SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 10. December, 1966.

Contents

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Introduction

In our last Bulletin we gave a list of contents, and this will be a regular feature from now on, and may help to save the time of the busy teacher. Also in response to several requests we have included with this Bulletin an index to the previous nine issues, and this is something which we hope to incorporate at regular intervals.

In this connection might we make an appeal to those who habitually throw the Bulletin in the waste basket to reconsider? We have had several requests from principal teachers who have succeeded such individuals for out of print issues which we can only supply by photocopying at a cost of around 1/- per foolscap sheet. Although we normally print 10 - 15% in excess of our mailing list it is inevitable that issues will sooner or later go out of print.

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The Centre will be closed on Mondays, December 26th and January 2nd.

Conductivity Experiments

Section 8 of the alternative Chemistry syllabus requires that experiments be carried out to provide evidence for the existence of ions, and of their mobility in solution. Teachers in the main may have read more into this section than was originally intended, and one commonly finds the term "conductimetric titrations" or even in one journal "amperometric titrations" used to describe the work involved. Our own investigation was carried out to determine what power supplies, meters and techniques were adequate for dealing with this section of the syllabus.

Two versions of electrolytic cell are available.

(1) a beaker with electrodes pushed through a top cover which may be of hardboard or plastic.

(2) a conical flask with special side entry hole or holes to accommodate the electrodes.

The first, although easier to construct by laboratory technicians, has several disadvantages. The electrodes are not immersed to a constant depth and the addition of large amounts of reagent during titration increases depth and cell conductivity by increasing the immersed area. This, however, can easily be surmounted by a variation in technique by using comparatively few drops of one reagent in distilled water in the cell and adding the second reagent dropwise. A titration is then completed in 20 - 30 drops giving negligible increase in depth. Adequate mixing is essential for success with this technique; it was, nevertheless, the one used during our investigation. A more serious disadvantage of the beaker cell is that the solutions cannot be adequately mixed without removing the electrode assembly; this has to be done each time a fresh dose of reagent is added. Swirling the beaker leads to spillage so that hand or mechanical stirring is the only alternative. A third disadvantage is that

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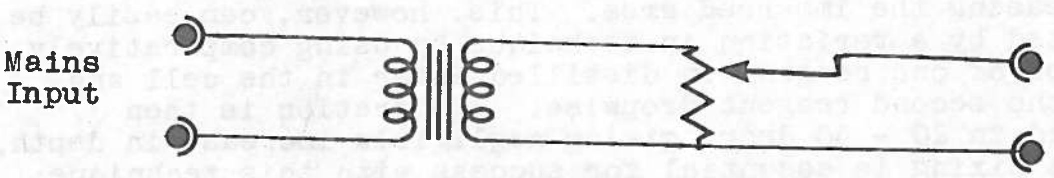
the electrode leads, which in the apparatus by Griffin and George, S75 - 694/15, carry 4 mm connectors, must be brought off the top of the electrode assembly thus making it top heavy, and due to trailing leads we would expect a large number of spilt beakers during pupil handling. Finally, in pupil hands with the beaker top mostly covered, there is a risk that the added reagent will go anywhere but into the solution.

The conical flask with side-entry electrodes can be swirled without spillage; moreover the top is open for addition of reagent. The electrode assembly being near the base, increases the stability, although the Griffin and George version S75 - 694/20 which uses a two-holed stopper for the electrodes is consequently lop-sided and the leverage of the electrodes tends to topple the flask unless it is more than half-full. The Monax flask has two diametrically opposed electrodes and thus avoids this difficulty. A disadvantage of the conical flask is that mechanical stirring is difficult.

On the subject of power supplies, we found it possible to carry out all the experiments listed in this report with a battery of 10 Nife cells, giving approximately 12 volts. At the risk of being labelled old-fashioned, and while agreeing fully with John Lewis when he says - "Perhaps the greatest revolution has been brought about in schools by the acceptance that special power supplies are necessary. The limitation, set in the past by the almost universal use in schools of dry cells, Daniel cells or accumulators, was considerable." - we think it possible that the pendulum may have swung too far, and that chemists buying Radford Lab-packs are as misguided as the physicist who still orders an Advance J2B signal generator. The cheapest mains power equivalent to the Nife battery is the Unilab low voltage AC and DC bench power supply, 022.313, at £12. This power unit, like all others commercially available, has been designed for physics experiments and is hence over-elaborate for use in chemistry and consequently extravagant. In our "Workshop" section we give details of a simple rectifier unit which has been tested on these conductivity experiments and proved successful. Now that the miniature Nife cells have disappeared from the Proops catalogue - See Trade News - this unit is almost as cheap as the Nife battery.

