

# TABLE OF CONTENTS

<b>PART I : THE CHEMISTRY IA GUIDE.....</b>	<b>9</b>
1. GENERAL INTRODUCTION .....	10
2. IA REPORT STRUCTURE .....	11
3. PURPOSE OF SECTIONS .....	13
4. GRADING CRITERIA .....	21
5. FINAL NOTES AND TIPS .....	28
<b>PART II: SEVEN EXAMPLES OF EXCELLENT INTERNAL ASSESSMENT .....</b>	<b>30</b>
1. THE EFFECT OF INCREASING VOLTAGE ON THE RATE OF ELECTROLYSIS OF COPPER (II) SULFATE ....	33
2. TO DETERMINE THE EFFECT OF INCREASING TEMPERATURE ON DISSOLVED OXYGEN IN TAP WATER USING WINKLER TITRATION METHOD.....	46
3. HOW DOES THE RATE OF FERMENTATION IN YEAST VARY BASED ON THE TEMPERATURE? .....	61
4. THE EFFECT OF ELECTROLYTE CONCENTRATION ON THE CELL POTENTIAL OF A GALVANIC CELL.....	73
5. KINETICS OF THE HYDROLYSIS OF ETHYL ETHANOATE .....	87
6. HOW DOES THE TEMPERATURE OF AN ELECTROLYTE AFFECT ITS E VALUE AND THE EQUILIBRIUM POSITION? .....	100
7. WHAT IS THE EFFECT OF TEMPERATURE ON THE CONCENTRATION OF SALICYLIC ACID WITHIN ACETYLSALICYLIC ACID? .....	118



# **PART I**

## **THE CHEMISTRY IA GUIDE**

## 1. GENERAL INTRODUCTION

The Internal Assessment (IA) is a significant component of the overall assessments, composing 20% of your overall grade. In terms of points, it is worth  $0.2 \times 7 = 1.2$  points!<sup>1</sup> Comparing this to the extended essay, which together with TOK is worth 3 points:  $0.5 \times 3 = 1.5$ . Yet, many students spend significantly more time on their EEs than their IAs. According to the subject guides, the investigation itself should take approximately 10 hours, which includes time in discussion with your teacher/supervisor. Following this you should make a writeup of about 6 - 12 pages long. Note that the examiner is not required to read anything beyond 12 pages, so anything past that point is potentially ignored. The 12 pages do not include appendices and bibliography.

The purpose of the IA is to examine your ability to take concepts you have studied theoretically, and apply them to a research question of your choice. You are aiming to show your ability to think critically in terms of planning an experiment, as well as reflecting on the analysis and implications of your results. It is also meant to serve as an application and extension of the laboratory skills you acquired in the labs experiments you have performed as part of the curriculum teaching.

Examiners are looking for demonstration, to various degrees, of the ten qualities identified in the IB learner profile. These qualities are assessed in the more concrete and specific requirements of the IA's assessment criteria, so these should be borne in mind at all times when planning and writing the IA.

Barring unusual circumstances, such as the May 2020 exam season<sup>2</sup>, IAs are marked **internally** *i.e.*, by your teacher, then **moderated** by an external examiner. This has the following implications:

1. **Internal assessment:** Your teacher is the one with the most influence on the grade you are assigned. Ensure that you are writing in line with your teacher's expectations in terms of formatting, notation, page limits, citations, and any other peculiarities. For example, in the procedures/methods section, some teachers prefer a numbered list of steps for easy reading, while others favour prose-style writing in line with scientific journals. In any case where there is a conflict between the advice in this book and your teacher's requirements, follow your teacher's requirements!
2. **External moderation:** This is where a random sample of IAs from each school is sent to an external IB examiner, for independent marking. If the examiner's marking differs from the teacher's by more than two points, the entire cohort is *moderated*, *i.e.*, the grades are adjusted up or down. This means that while you are given a grade by your teacher, there is a chance that this will be adjusted by the IB Organisation (IBO). Note that the adjustment involves an algorithm by the IBO which is not published, and each student's grade may not be moved up or down by the same amount.

