

Communication

Preparation of aluminium lakes by electrocoagulation

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Abstract: Aluminium lakes have been prepared by electrocoagulation employing aluminium as electrodes. The electrocoagulation is conducted in an aqueous alcoholic solution and is completed within one hour. The dye content in the lake ranges approximately between 4-32%.

Keywords: lake, lake pigment, aluminium lake, electrocoagulation

Introduction

Lake pigments or lakes [1] are a class of pigments composed of organic dyes that have been rendered insoluble by interaction with a compound of a metal, e.g. barium sulphate, calcium sulphate, and aluminium hydroxide. The interaction may involve the precipitation of a salt in which the proportions of dye to metal are fixed, or it may be a less well defined attraction between the dye and the surfaces of particles of the inorganic compound. Some lakes are prepared by a combination of both processes. Lakes considerably extend the range of colours available in the production of paints, cosmetics, and inks for printing and lithography. Moreover, they can also be used as food colours [e.g. 2].

Basically, a lake pigment is prepared by interaction of a freshly formed metal compound with a dye. As an example, madder (alizarin) lake can be produced by reacting the dye alizarin (in the form of an emulsifiable paste) with aluminium hydroxide formed by reaction between aluminium sulphate and sodium carbonate [3]. A little phosphate and calcium salt are also added. The method suffers, however, from a relatively high reaction temperature (100°C or boiling temperature) and a long reaction time (6 hours in this case).

Discussion

We have attempted successfully to prepare a number of lake pigments by a simple method which requires a lower temperature and a much shorter preparation time. The method makes use of electrocoagulation, an electrochemical process long known in waste water treatment researches [4]. In this process, a set-up for electrolysis is employed. In its simplest form, a pair of metal plates, usually aluminium or iron, is used as electrodes. They are dipped into an aqueous solution or suspension containing a supporting electrolyte (usually sodium chloride of about 0.2 % concentration). Direct current is then passed through the aqueous medium in a container via the two electrodes.

The reactions that occur as the result of the above operation have been elucidated and established [e.g. 5,6]. In the case of using aluminium as electrodes, the aluminium will be oxidised at the anode to aluminium ions, while water molecules are dissociated into hydrogen molecules and hydroxide ions at the cathode. Aluminium hydroxide (and other hydrated forms of aluminium) molecules are thus formed as a result. As well known, these molecules are efficient adsorbents for many types of molecules or particles, including those of most dyes.

However, if the dye molecules happen to be phenolic in nature, e.g. most natural anthraquinones and flavonoids, another type of interaction is most likely to occur in which a complex in the form of a metal phenolate salt is formed from the metal ions (e.g. Al^{3+}) and the phenolic dye molecules [6]. If the dye molecules are acidic in nature due to the presence of a carboxyl group or sulphonic acid group, similar salt formation will also occur. All these metal salts or complexes as well as the adsorbate containing $\text{Al}(\text{OH})_3$ above are insoluble and will precipitate or coagulate from the aqueous solution. Thus, in effect, a lake has been formed. If the electrodes used are aluminium, this will then become an aluminium lake.

Preparation of a lake by electrocoagulation has two important advantages over conventional methods of preparation. Firstly, the preparation time is much shorter since coagulation of a dye electrolytically can be completed in an hour or less. Completion of coagulation can be observed visually when the electrolysed solution becomes colourless or very pale in colour. Secondly, no external heating is required since the electrolytic process can be and is normally carried out at ambient temperature, although the electrolysed solution will gradually warm up slowly by itself.

Factors that determine the percentage of dye in the resulting lake include the relative solubility of the dye in water and alcohol, and the coagulation time, although these are not always mutually exclusive. Normally, the water-soluble dye will be electrocoagulated most readily. The percentage of the dye in the coagulum will then be large. If the dye is less water soluble, alcohol has to be added to make it more soluble. Electrocoagulation in an aqueous alcoholic solution [7-9] usually takes place less readily, i.e. requires more time and even then may not be complete. In this case the percentage of the dye in the coagulum will be smaller due to more formation of the metal compound (e.g. aluminium hydroxide). In our case, we can achieve a percentage range of approximately 4-32 depending on the individual dye.

Preparation Details

Lakes from 5 dyes, viz. alizarin, purpurin, erythrosine, chlorophyllin, and amaranth, were prepared. A representative procedure is as follows.

Two aluminium plates (dimension 14 x 5 cm) were used as electrodes. These were spaced 3 cm apart and dipped 5.5 cm into a magnetically-stirred ethanolic (up to 85%) dye solution (250 ml) contained in a 400-ml beaker. Sodium chloride was added to the solution as supporting electrolyte at a concentration of 0.2%. Direct current (about 0.6 A) was passed through the solution via the two aluminium electrodes until the dye solution was colourless or very pale in colour. The resulting precipitate was filtered and dried to afford the lake pigment. The IR spectra of all the lakes prepared were very similar to that of aluminium hydroxide, which confirms the presence of this compound as the main matrix in the lakes obtained. Typical results are shown in Table 1 and Figure 1.

