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THE EFFECT OF A CROSSED MAGNETIC FIELD ON CAPILLARY ELECTROPHORESIS

Saeid RAZEE, Atsushi TAMURA, and Tsutomu MASUJIMA*

Institute of Pharmaceutical Sciences, Hiroshima University, School of Medicine,
Kasumi 1-2-3, Minami - ku, Hiroshima 734, Japan

A powerful permanent magnet which can perform a uniform 10 KG magnetic field was directed perpendicular to the applied electric field in a Capillary Electrophoresis (CE) system. It was found that the current passing through the capillary was decreased due to application of a magnetic field. The electroosmotic flow and electrophoretic mobility of ionic solutes were also observed to be affected and slowed down by this new external field.

KEYWORDS capillary electrophoresis; crossed magnetic field; magnetic capillary electrophoresis; capillary electromagnetophoresis

In recent years, capillary electrophoresis (CE) techniques have been used as powerful separation methods in a wide range of applications from biological macromolecules to small inorganic ions[1-3] and from charged to neutral species.[4,5] Although the magnnetic field has already been applied in electrophoresis to affect the ionic fluidity[6] and to propel the solute in a circular and/or non-circular endless belt electrophoretic separation apparatus,[7] there is no report on its application in CE. In our approach, we introduced an external crossed magnetic field by means of a powerful permanent magnet to couple with electric field and influence the movement of ions inside the capillary. Both major phenomena in CE, i.e. electroosmosis and electrophoresis, were found to be affected by applied crossed magnetic field.

The experiments were conducted on a laboratory - assembled CE system. To carry out the capillary electrophoresis under magnetic field, a definite length of capillary was coiled and inserted inside the gap of a permanent magnet which can create a 10 KG magnetic field in a 65 x 65 mm area (Fig. 1). At first the effect of a crossed magnetic field was studied by Ohm's law monitoring a capillary in the presence and absence of a magnetic field. As shown in Figure 2, due to an applied crossed magnetic field, the current passing through the capillary is diminished, which can be the evidence for decelerated movement of ions. On the other hand, the ionic mobility is decreased and caused a decrease in the current. This phenomenon can be explained by coupling of the electrical and magnetic fields which are perpendicular to each other. With the aid of the three- fingure rule it is possible to predict the direction of the force on a moving ion across a magnetic field. By this induced force, ions were pushed toward the capillary wall. Since this force is perpendicular to the direction of the ionic movement, it can be considered a frictional force on moving ions which can increase the resistance(or decrease of the current) across the capillary.

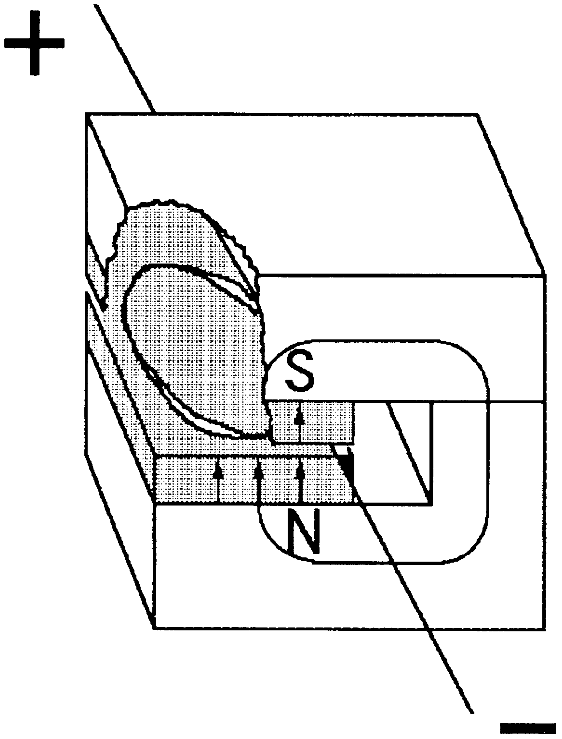

Fig. 1. Representation of Magnetic Field Capillary Electrophoresis System, in Which the Magnetic Field Is Applied Perpendicular to Ionic Movement