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<sup>1</sup> For May 2021 sessions, the assessment weightings have been revised to take into account the removal of the Paper 3 examination. However, the IA weighting remains as 20% of the final grade, with the proportion of Paper 3 going to Papers 1 and 2.

<sup>2</sup> In this season the exams were cancelled and all IAs were marked externally.

In the rest of this document, we will first lay out a recommended structure for the report. This structure is a standard format for scientific writing - most reports, from master's theses to scientific journals, will follow this in some form. However, for many students, this may be the first time they are required to produce a detailed report, so this structure will be of some use as a starting framework. This framework will also include more detailed discussions of what should go into each section, and how to address each of the points required.

Next, we will examine the Assessment Criteria for the IA in detail, which provides a rubric for teachers and examiners to grade the internal assessment. This is freely available in the syllabus of the subject, but quite often students are not directed to this (or they syllabus!). There will also be notes on how to meet the criteria, which include which sections of the report structure serve to address them. Checking your IA against the criteria in the rubric as you write will ensure that you will receive a good result for the internal assessments.

Finally, we will close out with some miscellaneous tips and things to bear in mind, which did not fall under any of the previous sections.

## 2. IA REPORT STRUCTURE

Laid out here is a recommended structure for your IA report, which is similar to the structure of most forms of scientific writing. Following this structure will ensure that you have dedicated sections to address each of the points in the grading criteria, as well as a sensible flow for the report, which is vital for picking up the marks in the "Communication" criteria. The structure is followed by a detailed description on the purpose of each section and what you should aim to cover. As always, if you have a prescribed structure from your teacher, place your content into the relevant equivalent sections of their structure.

### Sample Structure

#### Introduction

- Motivation
- Research question
- Background theory
- Hypothesis

#### Materials and Methods

- Variables
  - Controlled
  - Independent
  - Dependent

- Apparatus/Materials
- Diagram of apparatus
- Methodology
- Risk assessment
  - Safety hazards
  - Environmental hazards
  - Ethical concerns

#### Data Collection and Analysis

- Raw data:
  - Quantitative (tables)
  - Qualitative (notes/observations)
- Example calculation for analysis
- Example uncertainty calculation
- Processed data
  - Tables
  - Graphs and other charts
  - Discussion of results with each chart

#### Conclusion and evaluation

- Conclusion
  - Review of results and comparison to hypothesis
  - Answer the research question as much as possible
  - State if results support the hypothesis.
- Evaluation
  - Comparison of result with literature
  - If conclusion disagrees with hypothesis or literature, why?
  - Limitations of experiment
  - Sources of error
  - Possible improvements

- Future investigations/extensions

Bibliography

Appendix

### 3. PURPOSE OF SECTIONS

#### Introduction

The introduction serves to lay the background and the context of the investigation, both in terms of the scientific understanding, as well as the reasons that you are investigating the particular experiment.

The motivation subsection states the personal reason you chose this topic. Perhaps it is related to one of your hobbies, or it drew your interest when you learnt about it through your course or investigations. Keep this section short: no longer than one paragraph! You do not need to tell a long story. The personal interest is only one small part of the personal engagement criteria. For example, you may say something like,

*“I regularly take vitamin supplements in the form of effervescent tablets. I was interested in how the mixing of the tablet with water could produce gas so quickly, and so wished to investigate the rates of reaction between the ingredients causing the release of  $CO_2$ ”*

would suffice.

Dedicate a subsection to your research question: the explicit statement of the research question is a concrete criteria which is easily achieved. Make sure it is expressed as a question, such as,

*“How does raising the concentration of  $Cl$  in the reaction with  $AgNO_3$  affect the amount and rate of precipitate production?”*

For more information on how to choose your research question, see the “Choosing Your Research Question” in the final tips section.

Background theory is where you will lay out the theoretical information required for analysing and understanding the experiment. This should be quite a lengthy section, typically spanning about two pages, as you will need to include a summary of the key concepts of the theory, and how they apply to the specifics of the experiment. For example, if you were conducting a kinetics experiment, you would describe the principles of reaction rates and the rate expression, the particular chemical reaction you are investigating, and how its molecularity and mechanism may be a predictor of the rate expression. You would likely wish to go into particulars of how to calculate the order of reaction and activation energy from the experimental data which you intend to collect, with the relevant equations and manipulations. In this part, use general formulas and equations, rather than the data you have generated. Putting the data into the calculations should be left for the data analysis section.