Many chemists, however, believe that because of polarisation the experiments ought to be carried out using alternating current. Here again the commercial power supply is an extravagance since its power output will be some 50 times greater than required. Conductivity in aqueous solution requires currents less than 100 mA, and the power supply designed for a physics laboratory will have a current output of 5A or more. The sensible thing here is to obtain a 12V, 1A filament transformer (R.S.C., 8/9) and connect a 100 ohm wirewound potentiometer (Radiospares, 5/-) as a variable control as in the circuit below. Some form of box will be necessary to house these components, as the filament transformer will have open mains terminals.



Another difficulty to be met with alternating current is the provision of a suitable meter. A few years ago reconditioned multi-range Avometers were available cheaply, and were one solution. A new Avo 8 at £21.8.-d is not, certainly not in pupil quantity. Moving iron meters are unsuitable because of their high resistance.
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Typically the resistance of a cell may vary from 40 to 100 ohms during neutralisation. (For comparison, tap water may be ten times, and distilled water 100 times this value). To obtain a high percentage change of current during titration it is therefore necessary to ensure that other resistances in the circuit are much less than this. There is no difficulty on DC, as a 50 or 100 milliammeter will have a resistance of about 1 ohm. A moving coil milliammeter, which of course will only measure DC, cannot be fitted directly with a rectifier, as the diode rectifiers have themselves a high resistance. The only solution is that used by multi-range meters of the Avo type, viz. to use a step-up transformer which converts the current to be measured into a proportionally higher voltage, which is then measured by a moving-coil DC milliammeter plus rectifier.

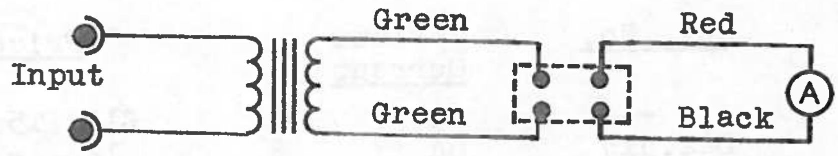
To do this cheaply requires the following apparatus -

(a) Japanese 1mA moving coil meter, either MR38P at £1.2.6d or a slightly larger MR65 at £1.9.6d, both from G. W. Smith and Co.

(b) 35:1 ratio microphone transformer at 13/- from Radiospares.

(c) 1mA bridge rectifier at 9/- also from Radiospares.

The cost of components is then £2.11.6d; in addition some form of box will be required to mount the apparatus, and terminals will be needed, so that the final cost may be in the region of £3. This compares favourably with the commercial equivalent, e.g. Griffin and George L93-462, 0-100mA AC at £6.19.6d. The circuit is given below, the coloured leads being those on the rectifier.



The circuit was checked against a commercial AC milliammeter, and has a full-scale deflection of just over 50mA, and the calibration curve is linear down to under 5mA.

For conductivity experiments on DC, only the meter specified above, i.e. either the MR38P or MR65, range 0-100mA, will be required together with a DC power supply. Of the two meters, the MR65 although slightly dearer is perhaps better for pupils to use because of its smaller scale interval. Some of the phenomena to be observed occur over a few milliamperes, e.g. the "dog-leg" curve for sodium bisulphate. If the scale interval is more than 2% of the full scale deflection, it becomes necessary for pupils to estimate current readings to 0.2 of the scale interval. With the larger meter of the same range, half a division accuracy is adequate.

Because of the higher cost of AC equipment, we resolved to carry out all experiments with DC and to change to AC only if results on DC were unsatisfactory. In practice, we found that results which we considered satisfactory were obtainable despite polarisation if one adopted a consistent meter reading technique. It is necessary either to read always the initial kick of the meter on switching on or to agree on a degree of pointer movement which would be acceptable, e.g. not more than one division (the scale interval) while the pupil counts five, before reading. It is not always possible to wait until pointer movement has completely stopped before taking a reading. Other parts of the technique also require to be consistent e.g. whether to switch on before or after stirring etc.

