

Letters to the Editor.

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Spectrum Lines of Neutral Helium.

DR. SILBERSTEIN'S letter in NATURE of August 19, p. 247, induces me to write to say that some time ago I found the key for unravelling the constitution of the secondary spectrum of hydrogen to be of a kind similar to, though more generalised than, that used by him for helium. Practically the whole of this spectrum depends on the sequence of the Balmer series. If $f(m)$ denote the m th sequent, the wave number of any line is of the form $\sum k_m f(m)$, where the k_m are positive or negative integers; e.g. the line $n = 16892.72$ is $f(2) - f(3) + f(4) - f(5) - f(6) + f(7) = H_\alpha + (H_\gamma - H) - (H_\delta - H_\epsilon)$ within an observation error $d\lambda = 0.01$. In fact the spectrum is a kind of linkage spectrum in which the usual links are replaced by the separations between the successive lines of the primary, namely, 5331.57, 2467.75, etc. The same machinery of analysis used for linkage spectra is then directly applicable, but as the total number of observed lines is about 1600 it may be understood that a considerable time is required for the completion, arrangement, and discussion of the various physical effects in different groups of lines. The preliminary work of forming the linkage maps is practically completed. The results so clearly suggested that Curtis's helium spectrum was built in the same way that I was on the point of writing to him to suggest his testing them, and now Dr. Silberstein's very interesting letter comes to show independently that this is the case.

It has always seemed to me that the existence of these linkage spectra forms a difficulty in the orbital theory of spectral lines. This difficulty Dr. Silberstein's theory does not meet. According to his theory, and apparently in any orbit theory, the two electrons are moving independently, and each passes between two of its corresponding paths. But if the combined change of energy is radiated, these two events must be absolutely simultaneous, and would happen, say, once in an æon.

W. M. HICKS.

August 19.

Micro Methods in the Practical Teaching of Chemistry.

A CHANGE in teaching methods which brings with it simplicity and economy should appeal to all. May I therefore direct attention to methods I have myself begun in Cairo of teaching chemistry from the beginning by "microchemical" methods—that is, by working with very small quantities? (We really need a better word than "microchemical," which seems to suggest the microscope.)

It is strange that even in science we are so conventional. Pieces of apparatus once introduced by some one of repute remain in the shape and form, size and weight in which they were first employed as if they were consecrated objects. The Bunsen burner, for example, although it may be far bigger than required and very expensive in its consumption of gas, is scarcely ever changed. Even where a far less consumption of gas would suffice it seems to be the tradition to burn a large quantity. It is the same with the size of the test tube, beaker, or flask in

common use, and the same also with the quantity of material used by the student in carrying out his chemical tests: he will as a rule take a quarter, if not a half, test tubeful of some solution and add as much of the testing reagents as he can get into the test tube. There seems to be no necessity for these large quantities, and most of the tests carried out by students in chemical laboratories could be done with far less material. I propose to describe some of the methods which have been used in the Government Medical School Chemical Department, Cairo, during the past year, feeling that many laboratories would gain much in time, materials, and money by following methods which have proved very successful there.

These methods arose out of necessity. Too many students and too little space is probably a state of things not special to Cairo; the extreme was reached when it became necessary to teach two hundred students without any proper laboratory at all. Rather than refuse admission to the students a solution of the difficulty was sought in microchemical methods, and the result was successful beyond anticipation. Many who visited the laboratory at the time were surprised to see a hundred students seated in perfect silence busily engaged in applying microchemical methods in a hall in which there was neither water nor gas nor any of the appurtenances of a chemical laboratory. The necessity for such an improvisation could scarcely arise under more settled conditions, nor for that reason is it likely that any one would have the opportunity of carrying out such a teaching experiment on so large a scale.

The root idea of the method is economy in its broadest sense: in time, labour, and materials. Clearly if the student uses nothing larger than a drop instead of the habitual inch or half-inch in a test tube the expense in chemicals can be readily reduced one hundredfold. The expense in students' chemicals represented during the year only a few pounds of materials, the consumption of most of which is to be attributed to second-year students doing special work. About 500l. has been saved out of chemicals alone, which saving can be applied to the purchase of permanent apparatus.

The economy in apparatus has been even greater than in chemicals. The bottles throughout the laboratory have been reduced to one-tenth of the conventional size. Each student is given at first a small rack, and later another, containing six reagent bottles of one ounce capacity. These bottles are unstoppered but fitted with small dropping-pipettes. The bottles are cheap and the pipettes are made in the laboratory. The racks are easily collected and stored, and it is possible in this way to keep a class constantly supplied with freshly prepared solutions by issuing only those reagents which it is intended to employ at the time, thus avoiding the making up at the beginning of term of large quantities of solutions which may not be required till many months later. No test tubes are used till the student comes to actual separation of the groups, so that for the first half of the course all the expense and annoyance of breakage, difficulties of cleaning, and mess due to test tube work on the benches is avoided.

Indiscriminate test-tubing by students untrained in delicate manipulation and without any quantitative sense is, as it seems to me, a bad influence in their training which it is important to combat. In so many schools has it been the custom to use materials in wastefully large quantities that the name "stinks" only too aptly describes what goes on. But if the student be taught from the outset to regard the drop as a suitable, if not already a large quantity, he will get nearer to the quantitative notion and may acquire some of that delicacy of manipulation so essential to

his proper training; and when he comes to use larger quantities of materials and more expensive apparatus he is more likely to do so with economy and care.

