SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 46. April, 1971.

Contents

Introduction

A major part of this Bulletin is given over to an account of revised specifications and test procedures for microscopes. There are two main reasons why such a revision was considered necessary. Our original specifications and test procedures were drawn up over four years ago, before the introduction of the new biology syllabus. This syllabus has now had time to make its requirements known, which in turn has resulted in a need to modify our specifications in certain directions. Also, the work of Keith Thomas on the testing of microscopes, which is referred to in the Bulletin, had not been published. Our Assistant Director of Biology spent some time in the University of Ulster with Mr. Thomas, learning at first hand the techniques he uses, and has benefited greatly from his visit.

Microscopes are probably the most expensive single item the biologist needs in his school, and they are certainly the one in which there is the greatest variety of choice. The teacher who sees a number of models at different times throughout the year, depending on when the various representatives call, may find such a choice bewildering. Our reports are available to help all such teachers. If the teacher can arrange a visit, most of the models we report on are available for inspection in the Centre, and nothing can be more helpful and instructive than a direct comparison of the various instruments sitting side by side on the same bench, with the same slides.

Chemistry Notes

We give below a letter we have received from a chemistry teacher concerning the hazards associated with heating a mixture of zinc and sulphur.

"In Bulletin 43 you mention this well-known hazard, and an alternative deemed safer. There is in fact a fallacy in the safety. In this experiment the following points have to be noted: always see that the sulphur is lump-free, quite dry, and will not give an acid reaction to litmus left sitting on it. This ensures that the sulphur cannot start a spontaneous action during mixing. Always use industrial, not Analar zinc powder. This is covered with zinc oxide which also prevents spontaneous action in mixing. Spontaneous action is a real hazard in these experiments, all of which, with these precautions, I have done for years. They are the finest examples of the maxim that you should tackle technically difficult experiments which require genuine precautions; these precautions have to be got over and are far more important than the actual/

actual 'official' experiment objective. The sulphur experiments are striking and crammed with good teaching in chemistry and method.

Now proceed: mix about equal volumes of sulphur and zinc - which gives a Zn excess - using about a teaspoonful of each. In a tube this would be suicide. Mix by pouring gently from two papers into a third (all quite dry) and then mix further by manipulating only the paper with the mixture. Avoid pressure or undue haste. Perfect mixing is not at all necessary as the sulphur will vaporise during heating; about 10 seconds mixing and it is complete. Place a new, clean, dry, unpainted tin lid on a tripod; pour the mixture in the middle in a conical pile and have the whole tripod on a large, smooth asbestos surface. Place the bunsen near but not under the lid yet and have a long pointer ready. Emit dreadful warnings about possible repetitions; don goggles and face visor. Make the class retreat to the opposite end of the classroom. Teacher (who has practised without the mixture) uses the pointer to push the bunsen directly under the pile on the tin lid and retreats also AT ONCE. If the bunsen is not correctly placed at once, it does not matter, as conductivity will do it, but don't delay the exit. Lights out is a good idea if the room is still under daylight, but do not do the experiment in complete darkness. There is some fuming, often a tentative local action, and then - woof - a silent flash of magnificent green and a plume of zinc sulphide (and zinc oxide, conveniently forgotten at the moment). Do not approach until three minutes have elapsed and then teacher approaches first; secondary reactions at the edge of the pile are possible and so is recalescence. The pupils will never forget this.

A similar action can be done down the activity series - I do magnesium, aluminium, zinc, iron, copper and all on the same scale, but recommend them for chemists only. With magnesium and aluminium the iron on the tin lid may vaporise or melt and the lid be perforated, allowing debris into the bunsen and perhaps onto the floor. Be ready to put sand on any particles; there are few and there is no real danger here. During the whole experiment be sure that all bottles of powdered metal are closed and far away from any flying particles. A whole bottle of burning magnesium powder in a glass bottle (silicate) is really something which puts the above action to shame for danger, yet I have students who invariably leave bottles open.

