The Analysis of Bismuth Effects on Reaction of Pyrogallol Red, Hydrogen Peroxide and Sulfuric Acid

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Abstract:

By utilizing spectrophotometry, the present study analyzes the effects of bismuth ion on the reaction of pyrogallol red, hydrogen peroxide and sulfuric acid. In this method, based on the previous experimental samples, the pre-defined concentrations of materials are used. These materials included bismuth 100 ppm, sulfuric acid 1 M, hydrogen peroxide 1 M and pyrogallol red 4 M. Based on the results, the effect of ion is catalyzing in some cases and inhibitive in others. After all, the optimal points of each reaction in different and optimal temperatures are examined.

Keywords: bismuth, pyrogallol red, hydrogen peroxide, sulfuric acid

1. Introduction

A method of chemical analysis is utilized for determining the type of chemical materials in sample or for measuring the amounts in which the first is called qualitative chemical analysis and the second type is a quantitative chemical analysis. Some experts of chemistry distinguish between chemical analysis and normal chemical measurements. A chemical analysis is a process for determining the type and amount of a material in a sample, collect samples, physical or chemical operations in order to prepare the mentioned sample, do (non-) laboratory tests, process data and eventually prepare report. A chemical measurement only consists of (non-)laboratory measurements. Historically speaking, the chemists have properly understood synthetic analysis and use it as a proper method of analytical chemistry. Among different analytical methods, catalytic analysis has drawn a lot of attention due to its synthetic nature. The catalytic analysis is mostly used for analyzing of micro and macro samples (i.e. samples with a weight of higher than 1 gram). [1-3]

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In 1992, J. A. Morti, in Poland, explained the reduction of catalytic effects of bismuth in phosphoric acid of molybdenum by using corbic acid which was an interesting synthetic method. In 1996, J. A. J., Zhou reported another method with the application of a similar reactive system but with higher sensitivity. In 1992, Y. Shiver, M. Mitashi and T. Shimizu used electrothermal method as one of the significant methods of atomic absorption spectroscopy to determine the effects of bismuth in sea water. [4-7]

1.1. Problem Statement

Nowadays, the study and application of chemical reactions in solution phase constitute a major part of the analytical chemistry. In fact, some analytical methods and techniques are based on the measurement of a physical or chemical property of a system or the intended chemical elements. In this regard, the analytical measurements are done in two ways:

I. Synthetic Methods
II. Thermodynamic or Balanced Methods

Synthetic and thermodynamic methods are two major categories of analytical measurement which have some differences with one another. In synthetic methods, the measurements are done in a dynamic condition in which the concentrations of reactants and products are continuously changing. For these methods, the rate of product formation or decomposition of reactants is used as an analytical parameter. In balanced methods, measurements are done when the system is in balance and the concentrations are static.[1,2]

1.2. Characteristics of Bismuth

Bismuth is a metal element which is crystalized with a rhombohedral structure and it might be found in free forms or in materials such as Bismuth (Bi₂O₃). In the past, this material was mistaken with tin and lead. This element was discovered by Claude Geoffroy in 1735. It is a metal with a pale pink color and a fragile structure. Bismuth is an element with diamagnetic property and with exception of lead, it is the only metal with low thermal conductivity. The electric resistance of this element is high and it is the top metal in term of Hall Effect. Of the most significant materials in which this element exists, we can point to Bismuthinite or Bismuth Glass. Peru, Japan, Mexico, Bolivia and Canada are the major producers of bismuth but the highest level of its production is in United States. This element is produced as an artificial product during mining lead, tin, silver and gold mines. Almost 3.32 % of this element found in nature is in solid form. This property makes bismuth alloys ideal for high-temperature molds. This element can be used in alloys of cadmium and tin. Bismuth alloys have a low melting point which have numerous applications in safety devices and systems of firefighting. Bismuth is also used for malleable iron products and detection of catalyzers for production of plastic fibers. When inflamed, Bismuth burns with a pale blue color and releases a yellow smoke in the form of bismuth oxide. This metal is used for thermocouple and fuel of atomic reactors such as Uranium U235 and U233. Bismuth oxychloride is widely used in cosmetic industry. Bismuth Subnitrate and Bismuth Subcarbonate are used in pharmaceutical industry. The crystal structure of its element has negative effects upon the health and its salts cause renal damages. Although this damage is negligible for low concentration of
Bismuth but its higher concentrations might be lethal. Some chemical and physical properties of bismuth are listed in table 1.

