SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 103. April, 1978.

Contents

Introduction

When we sell surplus equipment, equipment lists or back numbers of bulletins we have two methods of payment which broadly can be called cash or credit. Paying by cash means just what it says, either directly by personal attendance of the buyer or by postal order or cheque if the buyer is unable to visit the centre. Moreover this is the only method whereby small amounts of £1 and under may be paid.

Credit means that we supply an advice note with the goods, whether these are collected personally, or sent by post or freight. The advice note details the contents of the order, the individual prices and the total. At the end of each month we issue invoices for credit sales, these being sent to the headmaster of the school making the purchase. The invoice will be on an account form from the Education Department of Lothian Regional Council, who collect all monies on our behalf, and it will direct that payment be made to the Director of Finance, Lothian Regional Council, George IV Bridge, Edinburgh. Apart from carrying our name and address, and the number of the advice note sent with the goods, the invoice will give no details of the order except the cash total, although if the school has sent an official order, this reference number will be quoted.

It is important therefore that the buyer should see that the school secretary or other administrator responsible for processing payments made by the school, receives the advice note which we send with the goods, so that he/she can correlate this with the account which we send out at the end of the month. If there is no order number which we can quote, the secretary has no means other than our advice note number of tracing the purchase. It has happened too often that we have been telephoned by a school secretary denying all knowledge of the purchase. Things become even more complicated if the phone call is made to the Director of Finance instead of to ourselves. We appeal to all those who buy goods on credit to see that their school administration knows what they have bought, and how the school will be charged for it.

Cash sales are much simpler; we supply a receipt for each sale so that the buyer may use this to reclaim his outlay from whatever school funds exist for the purpose.

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We have received a number of requests for our hazardous chemicals manual, and the enquirers could be forgiven for wondering what has happened. Until recently, however, it has not been possible to make a definitive statement on the position. Our Governing Body has decided that two copies of the manual should be sent to each regional authority with the invitation to reproduce it in such quantity as may seem fit for distribution to their own schools, and this has already been done. Any teacher in a Scottish L.E.A. school wishing to have a copy should therefore ask their Science Adviser, Divisional Education Officer etc. The Governing Body's reason for distributing the manual in this fashion is that, as it consists of over 200 pages, financially SSSERC could not undertake direct distribution to the schools. Non-LEA subscribers to SSSERC will regrettably have to wait until the manual is published commercially. It has been accepted for publication by Oliver and Boyd, and it is hoped that it will be available before the end of the year at a price of about £4.

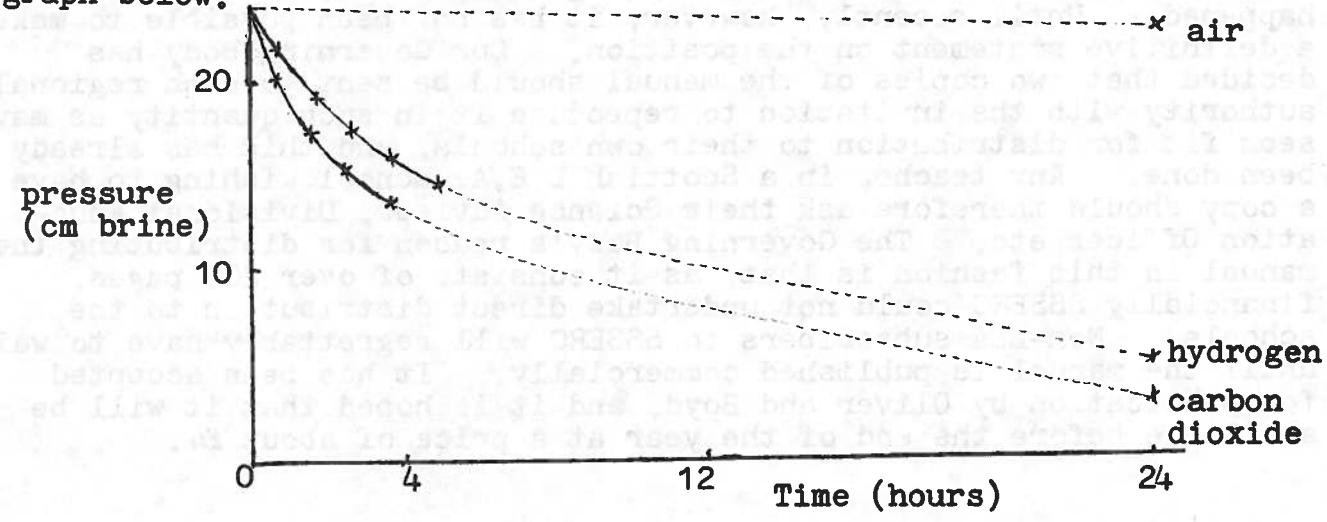
Chemistry Notes

Several well known texts indicate that the relative rates of deflation of balloons filled with air, hydrogen and carbon dioxide are in accord with what kinetic theory and Graham's law would predict (e.g. Expt 4.2 in 'Science for the Seventies'). That this is not so was pointed out to us by Galashiels Academy, who asked us to investigate further. More recently the results of an investigation by Lanark Grammar School pupils, given in a "Young Scientists of the Year" BBC television programme, and our own results described below, agree with these findings.

One possible explanation was that the rubber material used in the manufacture of balloons had been changed since the experiments in the textbooks had been tried out. However the 'leaky carbon dioxide' type must have been on the market for some time, as evidenced by the advice given in Nuffield Physics Teachers' Guide I, which was written after trials in the early 1960s. Instructions for preparing an exhibition which includes balloons filled with different gases advise the teacher to fill the balloons just prior to the class arriving, because 'both hydrogen and carbon dioxide leak out through rubber balloons...' Further, the inventor of the process has informed us that virtually all toy balloons are now manufactured according to the method he originated just after 1945. This balloon film is essentially one of 80% natural rubber, 2% pigment and 18% plasticiser - usually a mineral oil.

