

A Visual Demonstration of Solvent Effect in Chemical Kinetics through Blue Bottle Experiment

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ABSTRACT

In the study of chemical kinetics, usually solvent effect was explained to show the consequences on rate of reaction theoretically which is difficult to understand for under graduate students. The blue bottle experiment as a “one day activity” can be used to explain well visually the solvent effect through demonstration of color change. Kinetics of reduction of methylene green by sucrose and mannose in pure and aqueous methanol medium in presence of NaOH has been investigated for demonstration of solvent effect. The two sugars sucrose and mannose were selected for the experiment those acts as a reducing agents in a basic solution and reduces the methylene green into colorless form. The progress of this reduction reaction was followed by the color changes that the methylene green goes through in variable percentage of alcohol. When the bottle is shaken the oxygen in the air mixes with the solution and oxidizes the methylene green back to its intermediate state (purple). The color of the solution will gradually change and become purple (intermediate) and then colorless in 5-10% methanol but in pure methanol color transition were Blue-> purple-> pink indicate the color due to the alcoholic medium. It was observed that increase in percentage in the solvent composition decrease the rate of reduction. The pink color continues due to alcoholic medium which may be attributed with the solvent effect. The observed variation in reading with solvent compositions has been interpreted in terms of interactions of media with the reacting species and the transitions state involved in this reaction.

Keywords: Kinetics, color change, transitions state

1. INTRODUCTION

Solvents can in fact influence rates of reaction and order of a chemical reaction. A solvent effect is the group of effects that a solvent has on chemical reactivity. Solvents can have an effect on solubility, stability and reaction rates and choosing the appropriate solvent allows for thermodynamic and kinetic control over a chemical reaction.

Solvent interaction with reacting species related to the nature of product, if products more polar than the reactants, the reaction rate will accelerate in polar solvent but if reactants are polar then the products, rate of reaction will decrease in presence of polar solvent. If both reactant and products are non polar, polarity of solvents will have no influence on the rate of the reaction and the rate is independent of the nature of the solvent. When reactants interact with the solvent and are solvated, leading to lowering the potential energy of the reactants, then the activation energy increases which lowers the reaction rate. The dielectric constant of the medium plays an important role in case of ionic reactions

This experiment was designed in such a way that students of under graduate classes can learn and observed effect of medium visually with color loss of the dye.

2. EXPERIMENTAL

1. Before starting the visual demonstration of blue bottle experiment a “theoretical concept of redox reaction” of about 20 - 30 minutes was delivered.
2. All required solution of dye, reducing sugar and alkaline medium (NaOH) were prepared by usual methods as reported earlier¹.
3. Shaking of solution allow to dissolve the oxygen in reaction mixture which give blue color.
4. Upon standing color permanently change in aqueous media.
5. The solvent effect were monitored via different percentages of alcohol and pure alcohol
6. Upon standing in pure alcohol pink color permanently exists.

2.1 The demonstration of methodology

1. Flask which contains dye, mannose and sodium hydroxide solution was shaking vigorously to show that blue color appear due to the dissolve oxygen from atmosphere.
2. The blue color of the dye showed the oxidized state of the dye or oxidation of dye occurs.
3. Now allow to stand the flask, blue color will change into the color less which showed that oxygen is consumed by the sugar which converted into respective acid and now hydrogen from sugar acid will abstracted by the dye or “H” will added into the dye molecule for its reduction and reduction is indicated by the color less state after addition of hydrogen¹ (Figure).
4. Variable percentages of alcohol and pure alcohol were used for the preparation of solutions of all reagents for the demonstration of solvent effects.

3. RESULTS AND DISCUSSION

Dyes are the best indicators of rate of chemical reaction, they provide help in determining order of reaction through their color change ability by clock method¹⁻³. The change of color of the dye is related with the presence and absence of oxygen, also related with the medium which is in chemical kinetics refers as a solvent effect.

The study of solvent effect in chemical kinetics usually explained to show the consequences on rate of reaction theoretically which is difficult to understand for under graduate students. The famous blue bottle experiment can now be used to explain well visually the solvent effect through demonstration of color change⁴. This will make the chemistry easy and interesting for the students. Kinetics of reduction of methylene green by sucrose and mannose in pure and aqueous methanol medium in presence of NaOH has been investigated for demonstration of solvent effect. The two sugars sucrose and mannose were selected for the experiment which acts as a reducing agent in a basic solution and reduces the methylene green into colorless form. The progress of this reduction reaction was followed by the color changes that the methylene green goes.

When the bottle is shaken the oxygen in the air mixes with the solution and oxidizes the methylene green back to its intermediate state (purple). Note the effect of reduction of methylene green by varying the volume of each parameter. The color of the solution will gradually change and become purple (intermediate) and then colorless in 5-10% methanol but in pure methanol color transition were Blue-> purple -> pink color due to the alcoholic medium. When the solution is shaken gently it will turn back to purple (intermediate) in 5-10% methanol but in pure methanol pink color reappears⁵⁻⁸. The pink color continues due to alcoholic medium which may be attributed with the medium effect. This cycle can be repeated many times. After a while the indicator seems to "wear out". When this happens add more methylene green to enhance the color changes. It was observed that increase in % in the solvent composition decrease the rate. The observed variation in reading with solvent compositions has been interpreted in terms of interactions of media with the reacting species and the transitions state involved in this reaction. This is may be due to a polar solvent decreases the reaction rate if the reactants are more polar than the products. Either the reactant or the product or the activated complex interacts with the solvent, there may be considerable influence on the rate of the reaction⁸. When the reactants interact with the solvent and are solvated leading to lowering the potential energy of the reactants then the activation energy increases lowering the reaction rate.

4. CONCLUSION

It was concluded that the persistence of pink color in pure alcohol indicate the solvent effect on rate of reduction reaction. This experiment can be used as a one day open activity for learning and teaching Chemistry in an easiest way.

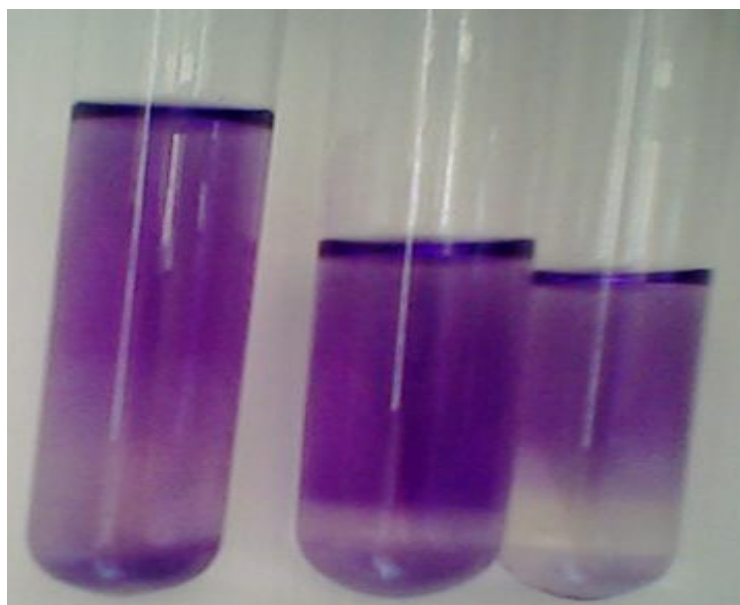


Fig-1: A visual solvent effect

5. REFERENCES

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