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Demonstration of Direct observation of Transition state through Blue Bottle Experiment, An undergraduate study in Chemical kinetics Education

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ABSTRACT
A new visual procedure for the characterization of transition states / intermediate state for chemical reactions is proposed and tested through the blue bottle experiment. The transition state of a chemical reaction is a particular configuration along the reaction coordinate. It is defined as the state corresponding to the highest energy along this reaction coordinate. **Blue Bottle Experiment** can now be used for learning of transition state / intermediate state through color change. An alkaline solution of methylene green and mannose when react in presence of atmospheric oxygen blue color of dye was first change into purple then colorless. The color transition from blue (oxidized dye) to purple (transition state) then colorless can be effectively used in demonstration of intermediate state of a chemical reaction visually to undergraduate students.

Keywords: methylene green and mannose, transition states, blue bottle experiment

1. INTRODUCTION
In chemical kinetics verbally transition-state theory, demonstrated as a reaction path between the initial and the final arrangements of atoms or molecules, there exists an intermediate configuration or state at which the potential energy has a maximum value also called activated-complex theory, or intermediate state or theory of absolute reaction rates, a treatment of chemical reactions and other processes that regards them as proceeding by a continuous change in the relative positions and potential energies of the constituent atoms and molecules. In transition-state theory, the activated complex is considered to have been formed in a state of equilibrium with the atoms or molecules in the initial state[1]. During studies of dyes reduction reaction in laboratory[2,6],We came across in a situation where we observe the transition of colors of dyes from blue to purple and purple to colorless instead of direct color less state in high concentration of alkaline medium. This experimental observation of transition of colors used for the development of visual concept of intermediate / transition state of a chemical reaction to the students on the way to formulate chemistry easy at every level.

2. EXPERIMENTAL
1. Theoretical concept of the intermediate or transition state i-e an unstable transitory combination of reactant molecules that occurs at a potential energy maximum was delivered[1]
2. An effort was made to demonstrate the activated state in one day open activity through color transitions[1].
3. All required solution of dye, reducing sugar and alkaline medium were prepared by usual method as reported earlier[7, 8].
4. Shaking of solution allow to dissolve the oxygen in reaction which give blue color.[5]
5. Upon standing color transitions persist i-e **Blue→ purple → colorless** and does not change into color less state permanently (Figure)

3. RESULTS AND DISCUSSION
A theory of the rates of elementary reactions which assumes a special type of equilibrium, having an equilibrium constant K^*, to exist between reactants and activated complexes according to the following equation,

$$\mathbf{a + b \leftrightarrow ab \rightarrow P}$$
$$\mathbf{K^* = [ab] / [a][b]}$$

Reactions of dyes can easily be used to explain the different theories of reaction rate of chemical kinetics through their color transitions from one color to other which may be used for representing the different state or molecular arrangement[1]. The students find great difficulties in verbal or theoretical concept improvement, of activated state or intermediate complex state in chemical kinetics. The intermediate or transition state is an unstable transitory combination of reactant molecules that occurs at a potential energy maximum[6]. Transition state theory through color change can be explained as follows

$$\mathbf{dye \leftrightarrow (dye)^* \rightarrow leuco\ dye}$$
blue purple colorless

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Figure showed that solution which is in contact with the air gives blue color whereas inside purple color showed transitions from blue to purple (intermediate configuration) indicate the presence of oxygen with change in molecular state whereas color less state showed that all the oxygen consumed due to the reduction of dye and oxidation of mannose [7,8]. This experiment specify that actually the blue bottle experiment is a complex system composed of water, the simple sugar mannose, the dye methylene green, the hydroxide ion, intermediate state of dye molecule and oxygen from the atmosphere. Hence, the blue bottle experiment[1] is an amazing tool for introducing the key concepts of transition state. As reported earlier that in the first stage of the blue bottle experiment, the methylene green acts an oxidizing agent and the mannose acts as a reducing agent. When the bottle is shaken, causing more oxygen to dissolve in the reaction mixture. The additional oxygen acts as an oxidizing agent that changed methylene green to its blue (oxidized) form. When allow to stand, blue color changed into the purple after sometime into colorless state. This dramatic change in color from blue to purple and finally into colorless state was the best visual explanation of *Transition state theory* through famous blue bottle experiments.

3.1 *Teaching comments*

- Dyes can change their color by absorbing a photon of light
- Photon of light gives electronic excitation and electronic excitation gives change in color
- Transition of one color into other gives new concept in chemical education to make chemistry easy and interested
- The transition of color is due to shaking and oxidation-reduction reaction, under alkaline conditions, which allow the oxygen in the solution which shift the equilibrium in backward direction and re-oxidizes the methylene green back to the blue form[1].
- This experiment can be can be used to demonstrate the transition state theory visually

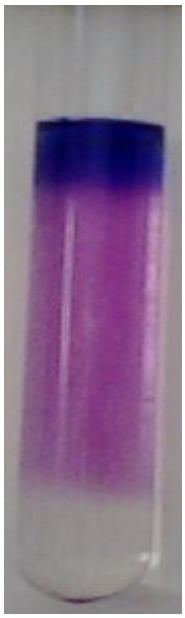

Fig-1: Visual demonstration of intermediate state through colors transition

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