# CONSTRUCTION AND EVALUATION OF A SOLID STATE PHOTOMETER AS AN ALTERNATIVE TO CONVENTIONAL SPECTROPHOTOMETERS

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## ABSTRACT

A Solid State Photometer has been constructed, using light emitting diodes (LEDs) as light source and a photodiode as photodetector. Rate constants as functions of reactant concentration, hydrogen ion concentration and ionic strength were obtained using the kinetic set and compared with those obtained from a Unicam SP 1750 uv-visible Spectrophotometer. Statistical parameters applied to the results obtained with the two systems showed that there was no significant difference between the two methods at 0.05 confidence level. The solid state photometer can be interfaced to a computer (Datadisc Pro for windows) to automaticaly record the rate of change of absorbance or transmittance. This arrangement provides the user with digitized version of the experimental signal which can be processd in a multitude of increasingly complex ways in order to extract as much chemical information as possible. Apart from the fact that the LEDs are cheap, compact and commercially available, equipment constructed from this system have small size, light weight, low power consumption and negligible warm up time. The solid state photometer is a rugged, reliable, low-cost alternative to commercially available spectrophotometers. Its use is therefore recommended as a compliment or an alternative to the expensive spectrophotometer.

## INTRODUCTION

A solid state photometer is a system which employs light emitting diodes (LEDs) as sources of visible radiation and photodiodes as the detector components[1]. This system has been shown to give comparable results with those obtained using a conventional spectrophotometer[1-3]. The LEDs and photodiodes are cheap, compact and commercially available. The small size, light weight, low power requirement and negligible warm up time of equipment constructed from this system make them the obvious alternative to the expensive spectrophotometers. In addition, LEDs emit more than 5 times the radiant energy of a 40W tungsten lamp after using a monochromator to select the corresponding bandwidth[4]. The normalized intensity versus wavelength profiles[5] for the most widely used LEDs are shown in Figure 1. LEDs have also been used as sources of visible radiation in Flow Injection Analysis (FIA)[2,3], in ion exchange chromatography detector for determination of cations and in optoelectronic devices[6-8]. In this paper, we present the method of construction of the solid state photometer and the evaluation of it in comparison with the conventional spectrophotometer.

## EXPERIMENTAL

### *Design and construction*

The solid state photometer was constructed as represented by the block diagram in Figure 2. The arrangement is such that the light emitting diode (LED) and the photodetector are located behind two small focusing lenses enclosing the cuvette holder. A glass coil through which thermostated water can be circulated to the cuvette holder was also constructed. The coil and accessory are shown in Figure 3. The associated electronic component consisting of an LED driver circuit and a detector signal processing circuit was also

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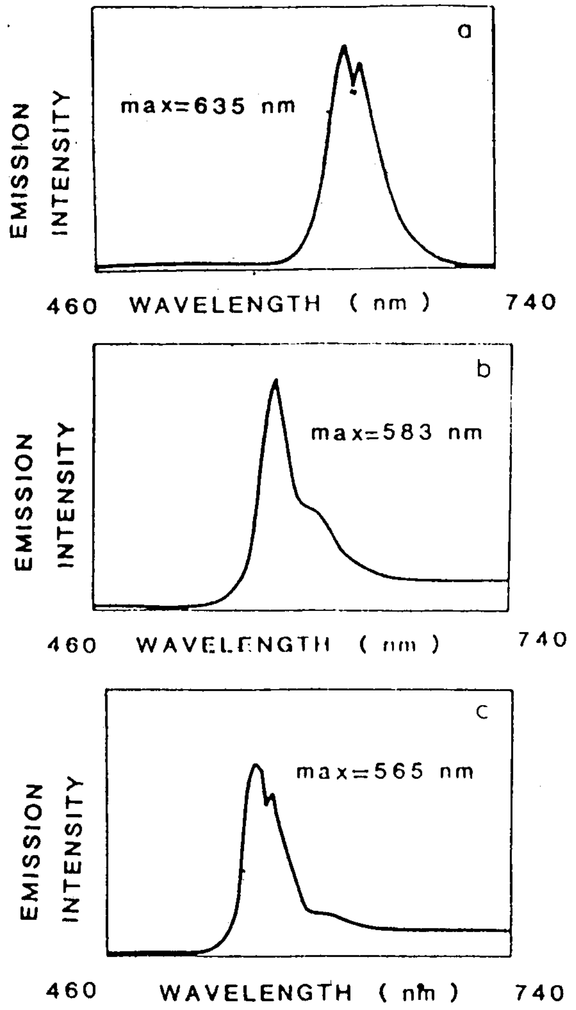