Table 1. Results of preparation of 5 lake pigments by electrocoagulation

Dye used	Starting weight of dye (g)	Dye concentration in electrolysed solution (%w/v)	Time for complete coagulation (minutes)	Weight of lake obtained (g)	% Dye in lake
Alizarin	0.05	0.02	30	0.87	5.7
Purpurin	0.10	0.04	30	0.97	10.3
Erythrosine	0.10	0.04	30	0.90	11.1
Chlorophyllin	0.10	0.04	5	0.31	32.2
Amaranth	0.10	0.04	60	2.78	3.6

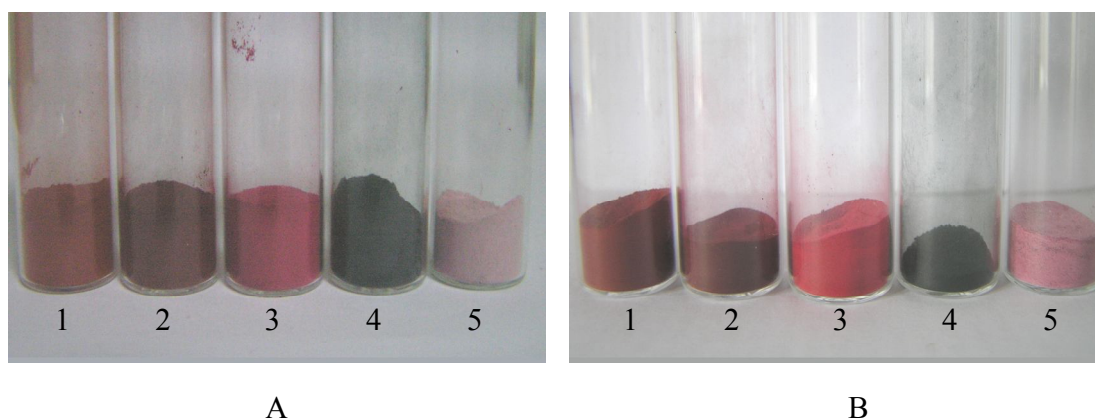


Figure 1. Aluminium lakes prepared by: (A) conventional method [3] and (B) electrocoagulation method (1 = lake alizarin, 2 = lake purpurin, 3 = lake erythrosine, 4 = lake chlorophyllin, and 5 = lake amaranth)

Conclusions

Electrocoagulation can be used to prepare lake pigments from dyes. In this short report, aluminium lakes from a number of dyes have been prepared successfully by this simple technique, in which a much shorter time as well as a lower temperature is required.

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References

1. Encyclopaedia Britannica, 15th Edn., Micropaedia Vol. 5, Encyclopaedia Britannica Inc., Chicago, **1981**, p. 996.
2. A. Downham and P. Collins, "Colouring our foods in the last and next millennium", *Int. J. Food Sci. Tech.*, **2000**, 35, 5-22.
3. "Pigments through the ages",
<http://www.webexhibits.org/pigments/individ/recipe/alizarin.html> (retrieved on 23 July **2008**).
4. W. Phutdhawong and D. Buddhasukh, "Applications of Electrocoagulation", Chotana Print Co. Ltd., Chiangmai, 2007.
5. M. Y. A. Mollah, R. Schennach, J. R. Parga, and D. L. Cocke, "Electrocoagulation (EC)--science and applications", *J. Hazardous Mat.* B84, **2001**, 29-41.
6. W. Phutdhawong, S. Chowwanapoonpohn, and D. Buddhasukh, "Electrocoagulation and subsequent recovery of phenolic compounds", *Anal. Sci.*, **2000**, 16, 1083-1084.
7. K. Jumpatong, W. Phutdhawong, S. Chowwanapoonpohn, M. J. Garson, S. G. Pyne, and D. Buddhasukh, "Electrocoagulation in aqueous alcoholic solutions", in "Trends in Electrochemistry Research" (Ed. M. Nunez), Nova Publishers, New York, **2007**, Ch. 5.
8. N. Chairungsi, K. Jumpatong, W. Phutdhawong, and D. Buddhasukh, "Solvent effects in electrocoagulation of selected plant pigments and tannin", *Molecules*, **2006**, 11, 309-317.
9. N. Chairungsi, K. Jumpatong, P. Suebsakwong, W. Sengpracha, W. Phutdhawong, and D. Buddhasukh, "Electrocoagulation of quinone pigments", *Molecules*, **2006**, 11, 514-522.