

of the main arms where they cross at the center of the wheel weakens them seriously. Were this avoided by placing one set nearer the middle of the shaft, leaving space enough so that the rim of 1-inch boards could be nailed on the inside of one set and on the outside of the other, 2 by 4-inch material would be strong enough. While the 8 by 8-inch shaft would sustain a weight at the center of over 10,000 pounds, still it is none too heavy for the wheel weighing 1,600 pounds; since it is

#### BLACK DIAMOND.

This has a very dark purple brown color, is an amorphous, granular stone with rarely any crystallization visible or traceable, and is called carbon or black diamond. It is the hardest material known and has great strength.

#### BORT.

This, called bort, is entirely crystalline, and generally transparent and of all colors of the rainbow, as

symmetrical distribution of weight about spindles and shafts, it became necessary to use a material harder than steel, and hence diamond was again resorted to. This made it possible to avoid delays in replacing worn dies, and because of the great permanence of accuracy of the calibers of the holes in the diamonds, materially reduced the cost of producing fine wire of copper, brass, steel, iron, nickel, and of other metals.

It is of course well known that stone is drilled and

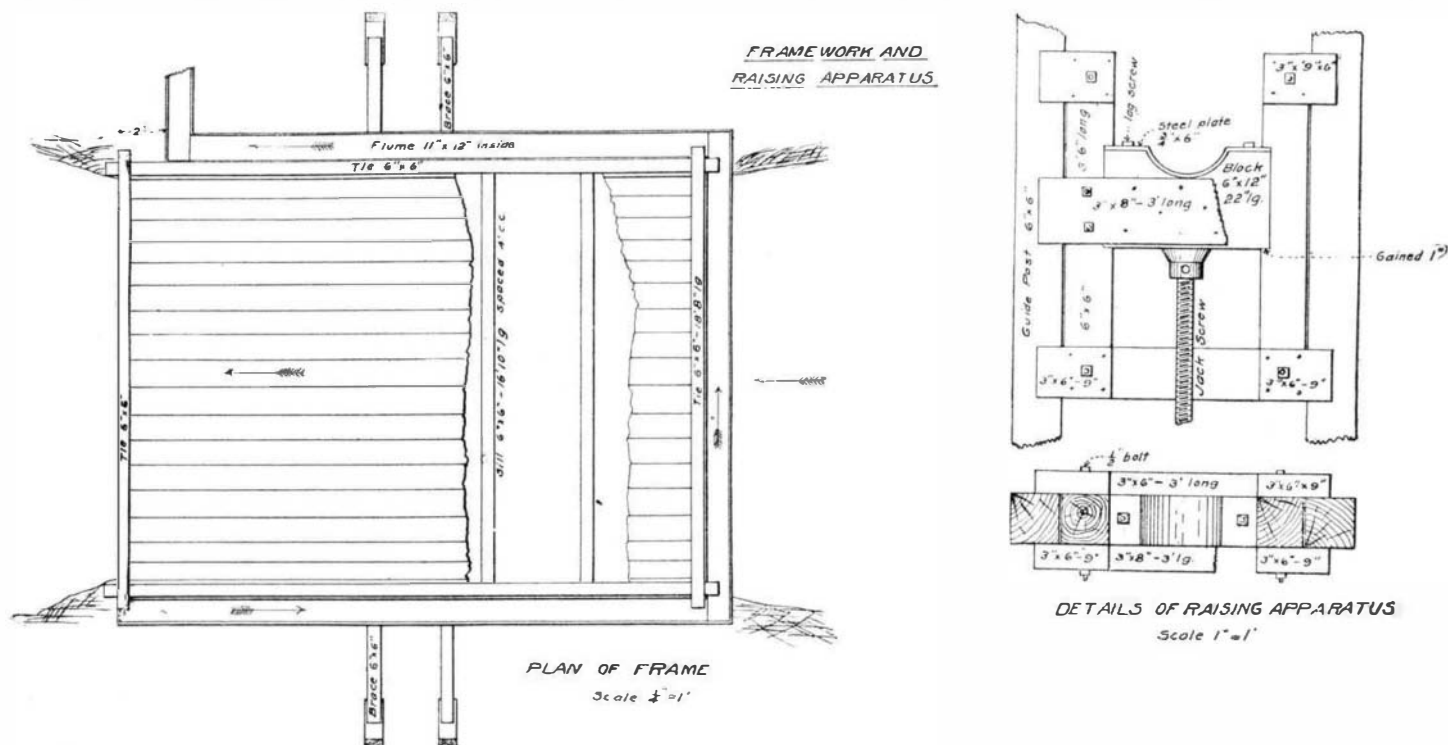


FIG. 16.—FRAMEWORK AND RAISING APPARATUS FOR WHEEL SHOWN IN FIG. 14.

evident that the friction in the bearings is greatly increased by a comparatively slight bending of the shaft.

The wheel raised sufficient water to irrigate the 2.25 acres in forty-eight hours, the water being applied four or five times in the season. It should then raise sufficient water for the successful irrigation of forty acres using the water for one hundred and sixty days.

#### Direct-Lift Wheels in Idaho.

In the Payette Valley, Idaho, are a dozen direct-lift wheels of the same general type shown in Fig. 14. This large wheel is very carefully made, fitting into a flume with only 2 inches clearance. The construction is shown in Figs. 14, 15, 16, and 17. The crude method of raising and lowering the wheel contrasts with its excellent workmanship. At the end of the season it is laboriously raised out of the water by jacks and is blocked up till the opening of another season. While in use it remains at one height regardless of the stage of the water.

