Analysis of OxiClean: An Interesting Comparison of Percarbonate Stain Removers

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We have created a general chemistry experiment that involves a well-known household product, OxiClean. The popularity of these oxygen-containing laundry detergents has increased in recent years. The chemistry of these sodium percarbonate or sodium perborate multipurpose stain removers has been described previously *(1)*. Several different brands of these stain removers utilize a solid mixture of sodium carbonate and sodium percarbonate, $2Na_2CO_3{:}3H_2O_2$. While the label on the OxiClean container states that it contains this homogeneous mixture, no actual percentage of each ingredient is listed.

An investigation into this area was initiated to determine if simple experimental methods could be used to calculate the percentages of each component of this granular mixture.

$$\text{mass}\begin{pmatrix}\text{Oxi}\\\text{Clean}\end{pmatrix} = \text{mass}\begin{pmatrix}\text{sodium}\\\text{percarbonate}\end{pmatrix} + \text{mass}\begin{pmatrix}\text{sodium}\\\text{carbonate}\end{pmatrix}$$

$$\text{mass}\begin{pmatrix}\text{Oxi}\\\text{Clean}\end{pmatrix} = \text{mass}\left(2Na_2CO_3{:}3H_2O_2\right) + \text{mass}\left(Na_2CO_3\right)$$

A **B** **C** **D**

This article reports a simple method to calculate the actual masses of **B**, **C**, and **D** that are in close agreement with the manufacturer's values. This study focused on the percarbonate-based stain removers since the percarbonate could be heated to produce additional sodium carbonate. Thus, after five minutes of heating the OxiClean, we could obtain pure sodium carbonate. Upon heating:

$$\begin{pmatrix}\text{Oxi}\\\text{Clean}\end{pmatrix} \rightarrow \begin{pmatrix}\text{sodium}\\\text{carbonate}\end{pmatrix} + \text{water} + \text{oxygen}$$

$$2Na_2CO_3{:}3H_2O_2(s) + xNa_2CO_3(s) \rightarrow (2+x)Na_2CO_3(s) + H_2O(g) + O_2(g) \quad (1)$$

Typical Student Experimental Procedure: Thermal Decomposition of OxiClean

The original formula of OxiClean[1] (2.191 g) was added to a Pyrex test tube (20 mm × 150 mm) that was held at a 45° angle with a test tube clamp. The OxiClean powder was spread across 3–4 cm of the lower end of the test tube before heating strongly for 3–5 minutes with a Bunsen burner. Water droplets could be observed within 30 seconds of heating. The mass of the resulting white solid was 1.723 grams. The sample was reheated for an additional 3 minutes, but the mass of the white solid was unchanged.

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Hazards

Care should be taken during the heating process as a small quantity of solid material from the test tube may spatter while heating. Sodium percarbonate is irritating to mucous membranes, eyes, and skin. Students should avoid contacting the solid OxiClean with their hands. Hydrochloric acid and sodium hydroxide are corrosive and should be handled with care. Appropriate safety goggles should be worn when working with all chemicals described in this experiment.

Calculations

The decrease in mass upon heating results from the loss of water vapor and oxygen gas, which equals the mass of the hydrogen peroxide present in the initial OxiClean sample.

$$\text{mass}(\text{sample}) - \text{mass}\begin{pmatrix}\text{sample after}\\\text{heating}\end{pmatrix} = \text{mass}\left(H_2O_2\right)$$

$$2.191\text{ g} - 1.723\text{ g} = 0.468\text{ g } H_2O_2$$

Knowing the mass of hydrogen peroxide (**C**) contained in the sodium percarbonate, one can calculate the amount of hydrogen peroxide.

$$0.468\text{ g } H_2O_2 \times \frac{1\text{ mol } H_2O_2}{34.02\text{ g } H_2O_2} = 0.0138\text{ mol } H_2O_2$$

Recognizing the 2:3 mole ratio within the sodium percarbonate compound, we calculated the number of moles of sodium carbonate (**B**) in the original sodium percarbonate contained in the OxiClean sample.

$$0.0138\text{ mol } H_2O_2 \times \frac{2\text{ mol } Na_2CO_3}{3\text{ mol } H_2O_2} = 0.00920\text{ mol } Na_2CO_3$$

Knowing the amount of sodium carbonate (**B**) in the sodium percarbonate, we calculated the mass of the sodium carbonate (**B**).

$$0.00920\text{ mol } Na_2CO_3 \times \frac{105.99\text{ g } Na_2CO_3}{1\text{ mol } Na_2CO_3} = 0.975\text{ g } Na_2CO_3$$

By subtracting the masses of the sodium carbonate (**B**) and hydrogen peroxide (**C**) from the initial mass of the OxiClean (**A**), we obtained the mass of the original sodium carbonate (**D**) that was present in OxiClean.

$$\text{mass}\begin{pmatrix}\text{Oxi}\\\text{Clean}\end{pmatrix} = \text{mass}\left(2Na_2CO_3{:}3H_2O_2\right) + \text{mass}\left(Na_2CO_3\right)$$

A **B** **C** **D**

$$2.191\text{ g} = 0.975\text{ g} + 0.468\text{ g} + \mathbf{D}$$

Therefore, **D** must have a mass of 0.748 g.

These calculations suggest that OxiClean consists of 34.1% sodium carbonate and 65.9% sodium percarbonate. Based on our simple experimental methods, OxiClean contains approximately 21% hydrogen peroxide by mass, which is in close agreement with the company's reported 18%. This slight difference could be attributed to the fact that anhydrous sodium carbonate is hygroscopic and the dehydration may occur upon heating. A small quantity of water may have been present in the original OxiClean sample.

