Dissolved Oxygen

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R.Q. How does the temperature of water effect the amount of oxygen dissolved in a pond?

1 Background info

The amount of dissolved oxygen found in water has many applications, including determining the health and cleanliness of a lake or stream, the amount and type of biomass a freshwater system can support, and the amount of decomposition occurring in the lake or ocean. Water bodies can receive oxygen from the atmosphere and from aquatic plants. All aquatic animals need dissolved oxygen in the water to survive. Aquatic animals are able to breathe the dissolved oxygen through their gills. Without enough dissolved oxygen, aquatic animals will suffocate from not having enough oxygen. Low levels of oxygen can be caused by excess organic materials being decomposed by microorganisms. Additionally, dissolved oxygen levels can fluctuate due to seasonal changes or even throughout the day. Typically, dissolved oxygen levels under $3\frac{mg}{L}$ are of concern and levels under $1\frac{mg}{L}$ are considered hypoxic and usually contain low or no aquatic life.[1]

The temperature of the water is able to affect the amount of oxygen dissolved in water because as temperature changes, so does the kinetic energy of the individual molecules which could allow for oxygen atoms to either stay trapped or get pushed out of the water.

The winkler method is a method that is used to calculate the amount of dissolved oxygen in a body of water. It works by adding reagents that form an acid mixture that is then titrated with a neutralizing compound that causes the color of the mixture to change. The reagents that are used are sodium thiosulfate, potassium iodide and sodium oxide hydroxide mixture, manganese sulfate, and concentrated sulfuric acid. Starch will be used as the indicator.

$$\begin{aligned}
MnSO_4 + 2NaOH &\longrightarrow Mn(OH)_2 + Na_2SO_4 \\
2Mn(OH)_2 + O_2 &\longrightarrow 2MnO(OH)_2 \ (brown\ solid) \\
MnO(OH)_2 + 2H_2SO_4 + 3H_2O &\longrightarrow Mn(SO_4)_2 + 6H_2O \\
Mn(SO_4)_2 + 2KI &\longrightarrow MnSO_4 + I_2 + K_2SO_4 \\
2Na_2S_2O_3 + I_2 &\longrightarrow Na_2S_4O_6 + 2NaI
\end{aligned}$$

To calculate the amount of dissolved oxygen:

V is the volume of thiosulfate $[Na_2S_2O_3]$ used
C is the concentration of the thiosulfate $[Na_2S_2O_3]$ (0.05 mol dm^{-3})
η is amount of mols

$$\begin{aligned}
\eta(Na_2S_2O_3) &= C \times V \\
&= 0.05 \times \frac{V}{1000}
\end{aligned}$$

$$
\begin{aligned}
O_2 &= 2 \times 16 = 32 \frac{g}{mol} \\
amount &= \eta(O_2) \times 32 \frac{g}{mol} \\
\eta(O_2) &= 2\ mols\ of\ I_2 = 4\ mols\ of\ Na_2S_2O_3 \\
\eta(O_2) &= \frac{1}{4} \eta(Na_2S_2O_3)
\end{aligned}
$$

To find the amount of oxygen in grams, we just need to multiply this by 32 $\frac{g}{mol}$.

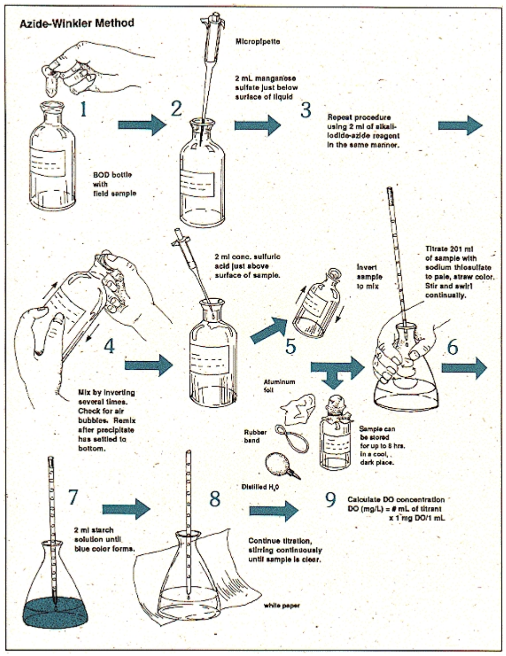


Figure 1: Winkler method

Figure 2: Titration process

1.1 Hypothesis

I believe that as the temperature of the water decreases, the amount of oxygen dissolved in the water will increase. This is because in cooler water, the water molecules move slower, trapping the oxygen in the water, as opposed to warming water where the water molecules move faster, sometimes allowing oxygen to escape the fluid.