In several ways the efficiency of this wheel could be raised. When the water is too high to run the wheel to advantage, part of it could be carried away in a second flume, leaving just enough running under the wheel to give the greatest speed. Or, better still, a "stop" could be placed in the ditch and the water run into the flume under a gate, giving it great velocity. In a great many cases a "stop" or "drop" already existing in a ditch could be utilized to good advantage in this way.

The cost of the wheel, flume, and supports was \$150. For six years there were no repairs and no running expenses except for grease and for raising and lowering the wheel twice in a season. In the seventh year, 1903, repairs cost \$50, mainly for a new shaft, and in subsequent years repairs will doubtless be required to the extent of \$10 or \$15 a year.

Twenty-five acres in alfalfa and fruit are irrigated by this wheel, the value of the crops raised being estimated at \$2,337 annually.

#### DIAMOND TOOLS.\*

By G. C. HENNING, New York, Member of the Society.

STEEL is, of course, the one material in almost universal use for cutting and working stone, metal, wood, and other materials, because of its great strength and the degree to which it can be hardened. There are some materials, however, which, because of their hardness, structure, or non-conductivity of heat, cannot be worked economically by means of steel tools. The latter become worn rapidly, losing their shape and dimensions to such degree and extent that the work produced becomes inaccurate, causing constant interruption of operation, loss of time, and the use of new tools or frequent regrinding or shaping of the old ones. This causes great expense and delay in production.

The great friction produced by cutting materials in some cases draws the temper of steel tools, making them useless.

Hard rubber, paper and hardened steel cannot be readily worked by use of steel tools, as is also the case with hard stone. In these cases a much harder material is required, and for this reason diamond is used. The diamond which is used is of two kinds, totally different in appearance and quality.

well as clear and transparent as glass. The latter is considered of greater hardness than all other bort except some which is almost black. Bort is extremely brittle and is readily fractured or "cleaved" in the three directions of its cleavage planes parallel to the sides of the octahedral crystal, in which shape it is most commonly found. The dodecahedral crystals are also readily cleaved in a similar manner.