All that can be claimed for the experiments is that they

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clearly illustrate changes in conductivity, and that these changes occur in the correct direction or sense at the various stages of a titration. An accurate end point to a titration, coinciding with indicator colour change is not always possible with acetic acid.

A quantitative verification of reacting volumes, e.g. 10 drops of M HCl neutralising 10 drops of M NaOH, is not to be expected with simple apparatus. Using a dropper teat with pointed glass tube as a means of adding reagent to the cell, which would be more convenient for pupils than a properly clamped burette, results in a large variation in mass of individual drops. We individually weighed 400 drops from the same dropper; the mean mass was 49mg; larges and smallest values were 88 and 12mg and the standard deviation was 13.5mg, although the distribution was not normal.

Those teachers who carry out their conductimetric titrations with alternating current will still require some form of DC power supply for the electrolysis of fused salts. Here again, we found the battery of 10 Nife cells adequate. The maximum current required, with an electrode spacing of order 5-8mm was 3½ amperes. The short circuit current obtainable from one of the cells we have specified is 7 amperes. For the teacher buying bench power supplies, it is here that the shoe pinches. He must budget for currents of 3½-4 amperes per experiment. This means that with any of the commercially available power units, he can run not more than two experiments from the same box, since the maximum current obtainable from these units is usually of the order of 8 amperes. The table below gives comparative values and costs of power supplies produced for use in physics laboratories.

Manufacturer	Cat. No.	Maximum Current	Price
Serinco	-	6A	£11. 15. -
Unilab	022.313	6A	12. -. -
Radford	N59R	8A	18. -. -
Radford	Labpack ML	6A	22. 10. -
Advance	Type 2	5A	15. -. -
Griffin and George	GN59	8A	28. 15. -
Philip Harris	P100/59	8A	29. 15. -
W. B. Nicolson	K95/1300	8A	29. -. -

*Note. The Radford Labpack specifies 6A maximum continuous current and up to 8A maximum "for short periods".

We do not think it is necessary for pupils to use a meter while carrying out experiments on melts; measurement of current detracts from the main point of the experiments, which is the evidence of decomposition and identification of the products of electrolysis. Moreover the point of the increased current needed for fused salts can easily be made by the teacher with a 0-5 amp. demonstration meter, and the expense of providing additional pupil meters can hardly be justified.

Listed below are the experiments which we carried out and which we would consider successful, unless otherwise stated.

1. Comparison of conductivities, using distilled and tap water, and solutions of hydrochloric acid, sodium hydroxide, acetic acid, and copper oxide and copper carbonate in distilled water.

These experiments are most easily carried out using beaker cells with equal volumes of different solutions in adjacent beakers, The electrodes are then dipped into one beaker after another, with an intermediary rinse in distilled water if this be thought necessary.

2. Ion mobility by comparison of conductivities of 0.1 molar solutions of hydrochloric acid, sodium hydroxide and sodium chloride.

