SCOTTISH SCHOOLS SCIENCE
EQUIPMENT RESEARCH
CENTRE

Bulletin No. 36. January, 1970.

Contents

Introduction

A number of teachers and technicians have expressed their disappointment at finding that items of surplus equipment listed in Bulletin 35 were already sold when they enquired about them. We try to be as fair as possible in a difficult situation, but cannot allow for the vagaries of the Post Office, probably in this instance aggravated by the Christmas rush. As it happened the complete issue of the last Bulletin was uplifted from the Centre by the G.P.O. on a Thursday, and some schools were buying equipment from the list next day. We know from evidence we have collected that other schools did not receive their bulletin until Tuesday or Wednesday of the following week.

It has been suggested to us that we should introduce a system of preferential posting to ensure that all bulletins arrive more or less on the same day, but apart from the sorting difficulty this would cause us, it would be difficult to decide without a large amount of consumer research the basis on which preferential posting should be founded. It cannot be purely geographical, for it is possible or even probable that a bulletin may take less time to reach Lerwick, going by air, than to travel 25-30 miles from Edinburgh to a border village.

What we have done, and will continue to do, is to accept verbal orders by telephone in advance of any paperwork which may be necessary, and we will hold any equipment so ordered for any length of time until the teacher can arrange its collection. In most cases this is preferable to sending the equipment to the school; for any apparatus which is too large or heavy to be sent by parcel post, freight charges may amount to more than the cost of the item itself.

We keep a file of unfulfilled requests so that should we obtain a similar item at any time in the future, the customer can be contacted and offered a first refusal of the new item. Teachers therefore who have a specific need should make this known to us; in this way we can build up information on the type of equipment most likely to sell. It is impossible to forecast this in advance; in the present instance we were surprised at the number of teachers wanting an E.H.T. unit (Item 29), while the alkaline batteries (Item 27) which we had expected to sell very quickly lingered for three weeks after publication of the bulletin. Meanwhile, there are two new items mentioned in the Physics Notes section of this bulletin, and a summary of current availability of surplus items will be given in a few month's time.

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The Integrated Science Course is now well under way in most Scottish schools, and in this connection many teachers will use the official worksheets produced by Heinemann. At the request of one or two teachers we are seeking here to collect information on the most satisfactory method of storing these sheets by pupils. Folders appear to be either good but expensive, or cheap and useless in that they fall apart after a few months in pupil hands. We would like information from both groups of teachers, satisfied and dissatisfied with the method they use at present, with details of the type of folder, brand name and cost in bulk as well as small quantities if this can be furnished.

Opinion

We have been sharply criticised by a University Chemistry Department for including in our recently issued list for Sixth Year Studies chemicals which are too dangerous to be allowed in schools. The writer went on to say that we should contact somebody familiar with the S.Y.S. Chemistry Syllabus in order to draw up a meaningful list of chemicals which would not involve danger and expense beyond that required for carrying out the work of the syllabus. Although I failed to mention it in the introduction to Bulletin 34, this we hope is what we do during compilation of all our equipment lists. In the present instance a draft list was prepared based on the S.C.E.E.B. circular on Sixth Year Studies, on the S.E.D. memorandum entitled Notes on Practical Work in Chemistry, and on two manuals of experiments used at the summer courses in St. Andrews University in 1968 and 1969, backed by the practical experience gained through attending the latter course. The draft was circulated to members of our Development Committee for consideration a month before it was discussed, amended and finally approved at a Development Committee meeting. Some of the alterations made to the list were so made on the grounds of safety.

I agree that there are chemicals on our list which could be considered dangerous: I would not remove them from the list on these grounds. To do so would be to detract from the value of the list as a comprehensive statement of what is required to teach the syllabus, and much more important, it would arbitrarily take out of the teacher's hands his responsibility of deciding the level of safety at which his pupils work. It may be that he is ill informed to take such a decision, and the hazards involved in handling specific chemicals are frequently ill publicised. It is then our duty to see that the teacher is supplied with such information as fully and as fairly as we can give it, and this we hope to do in an early future issue in respect of the chemicals we have listed.

But I believe it to be impossible to teach chemistry without introducing some hazard to teacher and pupils. To insist on complete safety would be to remove from the laboratory chemicals as widely used as sulphuric acid. It follows therefore that someone must determine an acceptable level of risk, and I believe that chemistry teachers, certainly those qualified to teach S.Y.S. Chemistry have taken, are taking, and will want to continue to take that responsibility.

