DOI: 10.13656/j.cnki.gxkx.2001.01.009
广西科学 Guangxi Sciences 2001, 8 (1): 26~29

# An Analysis Method of Spot Light Photometry
# 点射光光度分析法

Wu Weichang　　Lu Zhaoxia
吴维昌　　卢朝霞

(College of Chemistry and Chemical Engineering, Guangxi University,
10 Xixiangtanglu, Nanning, Guangxi, 530004, China)
(广西大学化学化工学院　南宁市西乡塘路 10号　530004)

**Abstract**　The mathematical inference equation about absorption of monoenergetic spot light in the solution is released as follows: $\ln a = kcb + B$. Where, $a$ is the range from spot light to the slot of phototropic surface in the absorption pool; $k$ is the absorption coefficient of spot light in the solution; $c$ is the concentration of light absorbers in the solution; $b$ is the thickness of absorption pool (2 mm); $B$ is a constant standing for light-transmission intensity. Self-manufacture spot light photometry instrument showed a good result in the test for this equation by $KMnO_4$ standard solution, $Cu(NH_3)_4SO_4$ standard solution and $Na_2CuY$ standard solution. There is also a good result (60.95%) in the test of the standard brass sample (Cu = 60.93%) in $Na_2CuY$ standard solution. Error analysis formula was obtained as $dc/c = da/a(\ln a - B)$, which is consistent with the error formula of differential photometry method at $a > 10$ and $T = 1 \sim 10$. The result indicates that this method could be adopted to heavy contend analysis.

**Key words**　photometry, spot light, heavy contend analysis

摘要　推导溶液对单色点射光吸收的数学方程式: $\ln a = kcb + B$,式中 $a$是吸收池上光栏与点射光源的距离(cm); $k$是溶液对点射光的吸收系数; $c$是溶液中吸光粒子的浓度; $b$是吸收池厚度 (2 mm); $B$是当 $a = 100$ cm 调节灯光电流使透光 (电流)强度为一常数的常数值。用 $KMnO_4$标准溶液、$Cu(NH_3)_4SO_4$标准溶液和 $Na_2CuY$标准溶液验证吸收方程式,并用 $Na_2CuY$为介质测定标准黄铜样 (Cu= 60.93%)取得良好结果 (60.95%)。对吸收方程式进行误差分析得到 $dc/c = da/a(\ln a - B)$ $a > 0$,在 $a > 10$和 $T$在 1~100之间,此式与差示光度法的误差分析式极像。该方法适用于高浓度分析。

关键词　光度分析法　点射光　高含量分析
中图法分类号　O 657.32

Photometry analysis is generally conducted under the parallel monoenergetic light shining. Because the energy of parallel light can be concentrated, and it is useful in the microanalysis. As we known, however, its error is bigger, and can be calculated by the following formula:

$$\frac{dc}{c} = \frac{0.4343 dT}{T(\log T)}.$$

In 1949 Hiskey established a differential photometry method, and it's error can be calculated as follows:

$$\frac{dc}{c} = \frac{0.4343 dT}{T(\log T_x + A_s)}.$$

It is the first time that photometry is applied in the determination of heavy contend. The parallel light is a special light in the spot light. For increasing the accuracy of the photometry analysis, we adopted the spot light instead of parallel light in the analysis, and obtained a more accurate result. Energy scattering of spot light is helpful in the analysis of heavy content. In the analysis of intermediate and heavy contents, we don't need to use microzone interpolation and adjust instrument with standard solution as we do by the differential photometry method.

## 1　Method and principle

The principle of spot light photometry is showed in Figure 1. Spot light which is created from the spot light source goes through the monochrometer, and becomes the monoenergetic spot light. The spot light source (or the absorption pool) could move along the track in order to change the distance ($a$) between the spot light source and the absorption pool. There is a rectangular slot diaphragm in the phototropic side of the absorption pool. Its width ($s$) and half-high ($R$)

2000-08-03收稿。

can be adjusted. The photoelectric battery ($p$) is behind the absorption pool. The light current is detected by a high sensitive multiple reflection galvanometer.

