**Measurement of system efficiency**

The efficiency of the system was determined by comparison of the theoretical percentage of the sodium hypochlorite formed in the solution using Faraday's law to the percentage of sodium hypochlorite obtained by titration with standard solutions of potassium iodate, sodium thiosulphate and starch as an indicator

**Equipment and materials**

50.00-mL buret, 250-mL volumetric flask, 25.00-mL volumetric pipette, pipette pump, 200-mL or 300-mL Erlenmeyer flask, 10-mL graduated cylinder, 100-mL graduated cylinder, 100-mL beaker, bleach solution , 10% potassium iodide solution (KI), 2.0-M hydrochloric acid solution (HCl), ~0.26 M sodium thiosulfate solution (Na2S2O3), starch solution.

**Discussion**

The concentration of sodium hypochlorite in bleach solutions can be determined by titration using a multi-step method.

In the first step sodium hypochlorite, hydrochloric acid, iodide ion, and starch are combined to form a starch–triiodide complex. In this step there are three reactions that take place:

1. Hydrochloric acid reacts with sodium hypochlorite to form hypochlorous acid

**NaOCl (aq) + HCl (aq) → HOCl (aq) + NaCl (aq)**

1. Hypochlorous acid reacts with iodide when the solution is acidic

**HOCl (aq) HCl (aq) 3I- (aq) → I3- (aq) + 2Cl- (aq) + H2O (l)**

1. Triiodide, I3-, is a dark red complex. A dark blue complex is formed when triiodide is combined with starch.

**I3- + starch→ [I3-] [starch]**

The result of these three reactions is that when sodium hypochlorite is present the starch-triiodide complex is produced. This is useful because the result of these three reactions is the formation of a dark blue complex that has a concentration that is proportional to the amount of sodium hypochlorite in the solution.In the next step, the starch-triiodide product is titrated by sodium thiosulfate to form a colorless solution of iodide, dithionate, and uncomplexed starch

**[I3-] [Starch] + 2S2O32- (aq) → 3I- (aq) + 2S4O62- (aq) + starch**

If iodide is added in excess to the hypochlorous acid then all of the hypochlorous acid will be reacted, forming the dark blue starch-triiodide complex. The hypochlorite acts as a limiting reagent, determining how much triiodide is produced. We can then titrate the triiodide-starch complex with the thiosulfate to determine the concentration of the complex formed. This can then be used to calculate the initial concentration of hypochlorite

**Procedure**

1. **Prepare Sodium Thiosulfate Solution:**

- Obtain 60 mL of sodium thiosulfate solution in a 100-mL beaker. Record its concentration.

- Rinse and fill a 50-mL buret with the solution, ensuring no air bubbles. Record the initial buret level.

2. **Dilute Bleach Solution:**

- Perform a 10-fold dilution of bleach using a 25-mL pipet and a 250-mL volumetric flask. Mix well to ensure homogeneity.

3. **Set Up Titration:**

- Add 25.00 mL of diluted bleach to an Erlenmeyer flask.

- Add 15 mL of distilled water, 20 mL of 10% potassium iodide, and 20 mL of hydrochloric acid to the flask.

- Add 2 mL of starch solution to the flask, turning the solution dark blue.

4. **Begin Titration:**

- Titrate with sodium thiosulfate until the solution turns pale yellow.

5. **Complete Titration:**

- Continue titrating dropwise until the solution becomes clear, indicating the endpoint. Record the final buret volume.

6. **Repeat and Clean Up:**

- Repeat the titration twice more.

- Measure or obtain the bleach solution density.

- Dispose of reagents properly and clean all glassware.

**Results and Calculations**

**Reagent data**

Theoretical percentage of hypochlorite: **5 %**

Density of hypochlorite **1.10 g/mL**

Volume of diluted hypochlorite used in the solution **25.0 mL**

Concentration of sodium thiosulfate **0.26 mol/ L**

Titration data

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | Initial buret reading mL | Final buret reading mL | Volume used mL |
| 1 | 0.00 | 10.60 | 10.60 |
| 2 | 0.00 | 10.58 | 10.58 |
| 3 | 0.00 | 10.55 | 10.55 |

= 10.58 mL

**Calculations**

To calculate the molarity of the sodium hypochlorite solution we use the titration volume, molarity of the thiosulfate titrant, stoichiometry of the reactions, and volume of the sample of diluted bleach solution.

1. Calculate the number of moles of sodium thiosulfate (Na2S2O3) for each titration:

2. The moles of hypochlorite are found from the stoichiometry of the reaction with thiosulfate. The stoichiometry of the equation shows that there are two moles of thiosulfate ion per mole of hypochlorous acid.

Note that the moles of HOCl are equal to the moles of NaOCl and OCl–

**H+ (aq) + HOCl (aq) + 2S2O32- (aq) → 2S4O62- (aq) + Cl- (aq) + H2O (l)**

3. The bleach solution that we titrated was diluted by a factor of 10. Multiply the moles of the   
hypochlorous acid by 10 to take this factor into account. This will give the number of moles of HOCl in 25.00 mL of undiluted bleach.

1. The mass of the NaOCl is found from the moles of NaOCl and the molar mass of NaOCl:
2. The mass of 25.00 mL of bleach solution is found from its density and the volume (25.00 mL):
3. The sodium hypochlorite mass percentage is found from the mass of sodium   
   hypochlorite in 25.00 mL and the mass of the 25.00 bleach solution:
4. System efficiency is calculated from the and the theoretical percentage of NaOCl from Faraday’s law