Lay out your hypothesis clearly, in terms of what you expect to find, together with the reasoning. This may be based on a particular formula from literature, derived from formulas from different

sources, or based off everyday observation and intuition. Remember to state the expected results and your expected general answer to the research question, *e.g.*,

*“From the proposed mechanism of the reaction, I would expect the reaction to be first order with respect to NaOH. Therefore, I would expect a linear increase in the rate of reaction as the concentration of NaOH increases until I reach the point where the surface area of the carbonate becomes the limiting factor”.*

## Materials and Methods

Lay out your variables and classify them as either **controlled** (what you will keep constant throughout the experiment), **independent** (what you will intentionally vary), and **dependent** (what you measure to change due to varying the independent). It may be useful to use a table such as the following:

Variable	Type	Reason	How to control
Temperature	Independent	The rate constant is dependent on temperature. Measuring the rate of reaction at different temperatures allows the calculation of activation energy	Use different temperature settings on the water bath and ensure the equipment has reached the thermal equilibrium before beginning the reaction.
Surface Area of marble chips	Controlled	The surface area of the solid reactant affects the rate of reaction.	Try to use marble chips of approximately the same size.

Note that in the example of the controlled variable, the surface area of the marble chips, we are unable to fully control the surface area since there will be natural variability in the materials. This is worth noting as a source of error/uncertainty, and doing so will demonstrate both reflection on experimental limitations, and personal engagement.

Apparatus/Materials is a somewhat optional section; a well-detailed procedure would include all the information here. However, it can be useful to state the concentrations of solutions and types of chemicals involved in the reaction. If you have a series of solutions of different concentration, you can also lay out how these different concentrations were prepared in this section rather than in methodology if you wish.

A diagram of the apparatus and experimental setup is very useful both in helping the reader to visualise the experiment, as well as save on text in the procedure section. You can either draw your own diagram of the experiment, or as is much easier these days, take a photo of the experiment as you are performing it, and annotate it appropriately.

Lay out the process step-by-step in the methodology. You can either use a numbered list of steps (preferred about 90% of the time), or describe the procedure in prose. Remember to detail which trials are repeated, in order to ensure that you have collected sufficient data (*“sufficient relevant quantitative and qualitative raw data”*). Usually, if you are plotting a trend you would need at least





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Note the inclusion of the absolute uncertainty in the headers of the table. If the uncertainty of each reading is different, you will need additional columns to place the specific uncertainty next to each datum. If you have a very large amount of data due to multiple trials and runs, you may choose to put this table in the appendix, and place a summary table in the raw data section, which could include just the averaged values. If you do, state that the raw data has been placed in the appendix.

In this section, also include qualitative results, describing any observations, such as

*“The colour of the solution was observed to change from blue to orange but became colourless after 10 minutes”, “Trial 1 did not show significant reaction”, or “the osmotic tubing ruptured in trial 5 so the results could not be obtained”.*

Qualitative observations will give support and rationale for discarding data points which may be outliers, or just missing.

Include an example calculation for analysis: this is simply an example calculation you made for one of the trials, written out step-by-step in detail. For example:

$$\begin{aligned} \text{average volume of titre} &= \frac{\text{trial 1} + \text{trial 2} + \text{trial 3}}{3} \\ &= \frac{0.24 + 0.25 + 0.21}{3} = 0.233\text{ml} \end{aligned}$$

$$\text{moles HCL} = \text{conc. HCL} \times \text{vol. HCL} = 0.1 \times 0.233 = 0.0233 \text{ mol}$$

$$\text{conc NaOH} = \frac{\text{mol NaOH}}{\text{vol NaOH}} = \frac{0.0233}{0.025} = 0.932 \text{ mol dm}^{-3}$$

All other calculations can then be presented in the analysis table without working in the processed data tables. Use your spreadsheet software, such as Excel, to perform the calculations on the data easily, so you do not have to spend the time to do so manually.