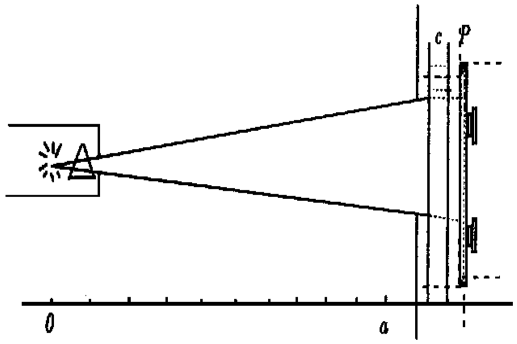


Fig. 1 The principle of analysis of spot light photometry

As the spot light source is removed, the incident intensity ($Ia$) from the diaphragm interception also changes. The transmission current flow is not only related to the concentration of light absorbers, but also related to the thickness of absorption pool ($b$) and the range($a$). When conducting a test, we let the absorption pool be full of blank solution, let $a$= 100 cm and adjust the current of the spot light source until the light current is an assigned value ( Let it is 10 format). Filling in the absorption pool with solution, changing the location of the spot light source until all the transmission current flow equal to 10 format of blank current, writing down the corresponding number ($a$), then we can obtain the concentration of absorbers of the solution by the following formulas.

## 2 Formulas and inferences

When a beam of monoenergetic light passes through the solution, the light is absorbed. If the absorbed light equals to the number of the absorbers that connect with the light, the percentage of the absorbed light can be computed by Formula (1):

$$-\frac{dI}{I} = k\,dm \quad \text{or} \quad -\int_{I_a}^{I}\frac{dI}{I} = k\int_0^m dm. \qquad (1)$$

Where, $Ia$ is the incident (light) intensity; $I$ is the light-transmission intensity; $m$ is the number of absorbers that connect with the light (in the light column); $k$ is the proportional coefficient; minus (−) stands for absorption.

Because of the spot light source, the illuminance ($J$) of any points on the illumination surface is inversely proportional to the square of the range ($d$) from the spot($r$) to the spot light source($Ls$), and proportional to the cosine of the incidence angle (AoA) (T). That is

$$J = J_0\frac{\cos T}{d^2}. \qquad (2)$$

For obtaining the incident intensity ($Ia$), we must get the integral quantity of Formula (2) to the whole light surface of the optical slot. That is

$$Ia = \int_{-R}^{R} sJ\,dr = \int_{-R}^{R} sJ_0\frac{\cos T}{d^2}dr = \int_{-R}^{R} sJ_0\frac{a}{d^3}\,dr$$
$$= \int_{-R}^{R} sJ_0\frac{a}{(d^2+r^2)^3}\,dr,$$

$$\therefore \quad Ia = J_0A/a^2 \quad (r \ll a). \qquad (3)$$

Where, $A$ is the area of the optical slot, $A = 2Rs$;
$s$ is the width of the optical slot;
$R$ is the half-high of the optical slot.

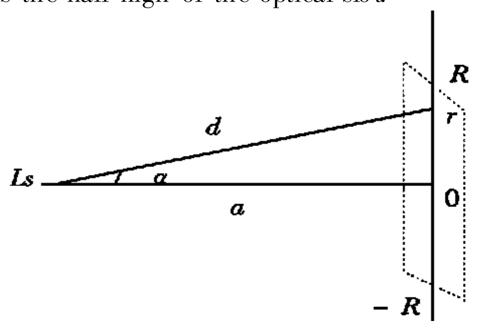


Fig. 2 The illuminance at the optical slot

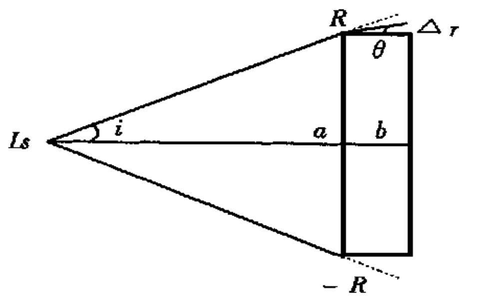


Fig. 3 The reaction of the light in the solution

The integral operation for the left of equal mark of Formula (1) is as follows:

$$-\int_{I_a}^{I}\frac{dI}{I} = \ln\frac{I_a}{I} = \ln\frac{J_0A}{Ia^2} = \ln\frac{J_0A}{I} - 2\ln a \qquad (4)$$

Under the spot light shining, the reaction of the light in the solution should be considered. From Fig. 3, we get

$$n = \frac{\sin i}{\sin\theta},$$

$$\Delta r = b\,\mathrm{tg}\,\theta = b\frac{\sin\theta}{\cos\theta},$$

$$\Delta r = \frac{Rb}{n^2a^2 + (n^2-1)R^2}. \qquad (5)$$

And the volume of the light column in the solution is

$$V = \bar{A}b.$$

Where, $\bar{A}$ is the average sectional area of light column; $b$ is the width of the absorption pool.

$$\bar{A} = s\frac{2R + 2(R+\Delta r)}{2} = s(2R+\Delta r)$$

$$V = s\,bR\left(2 + \frac{b}{n^2a^2 + (n^2-1)R^2}\right). \qquad (6)$$

And the integral of the right of equal mark of Formula (1) is

$$k\int_0^m dm = kcV = ksR\left(2+\frac{b}{n^2a^2+(n^2-1)R^2}\right)cb. \quad (7)$$