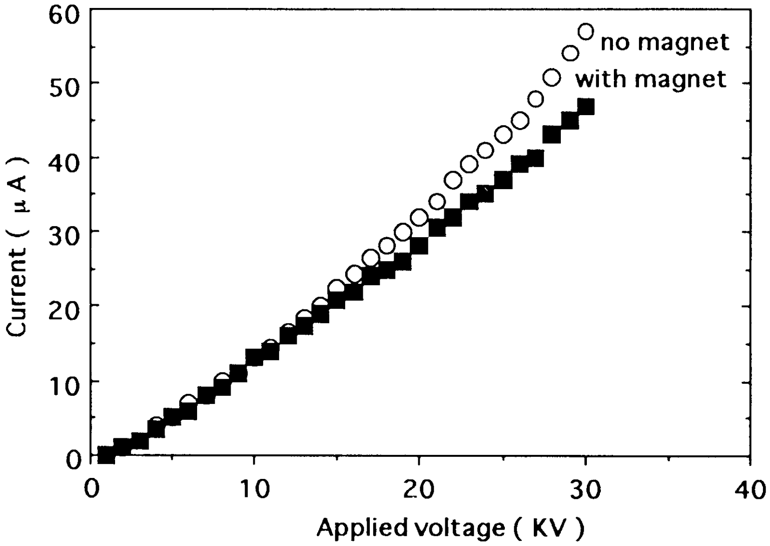

Fig. 2. The Effect of a Crossed Magnetic Field on Ohm's Law in CE. The magnetic field is coupled with an electric field and slows down the ionic mobility inside capillary. As a result the current is decreased. **Condition:** 100 cm x 50 μm i.d. fused-silica capillary (50 cm under magnetic field), filled with 50 mM Borax ; pH = 9.15

Since it was observed that the crossed magnetic field can affect and slow down the moving ions inside a capillary, its effect on electroosmotic flow (eof) was investigated using sodium tetraborate as buffer electrolyte and methanol as neutral marker. Under the influence of a crossed magnetic field, decrease of eof was observed. It is known that eof can be described as the relative motion of bulk electrolyte to the fixed charged capillary wall silanol groups, caused by an applied electric field. However in our system another force from the magnetic field was also induced on the ionic component of moving electrolyte. As mentioned, since this force is perpendicular to the direction of movement in the capillary, has a slowing effect on moving ions and the net result is decrease of eof.

To study the effect of crossed magnetic field on electrophoretic mobility, one model mixture containing : p - amino Salicylic acid, p - amino Benzoic acid and 1,8 -Antraquinone disulfonic acid dipotassium salt was selected and a JASCO (Tokyo, Japan) model 875 - CE, UV-VIS detector was used for the detection of peaks at 200 nm. As shown in Fig. 3, due to applied magnetic field two differences are observed : first, the migration times of all solutes were increased; and second, the separations between peaks were improved. The first observation was caused by about 19% decrease of eof when magnetic field was applied. For solutes 1 to 3 (Fig. 3) the decrease of electrophoretic mobility was 21.3, 23.4, and 25.4% respectively. Since the solutes received the different amounts of reduction of electrophoretic mobility, it is obvious that they felt different magnitudes of induced force from the magnetic field. It seems that the charge to mass ratio of solutes is an important factor in this case and can determine the amount of induced force from the magnetic field; thus it can be concluded that the solutes with higher charge to mass ratio were more delayed by a crossed magnetic field. This different deceleration effect is the reason for improved separation of compounds tested by the Magnetic Field CE system.

