Name ______________________________________

Seawater Chemistry Lab

In this 3-part lab exercise, you will:
PART 1: Investigate the effects of water temperature and salinity on seawater density and relate those effects to the circulation of ocean water masses.
PART 2: Investigate the effects of water temperature and salinity on seawater conductivity, and determine seawater salinity using two methods: electrical conductivity and refraction.
PART 3: Measure the dissolved oxygen in seawater samples and interpret your results.

PART 1: TEMPERATURE – SALINITY – DENSITY RELATIONS

The temperature and salinity of ocean water vary widely. These variations create differences in water density that control important aspects of ocean circulation.

Salinity is the total amount of solids (or "salts") dissolved in seawater, usually expressed in parts per thousand (written as $^0/_{00}$). For example, imagine that you had 1000 grams of seawater, of which 33 grams was dissolved salt, and 967 grams was water molecules (33 grams salt plus 967 grams water molecules = 1000 grams total). The salinity of that seawater would be 33 parts per thousand (**33 $^0/_{00}$**), which is equal to 3.3 percent (**3.3%**).

Effect of Temperature on Water Density (salinity held constant)

1. Take the Plexiglas tank and insert the divider into the middle slots. Push the divider all the way down.
2. Fill one side of the tank with **3 $^0/_{00}$ *chilled* water** to within an inch of the brim. Fill the other side with an equal amount of **3 $^0/_{00}$ *room temperature* water**. Your goal is to vary temperature while holding salinity constant.
3. Add a few drops of coloring to each side (use different colors for each side). Stir each side gently to mix the dye into the water. Keep track of which color marks cold versus warm water.
4. Remove the divider. Describe what happens, and explain why it happens.

5. Give the water masses a few minutes to reach equilibrium, then reinsert the divider. Gently stir *one side* of the tank (only one side) to mix the water and coloring. Now remove the divider. Describe what happens, and explain why it happens.

Effect of Salinity on Water Density (temperature held constant)

1. Empty the Plexiglas tank and reinsert the divider. Fill one side of the tank with ***30 $^0/_{00}$ room temperature* water** up to within an inch of the brim. Fill the other side with an equal amount **of *3 $^0/_{00}$ room temperature* water**. Your goal is to vary salinity while holding temperature constant.
2. Add a few drops of coloring to each side (use different colors for each side). Stir each side gently to mix in the dye. Keep track of which color marks saltier versus less salty water.
3. Remove the divider. Describe what happens, and explain why it happens.

4. Give the water masses a few minutes to reach equilibrium, then reinsert the divider. Gently stir *one side* of the tank to mix the water and coloring on that side. Remove the divider. Describe what happens, and explain why it happens.

5. Summarize in a sentence or two what you conclude about the effects of temperature and salinity on water density.

Interpretation and Questions

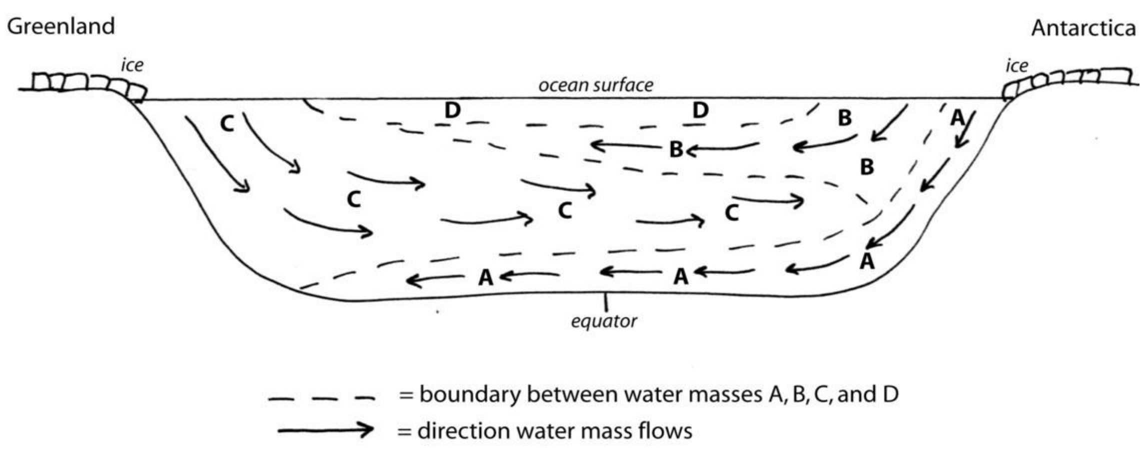
The behaviors that you observed in the Plexiglas tank explain a large-scale circulation pattern in the oceans known as **thermohaline circulation**. “Thermo” means temperature, and “haline” means salt, so thermohaline circulation is the movement of water masses of different densities caused by differences in temperature and salinity.

