COLLEGE OF ENGINEERING | Chemical, Biological, and Environmental Engineering | TEAM 10

COLOR CHANGING MEDICAL EXPIRATION LABEL

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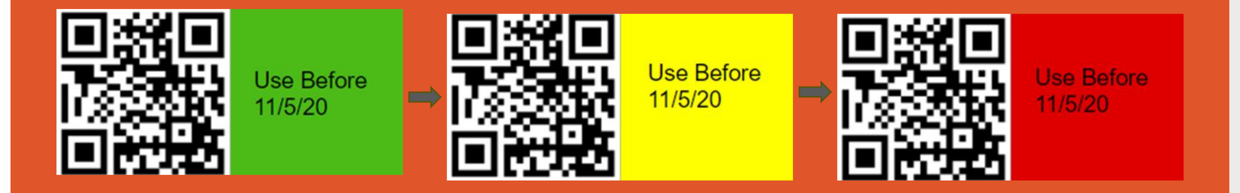
PROBLEM & OPPORTUNITY

- We identified an opportunity to solve a problem surrounding expiration dates located on prescription bottles. The current system employed could use significant improvements on both accuracy and customer satisfaction.
- The issues identified begin with how poorly printed expiration dates on medicinal products are. They are often difficult to locate and occasionally printed twice on top of another and/or on the edge of the wrapping which makes it difficult to read. Additionally, the current labels use unclear abbreviations that most individuals would not understand without using the internet. They do not provide any additional information regarding the expiration date such as if that date is only valid if kept refrigerated. The vast majority of labels do not provide any visual indication that conveys the product has expired.

OUR SOLUTION

- We propose a quick and easy method to immediately visualize if your medicine has expired. We designed a hydrogel 'sticker' that can be placed on any bottle at the time of manufacturing. This sticker, as time begins to elapse, will age and a chemical pH process occurs to slowly change the color of the sticker.



- Green indicates that the product is safe for use and consumption. Eventually, the label will change color from green to yellow to orange and finally to red, where it is finally unsafe for consumption. In essence, these colors demonstrate how fresh or old your medicine is and if it is safe for use.

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EXPERIMENTAL PROTOTYPES

I. To experimentally determine if color change works, we developed a prototype that would prove that BPB-Na changes color from blue to green to yellow. Specifically, we developed an experimental design surrounding tabulated concentrations of BPB-Na and CA from prototype II in water to achieve a certain pH and color (pH is directly proportional to the change in color; hence the term 'pH indicator'). We performed a titration procedure in which CA was titrated at small amounts into the BPB-Na solution to observe real-time color change.

II. To visualize color change, we developed a prototype model that would allow the user to determine concentrations for both BPB-Na and CA to achieve a certain pH and color. To do this, we utilized the *Henderson-Hasselbalch* equation and *ICE charts* to track the changing concentrations in the equilibrium reaction. This is important in visualizing a certain color in prototype I while also reducing the cost of materials needed. Prototype I used these tabulated values to prove that these calculations were accurate and reliable.

III. To determine the rate at which CA diffuses to BPB-Na to induce color change, we developed a prototype model that would analytically determine the diffusion coefficient through a hydrogel between basic and acidic layers. To do this, we utilized *Fick's Law* and its associated equations (*Wilke Chang* & *Hindered Solute*) and selected many assumptions to determine the rate of diffusion, which is proportional to both the surface area and concentration difference and is inversely proportional to the thickness of the membrane. This is important in understanding the time it will take for the reaction to fully complete.

I.

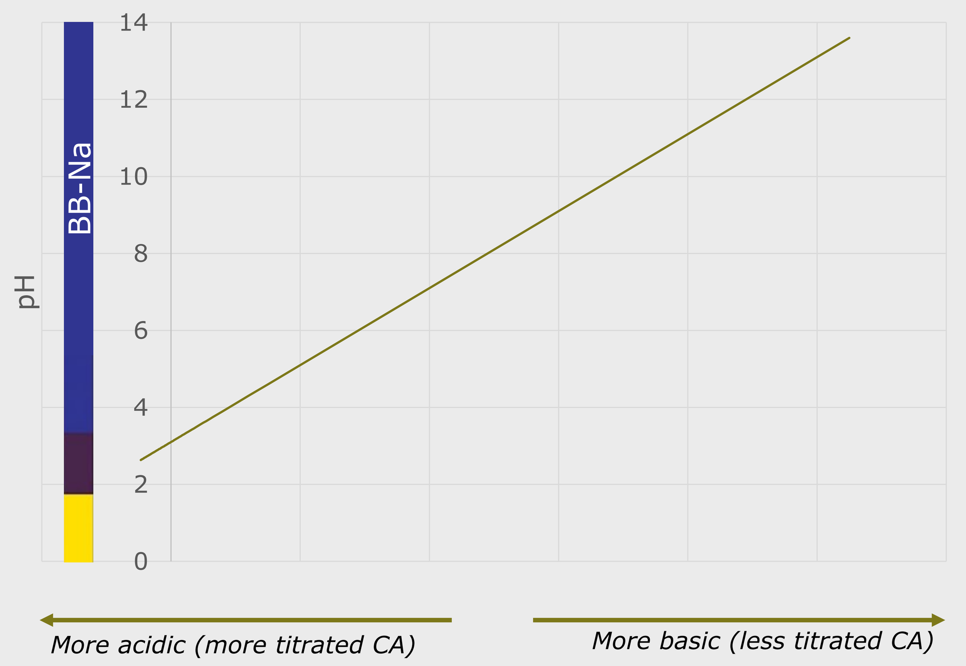
II.