2 Method

2.1 Variables

I.V. The temperature of the water that was collected for testing

D.V. The amount of dissolved oxygen in the collected water

Control variable	Why should it be controlled	How can it be controlled
The pond from which the water was collected	Using the same source of water can eliminate other factors that could affect the amount of oxygen dissolved such as fertilizer or aquatic life.	Collecting the water from the same pond (the pond near chemistry class).
The flow rate of the water that was collected	Higher flow rates of water can increase the amount of oxygen dissolved in the water.	Collect water far away from fountains to limit excess dissolved water.
The environment of the where the test was performed	Using different environments for testing the dissolved water can introduce unwanted variables	Perform the testing of dissolved water in the same room (chemistry class).
The method of testing the amount of oxygen dissolved	Using different methods of testing dissolved oxygen can affect the test results	Using the Winkler method to test the amount of oxygen dissolved in the water.
The method of transporting the water collected to being tested	Using different methods of transporting the collected water can introduce different amounts of dissolved oxygen	Using air-tight containers to transport the pond water to the classroom.

2.2 Apparatus

- 2 Air-tight container
- Collected water
- Burrette
- Pipette
- Conical flask
- Dropper

2.3 Chemicals used

- Sodium thiosulfate
- 2ml Potassium Iodide and Sodium oxide hydroxide mixture
- 2ml Manganese sulfate
- Concentrated sulfuric acid
- 2ml Starch

2.4 Safety precautions

- Sulfuric acid is a dangerous substance that must be handled carefully. Use gloves and safety glasses when handling.
- All chemicals must be properly disposed of to limit environmental impacts caused by the chemicals entering the surrounding environment.

2.5 Procedure

1. Rinse the reaction vessel (air-tight container) with the water being tested
2. Fill the reaction vessel to the top to eliminate any oxygen in the container
3. Add the manganese sulfate to the water using a pipette while making sure the tip of the pipette is submerged to limit oxygen exposure
4. Add the potassium iodide and sodium oxide hydroxide mixture to the water also using a pipette
5. Close the reaction vessel (air-tight container) and shake the container
6. Add the concentrated sulfuric acid while shaking until the precipitate disappears
7. Rinse the burette with some of the water being tested
8. Fill the burrette with the sodium thiosulfate solution until it reaches the 0 mark
9. Rinse the pipette with some of the solution in the reaction vessel
10. Using the pipette, add 100ml of the solution into a conical flask
11. Slowing add the sodium thiosulfate solution in the burrette into the conical flask until the solution is straw yellow
12. Add the starch indicator to the solution
13. Add sodium thiosulfate while shaking until the solution is colorless
14. Measure how much sodium thiosulfate was used [2]

3 Results

3.1 Raw data

Amount of water: 200ml, Amount of reagents used: 2ml

	Amount of $Na_2S_2O_3$ used (ml)			
Temperature of water sample (°C)	Trial 1	Trial 2	Trial 3	Average
30.5	4	3	3	3.333
31.5	3.6	2	2.8	2.8
32.5	2	1.6	3	2.2

3.2 Calculations

When the water sample was originally 30.5°C, the average amount of sodium thiosulfate used was 3.33 cm^3. To get the amount of mols reacted, we multiply the volume (dm^-3) by the concentration:

$$\begin{aligned}\eta(Na_2S_2O_3) &= 0.00333 \times 0.05 \\ &= 0.000165 = 1.65 \times 10^{-4}\end{aligned}$$

We know that 1 mol of O_2 is equivalent to 4 mols of $Na_2S_2O_3$. Therefore, the amount of dissolved oxygen in the sample is $\eta(Na_2S_2O_3) \times \frac{1}{4}$[3]

$$\frac{1.65 \times 10^{-4}}{4} = 4.125 \times 10^{-5}$$

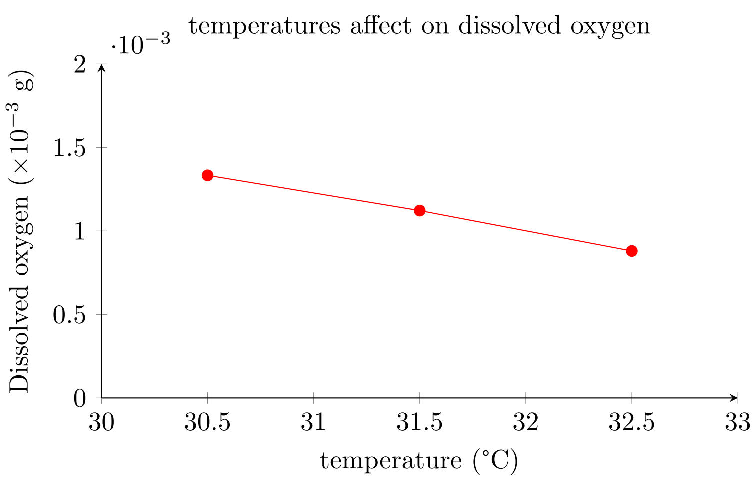
This means the amount of dissolved oxygen in the sample in mols is $4.125 \times 10^{-5} mol$
To get the amount of O_2 dissolved in the sample, we multiply the mols of O_2 by $32\frac{g}{mol}$:

$$\begin{aligned}amount &= 4.625 \times 10^{-5} \times 32 \\ &= 1.32 \times 10^{-3} g\end{aligned}$$

This gives us a final result of $1.32 \times 10^{-3} g$ oxygen dissolved in the initial sample.