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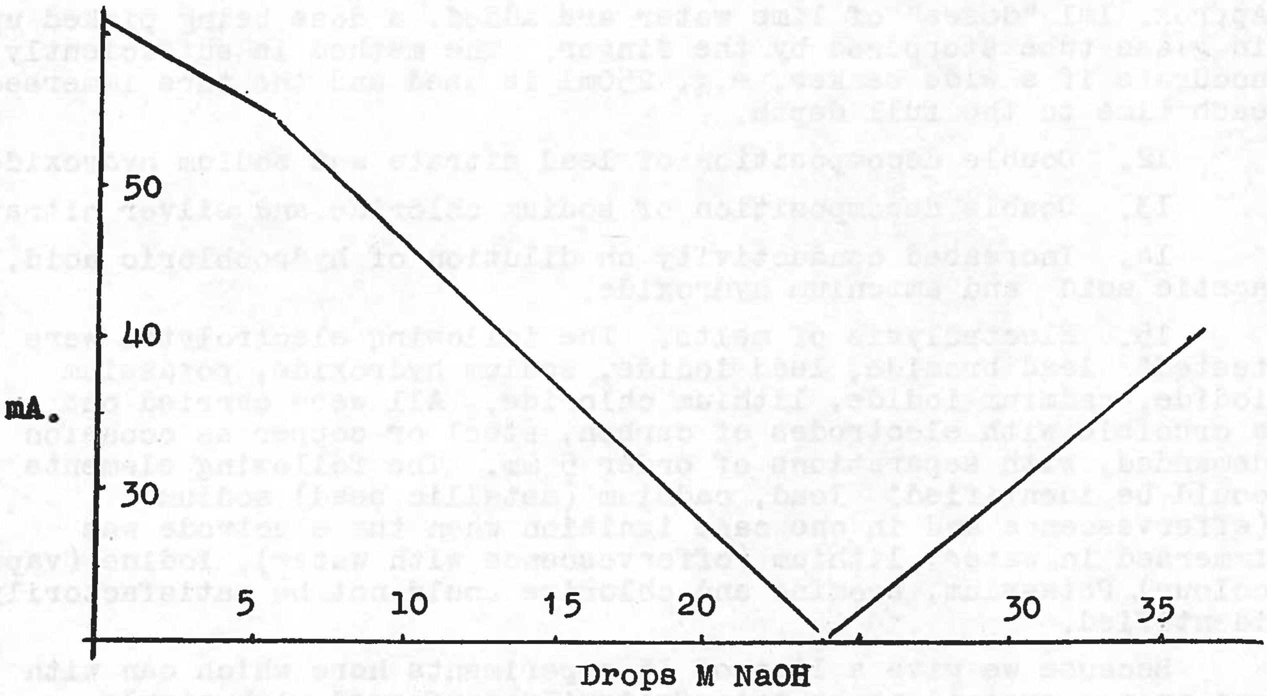
3. Neutralisation of sulphuric acid by sodium hydroxide. This is the by now famous dog leg curve which since its appearance in the 1966 O level examination will be considered a must by every chemistry teacher for years to come.

Our early experiments showed a definite discontinuity in the graph at the dog leg kink, caused by polarisation. The tests were repeated by a member of our Development Committee, and he claims satisfactory results with a class. He used a beaker cell with carbon electrodes pushed through a two-holed stopper, 100mA ammeter and power supply consisting of 3 dry cells, giving 4.5V. 20 drops molar acid are added to distilled water and molar sodium hydroxide is added two drops at a time. After addition the solution is stirred electrically, using a Proops DC motor (Mabuchi No. 15, 3/6). This motor works off $1\frac{1}{2}$V and a glass rod with one end flattened, connected to the motor shaft by rubber tubing, makes an effective stirrer. It has the advantage that it can also enter the conical flask type of cell. After stirring, current is switched on and the meter read after a count of 10, by which time it is usually stationary. We give below a typical graph of his results.



Our own results have been more inconclusive. Typically the kink has occurred much nearer neutralisation, and the curve from that point to neutralisation occupies some 6-8mA so that if one accepts errors of ± 1mA in pupil readings it is quite possible to miss the increased slope and interpret the graph as a smooth curve to the neutral point.

When we changed to the use of alternating current the results were basically the same; a kink was sometimes in evidence and sometimes it could only be detected by hind-sight, the graph being more nearly a smooth curve. Our experiments continue in the attempt to see whether the condition of the carbon electrodes is responsible for the inconsistencies which teachers are sure to meet under classroom conditions.

4. Neutralisation of hydrochloric acid with ammonium hydroxide, provided fresh electrodes are used.

5. Neutralisation of acetic acid with sodium hydroxide. The changing slope at end point on this graph is so slight that it may be easily missed and the result interpreted as a gradually rising curve. Best results were obtained by continuous stirring with the electrical stirrer of expt. 3 above.

6. Neutralisation of acetic acid with ammonium hydroxide.

7. Neutralisation of sulphuric acid with insoluble base.

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Bases used were magnesium powder, copper oxide and copper carbonate. These are experiments in observation; the base is added at the start and the meter reading observed as time passes, with continuous shaking or stirring. The current should drop regularly to a steady value within ½ minute of adding the reagent.