You will also need to do an example uncertainty calculation. This is presented in the same way as the example calculation. The uncertainties should be calculated according to the principles in Topic 11: Measurement, Data Processing, and Analysis. An example would be:

$$\text{abs. uncertainty of ave vol} = \frac{\sum \text{abs. uncertainty of trials}}{3} = \frac{0.01 + 0.01 + 0.01}{3} = 0.01$$

variability of trials greater than calculated abs uncertainty: largest variability taken as uncertainty:

$$0.233 - 0.21 = 0.023$$

$$\% \text{ uncertainty of ave vol} = \frac{\text{abs unc.}}{\text{value}} \times 100 = \frac{0.023}{0.233} \times 100 = 9.8\%$$

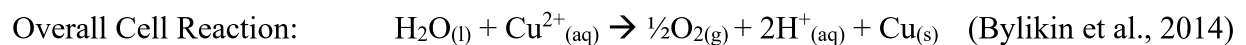
$$\% \text{ uncertainty of moles. HCL} = \% \text{ unc. conc HCL} + \% \text{ unc. vol HCL} = 1\% + 9.8\% = 10.8\%$$

# **1. THE EFFECT OF INCREASING VOLTAGE ON THE RATE OF ELECTROLYSIS OF COPPER (II) SULFATE**

Author: Marco Buttigieg  
Moderated Mark: 23/24

The main goal of this investigation was to determine the effect of increasing voltage on the number of moles of hydrogen ions produced in the electrolysis of copper (II) sulfate with inert graphite electrodes. This was done by creating an electrolytic cell and performing the electrolysis at various voltage settings while recording the change in pH of the solution.

Electrolytic cells are a type of electrochemical cell that utilizes electrical energy to drive a non-spontaneous chemical reaction in which electrons are transferred from one chemical species to another. Electrolytic cells consist of the battery or power source, wires, an electrolyte solution, and two electrodes: negative (cathode), where the reduction half-reaction occurs and positive (anode), where the oxidation half-reaction occurs. The two half-reactions combine to form the redox reaction that occurs in the cell (Bylikin et al., 2014). In the electrolysis of copper (II) sulfate with inert graphite electrodes, an electric current is driven through a  $\text{CuSO}_4$  solution via the graphite electrodes causing the following reactions:



The rates at which the products of this reaction are produced are dependent on a multitude of factors. The factor that was selected to be the independent variable for this experiment was voltage. Measured in volts, the power source of the electrolytic cell was set to various voltage settings (3V, 6V, 9V, 12V, 15V) to provide the different voltages to the cell.

Voltage is related to current through Ohm's Law, which states that the current (I) of a circuit is equal to voltage (V) divided by resistance (R).

The current of the circuit can be multiplied by the duration of the electrolysis (t) to find the electrical charge (Q) of the circuit. The two relations are as shown below:

$$\text{Ohm's Law: } I = V / R \quad \text{Electrical Charge: } Q = I \times t \quad (\text{Milikan and Bishop, 1917})$$

The charge of a circuit is related to the number of moles of electron flowing through it by Faraday's constant,  $96500\text{C} / 1\text{mol e}^-$ . According to Faraday's first law of electrolysis, the mass of an element deposited during electrolysis is directly proportional to the charge passing through during the electrolysis (Bylikin et al., 2014).

The dependent variable selected to measure this change is the moles of hydrogen ions produced by the electrolysis. As hydrogen ions are a product of the reaction, their concentration in the electrolyte solution is a good indicator of how far the reaction progressed. At the anode, hydrogen ions were produced via the oxidation of water molecules. First, the pH of the electrolyte solution was measured before and after the electrolysis performed using a Vernier pH

probe connected to a computer with Vernier Logger Pro 3.15 software that processes and displays the pH value. The pH, power of hydrogen, is a measure of the hydrogen ion concentration in a solution by the relation:

$$[\text{H}^+] = 10^{-\text{pH}} \quad (\text{Bylikin et al., 2014})$$

A hydrogen ion concentration in mol/L was calculated for both before and after. The initial concentration was subtracted from the final concentration to find the concentration change caused by the electrolysis. The concentration change of hydrogen ions was then converted to the number moles of hydrogen ions produced by the electrolysis. The results of the experiment were then analyzed to observe trends in the data and answer the proposed question.

