(1) as above noticed for all collisions by introducing the factor $u - U + c\varpi$ to denote frequency of collision; or (2) for all spheres as they exist at a given instant. Now, Prof. Burnside has calculated the average rotation energy by method (2), which gives $2A\overline{\omega^2} = \frac{1}{k}$. But when he comes to the translation energy, he takes the result $\overline{(u - U)^2} = \frac{2}{h}$ from Prof. Tait, not observing, I think, that that result is given by Tait as the average for all collisions per unit time. And then, equating two inconsistent things, he gets the conclusion $\frac{1}{k} = \frac{2}{h}$, or the mean energy of rotation is twice that of translation.

To be consistent, he should have given the mean of $(u - U)^2$ for all pairs of spheres—that is, $\overline{u^2} + \overline{U^2} = \frac{1}{h}$. And so his result should have been $\frac{1}{k} = \frac{1}{h}$, agreeing with Maxwell

It may be interesting to see what would have been the result of introducing the factor $u - U + c\varpi$ to denote frequency of collision. The expression whose average is required would then be—

$$(u - U + c\varpi)^2\{2\varpi - c(K + k)(u - U)\}.$$

As the frequency factor $u - U + c\varpi$ must be always positive, we must integrate between the limits $U = +\infty$ to $U = -\infty$, and $u = +\infty$ to $u = U - c\varpi$. After integration, we reject odd powers of ϖ.

I have worked it out to the first power of c, rejecting c^2, &c. We have, in that case, to evaluate—

$$\int_{-\infty}^{\infty}\int_{U-c\tilde{\omega}}^{\infty}\{2\varpi(u-U)^2+4c\varpi^2(u-U) - c(K+k)(u-U)^3\}\epsilon^{-hu^2}\epsilon^{-hU^2}\,du\,dU.$$

The first term gives zero. The second term gives $\frac{4c\varpi^2}{h}$, and the third term gives $\frac{2c(K + k)}{h^2}$. From which, on substitution, and integrating for ω, Ω, &c., from ∞ to $-\infty$, we easily obtain $k_1 = k_2 =$ &c. $= h$.

To extend the process to cases in which c^2, &c., cannot be neglected, would be difficult. But I think the *onus probandi* now lies on the other side.

S. H. BURBURY.

Double Orange.

ON a blood orange being cut open by my little daughter yesterday, a small orange was found inside, which, although no larger than a hazel-nut, was yet perfect in form and colour. It showed no point of difference, other than that of size, as compared with the parent orange, and there was nothing in the appearance of the uncut fruit suggestive of the miniature of itself carried within. My sole right to write upon this subject is one you have always recognized in your journal, viz. that to record an interesting fact.

GERALD B. FRANCIS.

Katrine, Surbiton.

METALS AT HIGH TEMPERATURES.[1]

I PROPOSE this evening to consider, first, the methods of measuring high temperatures, and, second, to describe certain effects they produce on metals.

Geber, writing in the eighth century, gives directions for obtaining high temperatures, but points to the difficulties that arise in practice, "because fire is not a thing which can be measured, '*sed quoniam non est res ignis, quæ mensurari possit.*'"[2] It is not sufficient to attain temperatures that are known to be high; it is necessary, for the purpose of modern investigation, to measure them with accuracy; and few of the early chemists in this country did more in affording a basis for the study of metals at high temperatures than Robert Boyle, the application of whose well-known law to solutions of metals in each other has been made evident by recent work. The 30th of December last was the third centenary of his death; it is well, therefore, that this lecture should begin with a tribute to his memory. He suggested improvements in the ordinary mercurial thermometer,[1] constructed what would appear to be the first air thermometer with an index; and although he did not do much for thermometry at high temperatures, he appears to have been struck by what must have been a quaint device for regulating high temperatures, for he points out that "the great mechanic, Cornelius Drebel[2] made an automatous musical instrument and a furnace which he could regulate to any degree of heat by means of the same instrument." He indicates various degrees of intensity of heat by reference to the colour of a glowing mass of fuel, and says that,[3] "tho' we vulgarly say in English, 'a thing is red hot,' to express a superlative degree of heat, yet, at the forges and furnaces of artificers, by a white heat they understand a further degree of ignition than by a red one." It is not a little strange that for three centuries after his death the same vague expressions have constantly been used in describing high temperatures.

A great step in advance was made in 1701 by Sir Isaac Newton,[4] who applied the law of cooling to the measurement of temperatures beyond the range of the mercurial thermometer, and in the notes which accompany his "Scala graduum caloris" he showed that he knew that the freezing-point of lead differs slightly from its melting-point.

Eighty years later, Josiah Wedgewood (1782),[5] aided by one of my predecessors, Mr. Alchorne, Assay Master of the Mint, determined a few melting-points of metals, and, in communicating a description of his "thermometer for measuring the higher degrees of heat" to the Royal Society, we find him, one thousand years after Geber had said that "fire cannot be measured," still lamenting the want of suitable instruments, saying: "How much it is to be wished that the authors [to whom he refers] had been able to convey to us a measure of the heat made use of in their valuable processes; . . . a red heat, a bright red, and a white heat are," Wedgewood adds, "indeterminate expressions, and even though the three stages are sufficiently distinct from each other, they are of too great latitude, and pass into each other by numerous gradations which can neither be expressed in words nor discriminated by the eye." Another ninety years brings us to the last time that the measurements of high temperatures formed the subject of a Friday evening discourse in this Institution. On March 1, 1872, the late Sir William Siemens addressed you on the measurement of "heat by electricity";[6] and, speaking of the mercurial thermometer, said: "When we ascend the scale of intensity we soon approach a point at which mercury boils, and from that point upwards we are left without a reliable guide, and the result is that we find, in scientific books on chemical processes, statements to the effect that such and such a reaction takes place at a 'dull red, such another at a 'bright red, or a 'cherry red,' or a 'white heat'—expressions which remind one," he adds, "of the days of alchemy rather than of chemical science at the present day."

[1] A Lecture delivered at the Royal Institution by Prof. W. C. Roberts-Austen, C.B., F.R.S., on Friday evening, February 5, 1892.
[2] From the edition of his "Summa Perfectionis Magisterii," p. 28, published in Venice, 1542.

[1] Boyle's Works, Shaw's edition, vol. i. p. 575, 1738.
[2] Cornelius van Drebel, 1572-1634, *loc. cit.* vol. iii. p. 38, 1738.
[3] *Loc. cit.*, vol. ii p. 28.
[4] Phil. Trans. Roy. Soc., vol. xxii. p. 824.
[5] *Ibid.* vol. lxxii. p. 305.
[6] Roy. Inst. Proc., vol. vi. p. 438, 1872.