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Demonstration of Chemical Equilibrium through Regeneration of Color in Blue Bottle Experiment

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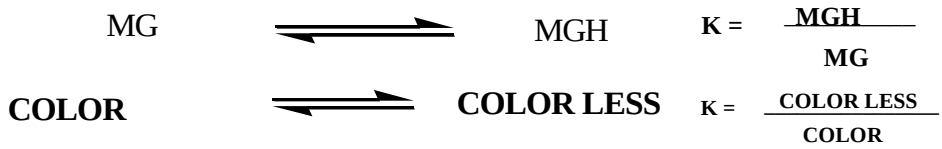
ABSTRACT

Concept of equilibrium is very difficult to understand for under graduate students. This experiment has a good visual impact of demonstration of equilibrium and would be one way of stimulating awareness in chemistry. An alkaline solution of arabinose and methylene green in aqueous medium can be used to explain equilibrium visually through reaction of dissolved oxygen which was observed in "**BLUE BOTTLE EXPERIMENT"** that showed the shift of equilibrium by regeneration of color during shaking and upon standing equilibrium shift in the forward direction and color loss was observed. Shaking the solution raises the concentration of oxygen in the mixture and oxidizes the methylene green back to its blue form. When the dissolved oxygen has been consumed, the methylene green is slowly reduced back to its colorless form by the remaining arabinose and the cycle can be repeated many times by further shaking. The experiment was repeated with various concentrations of dye indicator, arabinose and sodium hydroxide concentration. It was observed that regeneration of color and colorloss is the best visual example of explanation of equilibrium.



Key words: equilibrium, visual, blue bottle experiment, dissolved oxygen

1. INTRODUCTION

The concept of chemical equilibrium was developed after Berthelot (1803),establish that some chemical reactions are reversible. For any reaction mixture to exist at equilibrium, the rates of the forward and backward (reverse) reactions are equal. This study was found to be helpful in development of the visual concept of equilibrium by the color of dye. The color of reactant was blue while color of product was colorless in same test tube which can be used as a reversible reaction for the demonstration of chemical equilibrium.

2. EXPERIMENTAL

1. The demonstration needs a theoretical concept of equilibrium and about 20 - 30 minutes is needed for the preparation of laboratory to explain the practical.
2. Make a solution of 0.0182 g of methylene green in 500 cm^3 of water
3. Weigh 10 g of sodium hydroxide into the 100 dm^3 conical flask.
4. Add 100 cm^3 of water and 2 g of arabinose and swirl until the solids are dissolved.
5. Add 1- 5 cm^3 of the methylene green solution, 01 cm^3 sodium hydroxide and 0.8 $cm^3$of sugar in a five separate stopper flasks. The exact quantity used is not critical.
6. Similarly variation of sugar volume with constant volume (1 cm^3)of NaOH and 0.8cm^3 of dye
7. Base volume was changed in the range of 1-5 cm^3 keeping dye and sugar constant
8. The resulting blue solutions will turn colorless after about one minute.
9. Equilibrium state was appeared during regeneration of color where half color and half color less state was attained
10. Upon standing color permanently change after long time

2.1 *The demonstration of methodology*

1. Holding the stopper strongly in place, shake the flask vigorously so that air dissolves in the solution.
2. The color will change to blue and regenerate in about approximate 10 to 40 seconds in each flask.
3. The more shaking, the longer the blue color will take to fade.
4. The process can be repeated for over 10 cycles.
5. After some hours, the solution will permanently turn yellow and no color changes was observed

4. RESULTS AND DISCUSSION

4.1 *Demonstration of effect of volume of different variables on an equilibrium state*

Effect of increasing volume of reactants and products were monitored on equilibrium state according to Le Chateler's principal by increasing the volume of dye, arabinose and alkali as a medium.

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Results of increasing volume of dye on equilibrium state were reported in the Table-l which showed that equilibrium state attained more rapidly with the increasing concentration of dye and also reduced in the time of regeneration of color reflects the significant role of dissolve oxygen[1-3] at high concentration of dye[Table-1]. Now at this stage should be guided about the effect of stress on equilibrium related with the volume of dye and more rapid reaction with atmospheric oxygen. Effect of increasing concentration of sugar[4-6] was reported in the Table-2 which showed that increasing concentration of sugar reduces the time of de-coloration and an appreciable effect on regeneration of color reflect that dissolved oxygen is related with the dye concentration[Table-1].

The change in the concentration of sugar showed effects on K which may be demonstrated to the students as that sugar oxidizes by consuming oxygen and converted into product very slowly or increases the time of disappearance but on shaking role of oxygen was pragmatic.

These results suggest that according to le Chateler's principal equilibrium shift in forward direction to minimize the effect of increasing volume of sugar while an increase in time of regeneration of color after shaking represent the slow reaction of oxygen with the dye molecule due to high concentration of arabinose. Effect of increasing volume of alkali [Table 3] in an equilibrium state showed that disappearance and regeneration of color take long time to establish the equilibrium. This indicated that the effect of dissolved oxygen on equilibrium state of dye indicator is related with concentration of dye. But increase in the alkali concentration do not effect the value of K.

4.2 *Teaching Comments*

A white background helps to make the color changes more brilliant. A white laboratory coat is ideal to demonstrate equilibrium visually.

Methylene green is a redox indicator like methylene blue and is colorless when reduced but color restore on oxidation.

Reaction shift in forward direction to restore an equilibrium state more rapidly when dye volume was increased at equilibrium state

Long time for regeneration of color in presence of sugar and alkali showed that dissolved oxygen Consume by sugar molecule to convert into respective acid therefore it require long time to react with the dye molecule

Redox indicators other than methylene blue was used and found effective in demonstration of equilibrium.

The removal and regeneration of the color is due to oxidation-reduction reaction, under alkaline conditions, and shaking the solution allows oxygen enter into solution which shift the equilibrium in backward direction and re-oxidizes the methylene green back to the blue form.

This experiment can be a popular "**Open Day Activity**" but can also be used to determine the rate and equilibrium state under influence of different operational conditions.

It will be better to use plastic bottle to avoid the interaction of dye indicator.

Table-1: Effect of dye on equilibrium

Dye indicator (ml)	Time of color loss(s)	Regeneration Time(s)	K
1.0	227	17	0.06
2.0	230	16	0.06
3.0	213	14	0.06
4.0	156	13	0.08
5.0	139	10	0.06

Sugar =0.8ml, 10% NaOH = 1 ml

Table-2: Effect of sugar on equilibrium

Sugar (ml)	Time of color loss(s)	Regeneration time(s)	K
1.0	103	9	0.08
2.0	58	5	0.08
3.0	55	7	0.12
4.0	259	4	0.01
5.0	52	10	0.19

Methylene green =0.8ml, 10% NaOH = 1ml

Table-3: Effect of NaOH on equilibrium

Alkali (ml)	Time of color loss(s)	Regeneration time(s)	K
1.0	108	30	0.27
2.0	100	27	0.27
3.0	90	25	0.27
4.0	88	24	0.27
5.0	83	23	0.27

Methylene green =0.5, sugar = 0.8ml

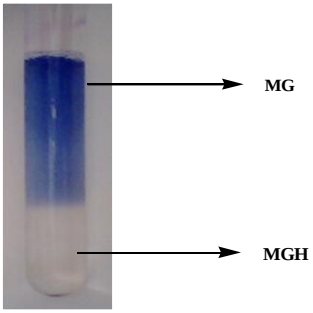

Fig-1: A visual demonstration of Chemical equilibrium by methylene green and Arabinose

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