In spite of the very great hardness of all kinds of diamonds, they are readily sawn, drilled, cut and polished; carbon (black diamond) cannot, however, be polished, as is the case with bort. Diamond cuts diamond, while steel saws and drills and cast-iron disks, charged with diamond dust, are used for the other operations.

All kinds of grinding wheels, being made of extremely hard materials, are most readily kept free from filling or glazing and in perfect shape by diamond tools. In certain classes of work, where great accuracy and precision are primary requirements, or extremely fine lines are essential, the diamond is the only material that answers the purpose. Thus lithographers, engravers, and scale-makers use them for

sawed by the use of diamonds, these having been used in core drills, which, in an extreme case, have cut solid cores of about 21 inches diameter. In diamond drills, stone saws and grinding wheel dressers, the rough diamond is used in appropriate holders, set either by staking, brazing, soldering, or by casting molten steel around the diamonds. A peculiar property of the diamond is that it can be plated like any metal; this property is made use of in the galvanoplastic setting. The galvanoplastic setting consists in first plating the diamonds and then casting other molten metal around them, which alloys with the deposited metal. Thus an absolutely firm and rigid setting is produced. Very high temperature does not affect the diamonds either in their hardness nor, when sound, in their solidity, and does not produce checks or other flaws. A temperature higher than that sufficient to melt steel will, however, burn the diamond, and that of the electric arc will do so readily. The diamonds in tools used for doing accurate work are, however, all "shaped" by cutting and polishing, so as to imitate the customary shapes of steel tools.