In the early part of the work many simple substitutes for the test tube may be used, and there is an advantage in variety, the chief of many considerations being the ease with which such things are washed: a glass slide, as used for the microscope, or any small piece of glass is suitable—for it may be rapidly cleaned after each drop-experiment—and the drop may be studied with the pocket lens, enabling the student to distinguish between crystalline and amorphous precipitates and to note whether the colour is in the precipitate or the solution; indeed the training of the student in the use of the pocket lens from the very outset is highly desirable. Other materials are porcelain tiles or broken china, readily replaced by the student himself. A third class of material, very convenient and possessing certain advantages in chemical tests, is filter-paper or some form of absorbent paper, or in its absence white paper of any kind. When a reaction takes place in a drop on filter-paper, the separation of the precipitate from the solution becomes even more obvious than when the same reaction takes place on a tile or piece of glass. He may learn something also about surface tension, adsorption, and the difference between crystalloid and colloid, and many elementary physical facts which he would never learn by the test tube method.

There are very few reactions commonly carried out in the chemical laboratory which cannot be carried out just as well or better in the microchemical way; for example, the reduction of a copper solution by an aldehyde. Let the student place several separate drops of Fehling's solution on a glass slide and to each add a drop of some different aldehyde solution; let him warm the slide gradually over a small flame and make comparison of the changes in the several drops. This is an example of an experiment of a simple kind where an attempt is made to obtain constant conditions, varying only one factor. Such instructive little tests as these are surely worth far more than mere colour or precipitation tests in test tubes. Many more such tests could be described, but each teacher will probably prefer to devise experiments of his own, suited to the needs of his class.

It is submitted, therefore, that microchemical methods form not only an excellent introductory training for the student but mean a great saving in time, labour, and money. We have saved in one year at least 1,000*l.*, enabling us to buy more apparatus of a permanent kind for teaching and research.

EGERTON C. GREY.

Government Medical School,
Cairo, July 1922.

An Atomic Model with Stationary Electrons.

BOHR's atomic model with its circling electrons appears at first sight quite incompatible with Langmuir's model, in which the electrons are stationary or oscillate about fixed positions of equilibrium. Dr. Langmuir himself, however, has pointed out that a static atom possessing many of the properties of the Bohr atom is possible provided a force of repulsion equal to $F = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2} \cdot \left(\frac{nh}{2\pi}\right)^2$ act between an electron (mass m , charge e) and a nucleus. Here n is an integer and h is Planck's constant. The distance r of the electron from the nucleus in stable equilibrium is the same as the radius of a circular orbit corresponding to a stationary state in Bohr's theory. The total energy of the electron is also the same as that given by Bohr's theory. The frequency of oscillation about

the position of equilibrium is identical with the frequency of revolution of the electron in the Bohr atom. Thus the Rydberg constant and the Balmer series can be deduced without assuming moving electrons.

I wish to direct attention to the fact that a force of exactly the type required in Langmuir's theory is provided by the quantum mechanism recently described by Prof. E. T. Whittaker in the Proceedings of the Royal Society of Edinburgh. The mechanism may be pictured as a magnetic wheel consisting of a number of magnetic poles (total strength M) revolving in a circle of radius a . When this magnetic wheel is rotating about its axis with angular velocity ω , it sets up an electric field such that an electron situated at a point on the axis at a distance r , large in comparison with a , is acted on by a force $Mea^2\omega/r^3$ along the axis. Prof. Whittaker has shown that the angular momentum of the magnetic wheel in its steady state (after the passage of an electron completely through it) is determined by $A\omega = 2eM$, where A is the moment of inertia of the wheel. We shall assume that, in general, the angular momentum is given by Nicholson's quantum relation, so that

$$A\omega = 2eM = nh/2\pi.$$

Substituting the values of Me and ω thus found in the expression for the force on the electron, we find that the "quantum force" is given by

$$\frac{a^2}{2Ar^3} \left(\frac{nh}{2\pi}\right)^2.$$

This agrees precisely with Langmuir's expression for the force of repulsion, provided we make the single additional assumption that $A = \frac{1}{2}ma^2$.

Thus we see that by means of Prof. Whittaker's quantum mechanism it is possible to construct an atomic model which will yield many of the results of Bohr's theory, without employing moving electrons. I have discussed the question more fully in a paper to be published by the Physical Society of London.

H. S. ALLEN.

August 15.

The Variable Depth of Earthquake Foci.

PROF. H. H. TURNER has given reasons (Mon. Not. R.A.S., Geophys. Suppt. No. 1) for believing that the depths of the foci of earthquakes differ among themselves by quantities up to about 300 km. It may be pointed out that this is precisely what may be expected from the theory of a cooling earth. The available information concerning the thermal state of the earth indicates that the rocks in the asthenosphere, at depths of 400 km. and more, must be very much weaker than those at the surface; this is amply confirmed by the geodetic evidence collected by Barrell, which also suggests that the rocks at depths comparable with 100 km. are considerably stronger than those at the surface. Accordingly, whatever may be the cause of crustal deformation in the earth, yield will occur in the asthenosphere for smaller stresses than are necessary to produce it in the upper parts of the crust. Thus the earthquakes arising from fractures below 400 km. would be more numerous but much less violent than those occurring at higher levels, and the greatest earthquakes should have their foci at the depth of greatest strength. We should therefore expect that the depths of earthquake foci may range from zero to 200 or 300 km.

DOROTHY WRINCH.

HAROLD JEFFREYS.

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