SUPPLEMENTARY MATERIAL

RGB-LED-photometer and the digital image-based method using a smartphone for Chemistry and Physics teaching

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EXPERIMENTAL PROCEDURE

Reagents and apparatus

UV-Vis spectrophotometer;
RGB-LED photometer;
Smartphone;
LED-chamber;
10 mL volumetric flasks;
20-200 μL micropipette;
10 mL beakers;
10 mL graduated pipette;
Deionized water;
Quartz cuvettes with 1.0 cm optical path;
pHmeter;
1.6 mmol L^{-1} bromothymol blue (BTB) solution;
0.5 mol L^{-1} phosphate solution at pH 2.0, 7.0 and 12.0;
1.0 mol L^{-1} NaOH aqueous solution;
1.0 mol L^{-1} HCl aqueous solution.

BTB solutions preparation

- Transfer approximately 15 mL of the phosphate solution into three different 10 mL beakers using a graduated pipette. Using a pHmeter, adjust the pH of the solutions to 2.0, 7.0, and 12.0 with the HCl and NaOH solutions;
- Measure 10 mL of each phosphate solution at different pH values using a graduated pipette and transfer to three 10 mL volumetric flasks, respectively;
- Using a micropipette, add 50 μL of 1.6 mmol L^{-1} BTB solution to each of the volumetric flasks;
- Complete the volume of the volumetric flasks using the respective phosphate solution;
- The phosphate buffer solution pH 7.0 should be used as a blank solution.

K_a determination of bromothymol blue using the UV/Vis spectrophotometer

- Add phosphate buffer solution at pH 7.0 to a cuvette to be used as a blank and transfer the three previously prepared solutions containing BTB to cuvettes;
- Select the wavelength of 435 nm and set the blank (absorbance equal to zero) using the cuvette with phosphate buffer solution pH 7.0. Then, record the absorbance of the other cuvettes containing BTB in a neutral solution, BTB in an acidic solution, and BTB in an alkaline solution. Repeat this procedure in triplicate (n = 3);
- Repeat the previous procedure with the wavelength of 615 nm in triplicate;
- With the data obtained at this stage, calculate the medium value of K_a and pK_a of BTB and the respective standard deviations.

K_a determination of bromothymol blue using RGB-LED photometer

- To define the blank in the wavelength of the red region (B-RED) set the photometer by choosing function 4. With the cuvette containing only a phosphate buffer, record the blank. The equipment automatically saves this value to be discounted from the BTB solutions in function 7 (next step);
- Set the RGB-LED photometer to measure samples in the red region (A-RED) by choosing function 7. Record the absorbance of cuvettes containing BTB in neutral solution, BTB in acidic solution and BTB in alkaline solution;
- To define the blank in the wavelength of the blue region (B-BLUE) set the LED-photometer by choosing function 2. With the cuvette containing the phosphate buffer, record the blank. Again, the signal of black solution cannot be annotated because the equipment automatically saves this value to be discounted from the BTB solutions in function 5 (next step);
- Set the LED-photometer to measure samples in the blue region (A-BLUE) by choosing function 5. Record the absorbance of cuvettes containing BTB in neutral solution, BTB in acidic solution and BTB in alkaline solution;
- All procedures need to be repeated in triplicate;
- With the data obtained at this stage, calculate the medium value of K_a and pK_a of BTB and the respective standard deviations.

K_a determination of bromothymol blue by digital images using a smartphone

- Take a side and top picture of the cuvettes containing phosphate solution, BTB in a neutral solution, BTB in an acidic solution, and BTB in an alkaline solution;
- Use Color Grab app (Franco *et al*)[27] to process image data;
- Select the most suitable areas of the cuvette images, avoiding regions of shadow and intense brightness;
- All procedures need to be repeated in triplicate;
- With the data obtained at this stage, calculate the medium value of K_a and pK_a of BTB and the respective standard deviations.

Analysis and discussion of the results

- Discuss the advantages and disadvantages of each equipment used to determine the acidity constant of BTB.
- Calculate the percentage relative error of the K_a and pK_a obtained experimentally in relation to the value reported in the literature.
- Make the necessary comparisons, observe each phenomenon, and show all the necessary calculations.