In the "safe" way described in your bulletin the snags are: the flash is a real danger even with tiny amounts - particles are scattered and there is a blinding light with temporary inconvenience to vision. There is an implication that you can stand by - you shouldn't. Asbestos is notoriously damp and may give hydrogen at the temperature with the metal, with even more explosive scatter. At high temperature with scatter, ultra-dry colloidally air-dispersed asbestos particles are likely, and these are a more insidious danger than the explosion. Just to show that chemistry is full of considerations, the asbestos would probably have adsorbed on it sulphur dioxide and trioxide.

If it were not against modern ideas I would suggest that there be written on all chemistry laboratory walls in 12" high letters - "Learn the chemistry before you try to demonstrate it."

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The summary which we give below of the comparative costs of obtaining a sample of the commoner gases is based on a survey carried out by a student in Moray House College of Education last year. At this lapse of time the costs have probably risen, but we believe that the comparison between different methods may still be valid. The methods used for laboratory preparation of the gases were:

Oxygen - from hydrogen peroxide, manganese dioxide and sodium hydroxide.

Nitrogen - from air by absorption of oxygen with pyrogallol.

Hydrogen - from zinc and sulphuric acid.

Carbon dioxide - from marble chips and hydrochloric acid.

The costing of gas obtained from cylinders etc. was calculated on the actual price of gas plus any cylinder depreciation costs, assuming that the cylinder were returned for refill within the minimum stipulated period. For instance, the B.D.H. lecture bottle carries an 80% refund on the cost of the cylinder if returned within six months, so that the gas cost is calculated as the actual price plus 20% of the cylinder cost. The table below gives the cost per litre of gas, in new pence.

Method	Capacity	Oxygen	Nitrogen	Hydrogen	CO_2
B.D.H. Lecture bottle	1.5 ft^3	4.17	5.00	5.20	10.2
Cambrian Chemicals	8-10 ft^3	2.81	2.50	2.71	4.37
British Oxygen	40 ft^3	0.02	0.02	0.04	-
Distillers Co.	58 ft^3	-	-	-	0.07
Lab preparation	-	0.94	1.15	0.31	0.25

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It has been brought to our notice that in Bulletin 41 we wrongly used the term toluol to denote the solvent which should more properly be named toluene, and for this we apologise.

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The presence of a halogen element in organic compounds can sometimes be demonstrated by a simple flame test. The end of a copper wire is held in the upper half of a small Bunsen flame. The material being tested is held in the flame below the copper and the existence of a halogen ion is shown by a green colouration at the copper. The test has been confirmed on P.V.C., iodo-ethane and bromo-benzene. It can also be used for certain inorganic compounds, e.g. zinc chloride, which do not give a noticeable colouration on their own.

* * * * * * *

An aspirator can be used in conjunction with a polythene bag to give a controlled supply of dry air., or of any other gas. Briefly, a polythene bag of approximately the same capacity as the aspirator is placed in the deflated condition into the aspirator, the neck of the bag is gathered up and secured against the neck of the aspirator by a single holed stopper carrying a delivery tube. The bag can be filled with the required gas through this tube and stored until use. Then by running tap water into the aspirator through the lower opening so that the water fills the space between aspirator and bag, a controlled flow of gas is obtained from the delivery tube. Thin grade polythene is better because there is a considerable amount of puckering involved in fitting the bag round the inside of the aspirator neck, and with thick polythene this might cause leaks against the stopper. The system is suitable for supplying many gases because of the resistance to chemical attack of polythene.

