diameter, and that as the specimens decrease in length the contraction of area at the point of fracture decreases also ; and, in consequence, the tensile strength increases when reckoned on the original area, and decreases when reckoned on the fractured area. The elongation in percentage of the original length is also very much increased in the shorter specimens, owing to the fact that the greater part of the elongation then takes place much nearer to the point of fracture, instead of being more equally distributed, as it is along the length of the longer bars.

A paper was read by Mr. A. A. Langley, descriptive of a hydraulic buffer-stop for railways, the chief advantages of which are absence of recoil after collision, continuous uniform resistance for bringing a train to rest, and absence of shock or breakage either in train or in buffer. The chief feature is the application of hydraulic resistance by the use of pistons working in horizontal cylinders filled with water, and fixed in line with the buffers of the rolling-stock.

THE VALUE OF THE REFRACTION GONIOMETER IN CHEMICAL WORK [1]

IMPORTANT advances in chemistry have often been the result of new methods of research, and these have generally involved the use of new apparatus. The introduction of the balance made the greatest of revolutions in chemistry ; but the thermometer, the blowpipe, the polariscope, and the spectroscope in its multifarious applications may also be cited as examples.

My object is to speak of the refraction goniometer or spectrometer, by which the refraction and dispersion of bodies can be measured. The construction of this instrument, and the use of it, which ought to be a part of the regular training of chemical students, may be learned from many works on physics, but it is very fully described in Glazebrook's "Optics," together with the manner in which the angular measurements are reduced to refractive indices. By means of this instrument the index of refraction is easily obtained for liquid bodies ; solids or gases require a more complicated apparatus, but those of them which can be readily dissolved in any liquid can be determined from their solutions.

The index of refraction (μ) of a body is a definite physical property, like its boiling-point, specific gravity, or solubility, and ought to form part of our knowledge of any substance. I have generally determined it for the line A of the spectrum of the sun ; but Continental observers have usually adopted the red line of hydrogen, which is coincident with the solar line C.

The length of the spectrum—that is, the difference between the indices of refraction of extreme rays, say the lines H and A, which may be taken as the measure of dispersion—is another physical property, and an equally important one.

If the index of refraction and the dispersion of a substance be accurately known, we have a double test of the purity of any specimen that may have to be examined.

As, however, the refraction varies with temperature and other circumstances, it is better to deal with the specific refraction, that is, the index, minus unity, divided by the density $\left(\dfrac{\mu - 1}{d}\right)$.

This is little, if at all, affected by pressure, heat, change of aggregate condition, mixture, solution, or, generally speaking, by chemical combination. Thus the specific refraction of water under different circumstances has been determined as follows, the observations being reduced for the line A of the spectrum :—

Water				Specific refraction
Liquid, at 1° C.	...	...	...	0·329
,, at 48° C.	...	...	...	0·329
Solid	...	...	...	0·331 [2]
Gas	...	...	...	0·324
Mixture with alcohol ...	...	...	0·330 [3]
Water of crystallisation	...	...	0·330 [4]
,, ,,	...	...	0·327 [5]

The identity of the specific refraction of a body in the solid state or in solution has been frequently proved ; the last instances

[1] Communicated to Section B of the British Association, at the Aberdeen meeting, September 1885.
[2] Rausch.   [3] Landolt ; mean of three observations.
[4] In ammonia alum ; Charles Soret.
[5] In double sulphates ; Topsoe and Christiansen.

determined were as follows, the observations on the crystals being made by M. Soret, and on the solutions by myself :—

Substance	Solution	Crystallisation
Ammonia alum	0·2780 ...	0·2784
Soda alum	0·2613 ...	0·2604

For the purpose of calculation, however, it is more convenient to adopt what Landolt denominated the refraction equivalent, that is, the specific refraction multiplied by the atomic weight $\left(P\dfrac{\mu - 1}{d}\right)$. The refraction equivalent of water may be taken, therefore, as $0·3295 \times 18 = 5·93$. Of this, the two atoms of hydrogen may be assumed from observations on other bodies to represent 2·6, leaving for the atom of oxygen 3·33.

The specific refraction and dispersion of a body not merely gives an indication as to its purity or otherwise, but tells the quantity of the substance with which it may be mixed, if that substance is known. Thus Landolt has applied it to the quantitative analysis of mixtures, and gives examples, such as ethyl alcohol and fousel oil, ethyl alcohol and ether. I have applied it myself in the estimation of carbolic acid in disinfecting powders, by dissolving the acid out in a known quantity of alcohol, and determining the refraction and density of the solution.

In chemical investigations among organic compounds the determination of the specific refraction of the products is very valuable. Thus, in a recent investigation on the action of the copper-zinc couple on bromide of benzyl by Mr. Tribe and myself, there were three different ways in which it led us to results which we should not otherwise have arrived at.