In the summer when I 12 years old, I was trying to get home from the park when I heard thunder, and while walking home I was struck by lightning. Miraculously, I wasn't seriously injured and had a quick recovery in the hospital. Ever since then, anything to do with electricity has intrigued me, as I always sought to fully understand the lightning that hit me on that summer afternoon. Learning about electrochemistry, specifically about electrochemical cells allowed me to connect one of my favourite subjects to the electricity I am so fascinated by. Being able to manipulate a chemical reaction with electricity seemed like it would make for an interesting investigation, so I decided to conduct an electrolysis.

### **Research Question:**

How does changing the voltage in an electrolytic cell affect the production of hydrogen ions in the electrolysis of copper (II) sulfate with inert electrodes?

### **Hypothesis:**

If voltage is increased, then more moles of hydrogen ions will be produced because according to Ohm's law, if voltage increases and resistance stays constant, current will also increase. Increasing current will allow more charge to pass through the circuit, thus producing more moles of hydrogen ions.

**Table 1: Controlled Variables**

<b>Controlled Variable</b>	<b>Significance of Variable</b>	<b>Method of Control</b>
Time Elapsed	If the electrolysis was left for different durations of time, different amounts of charge would pass through the electrodes, creating varying amounts of product.	Each electrolysis was performed for a duration of $900 \pm 1$ s (15min).
Ions in Solution	Ions with different ionic charge will require different quantities of electrons for a reaction to occur, producing different amounts of product. Different ions also have different electrode potentials and could take preference over the desired reactants.	Each electrolysis was conducted using a $\text{CuSO}_4$ solution, which dissociates into $\text{Cu}^{2+}$ and $\text{SO}_4^{2-}$ ions.
Solution Concentration	Solutions of varying concentrations will allow different amounts of current to pass through it, ultimately changing the amount of product formed.	Each electrolysis was performed using 1 mol/L $\text{CuSO}_4$ solution.
Solution Volume	Differing volumes of solution will contain different numbers of ions in the solution available for reaction, changing the rate of reaction, altering the amount of product produced. Different volumes will also dilute the products to different concentrations, thus making pH measurements inconsistent.	Each electrolysis was conducted with $200 \pm 1$ mL of $\text{CuSO}_4$ solution.
Electrode Composition	Different types of electrodes can be either inert (do not participate in the reaction) or active (participate in the reaction), changing the chemical species produced by the reaction.	Each electrolysis was performed using inert graphite electrodes.
Cell Components Used	Inconsistencies in wiring and in the power source can create discrepancies in the amount of current passing through the apparatus by affecting the resistance of the circuit, ultimately changing the amount of product produced.	Each electrolysis was conducted using the same alligator clips, wiring, ammeter, and power source to maintain a constant electrical resistance
Measuring Equipment Used	Inconsistencies in the measuring equipment used would cause different concentrations of the solution to be created, different currents measured, and differences in measured pH.	The $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ solute was measured using the same electric balance for each solution. The same ammeter was used to measure current for all trials. Each solution's pH before and after electrolysis was measured using the same pH probe.

### **Materials and Apparatus:**

- 1248.50g Copper (II) Sulfate Pentahydrate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) (Ward's Science)
- 4550mL Distilled Water
- 2 Graphite Electrodes
- 4 Alligator Clip Wires
- Elenco Precision Battery Eliminator Model XP-100 ( $\pm 5\%$ ) (Maximum Current - 1A )
- Globe EDM-05 Analog Ammeter ( $\pm 5\text{mA}$ )
- 500mL Beaker
- Vernier pH Probe ( $\pm 0.01$  pH)
- Vernier Logger Pro 3.15 Software
- Laptop Compatible with Vernier Logger Pro 3.15 Software
- Electronic Balance ( $\pm 0.01\text{g}$ )
- Weighing Boat
- Glass Stirring Rod
- 200mL Graduated Cylinder ( $\pm 1\text{mL}$ )
- Timer ( $\pm 1\text{s}$ )