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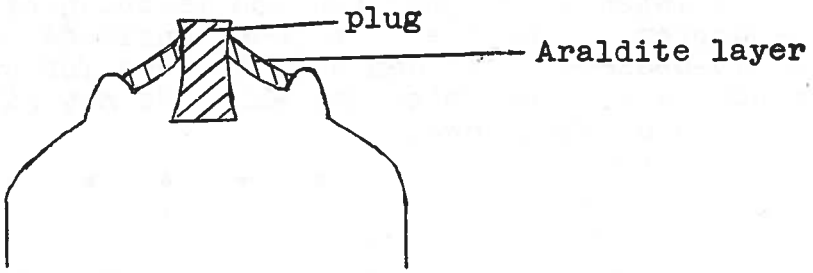
The method given below of determining the molecular weight of gases is an alternative to that described in Bulletin 21, and has been sent to us from Clydebank High School. An empty Ronsonol Multi-fill lighter fuel container is used. The nozzle is sawn off as near its base as possible and the hole widened out (the material is plastic) to 5-6mm dia. A 10mm length of rubber dowelling, 7-8mm dia. which is used for tubeless tyre puncture repairs and can be bought from garages, is used to plug the hole. Araldite to a depth of about 2mm is then added inside the ridged top of the container. A 50ml syringe is filled with the gas to be measured, fitted with a fine needle, and the whole 50ml is injected through the rubber plug into the container. By weighing the container before and after, the mass of 50ml of gas at atmospheric pressure is found. Because of the small quantity of gas used, a 1mg sensitivity balance is necessary. At the end of the experiment, the gas may be removed by pushing the syringe needle alone through the plug. Our results, corrected for temperature but not pressure, are given below:

Nitrogen	28.1	Methane	15.4
Nitrogen	26.8	Sulphur dioxide	62.6
Oxygen	30.3	Hydrogen	1.71
		Hydrogen	2.25

The poor results for hydrogen are due to the small mass of gas being measured. Although Ronson butane containers may be used unmodified (School Science Review No. 167, p.185) the seal after 10-12 injections is no longer gas tight, whereas this modification allows the container to be used many times.



Biology Notes

The specification and test procedure for H and post-H grade microscopes replace those given in Bulletins 7, 9 and 14.

Essential. Magnification from 50x to 400x; for post-H grade work one instrument must also go to at least 900x.

Optical Performance; the 40x objective must resolve the surface dots on the diatom Pleurosigma angulatum, dry mounted.

Phase Contrast; on one instrument per school.

Focussing; coarse and fine controls.

Desirable. Mirror rather than built-in illumination.

Objectives; spring loaded at 40x and above.

Eyepiece; high eyepoint, wide field, with pointer.

Graticules; focussable when on eyepiece field diaphragm.

Viewing Head; inclined and rotatable.

Safety Stops; on body (or stage) and condenser focussing mechanism.

Phase Contrast; on each instrument for post-H grade work.

One instrument to the above specification is needed per 2 pupils for H grade, and per pupil for post-H grade.

Before detailing the procedure we have used to assess whether or not microscopes come up to the above specification, we give a short discussion on what we consider are the desirable methods of achieving the specification.

The most suitable optical combination is a 10x eyepiece with 3x - 5x/0.10; 10x/0.25, and 40x/0.65 objectives. For post-H level an oil immersion objective of 90 - 100x magnification and 1.2 - 1.3 Numerical Aperture is also necessary. An additional low power eyepiece - say 6x or 7x - is often useful in providing a large field of view for low power work. Some teachers also find a 15x eyepiece helpful with the 40x/0.65 objective. It is worth pointing out, however, that resolution of detail is determined by the objective, provided that the condenser satisfactorily illuminates both it and the object; an eyepiece merely enlarges the resultant image. Most people find that the detail resolved by a 40x/0.65 objective can be seen comfortably at 400x magnification, so that a 15x eyepiece is unnecessary - indeed, definition can be lost by over-enlarging.

The Pleurosigma test slide can only be resolved by objectives of N.A. 0.65 or above, adequately illuminated. The condenser must therefore be capable of illuminating at least three-quarters of the aperture of such an objective; in practice this means that an Abbe type is needed, with an iris diaphragm to control glare and hence contrast. Other tests of optical performance - e.g. for astigmatism and aberrations - are listed in the test procedure. These are used qualitatively, to assess the overall optical performance for grading purposes.

