X.—*On Wollaston's Argument from the Limitation of the Atmosphere, as to the Finite Divisibility of Matter.* By GEORGE WILSON, M.D., *Lecturer on Chemistry.*

[Read 21st April 1845.]

In the year 1822, Dr WOLLASTON published a remarkable paper “on the finite extent of the atmosphere.”* Its object is to establish, by observations on the motions of certain of the heavenly bodies, that our atmosphere does not extend into free space, and to deduce from this limitation in its extent, the conclusion, that the air necessarily consists of particles “no longer divisible by repulsion of their parts;” *i. e.* of true atoms. From this there is the further inference, that, “since the law of definite proportions discovered by chemists, is the same for all kinds of matter, whether solid or fluid, or elastic, if it can be ascertained that any one body consists of particles no longer divisible, we then can scarcely doubt that all other bodies are similarly constituted.” In other words, the existence of a limit to the earth’s atmosphere is declared to supply a demonstration of the finite divisibility of matter.

In pursuing this argument, WOLLASTON first discusses the question, What is the probable height to which the earth’s atmosphere extends? And after stating, that, from the known laws of the elasticity of the atmosphere, we should infer that it extends to the height of 40 miles, with properties yet unimpaired by extreme rarefaction, he proceeds to say, “Beyond this limit we are left to conjectures founded on the supposed divisibility of matter; and if this be infinite, so also must be the extent of our atmosphere. But if air consist of any ultimate particles no longer divisible, then must expansion of the medium composed of them cease at that distance where the force of gravity downwards, upon a single particle, is equal to the resistance arising from the repulsive force of the medium.” WOLLASTON, it will be observed, takes for granted two things. *1stly*, He assumes that the law which is known to connect the density of the air with the compressing force, near the surface of the earth, prevails, without change, to the limit of the atmosphere. *2dly*, He identifies the divisibility of the mass with that of its component parts or molecules. If the molecule be infinitely divisible, the mass will be so also, and *vice versa*; so that if the divisibility (finite or infinite) of either be ascertained, that of the other will thereby be ascertained also. Now, the atmosphere is not merely divisible, but, consisting like other gases of mutually repulsive particles, contains within itself a power of division. We have only, therefore, to

* Philosophical Transactions, 1822, p. 89.

permit this self-dividing force to come into play, and the result, according to WOLLASTON, will shew whether the mass undergoing spontaneous division is infinitely divisible or not. This experiment we cannot try; but it has long ago been performed for us by the hand of Nature. Our atmosphere has divided itself to the utmost limit which its susceptibility of division permitted, and has thereby tested or ascertained that divisibility for us. Either that is infinite, in which case, the atmosphere must have spread into space, and portions of it will be found surrounding the different heavenly bodies, varying in amount according to their respective dimensions, temperatures and the like. Or it is finite, and the air has found a limit at no great distance from the earth; for the particles of which it consists, although free, so far as their mutual repulsiveness is concerned, to recede from each other, are not equally free to recede from the earth, to which the force of gravitation binds them. They must come to rest accordingly at the point where the attraction of gravitation is equal in amount, while it is opposite in direction to the force of repulsion among them; so that they are balanced in equilibrium between them. Now it appears on making the necessary observations, that probably the Sun, and certainly that Jupiter, is devoid of an atmosphere of the same nature as our own. Therefore, concludes WOLLASTON, our atmosphere is of finite extent, and consists of particles only finitely divisible. And as the air cannot be supposed to be peculiar in this respect, the conclusion is immediately extended to every other substance, and all matter is inferred to consist of finitely divisible particles, or *bonâ fide* atoms.

It cannot surprise us that so remarkable a paper as WOLLASTON's should have excited the greatest attention among men of science. If the argument pursued in it were just, the vexed question of the finite or infinite divisibility of matter, which, for some thousand years, physics and metaphysics had alike sought in vain to decide either way, had all the while been answered for us. Every attempt towards the solution of that problem by experiment had failed, not perhaps, because ultimate atomic particles had not been arrived at, by the dividing forces our command, (for this length the inquiry never reached); but because, long before the divisibility of a body could be supposed to be exhausted, the products of its division had become invisible to us, and we had no test by which to tell when the atoms of a substance had been attained to. Both of these difficulties, according to WOLLASTON, were taken out of the way, by the mode in which Nature made the experiment. A dividing force co-ordinate with the divisibility on which it took effect—finite, if it were finite, infinite, if it were infinite—was brought into play. The result of this division, moreover, could be ascertained, could, in truth, literally be seen; for it did not take place in a vacuum, but in a space containing bodies, each of which would infallibly indicate the extension of a self-dividing medium at least to itself; and as that, if it were infinitely divisible, must reach to them all in its progress towards infinite division, should it certainly

appear that it had not extended to any one, still more, if not to several, it would suffice to prove that it was not infinitely divisible. In short, our atmosphere being the self-dividing mass, and all the stars standing between it and infinity, the absence of an atmosphere like the earth's, from any one of them, shews that that it can only be finitely divided; and the decision in the negative of the question of infinite divisibility should have dated from the discovery of the telescope, and GALILEO's earliest observation of the eclipses of Jupiter's moons.