**Table 1.** Chemical and Physical Properties of Bismuth

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic Number</td>
<td>83</td>
</tr>
<tr>
<td>Standard Form</td>
<td>Solid Metal</td>
</tr>
<tr>
<td>Atomic Mass</td>
<td>208.9804</td>
</tr>
<tr>
<td>Ionization Energy</td>
<td>7.289 Kj/mol</td>
</tr>
<tr>
<td>Melting Point</td>
<td>271.4 Centigrade</td>
</tr>
<tr>
<td>Density</td>
<td>9.75</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>564 Centigrade</td>
</tr>
<tr>
<td>Decay Heat</td>
<td>11.3 Kj/mol</td>
</tr>
<tr>
<td>Color</td>
<td>Opaque White</td>
</tr>
<tr>
<td>Heat of Vaporization</td>
<td>104.8 Kj/mol</td>
</tr>
<tr>
<td>Oxidation Mode</td>
<td>3.5</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>0.12 Kj/g</td>
</tr>
<tr>
<td>Electronegativity</td>
<td>2.02</td>
</tr>
<tr>
<td>Electrical Resistance</td>
<td>0.00000115 Ohm/m</td>
</tr>
</tbody>
</table>

2. **Experimental**

2.1. **Chemical Materials and Making Solutions**

All chemical materials used in the present study are purified ones and all solutions are prepared with double-distilled water. The used solutions were maintained in a water bath within a temperature of 25 °C.

Sulfuric acid 1M. To prepare this solution, H\(_2\)SO\(_4\) is increased to 100 ml in a volumetric flask.

Hydrogen Peroxide 1M. To prepare this solution, 10.2 ml of this solution is solved in distilled water within a volumetric flask and its volume is increased to 100 ml.

Bi (III) Solution (100 mg/l). To prepare this solution, 0.0232 gram of Bismuth Nitrate was precisely measured and solving it in distilled water within volumetric flask continued till it gets to 100 milliliter.

2.2. **Necessary Devices and Equipment**

The used devices included pH-meter and a balance with 0.0001 accuracy. The simple laboratory instruments such as thermometer, pipette and volumetric flasks and other common glassy instruments in the laboratory were also used. All solutions attained balance in a thermostat bath until they get to a temperature of 25 °C. This temperature was kept constant during the test and a timer was used to register the time of reaction. To
measure the changes of solution absorption in the wavelength of 540 nm, a two-beam CECIL-7500 spectrophotometer was used.

3. Result and Discussion

3.1. Optimization of Reaction Conditions

In reactions of pyrogallol red, hydrogen peroxide and sulfuric acid, bismuth has an inhibitive effect and the rate of this reaction is a function of some variables such as the volume of sulfuric acid, volume of bismuth, volume of pyrogallol red, volume of hydrogen peroxide and temperature. To select proper conditions, the effect of each of these variables on the signal was verified. In these verifications, each measurement was repeated thrice and means of measurements were reported. In these studies, single-factor method was used due to its simplicity so that to study the effects of each item, the concentrations of other items and other reaction conditions were kept fixed.