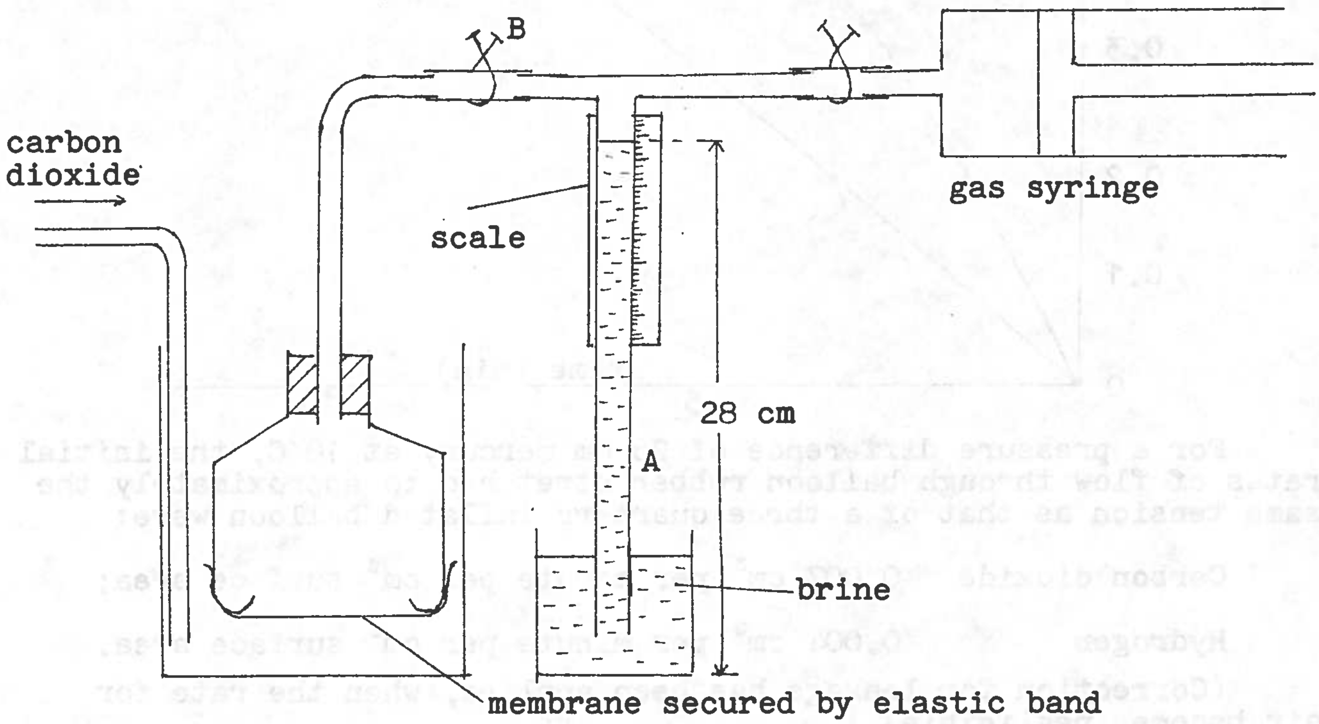
It might appear to students of human behaviour that most of us see what we are trained and prompted to expect. However there are a few brave spirits who have refused to turn a blind eye to pieces of jigsaw which do not fit. All credit to the young scientists of Lanark Grammar School who were able to present findings that left even the judges of the television programme without a ready explanation.

Our own work has so far only succeeded in confirming these findings and has concentrated on obtaining results that do not rely on merely measuring balloon sizes as they deflate. Three balloons, filled with carbon dioxide, hydrogen and air were each attached to a U-shaped manometer containing saturated brine, to which a pinch of sodium carbonate and one drop of concentrated hydrochloric acid had been added. This was in order to obtain a manometric fluid in which carbon dioxide would not dissolve. The rate of pressure decrease was monitored as the balloons deflated. Results are shown in the graph below.



The pressure 'half-lives' of both carbon dioxide and hydrogen are not constant, but usually lie between one and four hours for a fully inflated balloon. The air-filled balloon showed a negligible fall in pressure, whereas in one hour balloons filled with carbon dioxide and hydrogen to a pressure of 24.5 cm brine (21 mm of mercury) showed falls in pressure of 27% and 21% respectively. When the balloons were switched and the measurements repeated with an initial pressure of 13.4 cm brine (12 mm mercury) the decreases were 33% and 24% respectively. Another observation was that there is a surprisingly poor correlation between the sizes and pressures of different ballons as they deflate.