**Figure 1: Normalized emission intensity versus wavelength profiles for (a) red, (b) yellow (amber),and (c) green light emitting diodes**

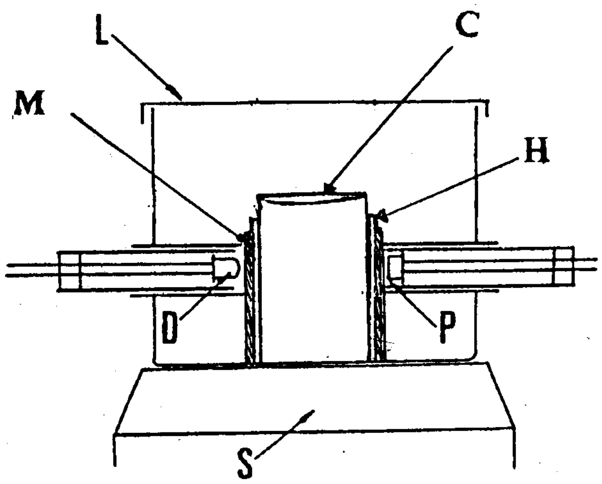

Figure 2: Cross section of the solid state photometer

L = lid
C = cuvette
H = cuvette holder
D = interchangeable LED
P = photodiode
S = circuit component
M = focusing lens

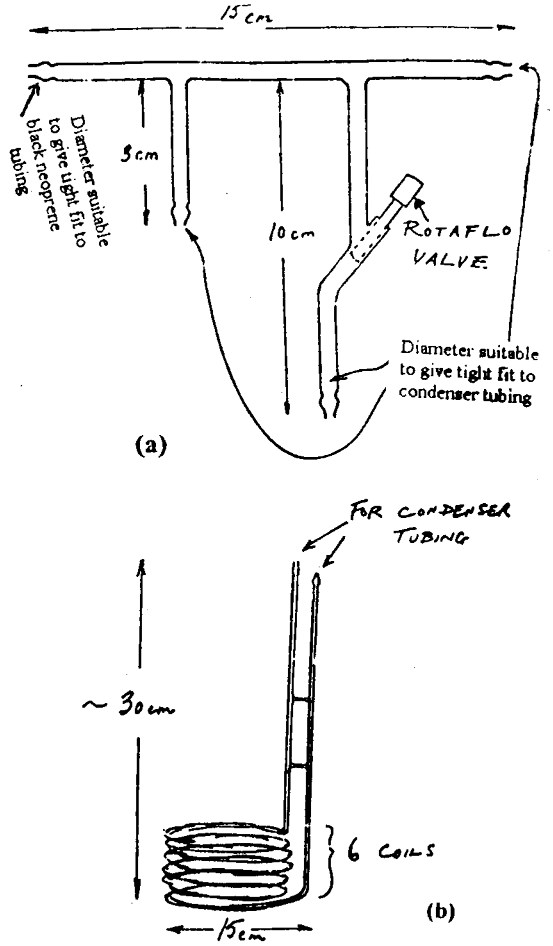

Figure 3: Parts of water flow system for thermostat (a) connecting accessory, (b) coil for the ice bath

constructed. The circuit diagram is shown in Figure 4. The solid state photometer has been interfaced with a microcomputer via a universal interface so that the reaction could be monitored automatically by using an appropriate soft ware. The flow diagram for the solid state photometer indicating the interfacing relay, is shown in Figure 5.

*Stability and sensitivity loss test*

The stability and sensitivity loss of the apparatus constructed was tested as follows:- The solid state photometer was switched on and allowed on for a period of 4 hours under a stabilized source of power. This was repeated three times and the loss in transmittance after the 4 hour period was observed and recorded as shown in Table 1. T-test analysis was performed on the results as indicated in Table 1.