The/

The optics needed for phase contrast are a 40x/0.65 phase objective, an Abbe condenser with suitable annulus, and preferably a phase telescope for accurate alignment of annulus with objective phase plate. A green filter will also improve the performance. There is much to be said for having phase and oil immersion optics on a good projection microscope, since in schools both techniques are used to demonstrate material to whole classes. A phase condenser can be used equally well for brightfield work, while 40x phase objectives show little loss in resolution over the corresponding brightfield ones. It is therefore cheaper to buy a phase instrument, as specified below, and to use it for brightfield work as well, rather than buying a brightfield instrument plus phase conversion kit. Such a phase instrument would then be made up optically as follows: 10x eyepiece; 3x - 5x/0.10 and 10x/0.25 brightfield objectives; 40x/0.65 phase objective; phase Abbe condenser with annulus for 40x objective; phase telescope, and green filter. A projection microscope would not need the low power objective, but would need a quartz/halogen lamp for adequate illumination; a 100W pearl bulb is adequate for most non-projection phase instruments. Preliminary searching of unstained material is best done under dark-ground illumination, using the 10x/0.25 brightfield objective with the 40x phase annulus.

In assessing optical performance, we attempt to find out both the amount and the accuracy of the information about an object which the instrument conveys to the eye. To this end, 'standard' test slides are used, together with several of the slides required for the new syllabus to ensure that the results obtained with the former are relevant to school courses, where the amount and accuracy of information required may be less than in, for example, a research laboratory.

Four factors chiefly affect the information about an object. Resolution describes the ability of an optical system to distinguish separate structures as discrete objects. Resolution depends primarily upon the resolving power of the objective, though this will not be fully realised unless the front lens of the objective is fully, and evenly, illuminated by means of the condenser. Resolving power directly depends upon the Numerical Aperture (N.A.) of an objective. This term essentially describes the light gathering of power of a lens, and is related to its focal length and diameter - the shorter the focal length and the greater the diameter, the higher the N.A.

Without adequate resolution, magnification is of little use, but once detail in an object has been resolved by the objective, the image produced must be sufficiently enlarged by the eyepiece to enable the eye to see comfortably what has been resolved. If the image is over-magnified, however, clarity is lost and therefore less information is obtained. The limits of magnification depend upon the N.A. of the objective; with the achromatic types used in school microscopes it is probably best to limit total magnification to about 700 times the N.A., though with research objectives this may go up to 1000 times.

Contrast is most simply defined as the relative difference in intensity between an object and its background. Thus an objective may resolve detail to a high degree, and yet the eye may not/

not be able to see this unless there is sufficient contrast to make the detail stand out. Contrast depends to a great extent on the elimination of glare, which is mainly caused by light entering the objective from parts of the slide which are not being viewed. Glare is therefore most efficiently reduced, when using high power objectives, by cutting down the size of the light source, and most bench lamps have a cover with a small hole or, better, an iris diaphragm in front of the bulb - the so-called field stop. For best performance the light in the plane of this stop must be focussed by the condenser onto the object; the stop is therefore closed right down, if an iris, and the condenser adjusted until the image of the stop is in focus with the object image, after which the stop is opened until it just clears the field of view. In the case of a simple cover with hole, a pencil held just in front of the hole is focussed. These arrangements reduce the diameter of the beam of light entering the condenser, which must therefore be capable of focussing such a beam onto a restricted part of the specimen and yet still filling the objective aperture with it. Non-Abbe, single lens, condensers cannot do this for objectives of N.A. 0.65 or more.

The substage iris diaphragm, or aperture stop is also used to control glare, but it must be used with greater care for, as its name implies, it also controls the fraction of the objective aperture which is illuminated, and thence resolution; it is normally adjusted to fill 2/3 to $\frac{3}{4}$ of the objective aperture. In theory, of course, the whole of the aperture should be illuminated, giving maximum resolution, but this reduces contrast too much, unless the object is very contrasty; indeed, for objects of very low contrast the aperture stop may have to be closed further, with a consequent further loss in resolution. To obtain the correct opening of this stop for a particular objective, it is adjusted while inspecting the objective back lens, having removed the eyepiece. Finally, glare also frequently arises because the internal surfaces of the instrument have not been sufficiently blackened.

