

Chemistry 12 IB **Factors Affecting Dissolved Oxygen**

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1 Planning A

1.1 Aim

The aim of this experiment is to investigate one factor that affects the amount of dissolved oxygen in water. More specifically, we aim to establish a relationship between the pH of a sample of water and the resulting level of dissolved oxygen, and analyze and explain any observed trends.

1.2 Hypothesis

We expect the concentration of dissolved oxygen in water to change noticeably by varying its acidity. This change occurs due to the number of bacteria in the solution. At room temperature, bacteria can flourish only within a small range on the pH scale. If the pH of the sample is outside this range, the number of bacteria in solution drops dramatically. This is further compounded by the fact that bacteria are extremely sensitive to even minute pH changes.

How does the number of decomposing bacteria in the water sample affect its oxygen concentration? Bacteria are responsible for decomposing organic material. This process requires oxygen which comes from oxygen dissolved in the water. The more bacteria available (resulting from a more favourable pH), the more oxygen consumed by decomposition, hence lowering the oxygen concentration in the water sample. On the other hand, a less favourable pH would decrease the number of bacteria in the sample, reducing the rate of decomposition, thus keeping the O₂ concentration fairly constant. Since we begin with water saturated with oxygen (9 mg/L), we expect the oxygen concentration to be around this value.

1.3 Variables

Independent – pH of sample → volume of acid added to the weak base

Dependent – Concentration of “available” oxygen

Intermediate – Number of decomposing bacteria

Controlled – Number of ions in solution, temperature, light, turbulence and exposure area

2 Planning B

2.1 Materials Required

1. Na_2HPO_4 powder
2. Oxygenated water
3. 0.5 M standard HCl
4. Standard NaCl (not table salt)
5. Beakers (7), Erlenmeyer flasks, graduated cylinders
6. Balance
7. Buret
8. 25-mL pipet and suction bulb
9. Standard sodium thiosulphate solution of known concentration ($[\] \approx 0.005 \text{ M}$)
10. Potassium iodide powder
11. Starch indicator solution
12. 6 M sulfuric acid (500 mL)

2.2 Procedure

Part I – Preparation

1. Wash and prepare seven identical beakers. Each beaker must have a minimum capacity of 100 mL, and must all have the same exposure area.
2. Using a precise graduated cylinder, add the indicated volumes of 0.05 M Na_2HPO_4 , 0.1 M HCl and 0.1 M NaCl as shown in Table 1. The number of ions in solution is kept constant by the addition of Na^+ and Cl^- ions.
3. For beaker #1, add 75 mL (measure using graduated cylinder) of oxygenated H_2O just to keep the volumes constant at 100 mL.
4. Store the beakers in a cool (constant temperature) and dry place, away from any direct sources of heat or light.

Beaker #	Na_2HPO_4 (mL)	HCl (mL)	NaCl (mL)
1	25	–	–
2	75	–	25
3	75	5	20
4	75	10	15
5	75	15	10
6	75	20	5
7	75	25	–

Table 1: Preparation of Water Samples

Part II – Titration

Refer to Appendix A *Water and Water Pollutants* (Procedure A *Determination of Dissolved Oxygen in Water*) for detailed procedures to determine oxygen concentration by standard titration. Note that the concentration of sodium thiosulphate solution is different from that specified in Appendix A.

$$[\text{Na}_2\text{S}_2\text{O}_3] = 0.00272 \text{ M}$$

The detailed procedures may be summarized as follows: “Available” oxygen will be determined by an iodine/thiosulphate method. An excess of potassium iodide will be added to the acidified water

sample. Oxygen (or other oxidizing agents) will oxidize a portion of the iodide ion to elemental iodine. The elemental iodine (actually, triiodide ion I_3^-) thus produced will be determined by titration with standard sodium thiosulphate solution, using starch as indicator.

It is important to perform the titration quickly as more oxygen enters the sample as it is reduced by I^- into H_2O . Furthermore, drops of sodium thiosulphate from the buret should not be allowed to splash into the flask as this induces turbulence. Swirling the flask by hand can be avoided by using a small, automatic magnetic stirrer (keep stirring speed constant between samples), which maintains the same turbulence level for all water samples.

3 Data Collection

Attached

4 Data Analysis

The individual calculations for determination of initial pH of each water sample can be found in **Part I** of the attached data analysis sheet. The results are summarized in Table 2.

Beaker #	pH
1	9.6
2	9.9
3	8.0
4	7.6
5	7.4
6	7.1
7	6.9

Table 2: Initial pH of Water Samples

Also see attached Excel worksheet and graph. The formulas used to generate the worksheet are indicated by a comment (see floating call-out) and the procedures outlined in **Part III** of the attached data analysis sheet.

5 Evaluation

On scrutinizing the attached graph, it is evident that there is an unmistakable correlation in between pH levels and oxygen concentrations. We find that the oxygen concentration drops at a pH of about 7.0 and then begins to increase *steadily* as the pH increases. This seems to indicate that the bacteria responsible for decomposition of organic material do not live over a pH of 7.0. As the pH is increased, more and more bacteria die out and the oxygen concentration is maintained at a high level.

These observations are in accordance with our hypothesis. We can also note that the curve of the water samples that were left for 6 days is more pronounced than that of the samples that were left only for 4 days. This indicates that it can take up to 5 days for our samples to reach a pseudo equilibrium state.