My object in the following remarks, is to shew that WOLLASTON's identification of the divisibility of the molecule, with the observed division of the mass of which it is a part, is altogether unwarrantable; that he takes for granted the very thing to be proved; and that his whole discussion leaves the question of the finite or infinite divisibility of matter exactly where it found it. Before doing so, however, I am anxious to refer very briefly to the criticisms already offered on this part of the paper under discussion.

The opinions hitherto expressed as to WOLLASTON's argument may be arranged, I believe, under four heads. 1st, A few natural philosophers have entirely assented to the truth of the conclusion contained in it. Among these was DAUBENY,* who has lately, however, withdrawn his assent;† and it is still advocated by DUMAS, who, whilst he objects to WOLLASTON's arguments, on other grounds which will be referred to immediately, appears to consider the conclusion of the latter unavoidable, if his premises are granted him.‡

2d, A greater number, including FARADAY,§ GRAHAM,|| and TURNER,¶ have implied, by the terms of commendation in which they have referred to it, that at least they detected no fallacy in the argument.

3d, It has been objected to by DUMAS (following out the views of POISSON), on the ground that the low temperature which is known to prevail in the upper

* Introduction to the Atomic Theory, 1831, pp. 103-5.

† Supplement to Introduction, &c., 1840, p. 11.

‡ DUMAS' assent was entirely negative, but was strongly manifested, and is the more remarkable, that he has directed special attention to the phenomena presented by those gases which combine without undergoing diminution of their volume, as irreconcilable with the idea of the chemical equivalents of these bodies being represented by single atoms, such as DALTON assumed, (*Leçons sur la Philosophie Chimique*, p. 263). Had this view been carried out and applied to the atmosphere, it would have struck at the root of WOLLASTON's whole train of reasoning, and would have obviated the necessity of appeal to the questionable views of POISSON, as to the cause of the limitation of the atmosphere. As WHEWELL's discussion of WOLLASTON's speculations, which was specially intended to meet the argument of DUMAS, has appeared since the latter published his views, it may have led to some modification of his opinion. But that distinguished chemist has not had occasion, so far as I am aware, to refer again to the subject in public; so that, in the meanwhile, I include him among the acknowledged supporters of the intrinsic validity of WOLLASTON's views.

§ On the existence of a limit to vaporisation, *Phil. Trans.*, 1826, p. 492.

|| *Elements of Chemistry*, pp. 68 and 273.

¶ *Elements of Chemistry*, 7th edition, p. 207.

regions of the atmosphere, may be such at its boundary as to destroy the elasticity of the air, and even to liquefy or solidify it.* DAUBENY,† KANE,‡ and others, have replied to this, that the temperature of planetary space, according to FOURIER, SCHWANBERG, and others, is much higher than that to which air has been exposed in experiments with solid carbonic acid and ether, without destroying its elasticity. DUMAS, in anticipation of such objections, has declared, that we are not to consider the temperature which a thermometer would exhibit if placed in the upper strata of the atmosphere, as necessarily identical with that of the air around it.§ By which statement he means to enforce, if I understand him aright, that non-elastic (liquid or solid ?) air may, like other diathermanous bodies, transmit heat without being thereby raised in temperature itself, so that the outer shell of air may be colder than the layers within it, or space beyond it. In allusion to such a view, Professor JAMES FORBES has pointed out the difficulty of understanding “how it is possible that the higher strata of the atmosphere can remain permanently colder than the strata beneath and the sky above them, without admitting a paradox of the same kind with a mechanical perpetual motion.”||

In reference to DUMAS' mode of disposing of WOLLASTON's argument, I would only further observe, that natural philosophers are not at one as to the temperature, either of planetary space or of the upper strata of the atmosphere; so that it is impossible at present to say what is the exact value of the objection I have been discussing.

