A SIMPLE ELECTRO-ULTRAFILTER.

BY JACQUES J. BRONFENBRENNER.

(From the Laboratories of The Rockefeller Institute for Medical Research.)

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It is frequently desirable to free colloidal solutions of electrolytes, but the process of ordinary dialysis is very slow and often cumbersome. Although the rate of diffusion of electrolytes out of the solution may be increased by means of electrophoresis, the limited choice of membranes available for use with the existing apparatus often leads to unequal rates of passage of the ions to the respective electrodes, and to greater or less marked changes in the hydrogen ion concentration of the solution subjected to dialysis.

We have encountered these difficulties in attempting to dialyze the solutions containing bacteriophage and have been successful in overcoming them by combining the principle of ultrafiltration with electrophoresis.

Our apparatus consists essentially of three concentric chambers, of which the middle one is formed by the collodion membranes deposited on the surfaces of two alundum thimbles (8 and 9, Fig. 1, a). The other two chambers serve for removing the dialyzed electrolytes from the membrane by means of a stream of cold water.

The different parts of the dialyzing apparatus are as follows:

1. A glass tube (3 mm. diameter), supplying distilled water from the reservoir (20) to the inner surface of the alundum thimble (8) carrying the positively charged membrane.
2. A rubber stopper securing the position of the glass tube (1) in place.
3. A glass T-tube draining by suction into receptacle (21).
4. A rubber collar securing an air-tight connection between the T-tube (3) and the carbon (5).
5. A soft core arc lamp carbon 12 mm. in diameter and 150 mm. long, bored

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1 This tube is slightly flared out at the lower end and carries a rubber washer to make an air-tight connection at the lower end of the carbon, so that at this point the glass tube is patent, but the hollow carbon (5) is not.
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out to admit freely the glass tube (1) and connected with the positive wire of the electric current. 60 mm. from the slightly tapered lower end of the hollow carbon, a 2 mm. hole permits the return flow of water from the inner chamber around the glass tube (1) and up to the collecting flask (21).

(6) A rubber stopper, No. 13, shelved at its lower end so that a projection 10 mm. deep and approximately 34 mm. in diameter is left to accommodate the outer alundum thimble (9).

(7) A piece of rubber tubing making an air-tight connection between the carbon and the alundum thimble (8).

(8) A Norton alundum thimble, No. 10472 RA 360, 17 mm. in diameter and 80 mm. long. After this part of the apparatus has been assembled, a collodion membrane of the desired degree of permeability is deposited, under pressure, on the outer surface of the thimble (8). For this purpose the T-tube (3) is connected with the vacuum pump, the rubber tube at (1) is clamped off, and the thimble, while under negative pressure, is dipped into the solution of collodion in glacial acetic acid for 60 seconds. The connection with the vacuum pump is now broken, the excess of collodion is allowed to run off, and the coated surface is placed into running warm water to coagulate the collodion and to remove the acid. The removal of the last traces of acid is most quickly accomplished by assembling the entire apparatus and using electrophoresis. The membranes can be used repeatedly, provided they are kept in water when not in use. Their permeability remains practically constant if they are not allowed to dry. To renew the membrane it is necessary to remove the thimble, allow it to dry in air, and when thoroughly dry to incinerate it in the open flame.

(9) Norton alundum thimble, No. 6406 RA 360, 34 mm. in diameter, 100 mm. long. The inner surface of the thimble must be glazed for a distance of 10 mm. from the top, and the collodion membrane that is deposited upon its inner surface ends at this glazed rim. For this purpose, the thimble is fitted by means of a suitably cut rubber stopper into a cylindrical funnel, and attached to the vacuum pump so as to apply negative pressure to the outside of the alundum. The thimble is then filled with collodion for 60 seconds, the collodion is poured off, and warm water used as before. The glazed surface will be found to slip easily over the projecting portion of the rubber stopper (6).

(10) Brass wire gauze, 120 mesh, tightly wrapped around the thimble (9) and held in place by clips connecting it with the lead (12) from the negative pole of the electric circuit.

(11) A glass tube with rubber stopper at each end, carrying the negative lead (12).

(12) Lead from the negative pole of the circuit.

(13) Glass tube carrying distilled water from the reservoir (19) to the middle chamber containing material for dialysis.

(14) Thermometer.
(15) A glass receptacle serving as an outer chamber and connected with receptacle (21) by a rubber tube forming a movable joint.
(16) Overflow carrying away the ions migrating to the negative electrode.
(17) Stop-cock for emptying glass receptacle (15).

Fig. 1.

(18) Inlet for distilled water.
(19) Fig. 1, b. Distilled water reservoir for middle chamber.
(20) Distilled water reservoir for inner and outer chambers.
(21) Intermediary receptacle for dialysates.
(22) Vacuum drainage carboy.
(23) To vacuum pump.
(24) Vacuum gauge.
(25) Vacuum motor (windshield wiper).
(A) Weston ammeter (Model 280).
(V) Weston voltmeter, with switch (Model 280).
(R) Sliding resistance, 650 ohms.

The parts, as well as the assembled apparatus, may be obtained from Eimer and Amend, New York City.

The high efficiency of this apparatus is due to several circumstances. The dialyzing surfaces are very large, considering the total capacity of the apparatus; the relative sizes of the membranes can be varied by using thimbles of appropriate sizes; the permeability of the membranes is easily varied by changing the density of the collodion used in coating the thimbles; the rate of dialysis is speeded up by a constant removal of the dialysate by a constant flow of water at each electrode; the constant flow of cold, distilled water at the electrodes permits the use of high voltage (110-115) without an excessive rise in temperature; the material subjected to dialysis may be kept from becoming concentrated by diluting it during dialysis; the whole dialyzing chamber is agitated, thus preventing the deposit of solids on the membrane. If necessary, the charges on the electrodes may be reversed by using a nickel screen instead of copper, and thus further adjustment in the relative rate of migration of ions may be accomplished.

In the sketch the outflow from both electrodes is mixed in the receptacles (21) and (22). If desirable, it is possible to collect the dialysates separately by leading tube (3) to a separate receptacle analogous to (21) and similarly connected to the vacuum pump.

The value of combining electrophoresis with ultrafiltration may be seen from the following. When 20 cc. of broth were placed in the dialyzing chamber and the full current was turned on, the ammeter read 4.5 amperes. If this amount of broth were dialyzed without current, it would require 3 hours to increase its resistance to the passage of current sufficiently to give an ammeter reading of 0.016. When dialysis was combined with electrophoresis, a reading of 0.013 amperes was reached in 45 minutes.