### **Procedure:**

1. Vernier Logger Pro 3.15 Software was downloaded and installed on the laptop
2. Vernier pH Probe was set up and connected to the computer as stated in the user manual
3. The components of the electrolytic cell were assembled
  - i) One end of an alligator clip was attached to the positive (red) output of the battery eliminator, with the other end attached to the top of a graphite electrode that will act as the anode
  - ii) One end of an alligator clip was attached to the negative (black) output of the battery eliminator, with the other end attached to the top of a graphite electrode that will act as the cathode
  - iii) One end of an alligator clip was attached to the positive (red, 500) terminal of the ammeter
  - iv) One end of an alligator clip was attached to the negative (black, -) terminal of the ammeter
  - v) The battery eliminator was plugged into a wall outlet
4. 200mL of 1mol/L  $\text{CuSO}_4$  solution was prepared
  - i) 182mL of distilled water was measured in a 200mL graduated cylinder and poured into the 500mL beaker
  - ii) 49.94g (0.2mol) of solid  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  was measured on an electronic balance using a weighing boat
  - iii) The  $\text{CuSO}_4 \cdot \text{H}_2\text{O}$  was poured into the beaker of distilled water and stirred with a glass stirring rod until dissolved
5. The pH of the solution before electrolysis was measured and recorded using the Vernier pH probe

**2. TO DETERMINE THE EFFECT OF INCREASING TEMPERATURE ON  
DISSOLVED OXYGEN IN TAP WATER USING WINKLER TITRATION  
METHOD.**

Author: Shreyansh Jain  
Moderated Mark: 23/24



**Research Question:** To determine the effect of increasing temperature on dissolved oxygen in tap water using Winkler Titration method.

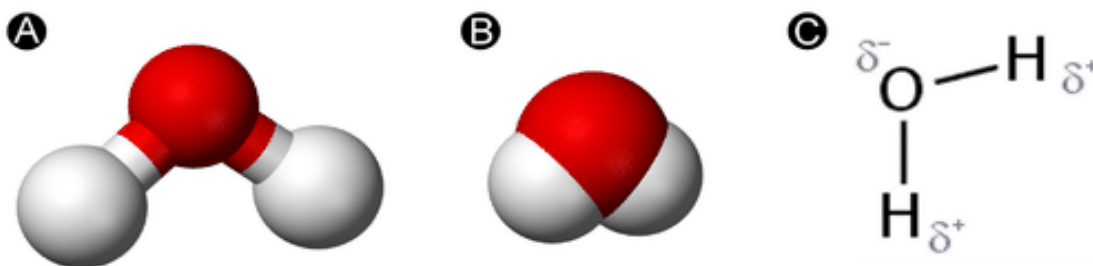
## Introduction

Global warming in the present time has taken temperature to the highest level. This rise in temperature had led to high mortality rate of organisms. I possess a major interest in Ecology so I frequently read articles related with these issues. A current article I read underlined the concern of increasing mortality rate of salmon due to extreme increase in temperature of water. The article highlighted the deaths of various Alaskan salmon. It also stated that around 850 unspawned salmon died due to heat stress<sup>3</sup>. Well, I was familiar with the fact that the metabolic reaction within the living body is affected by the temperature. Although, the increase in temperature was the reason behind the mass deaths but I was willing to know about the other factors also. Later in the article it was clearly mentioned that “Physiologically, the fish can’t get oxygen moving through their bellies”, and when I researched upon it, I discovered that one of the major factors was the depletion of oxygen level in water due to high temperature. This increased my curiosity level of determining the relation between dissolved oxygen level and temperature.

## Background Information

Dissolved oxygen is the amount of free oxygen present in water which is accessible to living aquatic species.<sup>4</sup> Water is a V-shaped molecule in which oxygen is the central atom joined (bonded) with two hydrogen atoms. Due to the difference in electronegativities of hydrogen and oxygen atoms it is a polar covalent molecule. Partial negative charge ( $\delta^-$ ) is present on the oxygen atom because of its higher electronegativity while the partial positive charge ( $\delta^+$ ) is present on the hydrogen atom.