1. The *temperature* of ocean surface water is related mostly to how much solar energy it receives. Surface water near the equator is warm, and water near the poles is cold. What about *salinity*? List two natural processes that could cause ocean water to become less salty versus more salty:

   Processes that make water less salty: 1) _______________________ and 2) _________________________

   Processes that make water more salty:1) _______________________ and 2) _________________________

The diagram below schematically portrays water masses along a “slice” through the Atlantic Ocean from north near Greenland to south near Antarctica. Four main water masses, labeled A, B, C, and D on the diagram, dominate the Atlantic. The reason the water masses occur where they do and flow the way that they do relates to differences in their *density*, which in turn come from variations in their *temperature* and *salinity*. Thinking about what you observed in the tank experiments, and your answers above, answer the questions that follow.



2. Which water mass on the diagram (A, B, C, or D) has the lowest density? ______. What factors probably give this water mass its low density? (Think about where it occurs and how that location might affect its temperature and salinity.)

3. Which water mass on the diagram (A, B, C, or D) has the highest density? ______. Why that one? What factors probably give this water mass its high density? (Think about where it originates and how that might affect its temperature and salinity.)

4. Oceanographers have given names to those four Atlantic Ocean water masses that reflect their origin and location. Looking at the diagram, identify each mass name by letter A, B, C, or D.

North Atlantic Deep Water	_______
Antarctic Bottom Water	_______
Central Atlantic Surface Water	_______
Antarctic Intermediate Water	_______

5. This table lists the average temperature, salinity, and density of the four water masses. Thinking about what the diagram indicates about the properties of the four water masses, write the name of each water mass in the correct space below.

Temperature	Salinity	Density	Water mass name
1 C^o	34.8 $^0/_{00}$	1.0280 g/cm^3	________________________________
5 C^o	35.0 $^0/_{00}$	1.0275 g/cm^3	________________________________
5 C^o	34.2 $^0/_{00}$	1.0270 g/cm^3	________________________________
12 C^o	35.0 $^0/_{00}$	1.0265 g/cm^3	________________________________

6. Imagine two seawater samples, X and Y, with equal density. Sample X has a salinity of 32 $^0/_{00}$ and Sample Y has a salinity of 36 $^0/_{00}$. Which seawater sample (X or Y) is colder? Explain your reasoning.

7. Imagine that a ship leaves a fresh water port and heads into the Persian Gulf, an area with high seawater salinities. Will the ship ride higher or lower in the Persian Gulf compared to a fresh water port? Explain why.

PART 2: MEASURING SEAWATER SALINITY

2a. Effect of Salinity and Temperature on Conductivity

Conductivity refers to the ability of a substance to conduct an electrical current. In this part of the lab, you will investigate the effect of salinity and temperature on the conductivity of water.

1. Using the <u>500mL graduated cylinder</u>, measure out <u>280 mL of fresh water</u>. Pour the water into one of the large beakers.