8. Neutralisation of sulphuric acid with barium hydroxide solution. The technique for this experiment is described in S.E.D. Newsletter No. 3, p.9.

9. Neutralisation of sulphuric acid with solid calcium hydroxide. Using a small screwdriver as spatula, pinches of the reagent are added, and meter readings graphed after shaking or stirring.

10. Neutralisation of lime water with carbon dioxide. A slow steady flow of gas is passed into the water and current read at 10s intervals.

11. Softening of calcium bicarbonate solution with lime water. Approx. 1ml "doses" of lime water are added, a dose being picked up in glass tube stoppered by the finger. The method is sufficiently accurate if a wide beaker, e.g. 250ml is used and the tube immersed each time to the full depth.

12. Double decomposition of lead nitrate and sodium hydroxide.

13. Double decomposition of sodium chloride and silver nitrate.

14. Increased conductivity on dilution of hydrochloric acid, acetic acid and ammonium hydroxide.

15. Electrolysis of melts. The following electrolytes were tested: lead bromide, lead iodide, sodium hydroxide, potassium iodide, cadmium iodide, lithium chloride. All were carried out in a crucible with electrodes of carbon, steel or copper as occasion demanded, with separations of order 5 mm. The following elements could be identified: lead, cadmium (metallic bead) sodium (effervescence and in one case ignition when the electrode was immersed in water) lithium (effervescence with water), iodine (vapour colour). Potassium, bromine and chlorine could not be satisfactorily identified.

Because we give a list of 15 experiments here which can with one or two exceptions be satisfactorily performed with simple apparatus, we would not like it to be thought that teachers should carry out all of these. We are not spokesmen for the S.E.D., far less the S.C.E. examination board and to the same extent as every practising teacher do we remain in ignorance of the requirements which the former had in mind when they wrote Circular 512, or which the latter will have in mind when they write future examination papers.

Trade News

In the past those who wished to carry out experiments on blood grouping usually obtained sera supplies from the nearest Blood Transfusion Service, who have always been very co-operative. Now that this appears in the syllabus it is too much to expect that this co-operation can stretch to many Scottish schools. Sera can be obtained from A.R. Horwell at approximately £2 for 5 ml each of anti-A and anti-B serum. A refrigerator is necessary to keep the sera fresh.

A more expensive but more convenient alternative are "Eldoncards" available from Philip Harris. A single card can be used only once, and gives identification of O, A, B, AB and Rh groups. The cards

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have a storage life of two years and cost £1.4.2d for packet of 10.

The Scientific Instruments Centre, stockists of Sartorius balances, have moved to new premises listed in our appendix of addresses.

The Service Trading Co. have moved to new premises listed in our appendix of addresses.

Technical and Optical Equipment have announced reductions in price on some of their microscopes, obtainable in Scotland from Andrew H. Baird, as below.

Model	Formerly	New Price
MBR1	£55. -.-	£49.10.-
MBR1e	44.17.6	39.19.6
MBD1	61. -.-	54.10.-

Vickers Instruments are developing a student phase contrast kit with x10 and x20 objectives which will fit most standard microscopes. The probable cost will be in the region of £25.

Griffin and George have asked us to point out that they are stockists of the Russian SHM1 microscope, under catalogue GN23(2) at a cost of £16.16.-d.

May and Baker have opened a warehouse in Cumbernauld and ask that all orders for chemical reagents be addressed there. Delivery is daily within the central industrial belt and a minimum of twice weekly elsewhere. The policy of the company is to offer only chemicals which they themselves manufacture and full stocks are carried in Cumbernauld. Communications other than those relating to orders should still be addressed to the main office at Dagenham.

Miniature Nife cells are no longer obtainable from Proops, but can be bought from Service Trading Co. at 12/6d each, plus postage.

Proops Brothers have amalgamated with Stern-Clyne to become Sound and Science: a new catalogue covering stocks of both firms has just been issued.

Handy Angle have introduced a new smaller size angle in 16 in place of 14 gauge steel. The sides are 1¼" instead of 1½", and although the loading is only 2/3 of the heavier gauge it is probable that this will be adequate for most school uses. Ties are L-shaped instead of triangular thus allowing full use of the space within the right-angle.