3.1.1. Analysis of Sulfuric Acid Volume Effects

In this analysis, the concentrations of materials in a 5ml flask were defined as bismut 100 ppm, hydrogen peroxide 1M, pyrogallol red 4M in a temperature of 25 °C. In each test, different volumes of sulfuric acid 1M is added to a 5ml volumetric flask and then, 1 ml of bismuth 100ppm solution, 0.5 ml of hydrogen peroxide 1M and 1 ml of pyrogallol red 4M were added. On addition of the last drop of bismuth, the timer initiates and after getting the volumetric flask to proper volume with double-distilled water and stirring the solution, a little portion of the solution is added to spectrophotometer cell so as to measure the variance of solution absorption in a time range of 0.5 to 3.5 min in wavelength of 540 nm.[1]

The above procedure was repeated for studying the variance of absorption of control solution with the difference that no bismuth was added to the solution. The results of this analysis are summarized in the following table and the following figure show the variance in absorption against the concentration of acid. As shown in the following Figure, 1M was defined as the proper concentration.

<table>
<thead>
<tr>
<th>V(ml) H₂SO₄ 1M</th>
<th>0.2</th>
<th>0.6</th>
<th>0.8</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>0.001</td>
<td>0.006</td>
<td>0.045</td>
<td>0.005</td>
</tr>
</tbody>
</table>

As shown in the Figure 1, the effect of volume of sulfuric acid on sensitivity of the method is shown in a range of 0.2-1. Figure 1 shows that 0.8 ml of H₂SO₄ 1M which equals 0.045 (absorbance) is the optimal concentration.
3.1.2. Analysis of Hydrogen Peroxide Volume Effects

In this analysis, the concentrations of materials in a 5ml flask were defined as bismuth 100 ppm, sulfuric acid 1M, pyrogallol red 4M in a temperature of 25 °C. In each test, different volumes of hydrogen peroxide 1M is added to a 5ml volumetric flask and then, 1 ml of bismuth 100ppm solution, 1 ml of pyrogallol red 4M and 0.8 ml of sulfuric acid were added. On addition of the last drop of bismuth, the timer initiates and after getting the volumetric flask to proper volume with double-distilled water and stirring the solution, a little portion of the solution is added to spectrophotometer cell so as to measure the variance of solution absorption in a time range of 0.5 to 3.5 min in wavelength of 540 nm.

The above operation was to study the variance in absorption of control solution with a difference that bismuth was not added to the solution. The experimental results of this analysis is shown in Figure 2.

<table>
<thead>
<tr>
<th>V(ml) H₂O₂ 1M</th>
<th>0.2</th>
<th>0.6</th>
<th>0.8</th>
<th>1</th>
<th>1.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>0.004</td>
<td>0.009</td>
<td>0.015</td>
<td>0.086</td>
<td><strong>0.001</strong></td>
</tr>
</tbody>
</table>
As the above figure shows, the effects of different volumes of hydrogen peroxide on the method sensitivity are shown in a range of 0.2-1.4. The above figure shows that 1 ml of hydrogen peroxide 1M at which the signal is 0.085 (absorbance) represents optimal concentration and volume.

3. Conclusion

In the present project, the analysis of bismuth ion effects on the reactions of pyrogallol red and hydrogen peroxide in acidic environment setting through spectrophotometry show that bismuth ion have inhibitive effects on the system. The single-factor method and fixed time were used to verify the effects of different parameters to achieve the best analytical signal. To increase the sensitivity of method, the effects of different parameters such as concentration and volume of sulfuric acid, concentration and volume of bismuth, concentration and volume of pyrogallol red, volume and concentration of hydrogen peroxide and temperature on catalytic and non-catalytic reactions were examined and then optimal conditions were determined.

Therefore, the optimal conditions show that bismuth ion can exert an inhibitive effect on the reaction of pyrogallol red, hydrogen peroxide and sulfuric acid. The reason of absorption decline in temperatures of higher than 25 °C is that a major portion of reaction occurred in the first 0.5 minute before the measurement of absorption variance. As a result, the variance of absorption in the interval of 0.5-3.5 min from the beginning of reaction, difference in the rates of catalytic and non-catalytic reactions and the method sensitivity decrease. Therefore, a temperature of 25 °C was selected as the optimal one.
References