5



<sup>3</sup> <https://edition.cnn.com/2019/08/16/us/alaska-salmon-hot-water-trnd/index.html>

<sup>4</sup> [https://www.lenntech.com/why\\_the\\_oxygen\\_dissolved\\_is\\_important.htm](https://www.lenntech.com/why_the_oxygen_dissolved_is_important.htm)

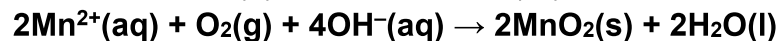
<sup>5</sup> [https://chem.libretexts.org/Bookshelves/Introductory\\_Chemistry/Book%3A\\_Introductory\\_Chemistry\\_\(CK-12\)/15%3A\\_Water/15.01%3A\\_Structure\\_of\\_Water](https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Book%3A_Introductory_Chemistry_(CK-12)/15%3A_Water/15.01%3A_Structure_of_Water)

Figure 1. Molecule of water visualized in 3 distinct ways: (A) ball-and-stick model (B) space-filling model and (C) structural formula with partial charges.

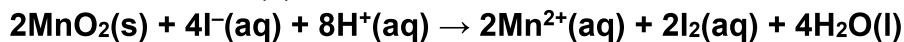
### Winkler Method.

Winkler method calculates the Biochemical Oxygen Demand (BOD) in water by redox titrations. The following sequence of redox reactions is based upon this method.<sup>6</sup>

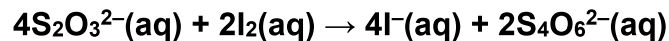
1. Initially  $\text{MnSO}_4$  is added to fix the dissolved oxygen in water and after the reaction in basic medium, Mn(II) oxidizes into Mn(IV).



2. Mn(IV) oxidizes iodine ion ( $\text{I}^{-}$ ) into  $\text{I}_2$  in acidic medium.



3. The iodine which is produced is titrated with sodium thiosulfate.



In these sequences of reactions, we can see that for every **1 mole of  $\text{O}_2$**  in the water, **4 mol of  $\text{S}_2\text{O}_3^{2-}$  are used.**

Variables

Independent variable:  $250\text{cm}^3$  tap-water temperature

- Electrical water maintains the temperature at  $35^\circ\text{C}$ ,  $45^\circ\text{C}$ ,  $55^\circ\text{C}$ ,  $65^\circ\text{C}$  and  $75^\circ\text{C}$  and is checked via thermometer before adding the reactants.
- The experiment was carried out in an air-conditioned room to maintain the constant room temperature and was measured by thermometer in middle of the experiment.

Dependent variable: Amount of dissolved oxygen in tap water

- It will be calculated by Winkler's method.
- We can calculate the amount of oxygen in tap water by making use of the reacted volume of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  (hydrated sodium thiosulfate) in titration.

Controlled Variables

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<sup>6</sup> <https://pdfs.semanticscholar.org/8a69/46d53088e4c66086c48ef8ff9c8451dbd2f4.pdf>

Controlled Variables	How can we control it?	Why should we control it?
The time for which the samples of water were being heated	The water samples were put into the water bath for 300 seconds at the selected temperatures and the time was determined by a stopwatch	Dissolved oxygen in water samples may get affected when provided with different heating time.
Volume of Alkaline KI and MnSO <sub>4</sub> added	2cm <sup>3</sup> of 0.6 moldm <sup>-3</sup> alkaline KI and 2cm <sup>3</sup> of 0.6 moldm <sup>-3</sup> MnSO <sub>4</sub> and was been added to the samples.	If there is any difference in the volume of alkaline KI and MnSO <sub>4</sub> then we cannot predict the number of moles of iodine consumed in the process of titration. Due to this we will not be able to determine oxygen content in the samples by stoichiometric coefficients.
Controlled Variables	How can we control it?	Why should we control it?
Molarity of Alkaline KI and MnSO <sub>4</sub> added	0.6 moldm <sup>-3</sup> alkaline KI, 0.6 moldm <sup>-3</sup> MnSO <sub>4</sub> and 0.6 moldm <sup>-3</sup> KOH were being used.	Any difference in the concentration of Alkaline KI and MnSO <sub>4</sub> would lead to identical results as difference in their volume.
Introduction of concentrated sulfuric acid	Using 2 cm <sup>3</sup> Pasteur glass pipette, 2 cm <sup>3</sup> concentrated sulfuric acid has been added.	Oxygen concentration could be affected by the difference in total volume, in order to avoid any difference, the similar volume has been used across each sample.
Addition of starch to the water samples.	1.2g of starch was added into the solution.	To maintain the same color intensity of solution to prevent differences in color subjectivity.
Amount of water being used	250.0cm <sup>3</sup> of water is being used and was measured by measuring cylinder.	If water of different volumes were taken into consideration then it could impact the count of dissolved oxygen moles in water & further influence its concentration. Apart from this, it could also impact the amount of heat being absorbed by distinct water samples.
Samples of water that are being used	Tap water is being taken into consideration.	Tap water samples are being used to know the different concentrations of dissolved oxygen content.
Environmental Pressure	Experiment was conducted under constant pressure of 100kPa with fixed room temperature being set by an air conditioner and also by making sure that the doors and windows of the labs are closed.	As the pressure increases, oxygen solubility also increases So, the pressure was kept constant to eliminate factors apart from temperature influencing oxygen solubility in water.