2. Plug in the bulb apparatus and place it in the beaker (bulb up!). What happens? __________________

3. Measure precisely <u>one level ¼ teaspoon of table salt</u> and pour it into the beaker. Stir the water with the bulb apparatus to dissolve the salt.

   What happens? ____

4. *Note: Be sure that all the salt has dissolved in the beaker before proceeding.* The solution that you just made (¼ teaspoon salt dissolved in 280mL water) has a salinity of about 6 parts per thousand (**$6.0^0/_{00}$**). You are now going to check the conductivity of water with half that salinity, or **$3.0^0/_{00}$**.
   Pour half (<u>140 mL</u>) of the $6.0^0/_{00}$ water sample from the beaker back into the 500mL graduated cylinder. Add an equal amount of fresh tap water to the graduated cylinder to bring the total up to <u>280 mL</u>. Pour this water—now diluted to **$3.0^0/_{00}$** salinity—into a second beaker. Move the blub apparatus back and forth between the **$6.0^0/_{00}$ salinity** beaker and the **$3.0^0/_{00}$ salinity** beaker. What do you observe?

5. Take a third beaker and pour in some **$3.0^0/_{00}$ chilled water** from bucket provided. (150-200 mL will be enough, it doesn't have to be exact.) Move the bulb apparatus back and forth between the **room temperature $3.0^0/_{00}$ salinity** beaker and the **chilled $3.0^0/_{00}$ salinity** beaker. What do you observe?

6. Summarize what you can now conclude by filling in the blanks in this sentence:

   Conductivity of water goes up (increases) when salinity _________________________ and/or when temperature_________________________.

2b. Determining Salinity from Conductivity

You have seen that **conductivity** depends on both water **salinity** and water **temperature**. Therefore, to determine the salinity of a seawater sample, we need to know both its temperature and its conductivity. In this part of the lab, you will determine the salinity of three water samples (labeled A, B, and C) by measuring their temperature and conductivity. You will also check your salinity results against results determined by **refraction** on the same three samples.

Follow your instructor's guidelines for this portion of the lab. (Ask for help if you are unsure.) Record your results in the data table that follows.

Temperature – Conductivity Results

	Temperature (C^{o})	Conductivity (mS/cm)	Salinity ($^{0}/_{00}$)
Sample A	________________	________________	________________
Sample B	________________	________________	________________
Sample C	________________	________________	________________

2c. Determining Salinity from Refraction

Another way to measure seawater salinity is with **refraction**, which means the bending of waves (including light waves) as they travel from one substance, such as air, into another substance, such as water. The amount of refraction that occurs as light passes between air and water is dependent, in part, on the water's salinity. The saltier the water, the more the light will bend. We can measure the amount of this bending very precisely using an instrument called a **refractometer**.

1. Open the daylight plate of the refractometer and use a dropper to put several drops of a water sample on the prism surface.
2. Close the daylight plate so the plate comes into contact with the prism. Be sure that the water spreads completely over the prism surface with no air bubbles.
3. Holding the refractometer by the rubber grip, point the prism end toward a light source. Focus the eyepiece, if needed, by the knob on the eyepiece.
4. A horizontal boundary line separating blue (top) from white view (bottom) will appear in the eyepiece. This boundary line passes through a vertical scale, on the right side (ignore the scale on the left side), indicating the salinity in parts per thousand ($^{0}/_{00}$). *Use the scale on the right side only.*

Refraction results

	Salinity ($^{0}/_{00}$)
Sample A	______________
Sample B	______________
Sample C	______________

Compare your salinity results derived from <u>temperature-conductivity</u> with those from <u>refraction</u>.

- **How do your salinity results using the two methods compare for samples A, B, and C?**
- **What's the point of making a scientific measurement (salinity, in this case), using two very different methods?**

PART 3: DETERMINING DISSOLVED OXYGEN

Please note: throughout this part of the lab, it is very important that you follow all instructions and safety guidelines. There are a number of steps to follow, and they must be done carefully and correctly to produce good results. Moreover, you will be working with breakable and expensive equipment, and dangerous chemicals, so care is required to ensure safety for you and your lab partners.