Equilibrium Reactions

$$BPB\text{-}Na_{(aq)} + H_2O_{(liq)} \leftrightarrows OH^-_{(aq)} + BPB\text{-}Na^+_{(aq)}$$
$$CA_{(aq)} + H_2O_{(liq)} \leftrightarrows Citrate_{(aq)} + H_3O^+_{(aq)}$$

Henderson-Hasselbalch Equation

$$HA \leftrightarrows A^- + H^+$$
$$pH = pKa + \log\left(\frac{[A^-]}{[HA]}\right)$$
$$pH = pKa + \log\left(\frac{[Conjugate\ Base]}{[Acid]}\right)$$



III.

Wilke Chang Equation
(Mass Diffusion Through Liquid Water)

$$D_{AB} = \frac{7.14 * 10^{-8}(\phi_{water} * M_{water})^{\frac{1}{2}} * T}{V_a^{\ 0.6} * \mu_{water}} = \mathbf{8.13 * 10^{-6}\frac{cm^2}{s}}$$

Hindered Solute Equation
(Diffusion of Solute Through Hydrogel)

$$D_{AE} = D_{AB} * F_1(\varphi) * F_2(\varphi) = \mathbf{5.04 * 10^{-10}\frac{m^2}{s}}$$

RESULTS

Prototype I: We were able to observe color change. However, while these results indicate that a chemical reaction occurred, it does not align with our initial hypothesis where we stated that BPB-Na would change color from blue to green to yellow. Instead, we observed color change from blue to red to yellow, as seen in the figure in subsection I. We determined this was because the BPB-Na compound purchased was not the correct product. Regardless of how color change was observed, the same transition in color would still hold true with the correct indicator die (based on literature), meaning that we would still observe a change in color from blue to green to yellow at the same titrations we see from blue to red to yellow.

Prototype II: We were able to visualize specific colors at tabulated concentrations of BPB-Na and CA. This means that our Henderson-Hasselbalch equation (shown in subsection II) proves to be accurate and efficient in obtaining a desired pH when accounting for several occurring reactions (equilibrium reactions shown in subsection II). Based on this, we obtained a linear model seen in subsection II that indicates how BPB-Na changes color at varying levels of acidity.

Prototype III: We were able to determine the rate of diffusion through a hydrogel by first determining the diffusion through water (shown in subsection III). This result, while not a perfect model, required many assumptions. The equations here are evaluated at room temperature assuming steady-state, unidirectional flow. Values, such as pore size and particle size, are also estimated from literature value ranges.

MATERIALS

- A pH indicator, Bromophenol Blue Sodium Salt (BPB-Na), was utilized for this design since it is known to elicit a color change from blue to green to yellow upon activation. This basic compound identifies as the 'indicator' compound as its vibrant colors offer the ability to be easily examined.
- An acid, Citric Acid (CA), was utilized for this design to begin the acid-base reaction with BPB-Na to reduce the pH and induce color change. This compound identifies as the 'activator' compound because it initializes the reaction.
- An optional and non-volatile base, Sodium Carbonate (SC), was utilized for this design to prolong the color change reaction. This base identifies as the 'barrier' compound since it creates a more basic environment for the CA to diffuse through, thus extending the duration for color change.

HOW IT WORKS

- A certain known concentration of BPB-Na is added within the indicator hydrogel matrix (concentration determined using the Henderson-Hasselbalch equation).
- A certain known concentration of CA is added within the activator hydrogel matrix (concentration determined using the Henderson-Hasselbalch equation).
- The adhesive side of the activator matrix is applied to the bottle. Pressure is then administered to allow for the hydrogel to adhere to the surface while also beginning the diffusion process.
- CA diffuses to the BPB-Na matrix. This enables the patient to observe color change of the hydrogel sticker as the reaction occurs.
- [Optional]: A third hydrogel matrix, termed as the *barrier matrix,* includes SC at a certain concentration to prolong the reaction, making the color change slower over time.