From Formula (1), we can obtain that Formula (4) = Formula (7),

$$\frac{\ln J_0 A}{I} - 2\ln a = ksR\left(2+\frac{b}{n^2a^2+(n^2-1)R^2}\right)cb. \quad (8)$$

Substituting $b(b=2mn)$, and $R \ll a$ into Formula (8), then we can get

$$\ln a = kcb + B, \quad (9)$$

and

$$k = -\frac{ksR\left(2+\frac{b}{n^2a^2+(n^2-1)R^2}\right)}{2},$$

$$B = \frac{1}{2}\ln\frac{J_0 A}{I}.$$

In the experiment, the light-transmission intensity is constant. If $c=0$ and $a=100$ cm, we adjust the current flow of light source until the transmission current flow becomes a constant (Let it is 10 format), and the $B$ is $\ln 10 = 4.605$. If $A$ or $I$ changes, so does $B$.

## 3 Proof of Formula (9) by experiment

For proofing Formula (9), we adopt three kinds of series of $KMnO_4$, $Cu(NH_3)_4SO_4$ and $Na_2CuY$ standard solution.

### 3.1 Method

Turn on the light source in the dark room, then put blank solution (water) into the absorption pool ($b$ = 2 mm), let $a=100$ cm, and adjust the voltage of the light source (The lamp current is $i_L$) until the light current ($i_g$) is right at 10 format.

3.1.1 In the $KMnO_4$ solution

Fill a series of $KMnO_4$ solution ranging from low to high in concentration into the absorption pool, respectively; then move the pool along the track in the darkroom until the $i_g=10$ format; then write down the corresponding number($a$). The results are listed in Table 1.

**Table 1 The absorption of spot light in the solution of $KMnO_4$**

| $C\times10^5$ (mol/L) | $a$ (cm) | $\ln a$ | $C\times10^5$ (mol/L) | $a$ (cm) | $\ln a$ |
|---|---|---|---|---|---|
| 1.00 | 96.50 | 4.570 | 6.00 | 80.7 | 4.391 |
| 1.50 | 94.7 | 4.551 | 7.00 | 78.0 | 4.357 |
| 2.00 | 93.1 | 4.534 | 8.00 | 75.1 | 4.319 |
| 2.50 | 91.5 | 4.516 | 9.00 | 72.5 | 4.284 |
| 3.00 | 89.8 | 4.500 | 10.00 | 70.0 | 4.248 |
| 3.50 | 88.2 | 4.480 | 11.00 | 67.5 | 4.212 |
| 4.00 | 86.7 | 4.462 | 12.00 | 65.2 | 4.177 |
| 5.00 | 83.7 | 4.427 | | | |

The regression equation is

$\ln a = 4.606 - 3573c$, $r = -0.9999$.

3.1.2 In the $Cu(NH_3)_4SO_4$ solution

The method for $Cu(NH_3)_4SO_4$ is the same as $KMnO_4$. The results are listed in Table 2.

**Table 2 The measurement of spot light in the solution of $Cu(NH_3)_4SO_4$**

| $c$ (mol/L) | $a$ (cm) | $\ln a$ |
|---|---|---|
| 0.010 | 93.2 | 4.535 |
| 0.020 | 89.8 | 4.500 |
| 0.030 | 86.8 | 4.464 |
| 0.040 | 75.4 | 4.323 |
| 0.050 | 70.2 | 4.251 |
| 0.060 | 65.5 | 4.182 |
| 0.070 | 61.0 | 4.111 |
| 0.080 | 57.0 | 4.043 |

The regression equation is

$\ln a = 4.639 - 7.508c$, $r = -0.9917$.

3.1.3 In the $Na_2CuY$ solution

The method for $Na_2CuY$ is the same as $KMnO_4$. The results are listed in Table 3.

**Table 3 The measurement of spot light in the solution of $Na_2CuY$**

| $c$ (mol/L) | $a$ (cm) | $\ln a$ |
|---|---|---|
| $5.00\times10^{-3}$ | 93.0 | 4.533 |
| 0.010 | 86.5 | 4.460 |
| 0.015 | 80.3 | 4.386 |
| 0.020 | 74.6 | 4.312 |
| 0.025 | 69.5 | 4.241 |
| 0.030 | 64.5 | 4.167 |
| 0.035 | 60.0 | 4.094 |
| 0.040 | 55.8 | 4.022 |

The regression equation is

$\ln a = 4.605 - 14.61c$, $r = -0.9999$.