Hazardous chemicals can be grouped into roughly three categories; toxic, explosive and carcinogenic. The weight of public opinion has caused some local authorities to order that chemicals in the last group be removed from school laboratories. This presages a continuing process as more and more carcinogens are identified. In this respect the comment of a cancer research worker is worth noting. "Many cancer research workers now believe that perhaps 80 - 90 per cent of human cancer is due to agents in the environment which should be capable of identification and removal." (School Science Review, No. 175, p. 282.) Such action by a local authority may well be the forerunner to national legislation designed to prevent carcinogens from being handled by teachers and technicians whose risk, if current evidence is to be believed, is far higher than that of pupils. Until such action is taken the necessity of including carcinogens in our S.Y.S. Chemicals list must remain a matter of opinion.

This difficulty spotlights another question which teachers (and local/

local authorities) sometimes ask - are all the items on the list necessary? This prompts another question - necessary for what? Of an S.Y.S. Syllabus I believe there are as many interpretations are there are teachers teaching it, and this is as it should be. If the questioner means necessary to teach the syllabus in the way in which it has been interpreted in the S.E.D. memorandum and the St. Andrews summer courses, then the answer is yes. But other interpretations are equally valid. If a local authority jibs at paying approximately £670 for the equipment on the S.Y.S. list and a further £210 for its chemicals (and may well have misgivings when it is remembered that in many schools the number of pupils will be vanishingly small, a situation which will be aggravated by the up-grading of 4-year comprehensive schools to full secondary status), then the teacher must himself decide which items are less necessary than others. The more expensive tools of physical chemistry on our list I would recommend only to those wishing to use them for project work. But in this, as in the field of chemical hazards, I believe that the teacher must make the decisions until such time as legislation takes it out of his hands.

pH Meters

We were asked to test and report on pH Meters suitable for school use and selected as an arbitrary ceiling those instruments selling for £50 or under, although some models have increased in price since our tests began and may now be over the £50 limit. Those tested were; Philip Harris B5160; Chandos A53 and A54; Analytical Measurements 100 and 700A and EEL 202 Module. Results of our tests on some of these models are summarised in the supplement to this Bulletin and others will be given later.

The normal practice in finding the pH of a given solution is to find the approximate pH, and then to standardise the meter by using a buffer solution of known pH within 1 or 2 pH of the unknown. This practice we followed using standard BDH solutions accurate to 0.01 pH at 20°C in a temperature controlled water bath. In addition, however, we tested the wide range properties of the instrument by buffering at pH values between 2 and 10. Buffer solutions outside this range are difficult to prepare to any accuracy, and it was thought that few teachers would wish to use the meter outside this range. In the summary we give the maximum error in pH, and the pH value at which this occurs for wide range and short range tests. Where the instrument is specified as giving the full pH range, we did test for its effect on the electrode the result of immersion in strong acid and strong alkali. In practice this is likely to arise through misuse, deliberate or otherwise, on the part of pupils.

The current flowing through the meter which registers the pH value is dependent not only on the P.D. across the electrode system but also on the gain of the amplifier. In making an extended series of pH measurements it is an advantage to be able to check that the amplifier section of the instrument has not changed in sensitivity without the time-consuming process of re-buffering. pH meters therefore have a 'check' position of their controls so that the amplifier setting may be verified with the electrode disconnected. In general this setting will not give the same reading as when the electrode, immersed in buffer solution, is connected up. The reason is that the electrode itself introduces a zero or shift error which is balanced out when buffering takes place. In most cases/

cases the value of this 'check' reading has to be memorised at the start of the experiment although on one model tested, the Analytical Measurements Model 100, two numbered dials are provided to allow this reading to be set.

At 20°C an increase of 1 pH corresponds to a potential difference of 58mV. It is therefore possible to test the performance of the pH meter independent of its electrode system by applying increments of 58mV to the meter input. The apparatus is then operating as a millivoltmeter of very high input impedance. We accordingly set up a potentiometer circuit driven from one or more Nife cells with a DC millivoltmeter in parallel with the pH meter input to check the accuracy of the electrometer system. The accuracy of measurement in this part of the tests we estimate to be ± 2%. One meter, the B5160, has a separate mV input and corresponding switch position; this was tested using the same technique. In the summary these are referred to as "amplifier test" and where applicable, the maximum error is specified.