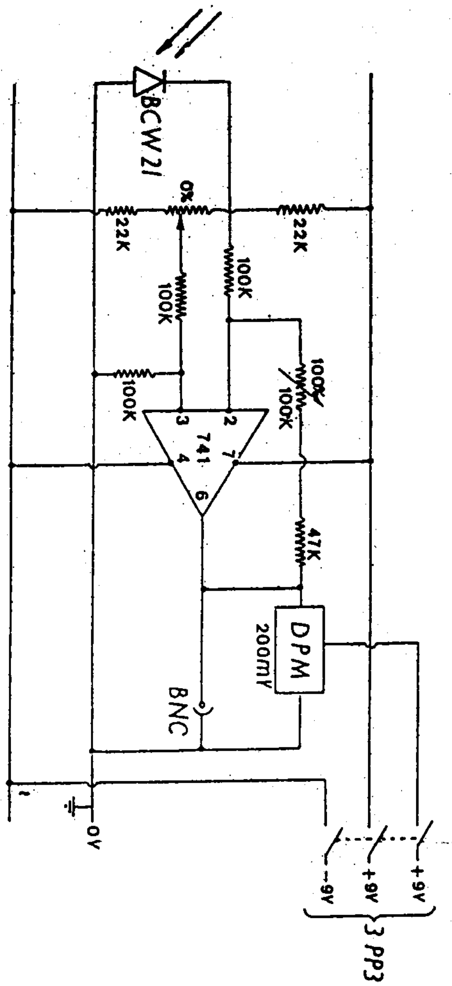

Figure 4: Circuit diagram for the photodiode

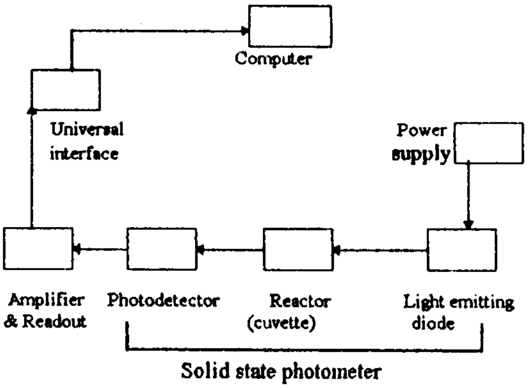

**Figure 5: Flow diagram for the photometer showing the interfacing relay from the photometer to the computer**

**Table 1: Sensitivity loss of the solid state photometer**

| Time (minutes) | Transmittance (%) | | |
|---|---|---|---|
| | A | B | C |
| 0 | 100 | 100 | 100 |
| 15 | 99.9 | 99.9 | 99.8 |
| 30 | 99.9 | 100 | 99.9 |
| 45 | 100.1 | 100 | 100 |
| 60 | 100.1 | 100 | 100.1 |
| 90 | 100.2 | 100.1 | 100 |
| 120 | 100.3 | 100 | 99.9 |
| 150 | 100.2 | 99.9 | 100 |
| 180 | 100.1 | 100 | 100 |
| 210 | 100 | 100 | 100.1 |
| 240 | 99.9 | 99.9 | 100.1 |

$t^{A}_{0.05} = 1.421 < t_t(1.812)$; $t^{B}_{0.05} = 1.106 < t_t(1.812)$
$t^{C}_{0.05} = 0.369 < t_t(1.812)$; $t^{Av}_{0.05} = 0.586 < t_t(1.697)$

*Comparability of results obtained using the solid state photometer*

Rate constants as functions of concentration, hydrogen ion concentration and ionic strength, were obtained using Unicam SP 1750 uv-visible spectrophotometer and the correlation coefficients for the relationships were calculated. The same procedure was carried out on the solid state photometer. F-test analysis was also performed on the 2 sets of results.

## RESULTS AND DISCUSSION

The block diagram of the solid state photometer and the glass coil constructed are shown in Figures 2 and 3 respectively. With the aid of a thermostated system, water is circulated to ensure constant temperature within the reaction system. The coil can be used in conjunction with a water circulator as a substitute for the thermostated system. When the coil is immersed in an ice bath, it will facilitate the study of the effect of temperature on the rate of a reaction.

The LED driver and detector signal processing unit are represented by the circuit diagram in Figure 4. This is a simple circuit system which can be constructed with minimal previous experience. The current output from the detector is converted to an analogue voltage signal via an operational amplifier and this voltage is linearly related to the transmittance of the solution contained in the cuvette. The absorbance, even in terms of concentration, can also be related to the transmittance changes as the reaction progresses.[4,9,10]. The signal is recorded digitally on the probe or relayed to a computer via an interface. The results can be analysed immediately or stored in files to be analysed later as and when convenient. This proides the investigator with the choice of collecting as much data as possible and analysing them later.