Measuring Dissolved Oxygen

We measure dissolved oxygen levels in milliliters of dissolved oxygen per liter of seawater (mL/L), which is equivalent to parts per thousand. Most fish require at least 4.0 mL/L to survive. Some fish species, such as trout and salmon, require more.

In this lab, we will use a modified form of the ***Winkler Method*** to determine the dissolved oxygen content of seawater samples. This method involves fixing the oxygen in a water sample (i.e. chemically attaching the oxygen to another molecule), and then titrating the sample using sodium thiosulfate solution. The amount of thiosulfate solution used to complete the titration is directly proportional to the amount of dissolved oxygen in the water.

Before we can determine the dissolved oxygen concentration of any unknown samples, we must titrate a water sample whose oxygen level we already know, to use as a calibration. To do this, we use fully aerated fresh water at a known temperature. The oxygen level of oxygen-saturated water is related to water temperature, as shown in the table below.

Table: Oxygen Saturation Value versus Water Temperature

Temperature (C^o)	Max Oxygen (mL/L)	Temperature (C^o)	Max Oxygen (mL/L)
0	10.22	13	7.37
1	9.44	14	7.21
2	9.66	15	7.05
3	9.39	16	6.90
4	9.14	17	6.75
5	8.90	18	6.61
6	8.68	19	6.48
7	8.47	20	6.36
8	8.27	21	6.23
9	8.07	22	6.11
10	7.88	23	6.00
11	7.71	24	5.89
12	7.54	25	5.77

QUESTION: What does the table indicate about the relationship between water temperature and how much dissolved oxygen the water can hold?

The table indicates that if we know the *temperature* of an oxygen-saturated water sample, we can tell the *amount of oxygen* it holds. We have provided for you an oxygen-fixed sample of water that was oxygen-saturated (by aeration) at a known temperature. You will titrate this sample to begin the procedure.

Steps for Oxygen Measurement

1. Your instructor will tell you the temperature at which the calibration sample had its oxygen fixed. Record this temperature in the calibration data table below.
2. Use the oxygen saturation table on the previous page to determine the oxygen level for the calibration sample at this temperature. Record this value in the calibration data table below.
3. Measure exactly 25 ml of the calibration sample into a 50mL graduated cylinder.
4. Transfer the 25 ml sample to an Erlenmeyer flask.
5. Read the burette to record the starting level of thiosulfate solution (in mL) under the “start point” in the calibration table below. Note that the burette reads in 0.1 mL increments.
6. Begin titrating with thiosulfate solution until the color of your sample begins to fade to light yellow. ***IMPORTANT: As the color of your sample begins to fade, you must proceed slowly with the titration so that you don’t over-shoot the minimum amount of thiosulfate needed to complete the titration.***
7. When the color of your solution has faded to light yellow, add 5 drops of starch solution. The sample will become dark blue. This will make it easier for you to see the color change that will signal the completion of the titration.
8. Continue the titration ***slowly***, swirling the flask the whole time, until the solution becomes colorless. Put a white index card under the flask to help determine when the solution becomes colorless. This is the end point. It is important that you not overshoot. Titrate just enough thiosulfate to turn the sample colorless.
9. Record the final level of the thiosulfate solution in the burette (to the nearest 0.1 mL) under the “end point” in the calibration table.
10. Subtract the “start point” from the “end point” to get the total mL of thiosulfate used to turn the sample colorless, and record the value in the table.
11. Repeat the procedure with another 25 mL of calibration sample, starting at Step 3 above. This will give you a second calibration measurement. Record the results in the table below.
12. Average the results of both calibration measurements to determine the average milliliters of thiosulfate required to titrate the oxygen-saturated sample. You will use this value as part of the calculation for determining the oxygen content in your unknown seawater samples.