(1) The viscid mass which resulted from the action appeared very unpromising, but, on examining it with the prism, its specific refraction and dispersion were so high that we determined to purify it, and this led to the discovery of the new hydrocarbon benzylene.

(2) When the reaction was performed in the presence of alcohol, it seemed probable that toluene would be produced ; but the liquid, when heated, distilled off at 78°, which is the boiling-point of pure alcohol. Instead, however, of throwing the distillate away, it was examined in a hollow prism, and seen at once to be something very different. Indeed, the increased refraction and dispersion led to the belief that one-fifth of it was toluene, though that boils at 110°. On adding water, a liquid separated, which was proved to be toluene by its boiling-point and density, as well as by its specific refraction and dispersion, 0·5604 and 0·0474, agreeing sufficiently well with the known figures.

(3) On another occasion, among products of fractional distillation was a liquid which had too small a refraction to allow of its being considered a hydrocarbon. It was suspected that the low refraction might be due to oxygen or bromine ; and this led to a further examination and the discovery that the liquid contained a new bromine compound.

But another important application of these physical properties is to the elucidation of the chemical structure of various bodies. A very large amount of information as to specific refraction is now at our disposal through the labours of different experimenters, not only in this country, but in Germany, Italy, Russia, Holland, and Sweden ; and the whole course of recent investigations goes to show (1) that the specific refraction of a body depends essentially on its ultimate atomic constitution ; but (2) that this is modified in certain definite ways by the molecular arrangement or structure. Thus, to take an instance : sugar, $C_{12}H_{22}O_{11}$, whether crystallised or dissolved, has the refraction equivalent of 119·3. If, however, we take each atom of carbon at 5·0, and water at 5·93, we should obtain the figure 125·1 as the calculated value. The discrepancy is far too great to be attributed to errors of experiment, and points to the fact that sugar is not, strictly speaking, a carbohydrate ; that really it does not contain water, but that the hydrogen and oxygen are otherwise arranged, as chemists have concluded on other grounds. The oxygen in all hydroxyl compounds is 2·8, according to Brühl, and this would give for sugar the theoretical value 119·5, which is almost identical with the experimental number.

In a similar way it has been very fully substantiated that carbon, whenever it is in the condition which is termed "double-linked," has the value, not of 5·0, but of about 6·1. Hence in any compound the constitution of which is doubtful, we can tell how many carbon atoms are in this condition. Thus, to take terpene, $C_{10}H_{16}$. This has been the subject of much discussion among chemists, one considering it to have one pair of carbon

atoms double-linked, others two pair, and another as many as three pair. On these three suppositions its refraction equivalent would be 73·0, 75·2, and 77·4 respectively. Now the various isomeric terpenes have a refraction equivalent of about 72·9, leading to the belief that only one pair of carbon atoms is in that condition. This conclusion is enforced by the specific dispersion, which averages 0·0299. From the analogy of other compounds containing ten atoms of carbon and which are of known constitution, about this amount of dispersion might be expected to occur in a $C_{10}H_{16}$ having one pair of carbon atoms double-linked.

I do not know how far chemists may be disposed to accept these optical properties as the arbiter between rival theories of constitution ; but their value as helps will not be denied.

With reference to this mode of experimenting, it should be borne in mind that a very small quantity of a substance suffices for the purpose of observation ; and whereas chemical processes use up material, the refraction of a liquid can be taken with no other loss than the small amount which unavoidably clings to the vessels employed. This even may be recovered if it is worth the trouble.

A table of the approximate refraction equivalents of forty-six of the elements was drawn up for my paper in the *Phil. Trans.* of 1869. Many of these have since been re-determined, either by myself or other observers; and a new edition of the table was prepared for the Montreal Meeting of the British Association, and appears in the *American Journal of Science* of January 1885. Carbon, oxygen, nitrogen, sulphur, phosphorus, iron, chromium, silicon, and doubtless other elements have two or three different values ; and the special circumstances under which these different effects upon the rays of light occur offers a most promising field for any future investigator.

J. H. GLADSTONE

THE RAINFALL OF THE BRITISH ISLANDS[1]

CLIMATE may be defined as that peculiar state of the atmosphere in regard to heat, moisture, and rainfall which prevails in any particular place, together with its meteorological conditions generally, in so far as these influence animal and vegetable life. The diversified characters which climate displays may be referred chiefly to the combined operation of these four different causes, viz., distance from the equator, height above the sea, distance from the sea, and prevailing winds.