4th, Finally, several physicists have denied the justness of WOLLASTON's conclusion, on the ground of its intrinsic invalidity. Among these are Professor JAMES FORBES¶ and Dr KANE,** who have not, however, so far as I am aware, stated in what way they dispose of the argument. Professor WHEWELL is likewise an objector, and dissents from WOLLASTON's inference, on the plea that the latter was not at liberty to assume that the law which connects the density of the air with the compressing force at the upper boundary of the atmosphere, is identical with that which is known to prevail near the earth. His own words are—“We know nothing of the law which connects the density with the compressing force in air so extremely rare, as we must suppose it to be near the boundary of the atmosphere. Now there are possible laws of dependence of the density upon the com-

* Leçons, &c., p. 239.

† Supplement to the Introduction to the Atomic Theory, p. 11.

‡ Elements of Chemistry, p. 441.

§ Leçons, &c., p. 241.

|| Report of British Association, 1841, p. 79.

¶ Op. cit., p. 77.

** Elements of Chemistry, pp. 15 and 358.

pressing force, such that the atmosphere would terminate in virtue of the law without any assumption of atoms. This may be proved by mathematical reasoning. If we suppose the density of air to be as the square root of the compressing force, it will follow that, at the very limits of the atmosphere, the strata of equal thickness may observe in their densities such a law of proportion as is expressed by the numbers 7, 5, 3, 1. For the compressing force on each being as the whole weight beyond it, will be for the four highest strata 16, 9, 4, and 1, of which the square roots are as 4, 3, 2, 1, or as 8, 6, 4, 2; and, though these numbers are not exactly as the densities 7, 5, 3, 1, those who are a little acquainted with mathematical reasoning will see that the difference arises from taking so small a number of strata. If we were to make the strata indefinitely thin, as to avoid error we ought to do, the coincidence would be exact; and thus, according to this law, the series of strata terminates as we ascend, without any consideration of atoms.”*

My object in the succeeding argument is to shew, that, although the law which WOLLASTON assumed to prevail in the higher regions of the atmosphere were in operation, it would not justify the conclusion which he supposed it to warrant. The discussion which follows differs from WHEWELL’S mode of disposing of the subject, in conceding to WOLLASTON his own law; and from that of POISSON and DUMAS, in permitting him to take for granted as high a temperature as he pleases, provided only the atmosphere have reached a limit.

On a little consideration of WOLLASTON’S reasoning, it will appear, that all that he succeeded at the utmost in establishing was, that the atmosphere consists of a finite number of repelling molecules. He seems to have conceived that this was sufficient, and that no one would dispute his subsequent assumption, that these repelling molecules were ultimate particles or true atoms.

But such an assumption is, on a twofold ground, inadmissible. The more important chemical components of our atmosphere are, water-vapour, carbonic acid, oxygen, and nitrogen. Let us set aside for the time, as we are at liberty to do, the influence of the low temperature of the upper regions of the air in condensing the water, and perhaps also the carbonic acid; and suppose our atmosphere, with a temperature at its boundary sufficient to retain all its constituents as elastic fluids, to find a limit, in virtue of the prevalence of WOLLASTON’S law. Each gas would cease to expand for the same reason, and present a row of bounding molecules, which were prevented from falling towards the earth by the repulsion of the particles between it and them, and from receding from the earth by their own weight. But the molecules of water-vapour, and carbonic acid, brought in this way to a stand, would certainly not be ultimate particles or indivisible atoms. The molecule of water, on the simplest view of its constitution, namely, that the chemical equivalent corresponds to a single atom, would consist of at least two

* Philosophy of the Inductive Sciences, vol. i., p. 420, and Athenæum, 1839, pp. 724-7.

atoms, one of hydrogen and one of oxygen, with a centre of repulsion common to both. The molecule of carbonic acid, for similar reasons, would consist of three atoms, one of carbon and two of oxygen. And who shall assure us that oxygen and nitrogen are not compounds with binary chemical molecules like those of water, or ternary ones like those of carbonic acid? It is true that the chemist names these gases simple substances. But the simplicity he attributes to them is only, as he is careful to define, *quoad analysis*; and the physicist is not at liberty to convert this negative and relative simplicity into an absolute one, and make deductions therefrom, as WOLLASTON has done. If we argue from analogy, in reference to this point, we should infer that oxygen and nitrogen are compounds; for we know a much greater number of gases in which the molecule is a group of chemically distinct atoms, than we do of elastic fluids, where, on the most favourable view, it can be supposed to be a single one. But it is not necessary to pursue any argument of this kind; nor is the objector called upon to shew that oxygen and nitrogen are chemical compounds. It is sufficient for his purpose to decline assent to WOLLASTON's conclusion till he, or those who agree with him, supply proof that the molecules of oxygen and of nitrogen are chemically simple. The *onus probandi* clearly lies, not with the denier but with the asserter, of a positive proposition like the one before us.