Experimental Evidence for Completion of Reaction 1: A Back Titration

Once cooled to room temperature, 1.330 g of the heated sample was transferred to a 250-mL Erlenmeyer flask where 40.0 mL of 1.00 M HCl was added. The flask was swirled for several minutes before it was heated with a Bunsen burner until the solution just started to boil. Three drops of phenolphthalein indicator solution were added, and the inner walls of the flask were rinsed with 5 mL of distilled water. The contents of the flask were then titrated to the pink endpoint by careful addition of 15.2 mL of 1.00 M NaOH.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2 \qquad (2)$$

$$HCl + NaOH \rightarrow NaCl + H_2O \qquad (3)$$

Back Titration Calculations

Amount of Na_2CO_3

$$1.330\ \text{g}\ Na_2CO_3 \times \frac{1\ \text{mole}\ Na_2CO_3}{105.99\ \text{g}\ Na_2CO_3} = 0.01255\ \text{mol}\ Na_2CO_3$$

Amount of HCl Added in Reaction 2

$$1.00\ \frac{\text{mol HCl}}{\text{L HCl}} \times 0.0400\ \text{L HCl} = 0.0400\ \text{mol HCl}$$

Amount of NaOH Needed To React with Excess acid in Reaction 3

$$1.00\ \frac{\text{mol NaOH}}{\text{L NaOH}} \times 0.0152\ \text{L NaOH} = 0.0152\ \text{mol NaOH}$$

Amount of HCl That Reacted with Total Na_2CO_3 in Reaction 2

$$0.0400\ \text{mol HCl} - \left(0.0152\ \text{mol NaOH} \times \frac{1\ \text{mol HCl}}{1\ \text{mol NaOH}}\right) = 0.0248\ \text{mol HCl}$$

Thus the theoretical amount of original Na_2CO_3 is 0.0124 moles (1.2% error). The actual amount of original Na_2CO_3 present is 0.01255 moles Na_2CO_3.

Further Evidence for Completion of Reaction 1: Gravimetric Analysis

Approximately 2.028 g of the white solid was dissolved in 50 mL of deionized water. An excess (3.426 g of anhydrous calcium chloride was then dissolved in 50 mL of deionized water. The resulting two solutions were then mixed and an immediate white precipitate formed. The precipitate was filtered and then dried in a lab oven for three hours to produce 1.811 g of calcium carbonate in 95% yield.

Comparison of Other Percarbonate Cleansers

As an extension to the initial investigation of OxiClean, this procedure was repeated with several other percarbonate-based stain removers *(2)*. Results for these brands are shown in Tables 1 and 2.

Conclusions

This simple experiment will provide general chemistry students an opportunity to apply their knowledge of basic stoichiometry to solve a relevant, real-world problem. The simple thermal decomposition procedure can be completed in 15 minutes, leaving sufficient time for the analysis of the experimental data in a single 50-minute high school class period. Additionally, if time permits, instructors can even have students perform a back-titration or a gravimetric analysis to provide supporting experimental evidence for the thermal decomposition reaction.

It is especially interesting to note that none of these brands contain the same percentage of sodium percarbonate. Given the popularity of these oxygen-based stain removers, high school and college general chemistry students will undoubtedly enjoy the challenge of analyzing several different brands.

Table 1. Comparison of the Peroxide Concentration in Commercial Stain Removers

Brand Name	H_2O_2 (%)
PowerHouse Organic Oxygen	6.47
Sun Oxygen Wash	13.7
Clorox Oxygen Action	17.6
OxiClean	21.4
Shout Oxy Power	31.4

Table 2. Comparison of the Carbonate and Percarbonate Concentrations in Commercial Stain Removers

Brand Name	Carbonate (%)	Percarbonate (%)
PowerHouse Organic Oxygen	80.1	19.9
Sun Oxygen Wash	57.6	42.4
Clorox Oxygen Action	45.4	54.6
OxiClean	34.1	65.9
Shout Oxy Power	3.41	96.6

Supplemental Material

A student handout is available in this issue of *JCE Online*.

Samples of Percarbonate Based Stain Removers

1. Clorox Oxygen Action Multi-Purpose Stain Remover, The Clorox Company, 1221 Broadway, Oakland, CA 94612.
2. Shout Oxy Power Multi-Purpose Stain Remover, SC Johnson and Son, Inc. Racine, WI 53403-2236.
3. PowerHouse Oxygen All Purpose Stain Remover, Personal Care Products, Inc. Bingham Farms, MI 48025-2463.
4. OxiClean Multi-Purpose Stain Remover, Orange Glo International, Inc. P.O. Box 3998, Littleton, CO 80161.
5. Sun Oxygen Wash All-Purpose Stain Remover, Huish Detergents, Inc. 3540 West 1987 South, Salt Lake City, Utah 84104-4940.

Note

1. The OxiClean that was used in this experiment is known as OxiClean Multi-Purpose Stain Remover (the original formula) and is no longer sold in stores. The OxiClean Multi-Purpose Stain Remover can still be purchased from the company's Web site, *http://www.OxiClean.com* (accessed Feb 2005). In 2004 Orange Glo International launched production of OxiClean known as OxiClean Versatile Stain Remover that contains silicates, detergent, and a proprietary polymer additives. The organic components char upon heating releasing noxious smoke from the test tube. The original formula should be used in this experiment.

Literature Cited

1. McCoy, M. *Chem. Eng. News* **2003,** *81* (3), 17.
2. For additional information on oxygen bleach products, see *http://oxygenbleach.homestead.com/files/* (accessed Jan 2005).