As a replacement for the time consuming Fehling's and Millon's tests, test papers are now available from Griffin and George for the identification of glucose, protein and haemoglobin. They can also be purchased from pharmaceutical chemists at the same price, as below:

Clinistix	(glucose)	bottle of 50 papers	5/-d
Albustix	(protein)	bottle of 60 papers	5/9d
Hemastix	(haemoglobin)	bottle of 40 papers	9/-d

Elesco Electronics and Fraser Electronics have moved to new premises, the address of which is given in our appendix.

Radiospares have introduced panel marking transfers which use the same principle as Letraset and are used to mark scales and labels on panels of any electrical equipment made up in the laboratory. Cost 4/6d for two sheets.

Two free wallcharts from Moore and Wright illustrate (i) parts and function of a micrometer, and (ii) components and typical applications of a combination set.

Philip Harris have opened a Scottish branch and all orders and correspondence with the firm should now be passed through that channel.

In The Workshop

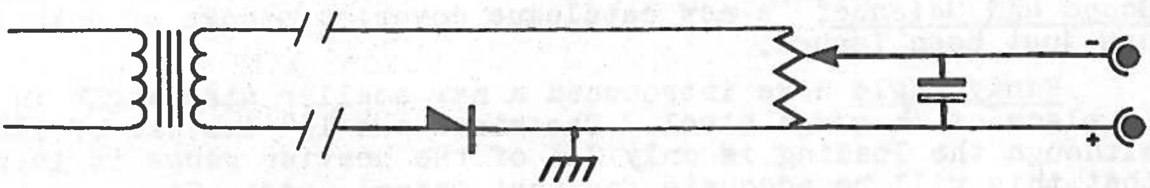
The simplest possible method of generating uni-directional from alternating current is to place a rectifier in series with the load. Add a capacitor in parallel with the load, and we have a degree of smoothing which will depend on the current taken. A potentiometer across the output is a refinement which costs little, and allows the voltage to be continuously varied.

Materials -

		£. s. d.
Silicon rectifier REC 30	Radiospares	18. 6
1.000 uF, 50V condenser	"	5. 3
250Ω, 3W, linear potentiometer	"	5. -
2 4 mm plugs, stackable	"	2. 4
2 4 mm sockets	"	1. -
Rubber grommet	"	-. 1
Control knob	"	1. 9
Tag strip	"	-. 2
Transformer, Nuffield Physics	Philip Harris	7. 5. -
Item No. 27	Griffin and George	7. -. -
	Radford Electronics	5.17. 6
	Morris Lab. Inst.	6. -. -
Twin flex and connecting wire		

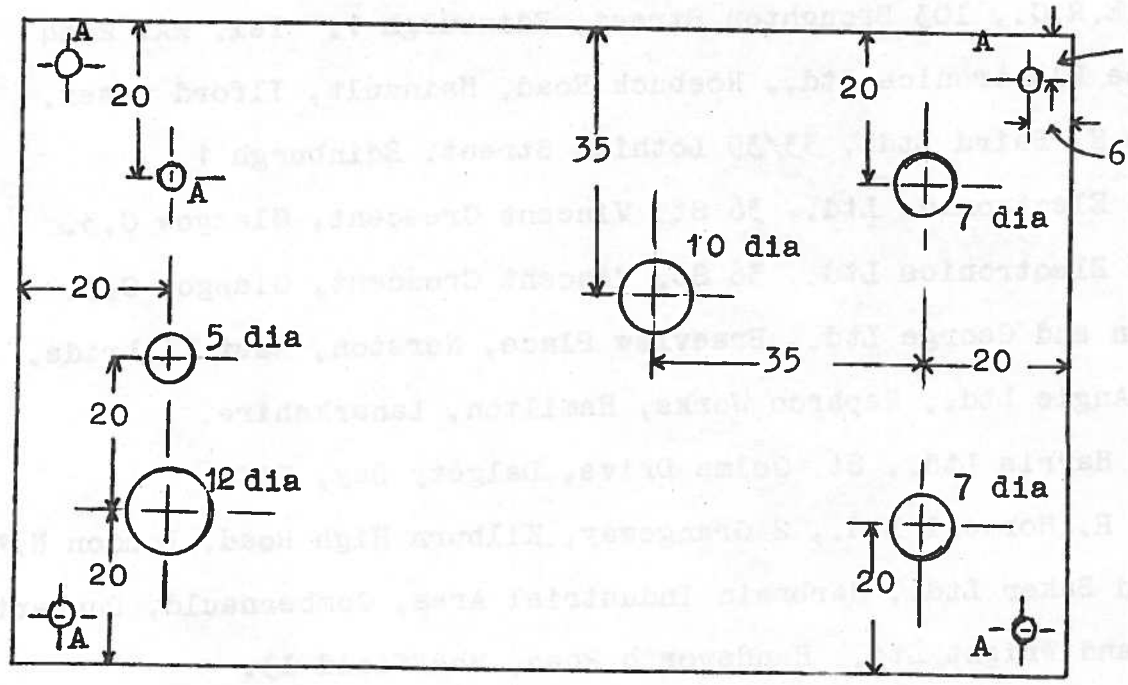
Only one transformer per two rectifier units will be required, bringing the cost per experiment to around £4.

