

The sound and movement of a titration: Low-cost instrumentation towards inclusive chemical analysis

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Highlights

The development of a low-cost colorimetric sensor, using LEDs and Arduino microcontroller board and custom JavaScript code to transduce color changes during volumetric titrations with visual indicators into sound or vibration, enhancing inclusivity for visually impaired students and expanding affordable measurement techniques.

Abstract

Volumetric titration is a fundamental technique in chemistry. In the scope of teaching, it is critical for understanding chemical equilibrium and a powerful tool for chemical analyses. Traditionally, a visual indicator, which changes color near the stoichiometric point of the reaction, is used to determine the endpoint.¹ However, this concept can be extended to other stimuli, such as sound or vibration, to enhance accessibility and broaden analytical methods. For instance, in a low-cost colorimetric setup (Figure 1A), a light-emitting diode (LED) can serve dual purposes as both a light source and a light sensor.² When integrated to titrations using visual indicator, the LED can detect the color changes during the experiment, with the color of emitting and receiving diodes tuned to the absorbance wavelength of the visual indicator. By connecting this system to an Arduino Uno R4 microcontroller and using a custom JavaScript code, the color signal can be transduced into dynamic sensory outputs: auditory feedback, where a low-pass filter modulates musical chords correlating with color intensity (Figure 1B), and tactile feedback, where vibration intensity of an unbalanced motor scale with color-change magnitude. Parallel pH measurements validated the system, demonstrating that the color-transduced signal curve has a sigmoidal profile, matching that of the pH curve (Figure 1C), with the inflection point, visual indicator color change, clearly seen. Our instrumentation not only makes titration more accessible for students with visual impairments or color blindness but by doing so at a low-cost (R\$155,67), it removes the financial barrier to accessibility.

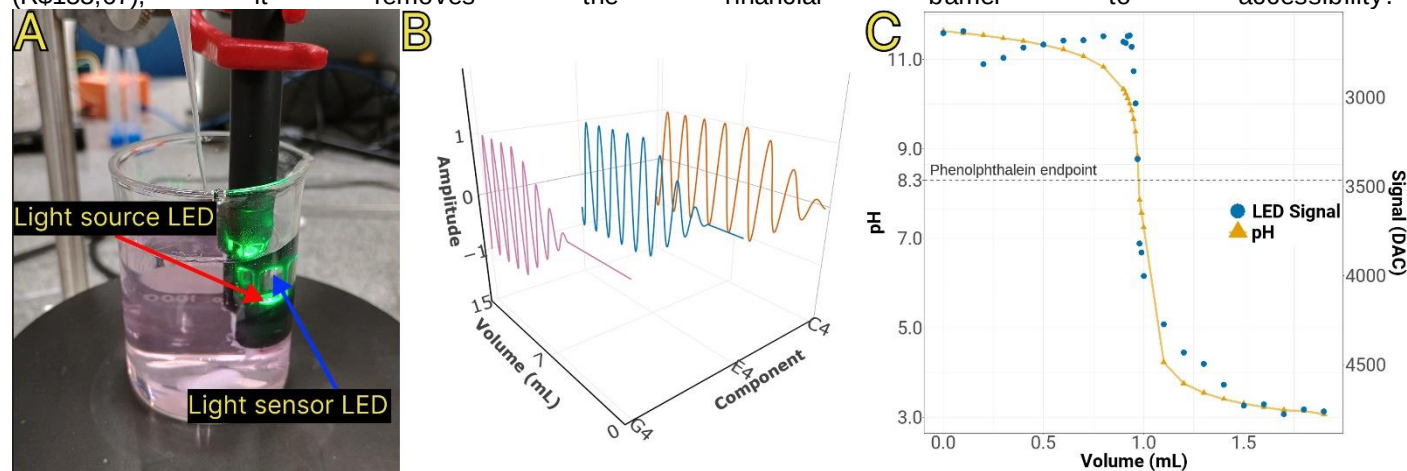


Figure 1: (A) Low-cost colorimetric instrumentation. (B) Modulation of C major chord due to color changing. (C) Titration curve measured with commercial pH meter and our low-cost system.

Reference: (1) Wang, Y.; Geng, J.; Zhu, Z. A Comprehensive Teaching Laboratory Program on Titration Analysis: Transition from Classic to Modern Approaches. *J. Chem. Educ.* **2024**; (2) Graybill, C. M.; Supalo, C. A.; Mallouk, T. E.; Amorosi, C.; Rankel, L. Low-Cost Laboratory Adaptations for Precollege Students Who Are Blind or Visually Impaired. *J. Chem. Educ.* 2008.

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