The greatest differences, however, in the local climates of places situated at no great distance from each other arise from differences in the rainfall. The arid plains of the North-Western Provinces of India as compared with the fertile higher slopes of the Himalayas contiguous to them, and the widely contrasted climates of the western and eastern slopes of Scandinavia respectively, may be cited as illustrations. In the British Islands there are perhaps no stronger contrasts of climate than those presented by Skye and the Laigh of Moray. The mean temperature of these two regions in no month of the year differ so much as two degrees, and for several of the months they are nearly identical. But the rainfall of Skye rises towards, and in many places exceeds, 100 inches annually, whereas over the Laigh of Moray it is only about 26 inches. Now it is this difference in the rainfall, with the clear skies and strong sunshine that accompany it, which on the one hand renders the south shores of the Moray Firth one of the earliest and finest grain-producing districts of Scotland ; and, on the other, renders the island of Skye quite unsuitable for the remunerative cultivation of cereal crops. It is this aspect of the rainfall which gives it so paramount a place in the climatology of a country.

Of all meteorological data, the rainfall is the most difficult to represent cartographically ; and there is no other way to arrive at even a tolerable approximation to the average rainfall of a district than by numerous rain-observing stations well distributed over its surface. Hence in this inquiry all available statistics of the rainfall for the period of years selected have been used,—the number of stations being 1080 in England and Wales, 547 in Scotland, and 213 in Ireland—in all, 1840 stations. Notwithstanding this comparatively large number of rain-gauges, very extensive districts remain wholly, or all but wholly, unrepresented.

The period selected for the investigation is the twenty-four

years ending 1883, and the principal sources from which the information has been obtained are the returns published by the Meteorological Societies of England and Scotland and by Mr. Symons. For the method of discussing the results we refer to the recently published Part of the *Transactions* of the Scottish Meteorological Society, pp. 131-33. It may be here enough to say that the whole of the averages have been calculated for, or reduced to, the same term of twenty-four years beginning with 1860 and ending with 1883.

The 1840 averages were then transferred to large maps of England, Scotland, and Ireland, and from the results thus shown the British Islands were shaded into six divisions, these shadings showing the districts where the mean annual rainfall

> 1st does not amount to 25 inches
> 2nd is from　25 to　30　,,
> 3rd　　,,　　30　,,　40　,,
> 4th　　,,　　40　,,　60　,,
> 5th　　,,　　60　,,　80　,,　and
> 6th above 80 inches.

On the map exhibited on the wall these divisions are shown by three tints of blue and three of red,—the blue showing a rainfall exceeding forty inches annually, and the deepest tinted blue the regions of largest rainfall ; and the red a rainfall less than 40 inches, the lightest tint marking off those parts of England where the rainfall is least, or where it is less than 25 inches annually.

The regions of heaviest rainfall, marked off by 80 inches annually, or upwards, are these four :—

(1) The greater part of Skye, and a large portion of the mainland to the south-east, as far as Luss.

(2) The greater part of the Lake District.

(3) A longish strip including the more mountainous portion of North Wales, and

(4) The mountainous district of the south-east of Wales.

The rainfall is also heavy on Dartmoor, and certain portions of the west of Ireland ; but in these parts it does not appear quite to reach 80 inches.

The West Highlands present the most extensive region of heaviest rainfall in the British Islands. The mountain-masses along whose slopes and plateaus the rainfall is precipitated, offer a practically unbroken face of Highlands directly in the course of the rain-bringing winds from the Atlantic. Particular attention is drawn to the circumstance that these mountain-masses present many lochs and valleys directly in the course of these winds, up which therefore the winds are borne, and these cooling as they ascend pour down the deluges of rain which deeply trench the sides of the mountains in the lines of their water-courses.

This region of heaviest rainfall lies so far to the north of Ireland that the rainfall is not lessened by a previous partial drying of the Atlantic winds in their passage thither. To southward, however, it is quite different. Over the whole of the extensive tract of Great Britain from Luss to the Lake District there is not a single rain-gauge whose annual average reaches 80 inches, even although a number of rain-gauges have been planted in the higher districts, and in positions likely to furnish approximately the maximum rainfall of these districts. The diminished rainfall is no doubt due to the partial drying of the Atlantic winds in their passage across Ireland before they reach Southern Scotland.

St. George's Channel and the Irish Sea open a free passage to the south-westerly winds, here diverted into a more southerly course, to the north of England and to Wales, and accordingly where the mountain masses of the Lake District and of North and South Wales oppose their course the rainfall over large portions of these high districts exceeds 80 inches.

The maximum falls in these four districts respectively are 185·96 inches at The Styx, in the Lake District ; 128·50 inches at Glencroe, Argyllshire ; 116·90 inches at Beddgelert, North Wales ; and 96·18 inches at Ty-Draw-Treherbert, South Wales.

The largest region of 60 to 80 inches rainfall is in the West Highlands, surrounding the region of still larger rainfall of 80 inches and upwards, and it extends from the Crinan Canal to beyond Loch Assynt in Sutherland. Then follow the hills to the north of Galloway, the hills to the north and east of Dumfriesshire, large portions of the Lake District, of North and South Wales, of West Galway, the mountainous districts of Kerry, and Dartmoor in Devonshire.