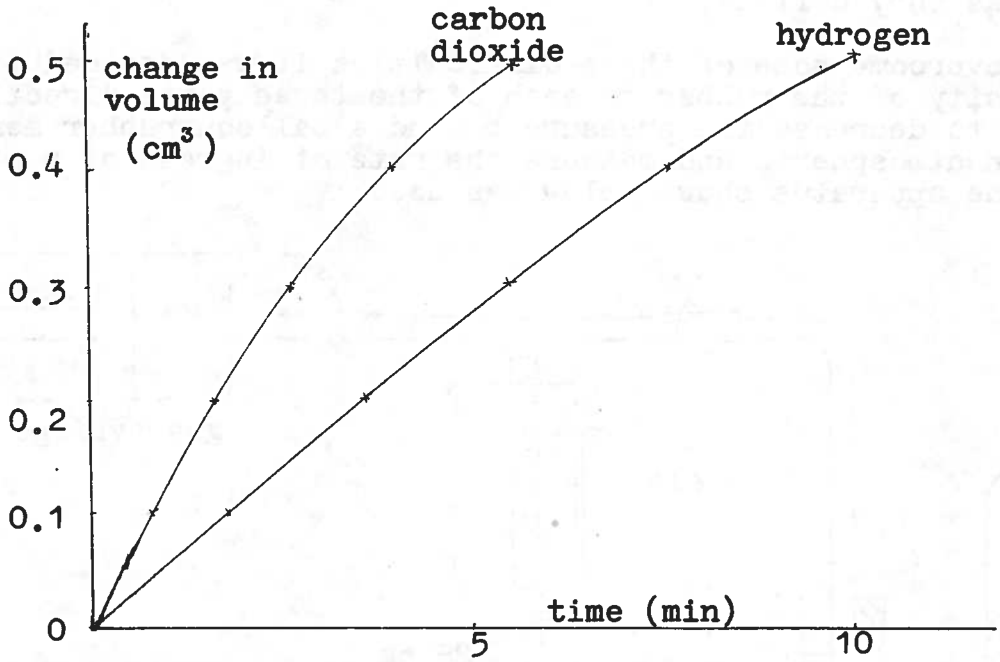
To overcome some of these difficulties it was decided to measure the porosity of the rubber to each of the three gases directly. The idea was to decrease the pressure behind a balloon rubber membrane to less than atmospheric and measure the rate of ingress of a particular gas. The apparatus shown below was used.



An old BDH concentrated volumetric solution container had a hole cut in its base and the rounded rims left to provide strength. The dimensions of the vertical tube A had to be a compromise. A fine tube would enable more accurate readings of volume to be made, but would suffer from the disadvantages of a large change in pressure as the level fell and from capillarity effects. Standard 6mm outer diameter soda tubing was used.

With a very good gas syringe it should prove possible slowly to withdraw the plunger and keep constant the level of brine in the tube. This would have the advantage of measuring directly the volume of gas penetrating the rubber under a constant pressure gradient. Most gas syringes leak slightly and it proved more satisfactory simply to use the syringe to draw brine up the vertical tube to a mark 28 cm above the surface for each run. Thus the pressure inside the diaphragm was 28cm brine (25 mm mercury) less than atmospheric, which is a typical pressure difference across an inflated balloon. A correction for slight leakage was measured by closing the tap at B and following the rate of fall of brine in the vertical tube.

By simple calibration the scale reading was converted to volume in cm^3. The hydrogen was supplied by a cylinder and dried with calcium chloride. Since it was likely that cylinder derived carbon dioxide would be damp, it was produced in a gas generator and washed and dried before use. A run with air after each of the other two gases showed that the membrane did not appear to have been changed. The results for carbon dioxide and hydrogen are shown below.



For a pressure difference of 25 mm mercury at 18°C, the initial rates of flow through balloon rubber stretched to approximately the same tension as that of a three quarters inflated balloon were:

Carbon dioxide 0.007 cm^3 per minute per cm^2 surface area;

Hydrogen 0.004 cm^3 per minute per cm^2 surface area.

(Correction for leakage has been applied, when the rate for air becomes negligible).

In addition to these findings, it can be shown qualitatively that the rate of deflation is determined by the gas in the balloon at the time and not by the pre-treatment of containing either of the other two. The placing of several pieces of dry ice in a balloon did not affect its ability to contain air and no improvement in the retention of carbon dioxide resulted when two balloons were treated with pentane vapour in an attempt to dissolve partially the rubber and possibly reseal it.

Clearly the process is not solely one of simple diffusion. At one stage we became so sceptical of accepted theory that we went so far as to investigate rates of diffusion of the three gases through an orfice. Readers may be relieved to know that we confirmed that Graham's law does apply! A few of the more interesting and salient findings from Lanark Grammar School include the following:

(i) Butane diffuses more rapidly than does methane:

(ii) The concentration gradient across the rubber membrane of an inflated balloon is 103 : 78 for nitrogen, but for most other gases is 103 : 0. This partly explains the slow rate of deflation of a nitrogen-filled balloon.

(iii) Sulphur dioxide whose adsorption by rubber is well known was found to escape rapidly from a balloon.

Hence deflation of a balloon is dependent both on diffusion and on a process of solution of the gas in the elastomer. The permeation rate is given by the formula:

$J=ADk\frac{p}{l}$, where l is the membrane thickness;
A is the membrane area;
D is the diffusion coefficient;
k is the solubility constant of the gas;
p is the pressure of the diffusant at the ingoing face of the membrane (the partial pressure at the outgoing face being negligible). Since A, l, and p are the same for all gases the permeation rate is proportional to the product Dk. As might be expected, D is smaller for butane than for methane, but k is much larger.

Hence in the experiments we do in the Integrated Science course, one should be careful against reading too much into the observations. An effect we ascribe to diffusion may be much more attributable to the solubility constant k. In order to explain why an air-filled balloon does not deflate, it may be helpful at this level to show, as we have done, that a balloon filled with carbon dioxide and placed in an atmosphere of the same gas does not deflate either. This will help to establish that, whatever process is going on, it is a two-way process with gas molecules passing both in and out of the balloon.

A further complication - if one were needed - is provided by micro-porosity. Each rubber globule in the original latex compound is surrounded by a proteinaceous skin or envelope, and on coagulation this skin persists as a continuous sheet. On inflation, however, the skin breaks up leaving micro-pores between the globules. If however, as seems likely these pores are much larger than the inter-molecular spaces which the Integrated Science course refers to as 'holes' in the balloon, their effect will be to add to the deflation rate a constant factor for all gases which depends on the pressure difference between inside and outside of the balloon.