3.3 Processed data

Temperature of water sample	Amount of $Na_2S_2O_3$ used (ml)	Moles of $Na_2S_2O_3$ reacted	Moles of O_2	Amount of O_2 (g)
30.5	3.333	1.667×10^{-4}	4.1667×10^{-5}	1.333×10^{-3}
31.5	2.8	1.4×10^{-4}	3.5×10^{-5}	1.122×10^{-3}
32.5	2.2	1.1×10^{-4}	2.75×10^{-5}	8.8×10^{-4}



4 Analysis

From my data, I can see that there is a negatively proportional relationship between the temperature of the sampled water and the amount of dissolved oxygen. When the temperature of the sampled water was 30.5°C, the amount of dissolved oxygen was 0.001333g or 1.333mg. At 31.5°C, the amount of dissolved oxygen was 1.122mg and at 32.5°C, 0.88mg. From this we can see that as the temperature increased, the amount of dissolved oxygen decreased. This means there is a negatively proportional relationship between the temperature and amount of dissolved oxygen.

5 Discussion

From my data, I can see that as the temperature of the sample water increased, the amount of oxygen dissolved in the water decreased. This is because as the water molecules move more freely at higher temperatures, the oxygen is more free to escape into up into the environment. When the temperature decreases, the water molecules well move around less, trapping the oxygen in the water, causing more oxygen to be dissolved in the oxygen.

The amount of dissolved oxygen in the water sample is proportional to how much sodium thiosulfate ($Na_2S_2O_3$) was used, meaning the more sodium thiosulfate used to neutralize the mixture, the more dissolved oxygen in the sample. Since as the temperature of the original sample increased, the amount of sodium thiosulfate used to neutralize the mixture decreased, meaning the amount of dissolved oxygen in the water sample also decreased.

The dissolved oxygen levels found in the various points where the samples were taken were 1.33mg, 1.122mg, and 0.88mg. The amount of tested water was 200ml. Multiplying the amounts of oxygen by 5 gives us dissolved oxygen levels of 6.65 $\frac{mg}{L}$, 5.61 $\frac{mg}{L}$, and 4.4 $\frac{mg}{L}$. Typically, dissolved oxygen levels under 3 $\frac{mg}{L}$ are of concern and levels under 1 $\frac{mg}{L}$ are considered hypoxic and usually contain low or no aquatic life. This means that the pond where the water was sampled have healthy oxygen levels for aquatic life.

6 Conclusion

In conclusion, as the temperature of water increases, the amount of dissolved oxygen decreases. This supports my original hypothesis *"I believe that as the temperature of the water decreases, the amount of oxygen dissolved in the water will increase"*. My results answer my research question as they show a correlation between the temperature of the sample water with amount of dissolved oxygen. My results show that as the temperature increases, the amount of dissolved oxygen decreases.

The amount of dissolved oxygen in the water is negatively proportional to the original temperature of the water sample, meaning that as the temperature increases, the amount of dissolved oxygen decreases. With cooler water, the water molecules have less kinetic energy, meaning they move around less which traps oxygen atoms, resulting in a higher gas solubility. When the water molecules have higher kinetic energies, meaning they move around more, oxygen is more free to escape from the water into the surrounding air, resulting in a lower gas solubility.

However these results do not perfectly represent real world values due to possible inaccuracies in our testing. The sources of water could have been affected by other variables such as sunlight and nearby plants. This could have affected our results, making them inaccurate. Additionally, keeping the water samples for a long period of time before testing the dissolved oxygen could have also affected the results.

7 Evaluation

Weakness/limitation	Impact on result	Suggested improvement
Other factors could have affected the amount of oxygen that was dissolved in the water sample.	Wouldn't directly be testing the independent variable (temperature).	Use more controlled water samples closer together so other factors will affect them less.
There was a long period of time between the sample collection and the testing.	The dissolved oxygen levels could have changed during the period of time before they were tested.	Test the dissolved oxygen levels closer to when the water sample was collected.
Used only 3 different temperatures water samples.	Could cause inaccuracies.	Use a more varied set of temperature.

References

[1] Monica Z. Bruckner. *The Winkler Method - Measuring Dissolved Oxygen*. URL: https://serc.carleton.edu/microbelife/research_methods/environ_sampling/oxygen.html.

[2] Lennox Dublin. *09 Determine the Oxygen Content of a Water Sample*. URL: https://www.youtube.com/watch?v=uF2VgDLh4Kw.

[3] Stewart. *9.1.8 The Winkler Method*. URL: https://www.savemyexams.co.uk/dp/chemistry_sl/ib/16/revision-notes/9-redox-processes/9-1-redox-processes/9-1-8-the-winkler-method/.