The potential developed between the electrodes by a given solution is temperature dependent, increasing as the temperature is raised. There are two basic methods of correcting for temperature variation; the more expensive involves altering the sensitivity of the amplifier and takes the form of a control knob with temperature scale. When set to the test solution temperature, the meter reading gives the corrected pH directly. Besides expense, the disadvantages of this method in pupil hands are accidental and unnoticed displacement on the control during an experiment and failure to check the temperature setting before initial use of the meter when it may have been left at a different temperature setting by the previous user. For these reasons we prefer the chart or graph type of correction supplied with the instrument wherein a correction or a corrected value can be read off for a given temperature and meter reading. Both Chandos meters use a built-in correction; the remainder use graphical methods.

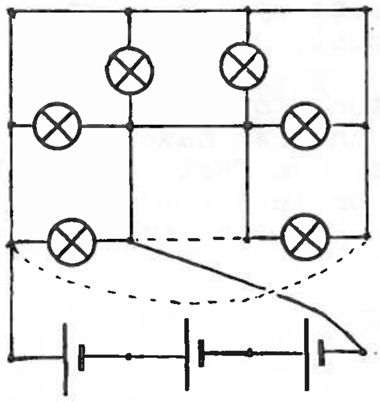
To check the temperature correction we used a primary buffer standard pH4 made up to BS 1647: 1961, the pH of which is known between 0 and 100°C in a water bath. The reports state the maximum error in the corrected pH and the temperature at which this occurs. When the pH of a solution is to be intermittently or continuously observed during a reaction which may take 30 min. or longer, it is important that the pH meter should be free from drift. This was tested by leaving the electrode in the primary buffer standard for 90 minutes, checking the pH at intervals.

An important aspect of pH meters is the cost and ease with which batteries in portable models may be replaced. In our summary where a power supply is listed as "special" this generally means that replacement batteries are unobtainable locally and must be ordered from the manufacturer or their agents.

The electrode system most common in use is a concentric one, the glass electrode being surrounded by the calomel reference electrode. Typically it measures 120 x 20mm diameter and is connected to the meter by coaxial cable. The size and weight of the electrode together with the pull exercised by the cable mean that when resting against a beaker lip the system is not stable unless a 250ml beaker and 100ml of solution are used. As buffer solutions are expensove teachers will wish to use less than this but must then clamp the electrode in a smaller beaker. The Analytical Measurements Model 100 which is a pocket meter for field work, overcomes this difficulty by the use of a sample holder round the electrode requiring only 3.5ml of solution for a test.

Physics Notes

Following the publication of our ring main model in Bulletin 33, we had a note from Glenwood Junior High School, Glenrothes, showing how this may be set up using standard equipment. The teacher suggests using a Worcester circuit board with standard connectors and lamps, in the pattern given below.



The lamps are 2.5V, 0.2A from Radiospares, and the dotted lines on the diagrams show the connections needed to tie the head of the ring to the tail. Although the experiment is worth trying out in advance of presenting it to a class because it uses equipment which should already be in the school, we cannot give any guarantee of success since this depends upon a built-in contact resistance which a good Worcester circuit board ought not to have. When we tried the experiment with the current Philip Harris version of board, the change in brilliance of the lamp at the tail of the ring was barely perceptible, the voltage at the tail of the ring rising by 0.1V only.

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We have to point out two errors in our equipment list for Physics: Revision of Circular 490. In Item 180, Eyepiece Lens, due to a confusion in the Nuffield numbering, the references given are for the objective instead of the eyepiece lens. The item should read:

Eyepiece Lens (P) (N113/1) 25mm dia lens required for 179; together with one of 176, this completes the telescope.

Baird	95/1565	-. 5s. 2d.
Harris	P8563/01	-. 5s. -d.

The second error concerns Item 165, Metric Wire Bridge, which should be listed (P) for pupil quantity.

On the same theme we have been asked why no form of optical bench features in the physics list. This is because these benches are expensive and we believe that satisfactory results can be obtained with a metre stick screwed to the bench top using lenses and other components in mobile holders.

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Many, but not all, of the new items 26-47 of second hand equipment listed in Bulletin 35 are sold out. We give details below of two other small items.