Diffusion is clearly involved when (i) gas molecules are reaching and colliding with the inner surface of the balloon, (ii) gas molecules having dissolved diffuse through the "liquid" elastomer, (iii) gas molecules "evaporate" at the outer surface and diffuse away into the atmosphere. Whichever of these three steps is the slowest will be the rate-determining step, and if the gas is of low solubility then the intermediate step (ii) is clearly limited.

The observation that a balloon deflates is still of great use in demonstrating that the 'particles' or molecules involved are probably very small if they can pass through a skin with no visible holes. Clearly this must be left as a simple observation and not have additional constructions placed on it. To look more deeply into this provides for the other end of the school very promising material for sixth year projects.

Physics Notes

This suggestion for a decimal to binary code conversion unit came from an Edinburgh school. It was suggested that a pupil should be able to set any number say up to 99 and see immediately the equivalent in binary code. Since 99 lies between 2^6 and 2^7, the binary code will have a maximum of seven bits, and seven indicators will be needed. While it is possible to indicate numbers in binary up to 9 by mechanical switching, the need to add 10 to each total when the tens switch is moved on one step requires the use of t.t.l. logic. There exists a system 74 chip which will carry out the conversion, SN74184 (£1.50 from Bi-Pak) and they can be cascaded to give decimal to binary conversion for any number of bits.

A ten-way rotary switch could be used to dial up the decimal number, but it would require four banks, one for each order of 2 up to 10, and the cost would be greater than a more convenient thumb-wheel switch which shows the number on its display as it is rotated. R.S. Components sell a minature, binary-coded-decimal switch, 338-339 at £2.10. Two of these are needed to allow numbers up to 99 to be dialled. The switch has nine contacts labelled C for common, and 1, 2, 4, 8, $\bar{1}$, $\bar{2}$, $\bar{4}$, $\bar{8}$. When a number is set on the switch, C is in contact with those binary bits needed to make the number and with its complement in invert bits. For example, with the thumbwheel set to 5, C will be connected to 1,4, $\bar{2}$ and $\bar{8}$. When the switch reads 0, C is connected to all the invert bits.

The operation of 74184 is shown schematically in Fig. 1. To handle a two figure decimal number, two '184s are needed, interconnected as shown. It requires four binary bits to represent each number up to 9 (e.g. 9 = 1001) and two of these to indicate up to 99. In Fig. 1 the two inputs are so grouped into two sets of four; the least significant bit of the four, corresponding to 2^0, is on the right of each group. Both inputs and outputs are active high i.e. logical 1. As an example, if the number 71 were dialled, the input code requires to be 0111 0001, and this would result in the outputs at the bottom of the figure showing 10000111 =64+4+2+1. The zero order binary does not require to pass through the t.t.l. since this is high or low depending on whether the decimal number is odd or even, i.e. whether the least significant bit of the units b.c.d. is high or low. Unconnected inputs of a '184 behave as if they are high, so that switching is needed only to ground those inputs requiring to be at logical zero.

The practical details of the circuit are shown in Fig. 2. Light emitting diodes are used as indicators. The common terminal of both thumbwheel switches is ground, and connections taken from the outputs as labelled to the integrated circuits. The '184 outputs are open collector type, so that each output feeding a l.e.d. requires to be connected to the +ve supply voltage through a 1 kΩ resistor. Unused outputs may be left unconnected.

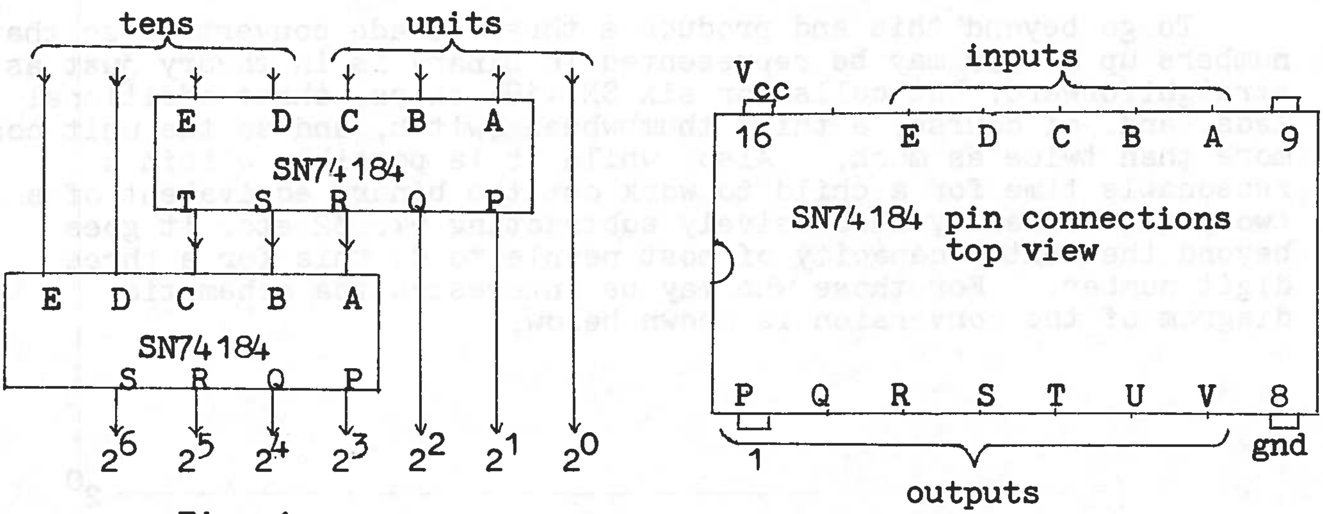


Fig. 1.