Oxygen Calibration Results

Calibration	Water Temp (^{0}C)	Saturation Oxygen (mL/L)	Start Point (mL)	End Point (mL)	Total mL thio-sulfate used (end point minus start point)
1	________	__________	__________	_________	__________
2	________	__________ *(use this value in the equation on the next page)*	__________	_________	__________
				Average =	__________ *(use this value in the equation on the next page)*

Having established your calibration standard, you are now ready to determine the dissolved oxygen levels in for your unknown samples. These samples, like the calibration sample, have already had the oxygen in them "fixed" for you (in other words, the oxygen in the water is attached to another molecule that you will be able to measure using titration). To determine the amount of dissolved oxygen in these unknown samples, **repeat the procedure above from <u>Step 3 through Step 11</u>** for each of the unknown samples, entering your data in the table below.

Oxygen Results: Unknown Samples

	Start Point	End Point	Total mLs of Thiosulfate used	Oxygen Content (mL/L)
Unknown 1 (lagoon surface)	___________	___________	___________	___________
Unknown 2 (lagoon deep)	___________	___________	___________	___________
Unknown 3 (harbor)	___________	___________	___________	___________
Unknown 4 (beach)	___________	___________	___________	___________

Using the titration data, calculate the oxygen content of the four unknown samples with this formula:

$$O_2\ (mL/L) = \frac{[\text{saturation } O_2 \text{ of calibration sample}] \times [\text{mL thiosulfate used for unknown sample}]}{[\text{average mL thiosulfate used for calibration sample}]}$$

Once you are finished, if your instructor has indicated to do so, put your group's oxygen results on the board. Then read the information and answer the questions that follow below. (If your group did not do all four unknown samples, then be sure to copy the missing data from other groups to complete the data table above.)

Interpretation and Questions

Biological factors that affect the amount of dissolved oxygen in seawater are mainly photosynthesis and respiration. Simply stated, <u>photosynthesis</u> carried out by plants and phytoplankton <u>produces oxygen</u>, and so increases dissolved oxygen in the water, whereas <u>respiration</u> carried out by animals, bacteria and other oxygen-using microbes <u>consumes oxygen</u>, and so decreases dissolved oxygen in the water.

$$6CO_2 + 6H_2O + \text{energy} \underset{\text{respiration}}{\overset{\text{photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2$$

Physical factors that affect the amount of dissolved oxygen in seawater include <u>water temperature</u> and <u>sea state</u>, meaning whether the surface of the ocean is calm or rough. Where waves break, they add oxygen to seawater much in the way that an aquarium bubbler lets oxygen diffuse into water by sending bubbles through the water. All other things being equal, large, breaking waves will put more oxygen into the water, whereas a calm ocean surface means that less oxygen will enter the water from the air. Also, cold water holds more dissolved gases, including oxygen, than does warm water, so other things being equal, cold water will generally have more oxygen.

1. Complete the following statements by circling the word *increase* or *decrease* and then finish the statement with a sentence or two.

    a. In an ocean area with many breaking waves, the amount of dissolved oxygen in seawater will probably *increase* *decrease* because…

    b. Near the ocean surface where there are lots of plants and phytoplankton, the amount of dissolved oxygen in seawater will probably *increase* *decrease* because…

    c. In deeper water where little sun penetrates but where animals or microbes may be living, the amount of dissolved oxygen in seawater will probably *increase* *decrease* because…

    d. In areas of quiet, stagnant, or polluted water, the amount of dissolved oxygen in seawater will probably *increase* *decrease* because…

    e. All other things being equal, if ocean water warms up, the amount of dissolved oxygen in the water will probably *increase* *decrease* because…

2. Thinking about your answers above, explain in several clear, detailed paragraphs why you think you found the oxygen results that you did in the four seawater samples. Begin with the sample that had the highest oxygen content, and end with the sample that had the lowest oxygen content.