Thermochimica Acta, 93 (1985) 401-404
Elsevier Science Publishers B.V., Amsterdam

NON-ISOTHERMAL KINETIC METHOD FOR THE ANALYSIS OF THE DYEING PROCESSES

Crişan Popescu[x], Centrul Cercetări Materii Prime, Auxiliare Ape Reziduale, Bucharest, Romania
Ana Diaconeasa, Centrul Cercetări Materii Prime, Auxiliare Ape Reziduale, Bucharest, Romania
Eugen Segal, Polytechnical Institute of Bucharest, Romania

ABSTRACT

The use of non-isothermal kinetic method to describe the dyeing processes is presented. Within the framework of this model the kinetic parameters of dyeing in a certain dye-fibre system are computed.

INTRODUCTION

Dyeing has always occupied a unique place among textile processes, as well as among chemical ones, the application of dyestuffs being regarded as a craft, or an art and not as complex process.

When a fibre is immersed in a dyebath dyeing takes place in 3 stages, viz. /1/:

a) transfer of dye from the solution to the surface of the fibre;
b) adsorption of dye at the fibre surface;
c) diffusion of dye from the surface to the bulk of the fibre.

Anyone of these processes may control, or influence, the rate of dyeing, but the laboratory conditions are usually adjusted so that stage (c) becomes the limiting step of the next quasichemical reaction:

dye + fibre $\rightleftharpoons$ dyedfibre (1)

The process evolution can be plotted in (T,t) plane as fig.

Proceedings of ICTA 85, Bratislava

(1) shows:

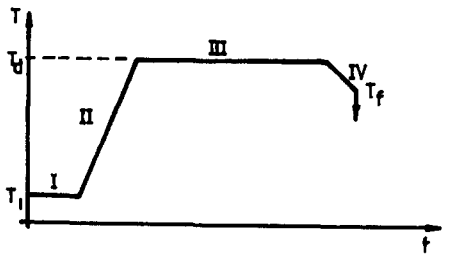

Figure 1. Dyeing diagram

Practically neither of the regions is a straight line, but they can be well approximated /2/. From this figure is obvious that isothermal kinetics apply only to regions I and III; during regions II and IV temperature varies. The second region (II) is recognised as being of a great importance for a good exhaustion of the dye and for good levelling of the dyeing and its satisfactory characterization may be of interest for dyers. The rate of a non-isothermal process, as region II represents, is given by eqn:

$$r = \frac{da}{dT} = \frac{1}{b} \cdot A \cdot f(1-a) \exp(-E/RT) \qquad (2)$$

where $a = c_t/c_\infty$ is the fraction of dye sorbed at time t;

$b = dT/dt$ is the heating rate, and the other terms have their usual meanings. Certainly the use of eqn.(2) to describe the dyeing process is limited by some restrictive conditions which have been emphasized elsewhere /4/ but here we considere all these conditions as being fulfilled. Of a particular interest for the optimum control of the dyeing is considered the problem of a constant uptake of dye within region II. Practice shows that a constant uptake of dye occurs when temperature programme has an exponential form /2/. But eqn.(2) offers the heating profile for this circumstances as follows /5/:

$$b = \frac{A}{E/RT^2} f'(1-a) \exp(-E/RT) \qquad (3)$$

Eqn.(3) is an exponential form, as the practice requires.

Another use of non-isothermal kinetic method consists in the calculation of dyeing parameters by mean of the

eqn.(2). As it was mentioned above, the diffusion of dye is the limiting step. Since it follows Fick's law, it appears that activation energy of the dyeing has to be close to the activation energy of the diffusion. Its value may be of help for the dyers to realize the optimum conditions for a certain dye-fibre system. In order to compute the kinetic parameters by means of a non-isothermal kinetic method, curves of the dye uptake against temperature, as well as the appropriate heting programme must be obtained. The loss of dye ammount from the bath is watched by spectrophotometrical measurements and the so-obtained curve is similar to the thermogravimetrical one. We have named it "thermoconcentration curve" (TC).

EXPERIMENTAL

Acid dyes on wool fibres have been found by us as the most suitable systems to exemplify the above discussion. The TC curves may be obtained by means of a laboratory dyeing apparatus, with some facilities to realize a controlled heating programme. Each of the glasses of the apparatus has the same content at the beginning of the process and the spectrophotometrical measurements are performed on the solutions from each glass which is taken off after certain time period. Such a curve, on wool fibre dyed with 2%(owf) C.I.Acid Blue 41, with a heating rate of 2 K/min and a liquor ratio of 1/40 is given in the fig.2.

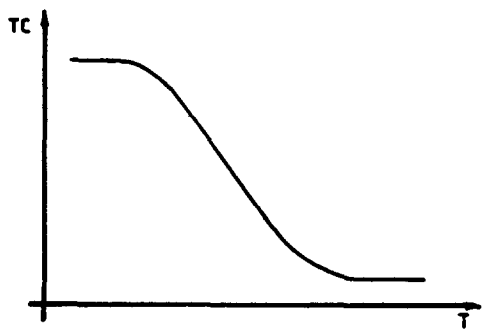

Figure 2. TC curve of C.I.Acid Blue 41 on wool

The spectraphotometrical data have been worked by help of Coats-Redfern method /6/ within the framework of the reaction order model1, and the next kinetic parameters have been obtained:

$E = 32$ kcal·mole^{-1}; $A = 10^{20}$s^{-1}; $n = 1$; corr.coef. = 0.99

The value of activation energy is within the suitable range for acid dyes on wool fibres /1/. Moreover the value obtained for C.I.Acid Blue 41 is in close agreement with the one computed through isothermal method /7/ of 35 $\frac{\text{kcal}}{\text{mole}}$.

CONCLUSIONS

The use of non-isothermal kinetic method to analyse the dyeing processes leads to the kinetic parameters values in a close agreement with the values obtained through isothermal method. Also the use of non-isothermal kinetic method helps the dyers to choose heating profiles for optimum control of dyeing.

It has to be, however, pointed out that "dyeing systems are so complex and dye structures are so varied even within a given class of dye that is usually possible to find exceptions to any general rules or general comments you can have"/8/.

Summing up, this work shows some possible applications of non-isothermal kinetic method in describing of dyeing systems but only many further works can prove if this method is a real tool for dyers.

REFERENCES

1 Vickerstaff, "The Physical Chemistry of Dyeing", 2nd ed., Oliver and Boyd, 1954
2 J.H.Brooks, J.Soc.Dyer Color., 91(1975)394
3 J.Šatáva,J.Šesták,W.W.Wendlandt, Thermochim.Acta 7(1977)333
4 C.Popescu,A.Diaconeasa,E.Segal, Thermochim.Acta(submitted for publication)
5 C.Popescu,E.Segal, J.Soc.Dyer Color. (in press)
6 A.W.Coats,J.P.Redfern, Nature, 201(1964)68
7 Medley,Holdstock, J.Soc.Dyer Color., 96(1980)286
8 R.Mc Gregor,R.H.Peters, ibid., 84(1968)267