Glass and china are also drilled by shaped diamonds,

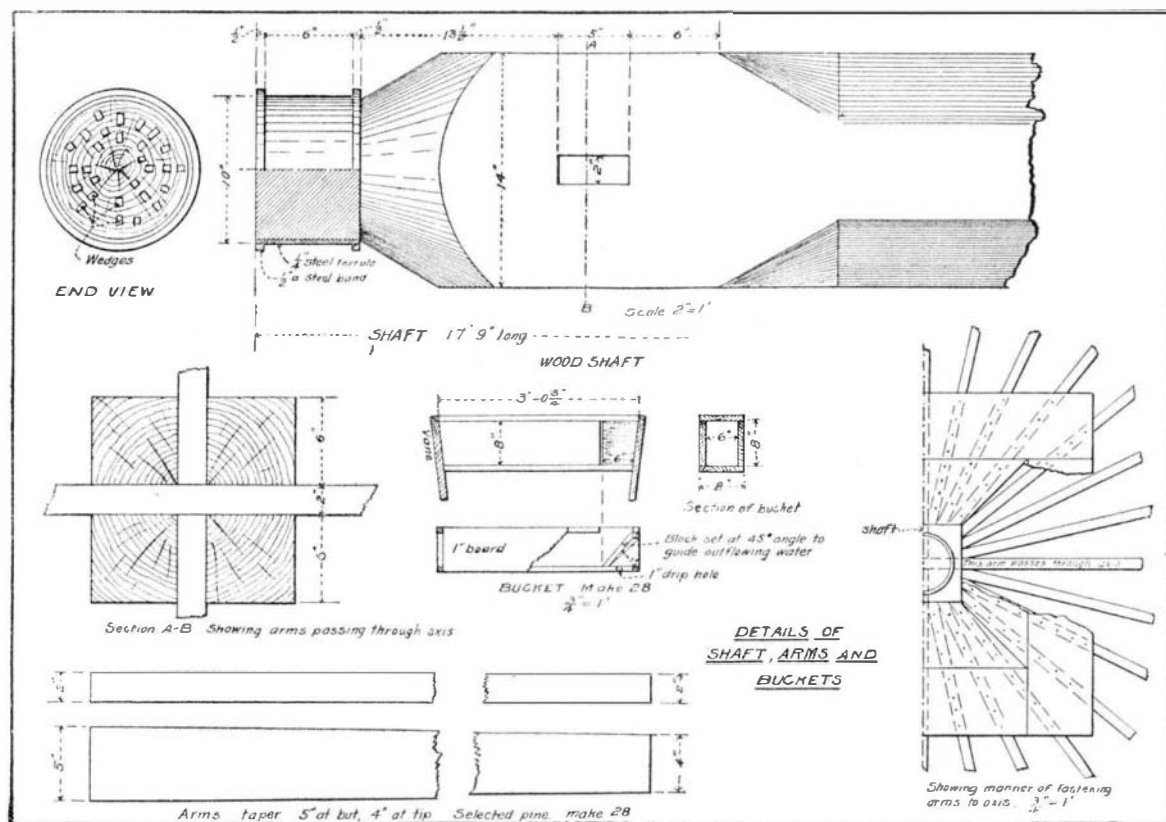


FIG. 17.—DETAILS OF WHEEL SHOWN IN FIG. 14.

fine work. There is another very important field of production in which diamond is all but imperative to obtain satisfactory results at reasonable cost, viz., that of wire drawing. Formerly all small wire was drawn through holes in hardened steel plates, but these wear so rapidly that the wire soon loses its caliber and becomes unround. As it is all-important, especially in electric work, that the wire be of absolutely uniform size, so as to maintain constant resistance and permit

in which case a triangular splint is generally provided with a flat triangular pyramidal point, which, when using turpentine as a lubricant, penetrates glass and china more readily than any other tool, and lasts for from one to two years, unless broken by carelessness or accident.

One other reason why it is economically advantageous to use diamond tools for turning hard rubber is that very high speeds can be used, 450 to 500 feet

\* Read before the American Society of Mechanical Engineers, and forming part of Volume XXVI. of the Transactions.

per minute being common. It may here be added that diamond tools are most suitable for working carbon used for electrical purposes.

In drawing copper wire, it is customary to draw a .064 wire in one pass from a rough wire of .072 diameter. Smaller sizes are then produced by the following consecutive reductions: to .053, .045, .040, .036, .032, .028, .025, .022, .020, .019, then by 1-1000 down to .0075 and by half-thousandths down to .001. It may be mentioned that diamonds wear increasingly when drawing the following metals in the order stated, viz.: gold, silver, copper, brass, bronze, platinum, soft steel, nickel, iron and crucible steel (plano wire).

In order to show why such expensive material as diamond can be used economically it may be stated that diamond dies wear up to eight years under constant use. One die of .004 caliber has, according to the record, drawn over 550,000 pounds of soft copper wire. Diamond drills for drilling glass wear from one and one-half to two years before requiring recutting. As is well known, diamonds are also used for spindle bearings in watches, and most recently have been introduced as cupped bearings for the pivots of electric meters, because they produce the minimum of friction, and do not wear out in many years.

Another purpose for which diamonds are used is that of drilling teeth, especially artificial teeth. In these drills minute chips of diamonds soldered into steel shanks are used. These diamonds are not prepared in any manner, as their points and edges when properly selected are sufficiently hard and sharp to penetrate bone and porcelain. The shapes of chips most generally used are flat, triangular points and three-sided pyramids. The most perfect drills for this purpose have diamonds of triangular sections with a pyramidal polished point.

### THE PROCESSION OF THE SUNS.\*

By AGNES CLERKE.

PHENOMENA are functions of time; and the form of the function has to be determined in each particular case. That is what the historical method comes to; and its use is prevalent and almost compulsory. We can no longer be satisfied with a simple bird's-eye view of the universe; our thoughts are irresistibly driven to grope into its past, and to divine its future. Static conceptions sufficed for our intellectual forefathers. They aimed at establishing the equilibrium of things, while we see them in a never-ending flux. One aspect of them calls up the next, and that another, and so on *ad infinitum*; we cannot, if we would, balance our ideas on the pivot of the transient present.

