Are They Worth It?: A Spectrophotometric and Volumetric Analytical Comparison of Brand Name vs. Generic Iron Tablets

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Abstract

Two different techniques, spectrophotometric and volumetric analysis, were performed to determine if higher-priced brand-name iron tablets had a greater quality of control compared to cheaper, generic iron tablets. It was found that both brands were inaccurate and imprecise in terms of their actual iron amount per tablet compared with the manufacturer's claimed amount. Results suggest that the higher-priced iron tablets are not worth the extra money, for quality of control is not ensured. The two techniques were also compared in terms of precision, accuracy, ease of use, and time involved. It was found that spectrophotometric analysis is the preferred technique.

Introduction

In supermarkets around the world, a dilemma is faced by consumers everyday: Should I pay more for the brand-name iron tablets, or should I tempt fate and buy the lower-priced generic iron tablets? Perhaps the situation is not as dire as it seems, but the question remains: Are brand name iron tablets of better quality than generic tablets? The fundamental goal of this experiment was to answer this very question, providing the consumer with the necessary information to make knowledgeable product decisions.

In this experiment, we compared the quality of control in two different brands of iron tablets: Feosol, the more expensive brand name tablets, and Nature's Blend, the generic brand tablets. The amount of ferrous (FeII) iron in each brand of tablet was determined using both spectrophotometric and volumetric analysis. In the spectrophotometric analysis of the iron tablets, the nature of interaction between light and matter allowed us to determine the amount of FeII in each brand of tablet. With the use

of a spectrophotometer, the absorbance (the amount of light absorbed) of a sample at a particular wavelength can quickly be determined, and from this, the concentration of a solution can be calculated. Using this method, the absorbance and concentration of FeII (phenanthroline)$_3$ complex samples were determined, allowing for the calculation of FeII amount in each tablet sample.

Titration is a common volumetric analytic technique in which a solution of accurately known concentration is gradually delivered to another solution of unknown concentration. The concentration of the unknown solution can be calculated if the concentration of the standard solution and the volumes of both the standard and unknown solutions are measured. In this experiment, the oxidation of FeII by permanganate (MnO_4^-) was studied, and the nature of this oxidation-reduction reaction allowed us to calculate the amount of FeII in each brand of tablet.

Besides answering our fundamental research question, another goal of this lab was to become comfortable with the inherent benefits and drawbacks of the two different types of analytic techniques.

Materials and Methods

Spectrophotometric Analysis

Using the standard solution of 1.060×10^{-3} M FeII(phenanthroline)$_3$ complex, the peak wavelength, given by the maximum absorbance reading, was determined with the spectrophotometer. To determine dependency of absorbancy on concentration, a ten-fold, five-fold, 2.5-fold, and a fold dilution of the standard FeII(phenanthroline)$_3$ complex solution were made (Fig.1). It was determined that a standard solution concentration of approximately 5×10^{-5} M would be most appropriate for determining the amount of FeII

in each sample. To obtain this desired concentration, a tablet was dissolved in 25 ml of HCl. This solution was transferred to a 100 ml volumetric flask and distilled water was added. 10 ml of this solution was transferred to another 100 ml volumetric flask and filled with distilled water. 5 ml of this solution was then transferred to another volumetric flask, and 5 ml of hydroxylamine (HHCl), 10 ml of 8% sodium acetate buffer(NaOAc), 10 ml of o-phenanthroline, in that order, were added. The flask was filled with distilled water. This process was repeated for three Feosol tablets and three Nature's Blend tablets. Absorbance values were then determined for all of the tablet samples.

Volumetric Analysis

Except where noted, the procedures from the Williams College Chemistry 102 laboratory manual were used.

To determine how much $KMnO_4$ was needed to make a standard solution of $KMnO_4$, we first determined how many moles of FeII we had in a 65 mg iron tablet.

65 mg Fe x 1mole Fe/55.8 g x 1g/1000mg = 1.2×10^{-3} moles Fe (~~Eqn. 1~~) (1)

Based on the molar ratios seen in Equation 2, the number of moles of FeII were multiplied by five to obtain the number of moles of MnO_4^- needed to fully react and oxidize the FeII.

$5Fe^{2+} + 8H^+ + MnO^{4-} \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4H_2O$ ~~(Eqn. 2)~~ (2)

Since six titrations were needed, one for each tablet, it was calculated that approximately .474 g. of $KMnO_4$ were needed to make a standard $KMnO_4$ solution with a desired concentration of .012 M. The steps are given below.

1.2 moles Fe x 5= 2.4×10^{-4}moles of MnO_4^- ~~(Eqn. 3)~~ (3)

2.4 moles MnO_4^- /.020 L = .012 M MnO_4^- ~~(Eqn. 4)~~ (4) etc.