## 4 Determination of Cu in the standard brass sample

$Na_2CuY$ was used as mediator, and the content of Cu in the standard brass sample (Cu = 60.93%) was measured. Take $G$ gram brass sample, and put it into the solution of $HCl + H_2O_2$, then remove the solution mixture into a 25 ml flask, and then add EDTA into the flask to 0.05 mol/L. Modulate the solution mixture to pH = 6 with NaOH, then limit the volume exactly with $H_2O$. The measurement was conducted in the same condition as Table 3. The results were calculated by the following formula, and listed in Table 4.

$$\text{Cu}(\%) = \frac{\frac{4.605-\ln a}{14.61}\times\frac{25}{1\,000}\times100}{G}.$$

**Table 4 Measurement of Cu in the standard brass sample**

| Sample | $G$ (g) | $a$ (cm) | $c$ (mol/L) | Cu (%) | $\overline{\text{Cu}}$ (%) |
|---|---|---|---|---|---|
| 1 | 0.1001 | 57.10 | 0.03840 | 60.94 | |
| 2 | 0.1010 | 56.84 | 0.03874 | 60.93 | 60.95 |
| 3 | 0.1038 | 55.95 | 0.03984 | 60.97 | |
| 4 | 0.1100 | 54.00 | 0.04223 | 60.98 | |

## 5 Dicussion

Error analysis to the absorption equation (Formula (9)) was obtained as $dc/c = da/a\ (\ln a - B)$.

It is the same as the error formula of differential photometry method. Because $0 < T < 1$ but $a \gg 10$ cm, the error of this method is smaller, and it can fulfill the requirement of heavy content determination ($dc/c \leqslant 0.1\%$).

The presented operation of photometry analysis is simple. It does not need adjusting instrument with standard solution, but requests the light source steady. In addition, it needs to measure the transmission current flow at $a = 100$ cm with blank solution for all the measuring transmission current flow being blank current.

The instruments and installation are also simple. The method does not need any optical lens. That can avoid the errors from chromatic aberration.

Because the transmission current flow is fixed, we can write down each $a$ by the automatic regulation system.

There are many factors that affect the transmission current flow, such as the width ($s$) and length of the slot ($2R$), and the thickness ($b$) of the absorption pool. However, the $b = 2$ mm of the pool thickness can meet the requirement of $b \ll a$.

If the refraction($n$) of light in the solution can not be neglected such as the n of the organic solvent and the $n$ changes with the concentration of the solution, and the $k$ isn't a constant, the result of the experiment can be processed by Formula (8).

## References


1 Chen Guozhen. Spectrophotometric method. Beijing: Science Press. 104.

2 Tian liqing. Chemistry Reporting, 1963, (5): 301.

3 Busnerπ M, Bochen M E. Chemical Mathematics. Beijing: High Education Press, 30.



(责任编辑: 蒋汉明)


# 中国甲型肝炎的感染率和发病率逐年下降

据《科学时报》2001年 2月 8日报道: 威胁中国人民健康的主要传染病之一—— 甲型肝炎的感染率和发病率已逐年下降。

甲型肝炎是由甲型肝炎病毒所引起的, 以肝实质细胞炎性损伤为主的世界性传染病。甲型肝炎是我国最常见的急性传染病之一, 全国每年发生急性病毒性肝炎约 120万例, 在每年发生的急性病毒性肝炎中, 约有 50% 为甲型肝炎。据推算, 我国约 9.7亿人已感染过甲肝病毒。

长期以来, 我国甲型肝炎流行的特点是, 农村高于城市, 5~ 15岁儿童感染率城市明显低于农村, 但 30岁以上感染曲线城市与农村呈平行状态; 长江以北高于长江以南, 西部地区高于中、东部地区; 各省市流行率的分布状况显示甲型肝炎发病或爆发流行仍以儿童为主。但根据流行病学的最新调查结果显示, 目前, 甲肝的流行模式在我国有了明显变化, 发病率和感染率逐年下降, 流行周期和季节性日趋不明显, 感染年龄和高发年龄后移。

医学专家指出, 甲肝流行率是同经济条件、卫生习惯密切相关。近年来我国经济不断发展, 物质文化生活、卫生条件不断改善, 以及肝炎疫苗的大规模推广使用是我国甲型肝炎感染率和发病率逐年下降的主要原因。80年代, 我国成功研制了甲型肝炎减毒活疫苗, 并于 1995年正式批准生产, 现已接种 1亿多人次, 证明甲型病毒性肝炎是可以预防的。秋冬季为甲型肝炎感染和发病高峰季节, 用手直接接触了被甲肝病人污染过的物品的人, 最经济有效的办法是用肥皂和流动的清水洗手。