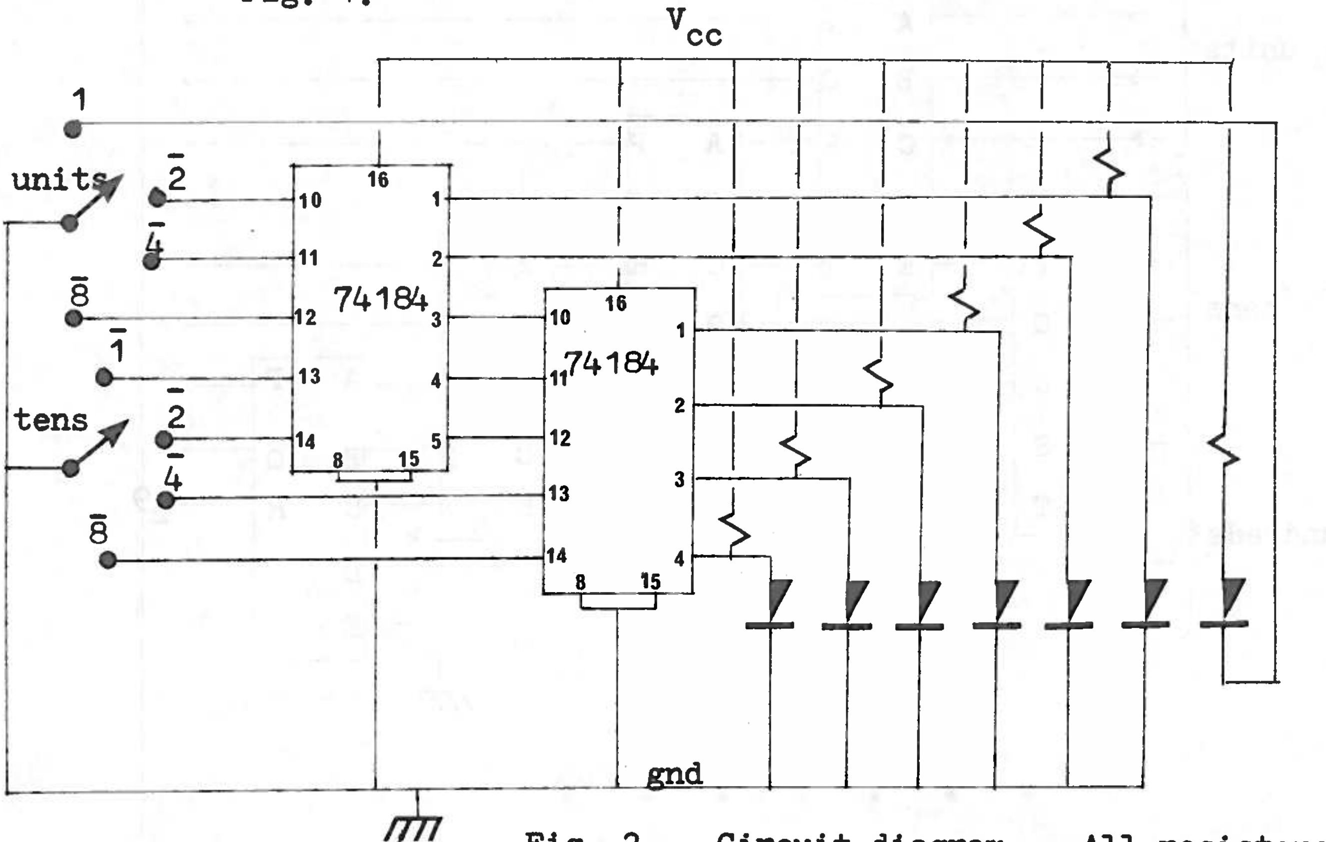
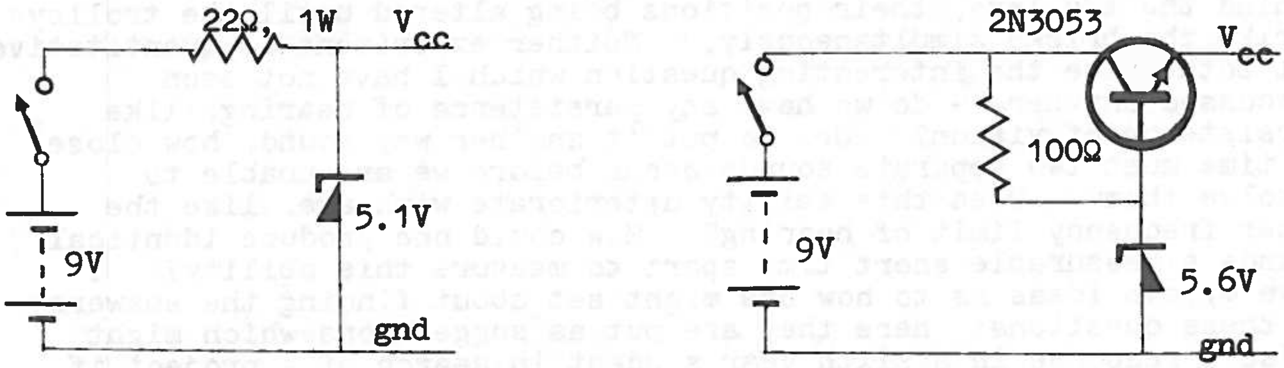