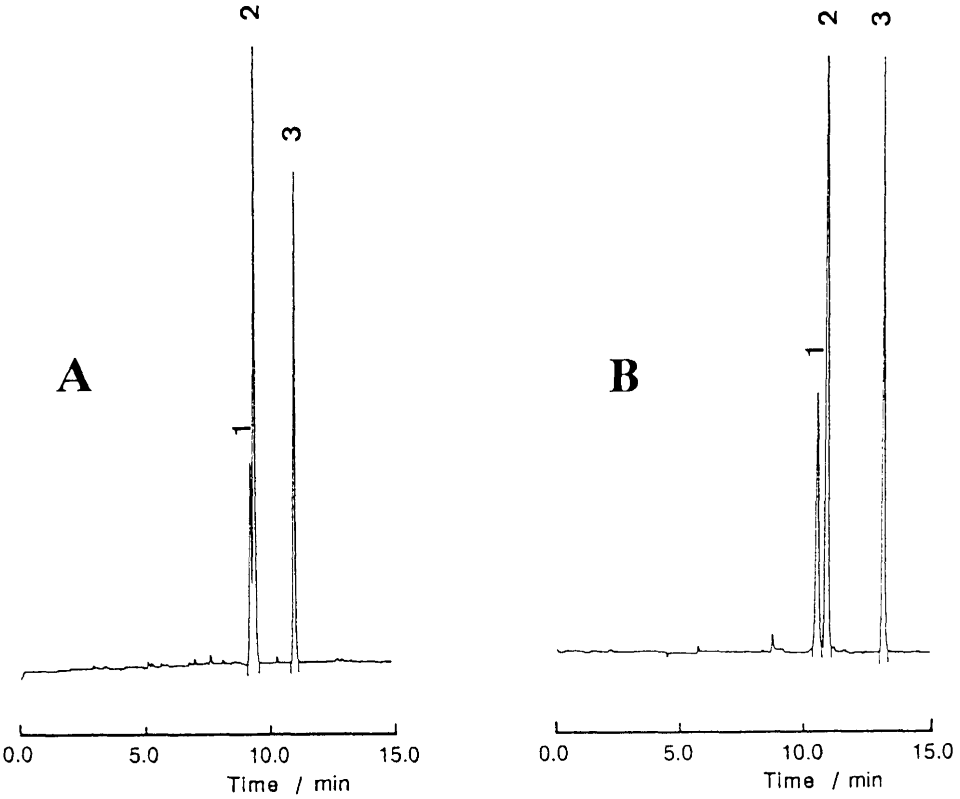

Fig. 3. The Effect of an Applied Crossed Magnetic Field on Migration Time and Resolution of Peaks in MFCE System. Electropherogram B was run with 30 cm of capillary under influence of 10 KG magnetic field. **Condition** : 80 cm x 50 μm i.d. fused - silica capillary (60 cm to detector) ; 50 mM sodium tetraborate ; pH 9.15 ; hydrodynamic injection ; 25 KV operating voltage. **Peaks** : 1 = p - amino salicylic acid, 2 = p - amino benzoic acid, 3 = 1,8 antraquinone -disulfonicacid dipotassium salt.

Further investigations are under way in our laboratory to examine several features of this phenomenon in CE. Potential applications in the field of metallo - proteins, behaviour of other magnetic susceptible compounds under a crossed magnetic field, and its influence in other modes of CE such as MEKC are currently under study.

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REFERENCES

1) R. G. Nielsen, R. M. Riggin, E. C. Rickard, *J. Chromatogr.* , **480,** 393 (1989).
2) Y. Shi, J.S. Fritz, *J. Chromatgr.* , **640**, 473 (1993).
3) A. Weston, P. R. Brown, P. Jandik, W. R. Jones, A. L. Heckennberg, *J. Chromatogr.* , **593**, 289 (1992).
4) T. Saitoh, H. Hoshino, T. Yotsuyangi, *J. Chromatogr.* , **469**, 175 (1989).
5) S. Terabe, K. Otsuka, K. Ichikawa, A. Tsuchiya, T. Ando, *Anal. Chem.* , **56**, 111 (1984).
6) Z. Karni, L. E. Kopito, *Med. and Bio. Eng.* , May, 457 (1975).
7) A. Kolin, *J. Chromatogr.* , **159**, 147 (1978).

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