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Evaluation of pH Value by Using Image Processing

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In this study strong HCl acid was titrated with a strong base of NaOH. Increasing pH values were observed during such titration. Depending on the existence of indicator in the solution, the equivalence point was determined when the color of the solution had turned into pink. After finding the equivalence point, images were taken after every addition of base to the acid solution. These images were evaluated using red, green and blue values of the pixels, through an image processing program. After analyzing the image results, it was found that the percentage of red values had increased with the increasing pH value. As a result, the image processing techniques can be used as an alternative approach to find pH values of titrated solutions.

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1. Introduction

pH tests are commonly used in chemical laboratories to measure acidic or alkaline levels of solutions. pH levels typically range from 1 to 14; 7 is neutral; 1 is very acidic and 14 is very alkaline [1]. There are various technologies available to measure pH value, but the most accurate pH measurements can be obtained with a pH meter. Calibration of the pH meter before each use extends the duration of the tests [2].

For such reasons, many researchers have begun to search for new methods for determining the pH values. With the help of computer-based technologies, many processes can be simplified and can be done in a shorter time. Nowadays, digital image processing and digital image analysis methods have gained popularity in these applications [3–6]. When the literature is examined, it can be seen that there are some studies available aimed to determine the pH value by using image processing techniques [1, 6-11].

In this study, usability of image processing techniques, as an alternative approach to determine the pH values of titrated solutions, was investigated.

2. Materials and methods

2.1. Materials

Burettes, Erlenmeyer flasks, and graduated cylinders were used as laboratory materials during the titration experiment. ImageJ program was used for evaluation of the images, obtained in experimental studies.

2.2. Method

Titration is a method of finding the concentration of an unknown acid or base with the help of a known acid or base. As follows from the description, it is based on a neutralization reaction [12].

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In this work, neutralization of HCl was carried out using NaOH. For this purpose 0.1 M NaOH solution and 0.1 M HCl (from 37% HCl solution) were prepared. 50 ml of 0.1 M HCl solution was then titrated with 0.1 M NaOH. Color change was observed and recorded in the study range of the indicator (phenolphthalein) by increasing the volume of NaOH by 1 ml after the turning point. The implementation of the experiment is given in Fig. 1.

Fig. 1. Implementation of the experiment.

The pOH value of solution was obtained using Eq. (1) and the pH value of solution was obtained from Eq. (2).

$$\mathrm{pOH} = -\log\left[\frac{n_{\mathrm{NaOH}} - n_{\mathrm{HCl}}}{V_{\mathrm{NaOH}} + V_{\mathrm{HCl}}}\right]. \tag{1}$$

Here n is number of moles, V is volume.

$$\mathrm{pH} = 14 - \mathrm{pOH}. \tag{2}$$

A digital image consists of a two dimensional matrix, composed of rows and columns. Each region where rows

and columns intersect is called a pixel. A pixel is the smallest unit of an image. A digital image is defined as a $[M, N]$ in a 2D limited space. The coordinates of pixels are denoted as $[m, n]$, where m, n are integer values. The function $a(x, y)$ is a function of many variables. Color depth is indicated by color z and time t [13].

Color spaces are mathematical models used to describe colors. Color spaces are created to represent all colors. The RGB color space is the most widely used color space, consisting of "Red" "Green" and "Blue" primary colors. The codes of all colors in the nature are specified, based on these three basic colors. Different colors can be obtained by mixing basic colors in different proportions. Color images are displayed on computer screens as data at different bit depths. Imaging occurs when three gray level images of the same object, encoded in R (Red), G (Green), and B (Blue), are transmitted to the screen on top of each other.

455–492 nm wavelengths correspond to blue color, 492–577 nm wavelengths correspond to green color and 622–780 nm wavelengths correspond to red color in the electromagnetic spectrum. If three grayscale images, obtained in these wave length ranges, are displayed on the computer screen in sequence with red-green-blue combination, a color image is obtained [13].

After application of the selected indicator, acid remains colorless, and color of base changes to pink. The titration process changes the color of the solution and as the pH value increases, the color of the solution changes from colorless to pinkish. In this study, the ImageJ program was used to determine the change in solution color as a result of titration. The average color values were determined for the digitally obtained color images in each channel of the RGB color space.