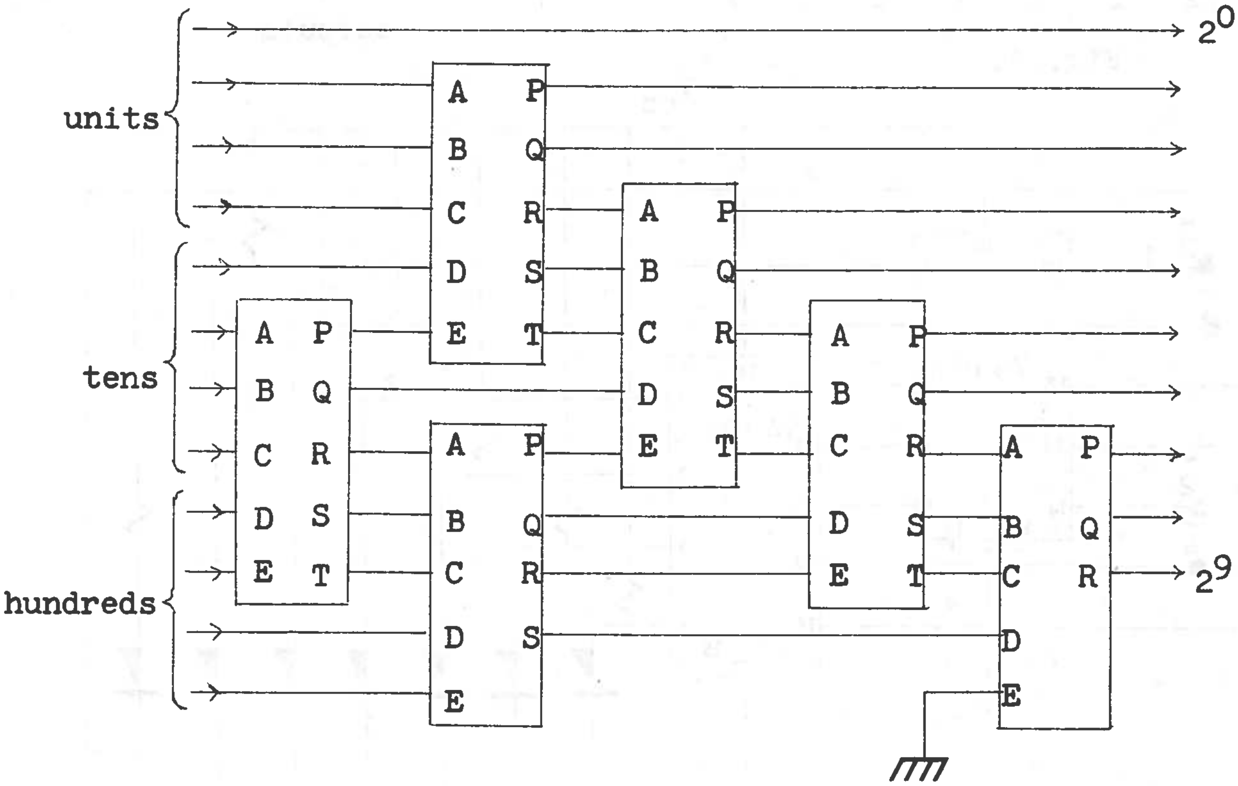
Fig. 2. Circuit diagram. All resistors are 1 kΩ.

The current consuption is 120 -160mA, depending on how many l.e.d.s are on, and one may either use a simple voltage dropper, or a transistor regulator (Figs 3a and b) from a 9 V PP7 battery.



(a) Fig. 3. (b)

To go beyond this and produce a three-decade converter, so that numbers up to 999 may be represented in binary is in theory just as straightforward, but calls for six SN74184 chips, three additional leds, and, of course, a third thumbwheel switch, and so the unit costs more than twice as much. Also, while it is possible within a reasonable time for a child to work out the binary equivalent of a two digit number by successively subtracting 64, 32 etc, it goes beyond the mental capacity of most people to do this for a three digit number. For those who may be interested the schematic diagram of the conversion is shown below.



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Two demonstrations in our physics syllabus require that students recognise simultaneity of two sounds. One uses an apparatus to project two steel balls in order to show that gravitational motion is unaffected by horizontal velocity, where the student is expected to hear both balls strike the floor together. The other is the exploding trolleys momentum experiment where bricks are placed behind the trolleys, their positions being altered until the trolleys strike the bricks simultaneously. Neither experiment is quantitative, but both raise the interesting question which I have not seen discussed anywhere - do we have any persistence of hearing, like persistence of vision? Or, to put it another way round, how close in time must two separate sounds occur before we are unable to resolve them? Does this ability deteriorate with age, like the upper frequency limit of hearing? How could one produce identical sounds a measurable short time apart to measure this ability? I have my own ideas as to how one might set about finding the answers to these questions: here they are put as suggestions which might raise a response in a sixth year student in search of a project if, say he were a hi-fi enthusiast.

Trade News

The following CLEAPSE reports have been received. Any of these may be borrowed for up to one month by writing to the Director.

L59a Low voltage power supplies,

L104 Digital multimeters,

L115c Greenhouses - automatic ventilation for small houses,

L142 Environmental equipment for schools,

L143 Hardy and half-hardy plants for use in science.

Available free from Esso Chemicals is a poster showing several of the fire dangers and health hazards likely to be encountered in the handling of solvents.

Griffin and George inform us that the size of the measuring cylinder with plastic feet, catalogue number CYP-350, has recently been changed. If customers have a set of old plastic feet they will not fit any new cylinders ordered. The old type of foot will be replaced free of charge if the feet only are returned to the nearest Griffin and George branch asking for replacements.