The circuit is -

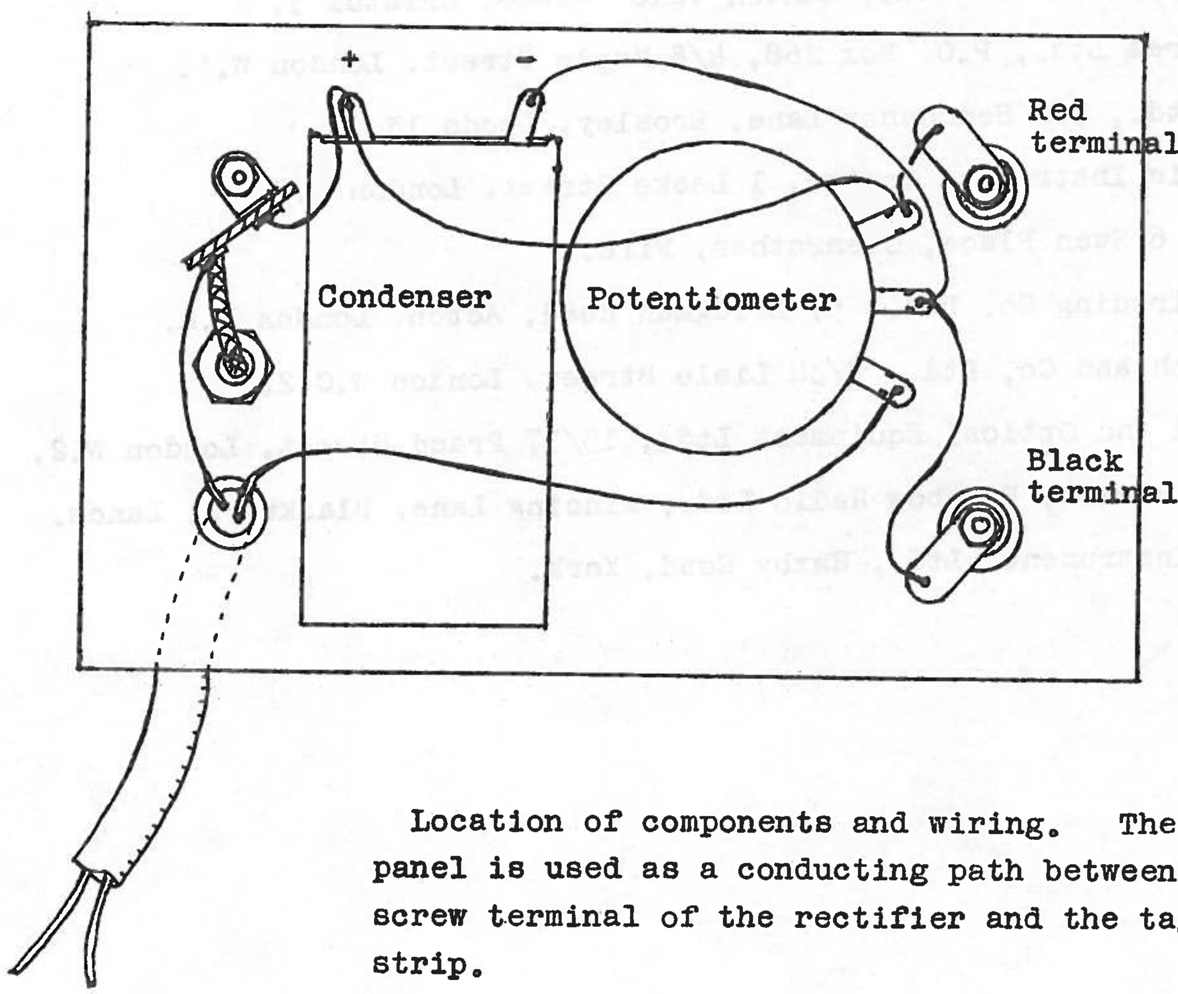


All components are mounted on a sheet of 16 gauge aluminium, measuring 140 x 88 mm, the condenser being fixed with Evostik. Four fixing holes in the sheet will enable it to be attached as a lid to some form of box to enclose the unit, made from wood or metal. The connection to the transformer is by means of twin flex with stackable plugs fitted so that two units can be run from the same transformer. All wiring, including the flex input should be with heavy gauge wire because of the large currents drawn. When using the equipment for the electrolysis of melts, the potentiometer control must be turned fully clockwise.

The aluminium sheet is essential, as it acts as a heat sink for the rectifier. With a 12V input from the transformer the maximum D.C. output at no load current is 17V, dropping to 13V at ½A and 9V at 1A. The maximum current from the unit is likely to be limited by the transformer or by the potentiometer contacts. The rectifier is rated to work at 10A and 150°C; on a two hour continuous test run at 3½A the aluminium heat sink reached a temperature of 50°C and the outside case of the potentiometer 80°C. For those who think they may want to use the unit for heavier currents than this for long periods, the potentiometer could be omitted entirely. The output voltage is then adjustable only by tappings on the transformer secondary.



Drilling of aluminium panel, viewed from underside. All dimensions in mm. Holes marked A are No. 33 B.A. twist drill.