The immutable heavens of the ancients strike us today as the invention of a strange race of beings. We, on the contrary, see them with Shelley as a "frail and fading sphere"—a "brief expanse," the seat and scene of change. The "fixed" stars long ago broke away from their moorings, and began to flit at large through space. Of late, a less obvious, more intimate kind of mobility has been attributed to them. Grooves of individual development seem prepared for them, along which they shift as the tardy ages go by; and since everything that grows must decay, the orbs of heaven, too, incur the doom of mortality. Modern science, however, has done much more than extend to them the dismal philosophy of the phrase, "*tout passe, tout casse, tout lasse*." The grandiose enterprise has been not unsuccessfully essayed of tracing in detail the progress of sidereal evolution, and of marshaling the vast stellar battalions in order of seniority. This has been rendered feasible by the disclosures of the spectroscope. Apart from their guidance, the track might have been glimpsed here and there, but could never have been laid down with any approach to definiteness. Herschel found for it a *terminus a quo* in nebulae of various forms, but attempted to pursue it no further. We do not hesitate to run it on, from station to station, right down to the *terminus ad quem*—not, indeed, without the perception of outstanding difficulties and insecurities. They appear, however, to be outweighed by a certain inevitableness of self-arrangement in the visible facts.

The argument from continuity is that mainly relied upon. An unbroken succession of instances is strongly persuasive of actual transition, provided only that a principle of development (so to call it) may reasonably be assumed as influential. A series of mineralogical specimens, however finely differentiated, does not suggest the progressive enrichment of one original mass of ore. In the stars, on the other hand, a species of vitality may be said to reside. They are not finished-off products, but self-acting machines. They are centers of energy, which they dispense gratis, supplying the cost out of their own funds. And the process is not only obviously terminable, but must be accompanied by constitutional alterations, which might be traceable by subtle methods of inquiry. They are traceable, unless we are deceived by illusory appearances.

Secchi's classification of the stars was unwarped by any speculative fancy. It was purely formal; it aimed only at providing distinct compartments for the convenient arrangement of a multitude of differently characterized items of information. Then by degrees, the close gradation of one class into the next came to be noticed; the partitions melted away; the methodized array showed itself to be in movement; and the bare framework took shape, under the auspices of Zöllner and Vogel, as a cosmic pedigree. The white stars were set forth as the progenitors of yellow, yellow of red stars; and the insensibly progressive reinforce-

ment of the traits of relationship between the successive types went far toward demonstrating some partial, if not a complete, correspondence of the indicated order with the truth of things. It has since been found necessary to divide the first stellar class into helium and Sirian stars; and here, too, essential diversity shades off imperceptibly into likeness approximating to identity. All the groups hang together; the entire scheme is on an inclined plane of change. Helium stars, as they condense, pass into Sirian, these into solar stars; which finally, reddening through the increase of absorption, exhibit the badge of post-meridional existence in fluted spectra. The finality of the red stage is, indeed, very far from being absolute, but what lies beyond is matter of conjecture.

There are several good reasons for taking helium stars to be the "youngest," or most primitive of the amazing assemblage that sparkle in the vault of the heavens. The first is their affinity with nebulae. Every star, perceived to be involved in folds or effusions of shining haze, has yielded—if bright enough for profitable examination—a spectrum of helium quality. Further, they are remarkably tenuous bodies. It has been ascertained with some definiteness, from the investigation of stellar eclipses, that helium stars are commonly, perhaps invariably, of far slighter consistence than the sun. Radiation, however, is maintained by contraction; hence, orbs at the outset of their course must be, on the whole, the most diffuse. A third note of youth is membership of embryo systems; and this is affixed very markedly to helium stars. One-third certainly, probably one-half of those lately submitted to trial by Profs. Frost and Adams proved to have spectroscopic companions. They are pairs believed to have been recently (in the cosmic sense) divided by fission. And this is an operation which must, we should suppose, be undergone early, or not at all.