48. Sine Cosine Potentiometer. This is a centre-tapped, 14.4kΩ rotary resistor with two wiper contacts placed at 90° phase relationship to each other. Price 10s.

49. D.C. Voltmeter Relay. This has a moving coil movement, with a change-over contact. The maximum current which the coil is capable of carrying is not known, but as sold the relay has a number of series resistors to give an operating range between 238 and 242V when the coil current is about ½mA. The operating range of the contact can be adjusted by a ratchet controlling the torsion spring of the movement. Price 5s.

We also carry large stocks of new fixed resistors which are given away free. Amongst them we have close tolerance, heavy duty and high voltage types; in fact almost the only type we cannot supply are the 1/3W or less used in printed circuit and similar work. Individual enquiries are invited.

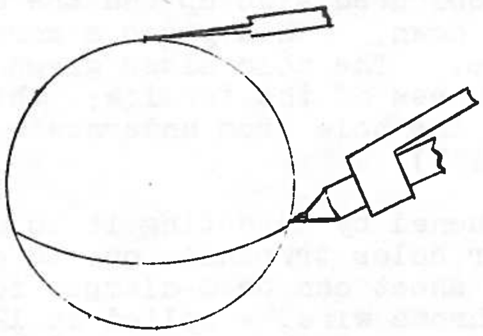
Chemistry Notes

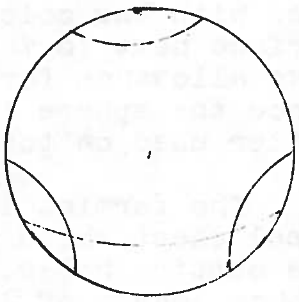
This note is background material for the model cutting jig described in the Workshop section of this Bulletin to give the general principles on which the system is founded and to enable teachers or technicians to prepare the spheres for cutting. The concept, and the jig for cutting the spheres come from Our Lady's High School, Cumbernauld.

A 1.5in diameter polystyrene sphere is used to represent carbon, oxygen and nitrogen atoms; hydrogen is represented by a 1in diameter sphere. A similar approximation is used in determining bond lengths, small differences are ignored and an average value used for a whole group. Thus the average hydrogen bond length with C, O and N is taken to be 1.0Å, scaled down to fit the selected sphere size to 0.8in. Single, double and triple carbon bonds are chosen to be 1.5, 1.3 and 1.15Å respectively with scaled lengths of 1.2, 1.1 and 0.9in. An exception to this scaling is the aromatic ring, in which case bond length is ignored and the spheres are cut so as to give a ring with a closed centre. From the above it will be seen that the cutting jig requires five different sizes of hole, one for hydrogen, one each for single, double and triple bonds for carbon, oxygen and nitrogen, and one for cutting aromatic rings.

For hydrogen, no marking is needed on the sphere; it is simply cut anywhere on the surface following the technique described. For a single carbon bond (tetrahedral atom) two points on the circumference of a 1½in diameter circle which subtend an angle of 109½° at the centre of the circle are marked off. A pair of compasses are set to a radius equal to the distance between these points. If a polystyrene sphere is examined, it will be seen that the mould from which it was formed is in two halves, so that there are on the surface two pips corresponding to 'poles' and an equatorial line. The compass point is placed on one of these pips and with the setting described above, a circle is drawn on the spherical surface. With the/

the same setting of the compass, this circle can be tri-sected by stepping round the circle starting anywhere. The three points of trisection together with the original 'pole' then form the four points of the tetrahedral atom and are the centres of sectors which will be sliced off when the sphere is cut in the jig. With the compasses set at $\frac{1}{2}$in separation, circles are described about each of these points; these circles allow the sphere to be centred accurately in the jig hole before cutting.





To cut single bond nitrogen atoms, the same procedure is followed, but only three sectors are cut off instead of four. For a single oxygen bond only two sectors are cut off and hence the detailed marking procedure need not be carried out. Instead, two points on the equatorial line are stepped off with the compasses; each is then circled for cutting. Again, although it will make little difference to the finished model, the angle for stepping off these points can be made 105° instead of $109\frac{1}{2}^\circ$.

For a carbon atom with one double bond (sp^2 hybrid) the resulting molecule is planar and hence all that is required is that the equatorial line of the sphere be trisected. This is done by setting the compass to 120° angle and stepping off around the equator, starting anywhere. Of the three sectors, two are cut in a single bond hole and one in a double bond hole in the jig. Nitrogen for NO_2 groups is treated in the same way except that two sectors are cut in the double bond hole and one in the single bond. A double oxygen bond is only one cut so it can be done anywhere without marking off.