Glassware of Czechoslovakian manufacture has been on sale now for some months by Hestair Hope at very competitive prices. We have had reports from several sources of unsatisfactory crucibles and beakers, and of unglazed evaporating basins which explode on heating. Despite several requests to the firm both by letter and personally at A.S.E. meetings we have been unable to obtain samples from them for testing. It could be that the problem is one of quality control and that most of the batches are satisfactory. We would urge that all such glassware be used with caution.

A large demonstration meter is now available from White Electrical Instruments. Called the Polymetron, it has eight d.c. ranges from 5mA to 10A; nine direct voltage ranges 100mV to 1kV; eight a.c. ranges 5mA to 10A; six alternating voltage ranges 3V to 1KV, and three resistance ranges. It can be used flat for bench work, or propped on its handle or stood vertically for demonstration. It can be viewed using the overhead projector, or a special light box, cost £47.25 may be attached to the back of the instrument for viewing the scale directly e.g. in a large lecture theatre. The Polymetron costs £146.50.

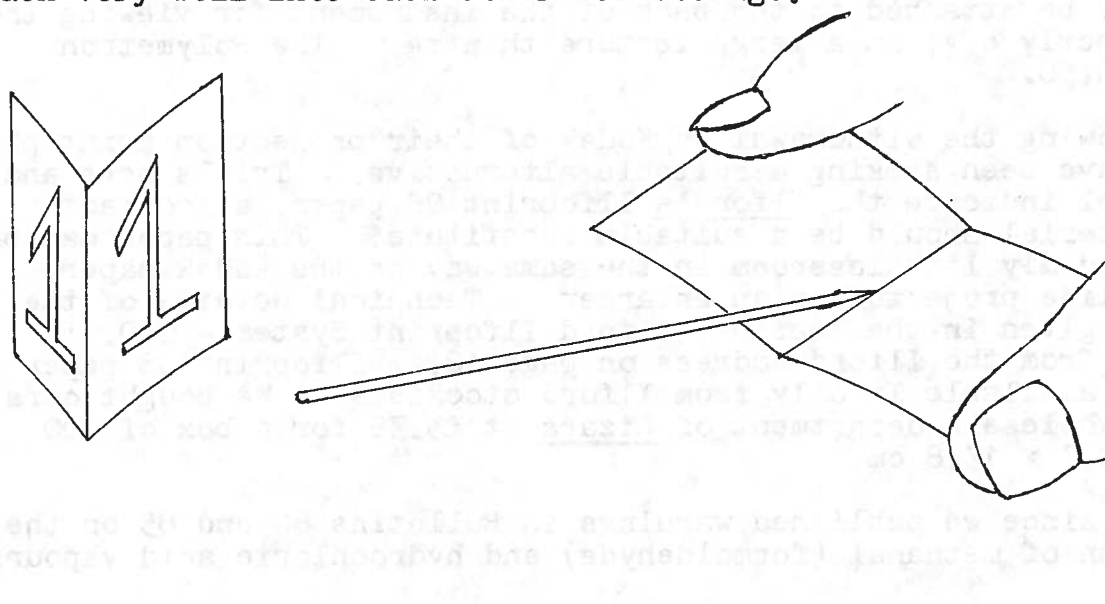
Following the withdrawal by Kodak of their projection print paper P153 we have been seeking a suitable alternative. Trials here and in a school indicate the Ilford's Ilfoprint CS paper, a 'contact speed' material should be a suitable substitute. This paper can be used in a dimly lit classroom in the same way as the Kodak paper, using a slide projector as an enlarger. Technical details of the paper are given in the leaflet 'Ilford Ilfoprint System - C80.9' available from the Ilford address on page 12. Ilfoprint CS paper should be available locally from Ilford stockists. We bought ours from the wholesale department of Lizars at £3.38 for a box of 100 sheets, 12.7 x 17.8 cm.

Ever since we published warnings in Bulletins 80 and 85 on the combination of methanal (formaldehyde) and hydrochloric acid vapours to form the carcinogen bis-CME, we have sought alternatives to methanal as a fixative/preservative. For a number of reasons we were never completely satisfied with those we were able to find Gerrard have now introduced a new material - Biofix - which, it is claimed, may with advantage be used as a substitute for methanal for most biological purposes. Biofix, Cat. No. ZZC-118-010S, is supplied in powder form at £3 per kg. For fixing and preserving specimens it is used at 10% by weight of powder in tap water, and for storing preserved specimens at half this concentration. We hope to evaluate this material and report on it and other alternatives to methanal in a future bulletin.

In The Workshop

Technicians who have to set up a laboratory for stations experiments, or for options under the mixed ability course may find a need to label the different experiments so that they relate to the information the pupil has on his worksheet, e.g. by sequential numbering. As the teachers will know, when we give an exhibition we provide each visitor with a copy of a catalogue in which the exhibits are described and numbered, so that we had the same requirement. In the early days of SSSERC we solved the problem by marker labels cut from empty plastic bottles.

The best type of bottle is one which has vertical sides over some part of its height, and is not too narrow, e.g. Parozone. Using a hacksaw or scissors cut a strip 4 cm wide from the bottle, cut and open out to a rectangle. Cut into smaller rectangles about 8 x 4 cm; a Parozone strip will conviently divide to make three labels. On the unprinted side, i.e. the inside surface of the bottle, print the necessary information on each half with felt pen. Fold backwards in half so that the information is on the outside. For some plastics, heavy pressure on the bend may be enough to make it permanent, so that the labels stand up. For others which tend to recover their shape, the bend can be made permanent by pressing the label backwards between finger and thumb, and while holding it in that position running a hot steel knitting needle slowly along the inside of the bend. The plastic will melt and this can be felt as a relaxation of the pressure on the fingers. As well as being free standing, labels made like this stack very well into each other for storage.