In so far, then, as WOLLASTON assumed the chemical simplicity of two of the gases of the atmosphere, he employed an *argumentum ad ignorantiam*. He was guilty also of a *petitio principii*. For even, if it could be shewn, that oxygen and nitrogen are chemically homogeneous, and do not, on that account, admit of comparison as to the constitution of their gaseous molecule with water and carbonic acid, it would not warrant the conclusion, that that molecule was an atom. Does it follow as a necessary inference, that because a body is simple, its gaseous repelling molecule must consist of but one atom? The answer is assuredly in the negative. The molecule might, on the other hand, be made up of a pair of atoms, like a binary star, with a centre of repulsion common to the two; or of 10, or of 100, or 1000 atoms (if such bodies there be), grouped together into a compound whole. We have no means whatever, in truth, of estimating what the complexity of the molecule may be. Without insisting at greater length on this, it is at least manifest, that we are not even at liberty to identify the combining chemical molecule with the repelling gaseous one, much less to identify either with the ultimate atom. Yet, unless WOLLASTON was at liberty to do so, his argument was useless towards settling the question of the divisibility of matter. To prove that the atmosphere consisted of finite molecules, was only to reach the threshold of the difficulty; for each molecule supplied as good a text whereon to dispute the question of infinite divisibility, as the whole atmosphere out of which it was taken. The point which most of all demanded proof, namely, that the molecule was an atom, was the very one which he took for granted.

WOLLASTON, in truth, erred, in assuming that the self-dividing power present in the atmosphere was able to divide, to the uttermost, the divisible mass subjected to its action; in taking for granted that the divisibility was co-ordinate with the actual division, so that the latter was the exact index and measure of the amount of the former. The fallacy of his argument will at once appear if the latter be thrown into a syllogistic form. It will then run thus :—

1. An atmosphere consisting of an infinite number of mutually repulsive particles, must be infinitely extended.

2. But our atmosphere is not infinitely extended.

3. Therefore our atmosphere does not consist of an *infinite number of particles*. Whereas it should have been.

Therefore our atmosphere does not consist of an infinite number of *mutually repulsive* particles.

The premises fully warrant the conclusion that our atmosphere does not consist of an infinite number of *mutually repelling* particles, but throw no light on the question, whether or not it may contain an infinite number of *mutually indifferent*, or *mutually attractive* ones.

WOLLASTON'S argument, then, supplies no decision of the question of the divisibility of matter. That problem still presents the same twofold aspect of difficulty which it has ever exhibited. If we affirm that matter is infinitely divisible, we assert the apparent contradiction, that a finite whole contains an infinite number of parts. If, pressed by this difficulty, we seek to prove that the parts are as finite as the whole they make up, we fail in our attempt. We can never exhibit the finite factors of our finite whole; and the so-called atom always proves as divisible as the mass out of which it was extracted. Finiteness and infinity must both be believed in; but here, as in other departments of knowledge, we cannot reconcile them.

It seems surprising that fallacies so palpable as those we have been discussing, should not have been detected long ago by the able philosophers who have noticed WOLLASTON'S argument. It is especially singular, that DUMAS, who holds that, in the combination of gases, a division of the chemical equivalent frequently occurs (so that he represents the latter as expressed physically by a group of many molecules), should not have applied his views, as he could so easily have done, to its full refutation.

As it is, I trust that the discussion I have laid before the Society will not prove unacceptable to its members. WHEWELL'S reasoning cannot be appreciated by those who are ignorant of mathematics; and the views of POISSON and DUMAS, even should they be fully established, leave unconsidered the question of the intrinsic validity of WOLLASTON'S conclusions. I am not without hopes, accordingly, that a demonstration of a fallacy in the argument in question, on purely physical grounds, which can be understood by every one, and which, so far as I am aware,

has not been offered already, will be of service in removing doubtful knowledge. In particular, it may save beginners from seeking for a demonstration where none is to be found, and from blaming themselves because they cannot acquiesce in a conclusion, the truth of which great names have appeared to warrant. I would, observe, however, that, although I have employed the words *molecule* and *atom* in the preceding discussion, it has been for the sake of simplicity and convenience, and to meet WOLLASTON on his own ground. I do not wish to be understood as offering any opinion as to the ultimate constitution of matter, except in so far as I deny the success of the only attempt which has been made in modern times, to establish, by direct observation, the existence of indivisible atoms.