For a triple carbon bond, the pole pips on the sphere are circled and one single and one triple bond hole used to cut the sectors. For carbon atoms in aromatic rings, the equatorial line is trisected as before, and two sectors are cut in the aromatic bond hole, the third being cut for a single hole, unless all three bonds are part of the aromatic system in which case all three faces are cut in the same hole.

A cement can be made by dissolving the polystyrene offcuts in benzene; only a little solvent is required as the material is very soluble, and if the solution is unsaturated the cement will dissolve away the model when it is being put on. Before cementing, spheres should be painted in some colour convention to indicate different atoms.

In The Workshop

The model jig to be described allows the correct size of sector to be cut from $1\frac{1}{2}$in diameter spheres to make the molecular models/

models decribed in the Chemistry Notes section of this Bulletin. The principle employed is to insert the sphere into a hole in a sheet of formica, the size of hole being so arranged that the sector may be sliced off the sphere by sliding a hot wire over the face of the formica sheet. Fig. 1 shows the five hole sizes required. These must be carefully cut, using a trepanning tool and a power drill. Even so, the spacing of the cutting tool should be adjusted by trial and error, drilling sample holes in scrap formica until the size is exactly that required. The formica should be drilled with the coloured side up and the completed jig used with the coloured side down. This gives a more resistant surface next to the hot wire. The hole sizes given in Fig. 1 make allowance for the thickness of the formica; this is necessary since the sphere is held in the hole from underneath and the wire cutter used on top (see Fig. 2).

The formica is strengthened by cementing it to a 22 SWG mild steel sheet which has larger holes trepanned out to coincide with the cutting holes, and this sheet can be G-clamped to a bench edge. A 50cm length of 26 SWG nichrome wire, supplied at 12V from a low voltage transformer is used as a cutter. One end is bolted on the jig, the other is attached to a piece of paxolin (or any insulating material) measuring 15 x 25 x 5mm which acts as a handle and also has a press button switch controlling current to the wire. To operate, the current is switched on and after a few seconds wait to allow the wire to heat up, the wire is stretched taut on the surface of the formica and slid across the surface with the sphere held up from underneath.

Permanent molecular models can be made by cementing the cut spheres together as described in the notes. Some advantage may be gained however by having pupils build their own molecules by assembly in such a fashion that they can be dismantled and used over again. For this we give two suggestions. The first is to cement on to the flat faces of every sphere two 5mm squares of Velcro, one square being the loop material and the other the hooks. Although it will cost twice as much, it will help identification if the loops are in one colour and hooks in another, e.g. black and white. Velcro is obtainable from drapery or haberdashery stores in 1 in strips at around 9s. per yard. When two faces are pressed together, they will adhere in almost any orientation except when white is directly opposed to white and black to black. The squares can be cemented to the polystyrene with Durofix or Seccotine, but not Evostik which dissolves the polystyrene. When fitted together, the join between atoms is not of course perfect, there being a gap of 2 - 3mm between faces due to the thickness of the Velcro, but this may still be considered satisfactory for pupil work with properly cemented models for demonstration. We believe there is an advantage in demountable models in that the orientation of two molecular groups can be discussed and experimented with. Also the Velcro version will last any number of fittings and separations, and the greatest wastage will probably be due to pilfering.

The second method which gives a better fit but is less permanent, is to screw the two atoms together using a short length of 2 BA screwed rod obtainable from <u>K.R. Whiston</u>, (see Fig. 5). The disadvantage is that the screws can be overtightened and after a few such fittings it is usually found that any thread in the polystyrene has been stripped and the rod is quite loose in the hole. The life of the atoms can then be extended a little further by cementing a length of P.V.C. sleeving (4mm size, obtainable from <u>Radiospares</u>) inside the hole.

Accurate centring and drilling of holes in the spheres is necessary and two metal jigs, one for each size of sphere, must be/

be made up. Two 50mm lengths, one 1in and the other $1\frac{1}{2}$in inside diameter are cut from mild steel tubing, and a 15mm wide slot cut out of each. A brass top 5mm thick is turned to fit the tube and drilled in the lathe, and then soldered on to the tube. The slot in the tube allows a finger to be inserted to hold a sphere up against the brass top while it is being drilled.