Aberrations all produce distortion of the image in some way. Spherical aberration occurs where light coming from different parts of an objective back lens is not all brought to the same focus; most objectives show this, but to varying extents. Chromatic aberration occurs when light of different wavelengths is brought to different foci. Achromatic lenses should be corrected for red and blue wavelengths, and black objects in the centre of the field should not show any colour, though they will when at the edges of the field. Astigmatism, if present in the centre of the field, is due to misalignment of the objective lenses; a certain amount must be expected near the edges of the field. The fault shows as the distortion of the image of a circular object into two ellipses, at right angles to each other, when above and below focus; when in focus the image is blurred. Coma, at the centre of the field, is also caused by misalignment; it causes circular objects to have a tail to one side, rather like that of a comet.

The test procedure which follows is a revision of that given in Bulletin 14. In addition to some alterations to the tests themselves, the format has been altered. The new format corresponds to that which will be adopted in future test reports.

General Construction The shape, dimensions and material of base and limb are described, together with any accessories - e.g. illumination - built into the stand. The body may be of metal or plastic, fixed upright, fixed inclined, or tiltable. Unless otherwise stated it is assumed it is monocular. It may be rotatable, with or without a lock, and is presumed not to have a draw tube unless specified. The shape, dimensions and material of the stage are stated. The total weight is stated, together with the normal working height. The mechanical stability of the instrument is subjectively assessed. The position of the mirror socket is given.

Optical Parts Eyepieces are assumed to have an outside diameter of 23.2mm. The internal diameter is stated, to allow comparisons to be made for the fitting of graticules. A graticule is inserted to determine whether it can be focussed when on the field diaphragm. Eyepieces may be fixed, fixable or free, and may possess a pointer. They may be Huygenian or Widefield; the latter usually have a big eye relief distance which is an advantage for spectacle wearers. Magnification is specified.

Objectives are assumed to be achromatic with standard R.M.S. thread. Magnification and numerical aperture (N.A.) are stated where possible, e.g. - 40x/0.65. 20x, 40x and oil immersion objectives may be retractable. The alignment of the objectives on the nosepiece is assessed as follows. Using a pointer or cross wire eyepiece, an object at the centre of the field of view is aligned under the 40x objective. The other two objectives are then viewed through in turn, when the image should remain substantially in focus and should not be more than 100μm off centre.

The condenser can be fixed or adjustable, by rack-and-pinion, spiral mount, or sliding in a sleeve. It may be Abbe or simple (single lens). The N.A. given is that stated by the manufacturer, though this can be misleading as even when the quoted N.A. is greater than 1.0, the achromatic part of the beam produced corresponds to an N.A. of not more than 0.4. "Swing out" means that the condenser mount and iris can be swung clear of the optical path when required. The diameter of the condenser mount is given to enable comparisons to be made for the fitting of phase condensers. If a phase condenser is available, this too is described.

The iris diaphragm can be either "true" or "Rotating disc" with various apertures. As the iris is often incorporated in the condenser mount the measurement of Control Ratio - diameter of widest/diameter of smallest aperture - is sometimes difficult. Where it can be measured, even approximately, it is given.

The mirror is assumed to be double-backed. Reflectors are specified as 'white' (paint or paper reflector), 'plane' or 'concave' and may be of metal or glass. The latter may be 'rear' or 'front surface reflecting'. A front surface reflector is liable to tarnishing. Mirror diameter is also specified.

Focussing Mechanism The standard coarse focussing mechanism is rack-and-pinion, moving body or stage. The standard fine mechanism is/

is by means of screw and lever, again moving either body or stage. Other types will usually be described in more detail. In some cases a diagram may be included. The precision of the fine focus mechanism is tested as follows. A blood smear slide is focussed under the 40x objective and the fine focus knob is gently turned. A delay before the focus is altered indicates that backlash is present.