The percentages of the red (red) value from the numerically obtained values were calculated using Eq. (3).

$$\text{Red\%} = \frac{R_{\text{Mean}}}{R_{\text{Mean}} + G_{\text{Mean}} + B_{\text{Mean}}} \times 100. \tag{3}$$

In this equation R_{Mean} is the average red value in an image, G_{Mean} is average green value in an image and B_{Mean} is average blue value in an image, %Red is the percentage of red value

3. Findings and discussion

The concentration of OH-ions and the pH values of solution, calculated after every increase of base amount by using Eqs. (1) and (2) are given in Table I.

TABLE I

Concentration of OH ions and pH values calculated for the digital images of the solution.

	$[OH^-]$	pH
1st image	9.9×10^{-7}	7.996
2nd image	1.98×10^{-6}	8.296
3rd image	2.97×10^{-6}	8.472

The images of the solution with the increasingly saturated color, as the result of addition of the base, are presented in Fig. 2. The image in Fig. 2a was obtained when the first 1 ml of base was added and the images in Figs. 2b and 2c are the images obtained after the addition of the second and the third 1 ml of base. The RGB values of the obtained images are shown in Table II. According to the findings, the pH value of the first image was calculated as 7.996.

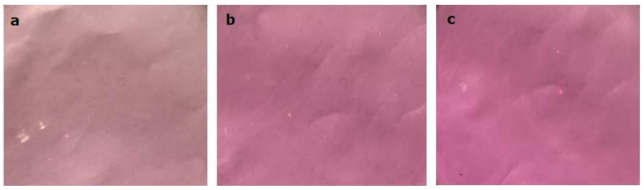

Fig. 2. Images used for evaluation in ImageJ program (a) 1st image, (b) 2nd image, (c) 3rd image.

TABLE II

Red% values obtained from ImageJ program.

	1st image	2nd image	3rd image
Red values [%]	39	42	44
Calculated pH values	7.996	8.296	8.472

The Red values obtained from the image analyses, performed using the ImageJ software, were converted into percentages using Eq. (3), and are shown in Table II. A regression graph shown in Fig. 3 was generated in order to reveal the linear relationship between the Red percentage values and the pH values.

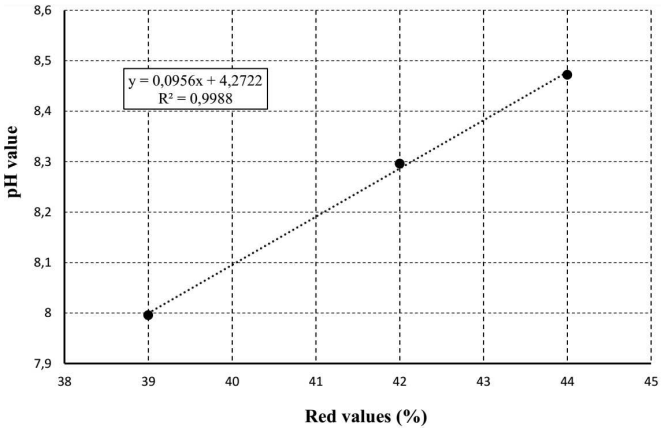

Fig. 3. Relation between the red values (%) and the pH.

When Fig. 3 is examined, it is seen that there is a linear relationship between the red percentages found using the ImageJ program and the pH values.

4. Results and recommendations

In this study, strong acid-strong base solutions were prepared; acid and base were titrated; and the images of the color changes of the solutions at the equivalence point and beyond it were taken. The RGB values of the images of solution were assessed in the ImageJ software. The percentage of Red values was calculated and correlated with the pH values. Even a slight increase in pH values has been shown to cause darkening of the solution color. With the help of this color change, a pH-Red value percent graph was plotted in the Excel software. The graph shows a linear relation between color darkening and the pH values. As a result, it was found that the obtained graph can be used as an alternative way to predict the pH values and the image processing approach can be a useful method for determination of the pH values of solutions.

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