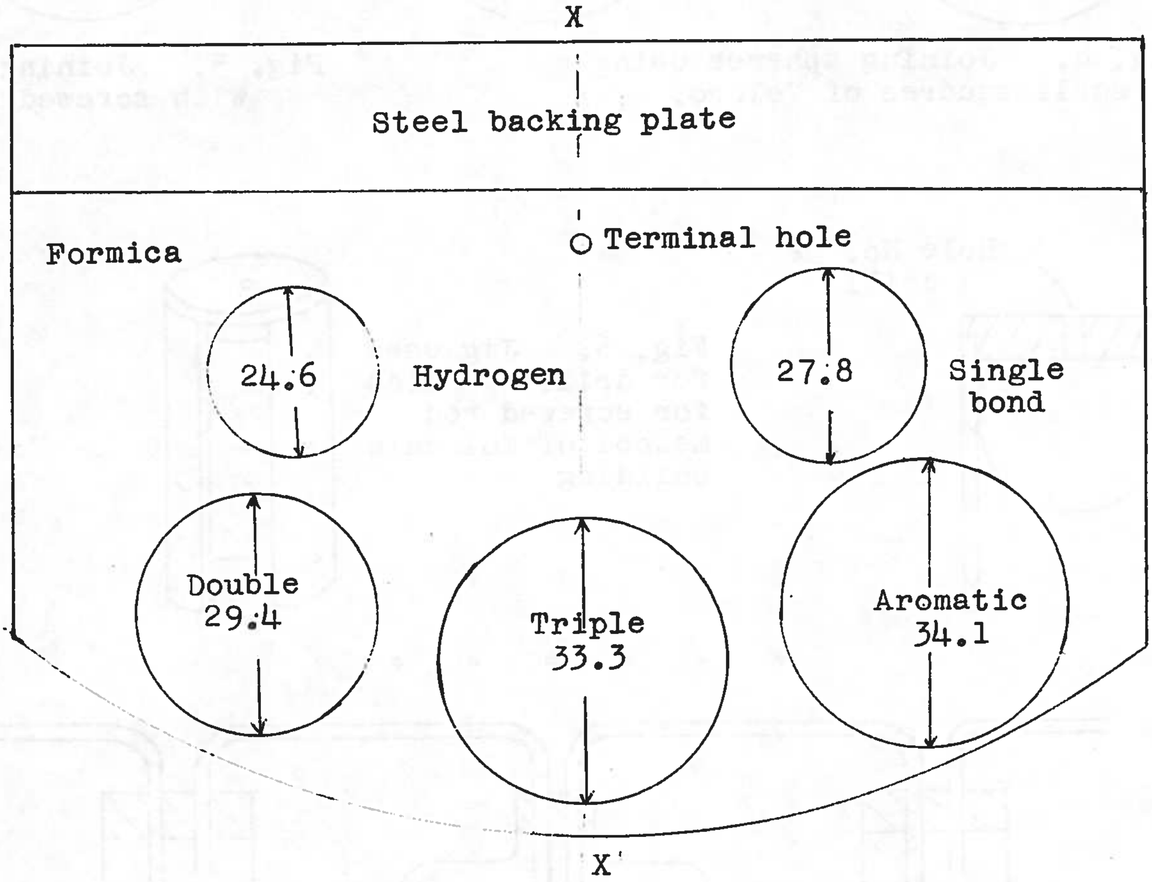


Fig. 1. Hole cutting jig. Dimensions in mm.

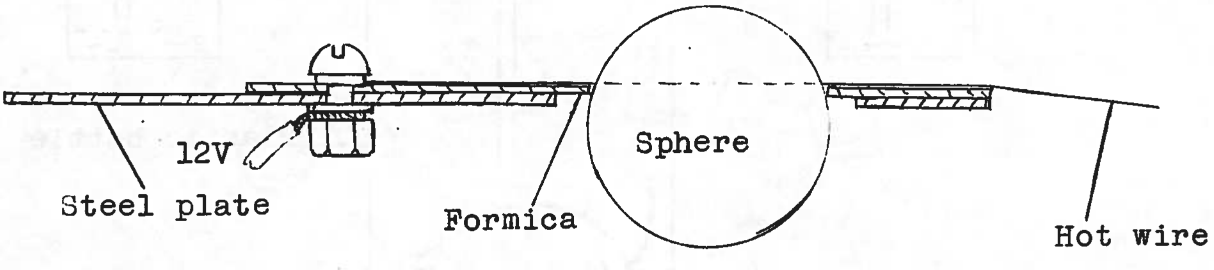


Fig. 2. Section through XX.