Stops are described if present. A stop at the lower end of the mechanism prevents contact of the higher power objectives with specimens; it may be fixed or adjustable. Occasionally a stop may be present at the upper end of the mechanism. Relative sensitivity is defined as the ratio of the arc distances of the fine and coarse adjustments necessary to effect the same movement of body and stage.

Where it is possible to purchase the instrument for phase contrast work, its performance under both brightfield and phase conditions is assessed. In brightfield tests, the lighting system used is a 60W pearl bulb in a lamp with iris diaphragm, unless the instrument has a built-in light source. The slides selected from the syllabuses are of striated muscle; blood smear; locust testis squash; root tip mitosis; herbaceous dicot stem, and yeast.

To test resolution the diatom Pleurosigma angulatum, air mounted, is viewed with the 40x objective, at 400x magnification. Any objective of N.A. 0.65 or more should resolve the surface dots, but the degree of blackness of these dots gives a further, qualitative measure of resolving power.

Two test objects are used for aberration and contrast; a Wild Abbe test plate, and an electron microscope grid mounted in Canada Balsam or similar mountant. The former consists of a silver film deposited on the underside of a wedge shaped coverslip, varying from 0.08 to 0.23mm in thickness, and all tests are carried out at 0.17mm, which is the thickness of the average No. 1½ coverslip. Three sets of parallel lines are ruled in this film, for the three powers of objective, and these are viewed in both direct and oblique light. The lines are focussed in direct light and then viewed in oblique; chromatic aberration shows as red and blue fringes to the lines, while spherical aberration causes them to be out of focus in the oblique light. The same test plate also has small pin holes in the film, and if one of these is viewed in direct light, spherical aberration causes the hole to appear as a ring when above focus, and as a 'cloud' when below. The hole is also used to detect astigmatism and coma.

With the electron microscope grid, spherical aberration can be estimated qualitatively from the clarity of the image of the cross bars, which is also affected by glare. Chromatic aberration causes the entire field to become coloured - green above and violet below focus. It must be stressed that all these tests are qualitative and therefore depend upon the tester having used a range of instruments, and on correlating the results with the images produced from the 'syllabus' slides.

For phase contrast testing, the lighting used is a 100W pearl/

pearl bulb, unless there is a built-in lamp. Unstained cheek epithelial cells are viewed under 400x, using a green filter. The contrast achieved is considered satisfactory if the cytoplasmic granules can be clearly resolved. Full instructions for setting up a microscope for phase work may be found in the Fifth Apparatus Report of the Association for Science Education, Education in Science, No. 30, November, 1968, or in Appendix III of 'Lecture Notes on the Use of the Microscope', by R. Barer, (Blackwells).

For one eyepiece - usually 10x - the diameter of the field of view is measured using a standard millimetre gauge. The product of this value and the magnification used is a constant, referred to as the FV factor. This ranges from about 130 to 190 with the Higher grade microscopes.

Operation The ease of handling of the focussing controls, condenser and objective changer are described. If built-in illumination is supplied, the controls for this are also described. (The tests for body rigidity and stage flexibility are described by A.K. Thomas in the Third Apparatus Report of the Association for Science Education, Education in Science No. 28, June, 1968. What follows is largely taken from this report). Most microscope coarse focussing mechanisms are of rack-and-pinion type, the body or stage moving in a dovetail slide. Badly fitted dovetails are tested for as follows. A stage micrometer scale is viewed under the 40x objective and aligned with a pointer or cross wire. A 1 kgf pull is made to the left and then to the right, on the body or stage. Well fitted stands show a steady deviation of the pointer along the scale, the maximum deflection being no more than 200μm. Badly fitted stands produce a jerky movement.

If the stage is too flexible, hand pressure while moving the slide may cause complete loss of image under the 40x objective. To test for this, the fine adjustment is first calibrated as follows. The thickness of a thin coverslip is accurately measured with a micrometer. It is placed dry on a clean slide and Lycopodium powder lightly dusted onto both.