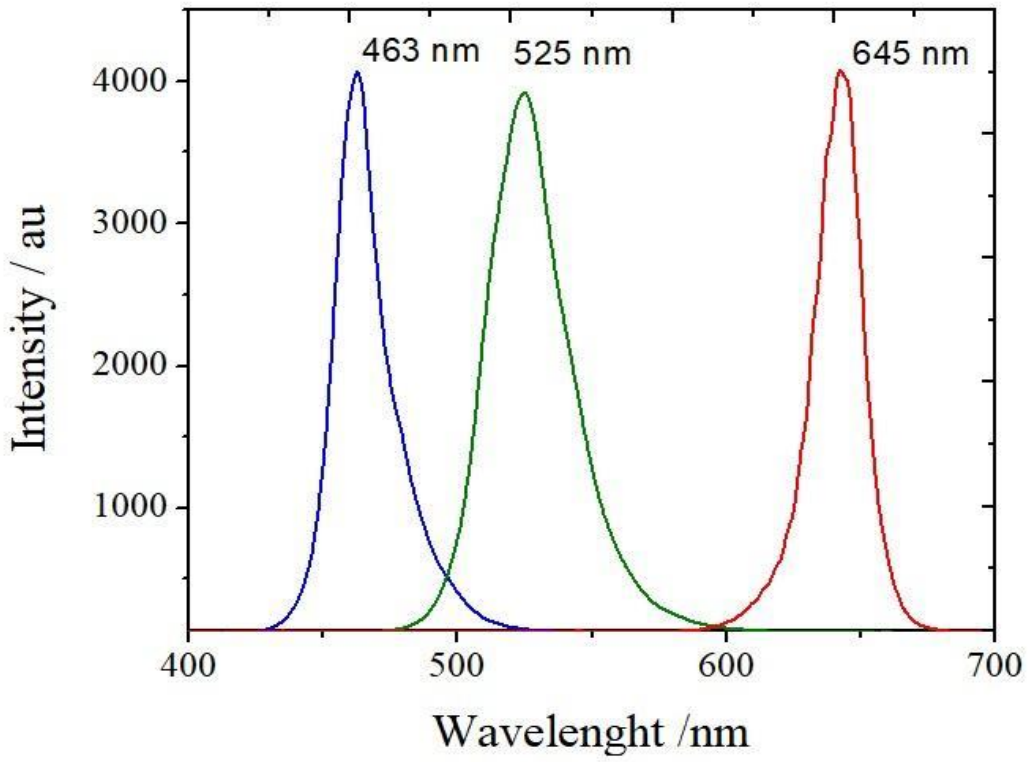

Figure 1S. *Spectra of the RGB-LED used as a radiation source in the RGB-LED photometer*

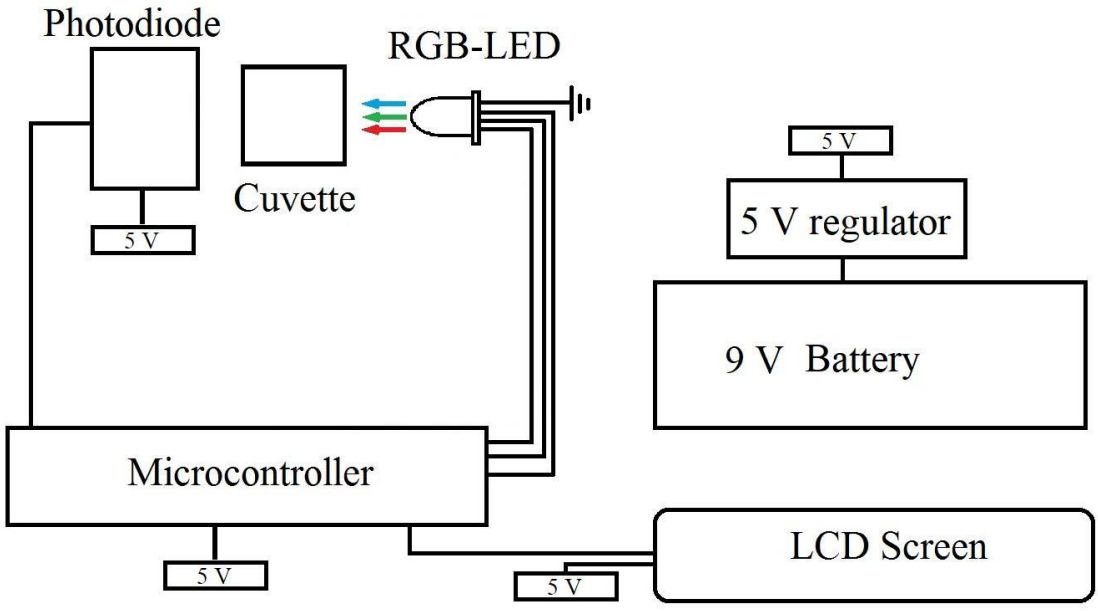

Figure 2S. *Schematic diagram of the basic electronic circuit of the RGB-LED photometer. After a 5 V regulator, the electronic circuit is powered by 5 V*