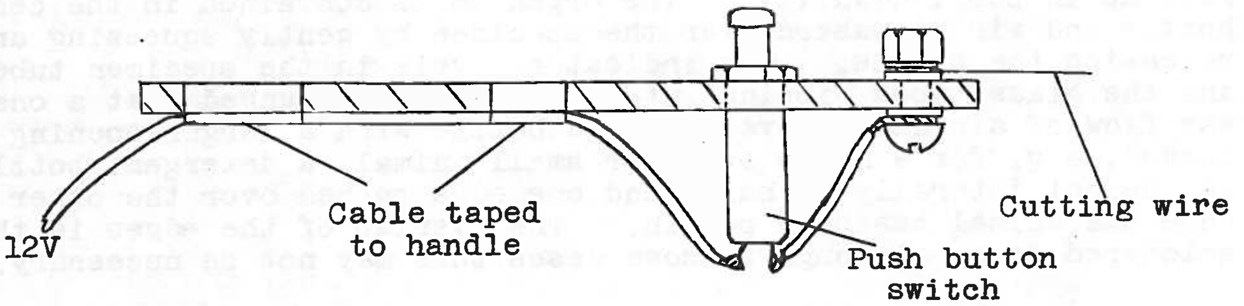


Fig. 3. Handle detail.

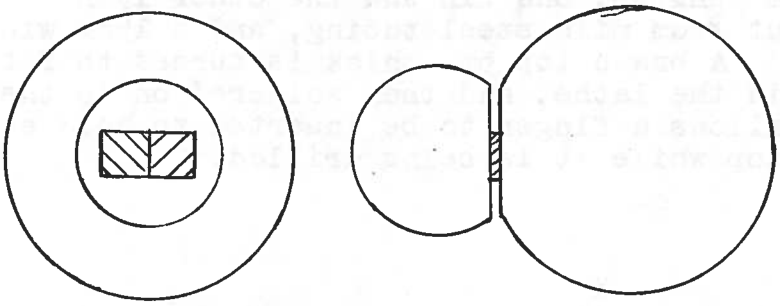


Fig. 4. Joining spheres using small squares of Velcro.

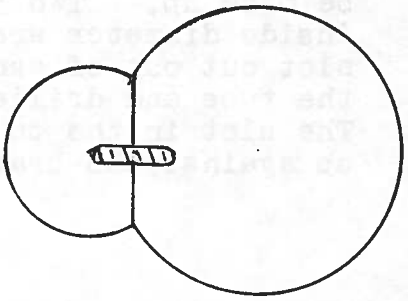


Fig. 5. Joining spheres with screwed rod.

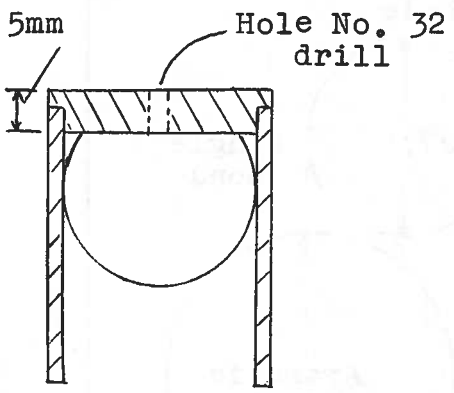
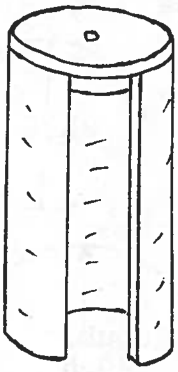


Fig. 6. Jig used for drilling holes for screwed rod method of molecule building.