We do not have enough data points to draw further generalizations (See procedural improvement 5.2.6). The pink curve (6 days) drops sharply at a pH of about 10.0. This seems to indicate that there is another set of bacteria that thrive at that pH. However, this could be an erroneous data point since we do not have data points greater than a pH of 10.0, and can thus not yield any useful information.

Unpredicted drops in oxygen concentrations are to be expected as there is a high chance for errors to creep into one or two of our titrations, thus skewing our data.

5.1 Errors

Since this investigation is not a quantitative analysis, any minute errors in either procedure or variable control will not show up significantly. We are only interested in spotting relative trends by varying the pH of water samples, and not a precise numerical value. This trend, we find, is conspicuous in the graph. Nevertheless, identification of sources of error is important in the event that a more refined investigation is conducted.

1. **Addition of inadequate amounts of potassium iodide.** Since KI was added without measurement, it is likely that certain solutions may not have received enough. If the amount of oxygen is more than the amount of iodide ion in solution, the amount of elemental iodine obtained by oxidation will not give us an indication as to how much oxygen was present, since iodide ion has now become the limiting reagent.
2. **Magnetic stirrer induced turbulence.** Each titration took about four minutes to complete and oxygen was constantly entering our samples during this period. This is particularly important as oxygen levels are extremely low while performing the titration, since all available oxygen has been reduced on addition of KI. Induced turbulence due to the magnetic stirrer only served to speedup this process.
3. **Warm sulfuric acid.** Although changes in temperature do affect oxygen concentrations, we do not expect this to happen in a matter of minutes. However, temperature changes affect redox reactions and since the reaction involving O_2 and I^- ions is redox, we might have gotten different results for different sets of titrations.
4. **Splashing while titrating.** Although we did take every effort to avoid it, splashing while performing the titration was almost unavoidable. Again, we do not expect splashing to have any considerable impact on oxygen concentrations in such a short amount of time. However, it is important to remember that we are titrating our samples in a *critical* state where all oxygen has been reduced to H_2O . Any turbulence due to splashing will very quickly dissolve oxygen from the surroundings into the samples, thus skewing our data.

5.2 Procedural Improvements

To further emphasize the obtained trends, it may be possible to enhance the procedures involved in this lab a bit more.

1. Disallow O_2 entrance into the solution, by say, stoppering the beakers containing the samples. However, it is important to make sure that there is always adequate O_2 for decomposition to proceed. To overcome this problem, we could bubble a fixed amount of O_2 into each solution every day.
2. Add a small amount of organic material into the water samples (e.g. a few drops of sewage, a tiny piece of apple or a fistful of earthworms) to render the trends more pronounced. In our current set-up, extremely favourable pH levels promote bacteria growth so quickly that there is not much organic matter left in the sample for the bacteria to decompose. This makes the trend reach a plateau.
3. Lengthen waiting periods as it takes at least 5 to 6 days for changes in pH levels to affect oxygen concentrations. It is important that the samples reach an “equilibrium” state before they are titrated. If the sitting time is increased, we may be able to see even minute changes in oxygen concentration.
4. Evaporation of water tended to change our pH levels due to the changes in concentrations of ions in solution. Since the favourable pH is within a very narrow range, even a slight change in our recorded pH would skew our results. To prevent evaporation, we need to make sure that any evaporated water is returned by lidding the beakers.
5. Record data over a wider pH range. This will help us find pH values for which very little bacteria survive thus keeping the oxygen concentration at an all-time high.
6. Have more data points to spot trends more accurately. This has the added advantage of being able to answer quantitative questions such as: “What happens when $[H^+]$ is doubled? Tripled? Halved?” and so on. It can also give us a precise indication of the favourable pH range.

6 Conclusion

In this investigation, we have looked at one major factor that either increases or decreases the concentration of dissolved oxygen in water. We have seen that if the registered pH is close to the favourable level (which depends on the type of bacteria and the temperature of the water), bacteria begin to thrive and the oxygen content reduces sharply. This might provoke industries situated near fresh water sources to conduct pH tests before dumping their wastes into the water body. Slight changes in pH levels do not affect aquatic life, but they affect bacteria which in turn affect oxygen levels. As a consequence, anaerobic decomposition may occur which can intoxicate the water body thus killing all organisms and resulting in *eutrophication*.

In addition to pH levels, there are many other factors that can rise or lower oxygen levels such as temperature, light, turbidity (propensity to absorb and scatter light), salinity and turbulence.

Why does this relationship between pH levels and concentration of oxygen bear any importance to our environment? In order to support aquatic life (fish and plants) water must contain not less than a particular minimum amount of dissolved oxygen gas. Fish and underwater plants must obtain

oxygen to live. However, many pollutants, especially industrial wastes which may contain acids and bases, can cause the amount of dissolved oxygen gas to decrease substantially below the level needed to support aquatic life. Since decomposing bacteria are much more sensitive to pH changes than are aquatic creatures, even a slight change in pH in a small region can cause organisms in that region to die rapidly due to insufficient oxygen.

This qualitative relationship between pH levels, bacteria levels and concentration of available oxygen can be useful to aquarists and culture farmers who monitor pH levels to safeguard their plants and fish. It can also benefit technicians at water purification plants who are required to keep pH levels under rigid control.