ALGORITHM FOR THE RGB-LED PHOTOMETER IN C LANGUAGE

```
unsigned long int x=0, i, h, v;
float t, *texto1[13], *texto[13],*texto2[13], dark, res, ref, temp;
void opcao()
          {
          if (portc.F2) x++, delay_ms(5);
          if (portc.F0) x--, delay_ms(5);
          if (x>7) x=7;
          if (x<1) x=1;
          }
void darkness()
{
         dark=0;
               portc=0x00;
          portd =0x00; // LED OFF
          res = 0;
          temp=0;
          i=0;
          for(i=0; i<=60; i++)
                    {
                    res = Adc_Read(0);
                    temp = dark;
                    dark = res + temp;
                    }
}
void main()
{
int z=1, a=0, o=2 ;
float f, c, y, g, b, k, l, m, n, q, u;
float ref2, ref3, ref4, ref5, ref6, ref7, ref8, res2, res3, res4, res5, temp2, temp3, temp4,
temp5, abs=0, abs2=0, abs3=0;
  TRISC   = 0x07;
  TRISD   = 0X00;
  TRISA   = 0X11;
  TRISE   = 0X00;
  porte.f0= 0x01;
  porta   = 0x08;
  ADCON1  = 0x0E;
   TRISB = 0;
   LCD_INIT(&PORTB);
   Lcd_Cmd(Lcd_CLEAR);
   Lcd_Cmd(Lcd_Cursor_Off);
          lcd_out(1,1,"RGB-LED photometer");
          Delay_ms(50);
          Lcd_Cmd(Lcd_CLEAR);
          Lcd_Cmd(Lcd_Cursor_Off);
          lcd_out(1,1,"Menu");
          Delay_ms(70);
          Lcd_Cmd(Lcd_CLEAR);
```

```
        Lcd_Cmd(Lcd_Cursor_Off);
        Delay_ms(50);
        lcd_out(1,1,"1)D 2)BB 3)BG 4)BR");
        lcd_out(2,1,"5)AB 6)AG 7)AR");
   //portd=0XFF;

while (1)  //
    {
   opcao();
    z=x;
    WordToStr(z, texto1);
    lcd_out(2,16,texto1);
    //portd=0X1c;
        delay_us(10);
        portd=0X00;

  if (portc.F1)
  {
  lcd_Cmd(lcd_CLEAR);
  Lcd_Cmd(Lcd_Cursor_Off);
    switch (z)
        {
        case 1:
        lcd_out(1,14,"Dark");
        darkness();
         floatToStr(dark, texto2);
        lcd_out(1,1,texto2);
        delay_ms(10);

break;
        case 2:
        lcd_Cmd(lcd_CLEAR);
          Lcd_Cmd(Lcd_Cursor_Off);
        lcd_out(1,14,"B-Blue");
        darkness();
        portc=0x80;
        res2 =0;
        i=0;
        temp2=0;
        ref=0;
        ref2=0;
        for(i=0; i<=60; i++)
                {
                  res2 = Adc_Read(0);
                temp2 = ref ;
                ref = res2 + temp2;
                }
                ref2= (ref-dark);
              ref4= (ref3/ref2);
                abs = -log10(ref4);
```

```
        floatToStr(abs, texto2);
        lcd_out(1,1,texto2);
        delay_ms(10);

break;
        Lcd_Cmd(Lcd_CLEAR);
        Lcd_Cmd(Lcd_Cursor_Off);
        Delay_ms(50);

case 5:

        lcd_out(1,14,"A-Blue");
        darkness();
        portc=0x80;
        res2 =0;
        i=0;
        temp2=0;
        texto2=0;
        ref=0;
        ref2=0;
        ref3=0;
        ref4=0;
                for(i=0; i<=60; i++)
                {
                  res2 = Adc_Read(0);
                temp2 = ref ;
                ref = res2 + temp2;
                }
                ref2= (ref-dark);
              ref4= (ref3/ref2);
                abs2 = -log10(ref4);
                abs3 = abs2-abs;
   floatToStr(abs3, texto2);
   lcd_out(1,1,texto2);
        delay_ms(10);
}}}}
```