Location of components and wiring. The panel is used as a conducting path between the screw terminal of the rectifier and the tag strip.

S.S.S.E.R.C., 103 Broughton Street, Edinburgh 1. Tel. WAV 2184

Advance Electronics Ltd., Roebuck Road, Hainault, Ilford Essex.

Andrew H. Baird Ltd., 33/39 Lothian Street, Edinburgh 1.

Elesco Electronics Ltd., 36 St. Vincent Crescent, Glasgow C.3.

Fraser Electronics Ltd., 36 St. Vincent Crescent, Glasgow C.3.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride.

Handy Angle Ltd., Reparco Works, Hamilton, Lanarkshire.

Philip Harris Ltd., St. Colme Drive, Dalgety Bay, Fife.

Arnold R. Horwell Ltd., 2 Grangeway, Kilburn High Road, London N.W.6.

May and Baker Ltd., Carbrain Industrial Area, Cumbernauld, Dunbartonshire.

Moore and Wright Ltd., Handsworth Road, Sheffield 13.

Morris Laboratory Instruments Ltd., 96-8 High Street, Putney, London S.W.15

W.B. Nicolson Ltd., Thornliebank Industrial Estate, Glasgow.

(Proops) Sound and Science Ltd., 3/5 Eden Grove, Holloway, London N.7.

Radford Electronics Ltd., Ashton Vale Estate, Bristol 3.

Radiospares Ltd., P.O. Box 268, 4/8 Maple Street, London W.1.

R.S.C. Ltd., 102 Henconner Lane, Bromley, Leeds 13.

Scientific Instrument Centre, 1 Leeke Street, London W.C.1.

Serinco, 6 Swan Place, Glenrothes, Fife.

Service Trading Co. Ltd., 57 Bridgman Road, Acton, London W.4.

G.W. Smith and Co. Ltd., 3/34 Lisle Street, London W.C.2.

Technical and Optical Equipment Ltd., 15/17 Praed Street, London W.2.

Unilab Division, Rainbow Radio Ltd., Mincing Lane, Blackburn, Lancs.

Vickers Instruments Ltd., Haxby Road, York.

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