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In the article in Bulletin 102 on oxygen meters, it was mentioned that the rate of stirring of the solution affected the rate of oxygen transfer, which could therefore affect the meter reading. Hence if one is to stir at all, it must be carried out under controlled conditions, i.e. the electrode and stirrer must be at a fixed distance apart during the series of observations. Obviously what is required is a common support for both the electrode and the stirrer so that the two will not get displaced relative to each other when readings are taken, but which will be sufficiently adjustable to allow this spacing to be varied if necessary to suit different conditions.

The system we designed uses a cocktail stirrer which has a cylindrical handle measuring approx. 100 x 35 mm dia. containing a HP11 dry cell. This or similar types can be bought in Woolworths and other stores. The holder is made from 13 mm thick plywood to the shape given in Fig. 1. One large Terry clip, size 480.125, holds the stirrer on one side of the holder, and the oxygen electrode is held by two size 480.037 clips on the other side. The relative positions of stirrer and electrode can be adjusted by moving either or both within the clips and at the same time the clips hold them firmly enough so that they cannot be accidentally displaced. To bring the stirrer nearer the electrode the large clip is mounted in a groove chiselled in the wood so that the clip rests at an angle to the wood. An end-on view of the holder is shown in Fig. 2. The pistol grip handle is convenient for holding the system in the solution, or it can be clamped by means of a retort stand for longer periods of work.

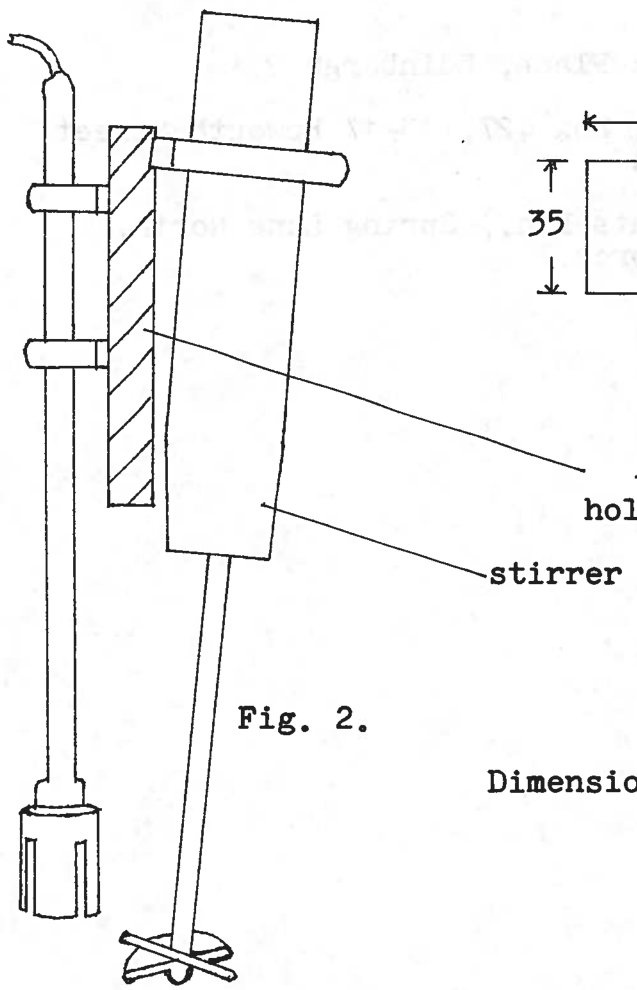

Fig. 2.

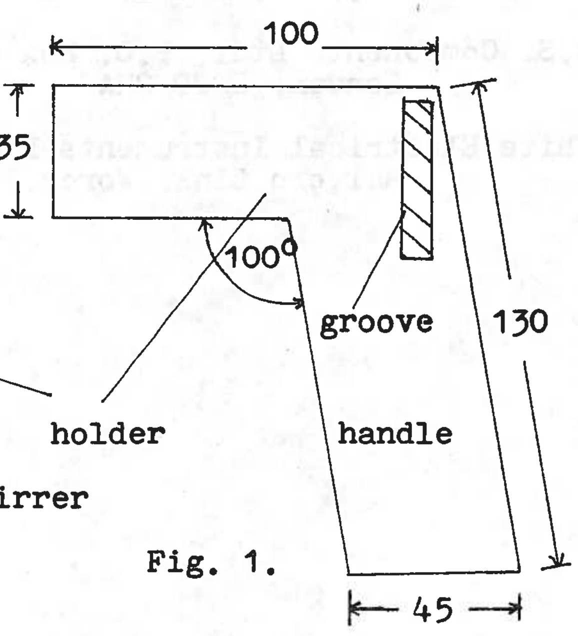

Fig. 1.

Dimensions in mm.

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

Bi-Pak Semiconductors Ltd., P.O. Box 6, Ware, Herts.

Cleapse Development Group, Brunel University, Kingston Lane, Uxbridge, Middx.

Esso Chemicals Ltd., Arundel Towers, Portland Terrace, Southampton.

T. Gerrard and Co. Ltd., Gerrard House, Worthing Road, East Preston, West Sussex, BN16 1AS.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride, Glasgow, G74 3XJ

(Hestair Hope) Thomas Hope Ltd, St. Philip's Drive, Royton, Oldham OL2 6AG.

Ilford Technical Services Dept., Ilford Ltd., Basildon, Essex, SS14 3ET

J Lizars Ltd., 6 Shandwick Place, Edinburgh 2.

R.S. Components Ltd., P.O. Box 427, 13-17 Epworth Street London, EC2P 2HA

White Electrical Instruments Ltd., Spring Lane North, Malvern Link, Worcs.