The spectra of helium stars are peculiar and suggestive. Those belonging to Miss Maury's earliest groups—many of them visibly nebulous—bear next to no traces of metallic absorption, showing instead lines of oxygen, nitrogen, and of hydrogen in all its three series. The conditions, accordingly, needed to produce the "cosmic" modification of hydrogen are realized in these inchoate bodies. What those conditions actually are, we cannot tell; yet it may be confidently surmised that they will prove to be of an electrical nature. Hydrogen resembles the metals in being electro-positive; it collects at the negative pole during the electrolytic decomposition of water. There is, however, an unmistakable tendency in primitive sidereal objects to display absorption-rays of electro-negative rather than of electro-positive elements. It is conceivable that hydrogen may be capable of altering its behavior in this respect; and that the molecules radiating the Pickering and Rydberg series, in addition to the more familiar Huggins series, have, in fact, through some corpuscular re-arrangement, assumed the electro-negative quality properly characterizing a non-metallic substance. The association of this form of hydrogen with oxygen and nitrogen in early helium stars could thus be more naturally related to the simultaneous quasi-disappearance from them of the spectral badges of metals.

The helium-line most distinctive of this stellar family is situated well up in the blue. It appertains to the same vibrational sequence with D<sub>3</sub>, which is also represented, at any rate in Rigel, a somewhat "advanced" Orion-star. Here, too, we meet a fairly prominent magnesium-ray, lying below the blue helium emanation; while as yet iron is unapparent. Numerous fine, faint streaks, due to its absorption, emerge, however, when the Sirian type is fully reached, and they are mostly of the "enhanced" kind. When the spark-discharge is substituted for the arc as the source of illumination, certain lines in the resulting spectrum brighten relatively to the others; and these have been distinguished by Sir Norman Lockyer as "enhanced." Now, the rule is strikingly prevalent that the absorption-rays in white stars are of this class; yet it can no longer be interpreted as indicating for them an excessively high temperature. Rather, it would seem that electrical conditions, still imperfectly defined, are in question; and their gradual removal, or subsidence, is, beyond doubt, largely instrumental in bringing about the transition to the solar stage. The effacement of helium-absorption is even more perplexing. No sooner does iron begin to show than it vanishes. There is still a faint trace of its "blue" line in Vega; none survives in Sirius.

In spectra of the solar type, two great bars of violet light are stopped out by calcium; otherwise, metallic arc-lines predominate, while those of hydrogen are no longer so powerfully emphasized as in white stars. Moreover, the whiteness of the unveiled Sirian photospheres has become tinged with yellow owing to the development of a shallow envelope partly impermeable to blue rays. For this reason, the comparative extension of their ultra-violet spectra affords, for stars of different types, no secure criterion of relative temperature. Sound in principle, it becomes inapplicable when the unknown factor of general absorption comes into play. The energy-curve of the solar spectrum as it is, can be determined; the energy-curve of the solar spectrum as it would be if unaffected by general absorption, has to be constructed from inference. But only bare photospheres give congruous results. Hence, there are no valid grounds for asserting that Sirius is hotter than the sun, or the sun than Betelgeuse. It may be so, but the evidence at present available is inconclusive. The appearance expounded in this sense may bear quite different meanings.

The reasons for holding that solar stars mature into Antarian stars are of the same nature, and of equal cogency with those tending to prove their own development from luminaries of earlier types. There is a similar continuity of specimens. They can be ranged one after another in an unbroken series, in which, as we descend the line, primrose shades into orange, and orange into red, general absorption arrests an increasing percentage of the blue radiations, while specific absorption becomes strengthened by dusky flutings of titanium. Carbon-stars are less easily located. Dr. Vogel regarded them as co-ordinate with the Antarian class. The two varieties of red stars with banded spectra descend, in his opinion, from the common stock exemplified by our sun. Prof. Hale also favors this view, some attendant anomalies notwithstanding. His photographs have certainly established for carbon-stars links of relationship both with the Antarian and the solar families; yet the fact remains indisputable that the carbon type is, to a great extent, isolated from all the rest. Tokens of a genuine migration toward it are few and obscure.