.012 moles MnO_4^-/ 1 L x .25 L = .003 moles MnO_4^- (Eqn. 5)

.003 moles MnO_4^- x 158.0g/1 mole MnO_4^- = .474g MnO_4^- (Eqn. 6)

Results and Discussion

Due to experimental error, one sample of Feosol was discarded. As a result of this, class data for the average amount of iron in Feosol tablets was used in the interpretation of results. Results from spectrophotometric analysis (Fig.2) showed that for the Feosol tablets, the precision was 5.3%, while for the Nature's Blend tablets, the precision was 2.8%. Thus, the Nature's Blend tablets are more precise than the Feosol tablets. That is, the amount of iron in Nature's Blend tablets was consistently closer to the average value than the amount of iron measured in the Feosol tablets. Concerning accuracy, however, the Feosol tablets had a relative accuracy of .9%, while the Nature's Blend tablets had a relative accuracy of 9.7%. These results showed that while the Nature's Blend Tablets were more precise, they were less accurate, i.e. they were farther from the theoretical value of 65 mg of iron per tablet than the Feosol tablets. However, as shown in Fig.2, both brands lacked good precision and accuracy, for both brands had deviations from the average and theoretical values that were greater than can be expected from constant errors inherent in spectrophotometric analysis. Some of these inherent sources of error include the uncertainties in measurement in the 100ml volumetric flask, 5.00 ml pipette, and 10.00 ml pipette. Taken together, these uncertainties resulted in a total error of 1.13%, which resulted in approximately +/- .8 mg of estimated error. Since the deviations in both brands were much greater than this inherent estimated error, some other factor must be contributing to the greater than expected deviations. One explanation is that perhaps not all of the iron tablet dissolved, which could account for

some values smaller than the theoretical value. However, a lot of values are also greater than the theoretical value, so this can not be the sole factor. It could simply be that the manufacturer's of these two brands do not tightly regulate the amount of iron in each tablet, which affects both the precision and accuracy.

Results from the volumetric analysis of the iron tablets showed that the average amount of iron measured in the Feosol tablets was 70.89 mg, the average deviation was 3.81 mg, or a precision of 5.37%, and the relative accuracy was 9.06%. The average amount of iron measured in the Nature's Blend tablets was 69.07 mg, the average deviation was .88, a precision of 1.27%, and the relative accuracy was 6.26%. Thus, volumetric analysis showed that Nature's Blend tablets were both more precise and more accurate than Feosol tablets, a significant finding considering Feosol costs almost three times as much as Nature's Blend. Overall, however, the results from the two methods of analysis were conflicting. In the spectrophotometric analysis, Nature's Blend tablets were more precise, and Feosol tablets were more accurate, whereas in the volumetric analysis, Nature's Blend tablets were both more accurate and more precise. Which data to believe? One thing can be said, both Nature's Blend and Feosol were neither as accurate or precise as expected, so this finding in itself casts doubt on the benefits of paying almost three times as much for Feosol. This result, taken with the finding that Nature's Blend tablets were more precise, suggests that paying the extra money for a brand-name iron tablet does not ensure better quality.

There were serveral sources of error inherent in our volumetric analysis that could have contributed to the observed imprecision and inaccuracy of our iron tablets. The 250 ml volumetric flask, 50 ml graduated cylinder, 10 ml graduated cylinder, buret, and scale

all have inherent uncertainties in measurement that can affect precision and accuracy. The average amount of iron measured in each brand of tablet was also higher in the volmetric analysis compared to the averages measured via spectrophotometric analysis, which suggests that there was a systematic error that was inherent in the volumetric analysis. A possible systematic error could be that there were substances other than FeII present in the iron tablet that were being oxidized. $KMnO_4$ is not a very specific oxidizing agent, and it is possible that it was reacting with other substances present in the iron tablet solution. This could increase the amount of iron reported in the tablet, since it would take more $KMnO_4$ to react with both the FeII and these other substances present. Support for this explanation is seen in the color change of the iron solution as it was being titrated. At first, the color of the iron solution was green. However, as the iron solution was titrated with more $KMnO_4$, the color changed from green to a light, colorless solution. It is possible that the green dye used to coat the tablet was being oxidized by $KMnO_4$, which could explain why all of the averages for the volumetric analysis were higher than the averages from the spectrophotometric analysis.

A comparison of the results obtained from both methods showed that the precision value of the spectrophotometric analysis, 4.1%, taken as the average precision between Feosol's and Nature's Blend's blend precision, is greater than the precision value of the volumetric analysis, which was 3.32%. Thus, volumetric analysis is a more precise technique for measuring the amount of iron present in a tablet. On the other hand, the accuracy value of the volumetric analysis, 7.76%, taken as the average between Feosol's and Nature's Blend's accuracy, is greater than the accuracy value of the

spectrophotometer. Thus, spectrophotometric analysis is a more accurate technique than volumetric analysis.

Given these two opposing benefits, spectrophotometric analysis is the preferred technique of this author. Time involved, as measured by how early this author was in bed after the laboratory had ended, was considerably less for spectrophotometric analysis than volumetric analysis. In spectrophotometric analysis, one could use the hood to facilitate the tablet dissolving, whereas in volumetric analysis oxidation had to take place naturally, which was more of a time consuming process. In the volumetric analysis, the Fe solution could not be heated for fear that the Fe^{2+} would turn into Fe^{3+}, which was an undesirable outcome, since the amount of Fe^{2+} was being measured. Also, spectrophotometric analysis was an easier technique to perform; all one had to do was load up a cuvette with iron solution, place the solution in the spectrophotometer, and measure the absorbance. Titrating was more of a laborious, drawn out process, with one adding the $KMnO_4$ drop-by-drop to the iron solution so as not to overshoot the endpoint.

References

Concepts of Chemistry, Laboratory Instructions (Chemistry 101-102/4), 2000-01. Williams College, pp. 17-18, 74-81.

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