## Method

The method is taken from the method which has been applied by the University of Idaho and Montana State University. Some changes have been made to overcome certain problems.

- We used Erlenmeyer flasks of 250cm<sup>3</sup> because of lack of availability of BOD bottles (Erlenmeyer flasks are been considered as the best alternatives of BOD bottles). Most of the time the flasks were kept closed during the experiment.
- Reagent concentrations were changed to 0.6 moldm<sup>-3</sup> alkaline KI, 0.6 moldm<sup>-3</sup> MnSO<sub>4</sub> and 0.06 moldm<sup>-3</sup> sodium thiosulfate. These concentrations gave the most suitable results, as many other concentrations failed to give the desired changes in the final value after titration and color.
- As an original reagent, in place of alkali iodide-azide, alkali potassium iodide was used.

## Preparing Standard Solutions and setting apparatus for titration

1. On a chemical balance, measure 25.33g of hydrated manganese sulfate ( $\text{MnSO}_4 \cdot \text{H}_2\text{O}$ )
2. Transfer this weighted manganese sulfate into  $250\text{cm}^3$  volumetric flask through a funnel and wash it with distilled water and fill the flask to the mark with distilled water.
3. Make sure that manganese sulfate is fully dissolved. This is  $0.6\text{ moldm}^{-3}$  standard solution of  $\text{MnSO}_4$  (manganese sulfate).
4. Repeat the steps from 1 to 3 with 24.9g KI (potassium iodide) and 8.4g of KOH (potassium hydroxide) added to a different volumetric flask to prepare  $0.6\text{ moldm}^{-3}$  of KI and KOH respectively.
5. Repeat the steps from 1 to 3 for 3.72g of hydrated sodium thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ ) in order to form  $0.06\text{ moldm}^{-3}$  sodium thiosulfate solution.
6. For titration, set  $50\text{cm}^3$  burette on clamp stand.
7. Wash the burette with  $\text{Na}_2\text{S}_2\text{O}_3$  (sodium thiosulfate) and fill it with  $0.06\text{ moldm}^{-3}$  of sodium thiosulfate solution.

## Heating water samples

8. Using a measuring cylinder, take  $250\text{cm}^3$  tap water and transfer it in the Erlenmeyer's flask. Don't forget to close the lid.
9. Half fill the electrical water bath with the water sample (tap water) and set the temperature to  $25^\circ\text{C}$ . Allow the water to heat to the set temperature and use a thermometer to monitor the temperature.
10. Place the flask of water sample in water bath for 300 seconds.
11. Use heat resistant gloves to take out the flask after set time i.e., 300 seconds.
12. Transfer  $2\text{cm}^3$  of manganese sulfate by graduated pipette ( $10\text{cm}^3$ ) to the water sample. Make sure that air does not enter while transferring.
13. Repeat the step 12 with  $2\text{cm}^3$  of alkali potassium iodide.
14. After closing the flask, shake the mixture thoroughly until brown precipitates appears.
15. Add  $2\text{cm}^3$  concentrated sulfuric acid through a pipette. Ensure, no oxygen gets introduced in the sample. Shake the flask so that the precipitate dissolves.



Figure 2:  $250\text{cm}^3$  of water sample

## Titration