The ultimate fate of both tribes of red stars can only be conjectured. Most vary in brightness, some to the verge of periodical extinction; and variability may be a symptom of interior dilapidation. The constitution, however, of such objects is still enigmatical. They appear to be exceptionally remote and inaccessible to inquiry. No indications have been gathered as to their density or intrinsic light-power. Very little is known about their movements. They rarely form binary combinations, and those that they do form are almost always relatively fixed. No red star travels in a computed orbit; only one,  $\gamma$  Geminorum, occurs on the long list of spectroscopic binaries. The revolutions of this curious system ought to prove, when thoroughly investigated, or high interest and instruction.

Coupled stars offer special opportunities to students of cosmogony. They are obviously contemporaries; they have started fair; identical influences have acted upon them; hence differences in their standing can only result from dissimilarities in mass or composition. It is commonly taken for granted that a body containing less matter than its fellow must develop faster, and incur the final quenching sooner. But Sir William and Lady Huggins have adverted to the probability of the very opposite being the case. Powerful surface gravity may, they consider, serve to hasten the transition from a Sirian to a solar spectrum; and we should then have giant suns like Capella advanced in type while at a very early stage of condensation. This, perhaps, explains the remarkable spectral relations of contrasted stellar pairs. Always, so far as we yet know, the Sirian spectrum is yielded by the lesser star, the mass of which, judging by analogy, must be small even below the proportion of its faintness. It is true that the distribution of mass in binary systems is often widely different from what might have been anticipated. Certain purplish satellites, for instance, of undetermined spectral quality exercise a gravitative sway of surprising force. Some results of this kind, lately obtained by Mr. Lewis and others, are likely to prove of fundamental importance to theories of stellar evolution.

What we know of "dark stars" has been mainly derived from the observation of stellar systems. They are assumed to be the denizens of a stellar Hades, dim wanderers amid the shades, who "have had their day, and ceased to be" as suns. In the "cold obstruction" of these viewless orbs the grand cosmical proceession is held to terminate. Their presence attests the downward progress of decay, and gives logical completeness to the argument for development. Yet there are circumstances warning us against too full an assurance that their status is really that of skeletons at the feast of light. They are very frequently found to be in close attendance upon brilliant white stars. Thus intimately, if incongruously coupled, they circulate, and compel circulation in brief periods, as members of systems just, it might be said, out of the shell. What are we to think, for instance, of the obscure body spectroscopically discovered to control the revolutions of the chief star in the Orion trapezium? It is evidently comparable in mass with that imperfectly condensed luminary; is it credible that it has already traversed all the stages of stellar existence, and cooled down to planetary rank? So violent an assumption should, at any rate, not be made without due consideration; and we may more prudently hold our judgment in suspense as to whether globes so circumstanced—and they abound—should be regarded as effete, or as abortive suns.

Speculations on the exhaustion of stellar vitality have, however, lately become inextricably involved with the complex problem of elemental evolution. A dim inkling has been acquired of the working in the universe of obscure forces, availing, we can just see, to falsify many forecasts. The theory, at least, of the dissipation of energy needs important qualifications. Nor was it propounded by Lord Kelvin with dogmatic certainty. He carefully noted the possibility that in "the great storehouses of creation" reserves of energy might be provided by which the losses incurred through radiation could be, wholly or in part, made good.\* The anticipated possibility is, perhaps, realized in the phenomena of radio-activity. But if we inquire how, we are met at the threshold by difficulties connected with the origin of helium. Helium appears to result from the disintegration of radium, its generation being accompanied by the setting free of enormous quantities of energy. Its copious presence,

\* Thomson and Tait, "Natural Philosophy," Appendix E, p. 494, edition 1890.

\* Knowledge.