.The sensitivity loss of the equipment was found to be between 0.06 and 0.15% within a 4 hour period. This effect is better than the reported 5 and 10% by Trojanowizc et al. for similar flow injection systems[1]. The values obtained from the t-test analysis of the data (Table 1) are less than the tabulated values at 0.05% confidence level, indicating that results obtained by this piece of equipment are reliable. It can therefore be stated that equipment constructed from these systems are efficient, reliable and have long lifetimes. Good industrial products of this type reach lifetimes of above $10^5$ hours or more than 11 years.[11-14].

The values of the rate constants versus reactant concentration, hydrogen ion concentration and ionic strength monitored with Unicam SP 1750 uv-visible spectrophotometer and the solid state photometer are reflected in Table 2.

Table 2: Rate constants and statistical correlation for some kinetic parameters using uv-visible spectrophotometer(I) and solid state photometer(II)

(a)

| | I | II |
|---|---|---|
| $10^2[CH_3CHO]$,M | $10^4k_o$, s | $10^4k_o$ $s^{-1}$ |
| 0.8 | 4.58 | 4.15 |
| 1.0 | 5.65 | 5.12 |
| 1.2 | 6.92 | 6.27 |
| 1.5 | 8.35 | 7.67 |
| 1.7 | 9.42 | 8.68 |
| 1.9 | 10.47 | 9.49 |
| 2.5 | 14.45 | 13.09 |

r(I) = 0.998; r(II) = 0.986; $F_{0.05} = 1.22 < F_t(3.79)$

(b)

| | I | II |
|---|---|---|
| $H^+]$,M | $10^3k$, $s^{-1}$ | $10^3k$ $s^{-1}$ |
| 0.05 | 0.52 | 0.50 |
| 0.10 | 0.77 | 0.75 |
| 0.15 | 0.96 | 0.95 |
| 0.20 | 1.07 | 1.02 |
| 0.25 | 1.22 | 1.21 |
| 0.35 | 1.65 | 1.60 |

r(I) = 0.978; r(II) = 0.993; $F_{0.05} = 1.06 < F_t(4.28)$

(c)

| | I | II |
|---|---|---|
| Ionic Strength M | $10^4k$, $s^{-1}$ | $10^4k$ $s^{-1}$ |
| 0.42 | 6.10 | 6.26 |
| 0.52 | 7.34 | 7.40 |
| 0.72 | 7.53 | 7.61 |
| 1.00 | 7.65 | 7.98 |
| 1.25 | 8.05 | 8.20 |
| 1.50 | 8.66 | 8.69 |
| 2.00 | 8.95 | 9.03 |
| 2.20 | 10.16 | 10.23 |

r(I) = 0.913; r(II) = 0.951; $F_{0.05} = 1.54 < F_t(3.44)$

The correlation coefficients for such data are also shown in Table 2 where I = SP 1750 spectrophotometer and II = solid state photometer. The values of the correlation coefficients (r) for the two systems are of the same order of magnitude and do not show any significant difference at 0.05% confidence level. The ratios of variances are less than the tabulated values, which inidcate that results obtained with the 2 pieces of equipment are not significantly different and so the photometer is suitable for spectrophotometric analysis.

Apart from using the photometer for manual monitoring of reactions, it can be interfaced with a computer to automatically record the rate of change of absorbance or transmittance of the reacting mixture. The interfacing is an attractive low cost option for multi-component spectrophotometric analysis. This arrangement provides the user with a digitized version of the experimental signal, which can be processed in a multitude of increasingly complex ways in order to extract as much chemical information as possible. There is an unlimited number of software packages that can be utilized for this purpose. One of such packages, Datadisc Pro for windows, (marketed by Philip Harris system) is being used with this system.

## CONCLUSION

The efficiency of the equipment constructed with solid state components compare well with that of conventional spectrophotometers. The LEDs and photodiodes are cheap, compact and commercially available. The small size, light weight, low power requirements and negligible warm up time of the photometers constructed from them are added advantages of the use of this sytem. It has a potentially long lifetime if properly operated. The application of this system is not restricted to visiblle spectrophotometry and flow injection analysis; it can also be employed in ion-chromatography and infra red methods. Chemical research in Nigerian Universities can be greatly enhanced by the effective exploitation of solid state photometry.

## ACKNOWLEDGEMENT

We are grateful to the University of Salford for providing the facilities for this work, to the National Universities Commission for funding and to the University of Jos for the award of study fellowship to YNL.

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*accepted 17/12/97*
*received 16/4/97*