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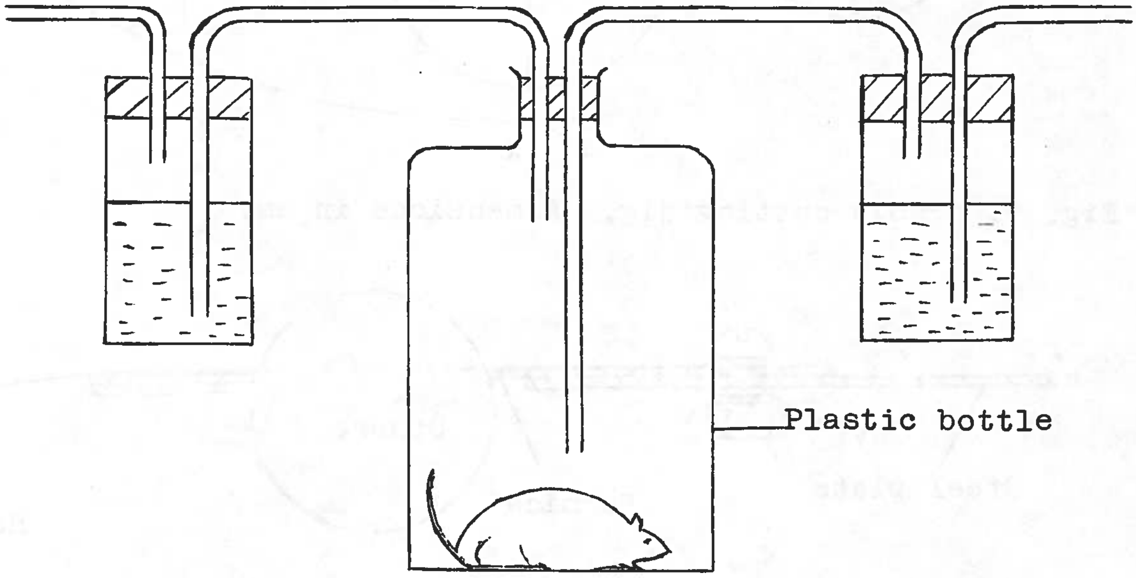

The sketch shows how a comparison of inhaled and exhaled air can be made for a small organism using pupil apparatus which can be made up in pupil quantity. The organism is contained in the central bottle and air is passed over the specimen by gently squeezing and releasing the bottle. The indicator levels in the specimen tubes and the glass tubes dipping into these are so arranged that a one-way flow of air is achieved. If a bottle with a larger opening is needed, e.g. for a mouse or other small animal, a detergent bottle can be cut laterally in half, and one edge pushed over the other once the animal has been put in. The overlap of the edges is then selotaped down, although in some cases this may not be necessary.

Bulletin Supplement

Below is a summary of the tests carried out on a selection of pH meters; others will be given in a future Bulletin. Individual reports on these meters can be borrowed for up to one month by writing to the Director. The classifications used are A - most suitable for school use; B - satisfactory for school use; C - unsatisfactory.

Model		100	B5160
Manufacturer		Analytical Measurements	Philip Harris
Price		£39.18s. 0d.	£32.10s. 0d.
Electrode	type	A.M. bulb	U17BP
	cost	£5. 0s. 0d.	£7.10s. 0d.
Battery	type	Special	2 x PP9
	cost	£1. 5s. 0d.	7s. 6d.
Range (s)		2 - 12pH*	0 - 14pH 0 - 1400mV
Sensitivity: 1 div =		0.2pH	0.2pH 20mV
Readability: division separation =		1.1mm	1.3mm
Accuracy: Wide range max. error		0.15pH at pH2	0.2pH at pH 10
Short range max. error		0.1pH at pH6	0.2pH at pH 10
Temperature range		0 - 70°C	0 - 80°C
Temperature compensation: max. error		0.2pH at 70°C and 2°C	0.15pH at 70°C
Amplifier		Satisfactory	Satisfactory
Drift		Satisfactory	Satisfactory
Classification		B	A

* By offsetting the amplifier balance control the range can be displaced to give either 0 - 10 or 4 - 14pH.

S.S.S.E.R.C., 103 Broughton Street, Edinburgh, EH1 3RZ. Tel.
031-556 2184.

Analytical Measurements Ltd., Dome Buildings, The Quadrant,
Richmond, Surrey.

Baird and Tatlock Ltd., Thornliebank Industrial Estate, Glasgow.

Chandos Intercontinental, Chandos Works, High Street, New Mills,
Stockport, Cheshire.

(EEL) Evans Electroselenium Ltd., Halstead, Essex.

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

Radiospares Ltd., P.O. Box 427, 13-17 Epworth Street, London, E.C.2.

K.R. Whiston, New Mills, Stockport, SK12 4HL.