The 40x objective is focussed on the upper surface of the coverslip, and a horizontal radial line is drawn on the end of the fine focus control knob. Using the fine adjustment only, the instrument is focussed on the upper surface of the slide. A second horizontal radial line is then marked on the control knob; the angle between these marks corresponds to the thickness of the coverslip. While still focussed on the slide, a 1 kg weight is hung from the edge of one side of the stage, using a hook covered in rubber tubing to prevent the stage from being scratched. The focus is then restored, using the fine adjustment, and a third horizontal radial line marked on the control knob. From the angle enclosed by the second and third marks, the deflection of the stage under a 1 kgf can be calculated by simple proportion.

Rigid stages should bend about 10μm, but some have been found with deflections exceeding 50μm.

The ease with which the assembly for phase contrast is set up is described.

General Comments If different arrangements are available on the same basic stand - including phase contrast - the more suitable of these are discussed. The cost of each arrangement is given and they are separately assessed. Assessments are in three grades: A - most suitable for school use; B - satisfactory; C - unsatisfactory. Price is a major factor in determining whether an instrument is given a C grade because of unsatisfactory optical performance, but in each case the full reasons are given. Any accessories supplied with the instrument - including a wooden case - are described and servicing arrangements are also indicated.

Trade News

Elesco-Fraser have asked us to point out that, contrary to what was stated in Bulletin 45, they are suppliers, not agents, for Polaroid, White Electrical Instruments and Weir Electrical Instruments products. The distinction to quote a member of the firm, is "subtle but important", although 15 minutes discussion failed to clarify it.

Handy-tube, which is the Handy Angle equivalent of speedframe can be bought cut to the lengths required for the mobile fume cupboard described in Bulletins 43 and 45, together with the necessary glazing section and shelf supports. The quotation number is T1632, price £13.63.

A. Christison have in stock the full range of Torbal top pan balances. Prices for digital read-out on these balances are £10 more than the vernier equivalent. The same firm have a range of wide-necked Dewar flasks having a tough rubber outer shield so that they do not break if accidentally dropped. Prices for the various sizes, with cost of a refill in brackets are: 1 litre - £3.75 (£1.25); 1½ litre - £5.25 (£2.25); 2 litre - £5.25 (£2.00); 4½ litre - £7.50 (£4.00).

As priced from their parts list, the cost of the Joseph Lucas car electrics kit is now £81.75; this does not include purchase tax or battery. It is therefore more than ever prudent to seek such components as can be found in car scrap yards.

A catalogue from Gemrocks lists over 40 different types of rough stone for gemmology, with prices varying between £0.40 and £3.25 per lb. Also in the catalogue are details of various cutting and polishing machines.

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

B.D.H. Chemicals Ltd., Poole, Dorset. BH12 4NN.

British Oxygen Co. Ltd., Hammersmith House, London, W.6.

Cambrian Chemicals, Beddington Farm Road, Croydon. CRO 4XB.

A. Christison (Scientific Equipment) Ltd., Albany Road,
Gateshead East Industrial Estate, Gateshead,
Co. Durham.

Distillers Co. Ltd., Great Burgh, Epsom, Surrey.

Elesco-Fraser Ltd., 36 St. Vincent Crescent, Glasgow, C.3.

Gemrocks Ltd., Halton House, 20-23 Holburn, London, E.C.1.

Handy Angle Ltd., Reparco Works, Hamilton.

Joseph Lucas Ltd., Great Hampton Street, Birmingham, 18.

Polaroid Ltd., Roseanne House, Welwyn Garden City, Herts.

(Torbal) Torsion Balance Co. Ltd., Vale Road, Windsor,
Berks.

Weir Electrical Instrument Co. Ltd., Bradford-on-Avon,
Wilts.

White Electrical Instrument Co. Ltd., Spring Lane, Malvern,
Worcs.