***P***CO_2).
7.8	1.3	Add an arrow pointing to the line with the label "800 µatm" This shows the carbon dioxide levels in partial pressure (***P***CO_2).
8.3	3.5	Add an arrow pointing to the line with the label "200 µatm" This shows the carbon dioxide levels in partial pressure (***P***CO_2).

Analysis Questions

22) What is the relationship between CO_2 levels and pH?

23) What is the relationship between pH and aragonite saturation state?

24) Based on the background information, describe the "chronic effects" and the "acute effects" that occur as aragonite saturation state decreases.

25) At what saturation state is a threshold crossed where bivalve larvae begin to experience detrimental effects? At what pH does this occur? At what ***P***CO_2 (µatm) does this occur?

26) Based on your trendline (smooth curve) on the *Oceanic carbon dioxide uptake* graph, in what year (approximately) will dissolved pH be low enough for bivalve larvae to experience "acute effects".

27) **The Effects of Ocean Acidification on Coral Reefs**

Coral reefs are produced when corals acquire calcium ions (Ca^{2+}) and carbonate ions (CO_3^{2-}) from seawater and deposit solid $CaCO_3$ to form their exoskeletons. Scientists are concerned that relatively rapid decreases in ocean water pH will hinder the deposition of $CaCO_3$.

Use the assumptions in the table below to perform the calculations that follow.

Assume that the total global area of corals growing in reefs is 2.5×10^{11} m^2.
Assume that corals grow only vertically and that the average vertical growth rate of corals is 3 mm/year.
Assume that the average density of $CaCO_3$ in corals is 2×10^3 kg/m^3.

a. Calculate the current annual global increase in volume, in m^3, of $CaCO_3$ in coral reefs. Show all steps in your calculation.

b. Calculate the current annual global increase in mass, in kg, of $CaCO_3$ in coral reefs. Show all steps in your calculation.

c. Because of ocean acidification, it is expected that in 2050 the mass of $CaCO_3$ deposited annually in coral reefs will be 20 percent less than is deposited currently. Calculate how much less $CaCO_3$, in kg, is expected to be deposited in 2050 than would be deposited if ocean water pH were to remain at its current value.