These general estimates are indefinite, and the minima, mean, and maxima are alike unworthy of final acceptance; but they stand for a real problem and not a merely ideal one, and represent actual conditions of the known earth; and, so far as the science of geology is concerned, the maximum estimate is quite as probable as the minimum, while the mean is much more probable than either.

As commonly made, the physical and astronomical estimates of the age of the earth are based on the assumption that the planet is (1) homogeneous, and (2) simple in structure. Thus the cooling of the earth would appear to be assumed analogous to that of a heated spheroid immersed in an ocean, and cooling at a rate determined by relative temperatures of spheroid and water, i.e., at a progressively decreasing rate. Now the actual planet is (1) heterogeneous and (2) complex in structure; and it may be questioned whether sufficient allowance is made for these facts in the non-geologic estimates.

By reason of terrestrial heterogeneity, the temperature of the earth's surface is not directly dependent on the relative temperatures of the terrestrial interior and surrounding space, but is chiefly determined by a complex and wonderfully efficient mechanism for collecting and conserving solar heat, in which the atmosphere and the liquid envelope play important *rôles*. Most geologists and physicists are of opinion that glacial periods might be explained by geographic changes, and hesitate to adopt such a theory only because of the dearth of positive evidence, or the existence of negative evidence, of such changes; and it is commonly recognized that, other conditions of sun and earth remaining unchanged, the earth might be materially chilled or warmed if the land and sea were disposed in zonal or meridional belts in such manner as to cut off or facilitate aqueous and aërial circulation. There is, indeed, reason for supposing that if the earth with its present mean interior temperature were divested of its heat-conserving mantles of air and water it would become a frozen planet. Thus, whatever may have been the case in the pre-geologic stages of planetary development, the present temperature of the external earth, and so its rate of cooling, depends on the sun rather than on the proper heat of the planet; and if (as is probable) the aggregate quantity of air and water enveloping the planet is diminishing, the efficiency of the terrestrial mechanism for conserving solar energy must have been even greater during the earlier ages of geologic development than now.

Again, the earth is complex in chemic constitution, and, moreover, it is probable, if not certain, that this complexity is correlated with temperature. If the course of terrestrial development, as commonly recognized, could be reversed for a time, the constitution of the earth-crust would be materially modified; as the temperature rose through a few degrees, the oxidation and fermentation of certain substances would doubtless be accelerated; with a few dozen degrees increase, life would be destroyed and the highly complex compounds manifesting that form of energy would be broken up; with a few hundred degrees rise, the coals would be consumed and the carbonaceous shales and limestones would be transformed, and these changes would be accompanied by profuse development of energy in the form of heat; and with a few thousand degrees increase in temperature, most of the compounds of the earth-crust would be modified or destroyed and the elements separated or re-combined in simpler forms. Consideration of the effects which would necessarily follow reversing the mechanism of planetary development indicates that the history of planetary growth is one of chemic differentiation coupled with molecular degradation, in which at least such molecular undulations as those of light and heat have progressively decreased in vigor. Moreover, this law appears to pervade the cosmos. It is probable that, as long since suggested by Kirkwood, the temperature of the cosmic bodies varies directly, while their chemic complexity (as determined by the spectroscope) varies inversely with their volume; and the meteorites, which give some indication of the constitution of other parts of the solar system, if not of still more distant portions of the cosmos, are made up chiefly of elements common to the earth, yet are united in frequently distinct and usually simpler compounds. Thus the phenomena of the planet, of the cosmos in general, and of meteorites appear to express a law of inverse relation between chemic constitution and temperature, i e., a law of chemic differentiation accompanying molecular degradation; and this law is in accord with the results of some of the latest researches concerning the ultimate relations of matter and energy. It follows that an aged planet like the earth must have stored up within it a vast amount of latent molecular energy; and incidentally that the law of cooling based on bodies of simple constitution is inapplicable. So it may be questioned whether the simple law of cooling, supposed to indicate the age of the earth, is more trustworthy than would be a formula for the volume-temperature relations of H_2O, derived from laboratory experiments on ice when extended to a body of the same substance passing through the gaseous, liquid, and solid conditions; or whether the simple law of cooling deduced largely from laboratory experiments conducted under circumscribed conditions are much more applicable to the highly complex earth than to the body of a hibernating animal.

In short, the geologic estimates of the age of the earth are based on direct observation under actual conditions so fully known, that, although certain factors are variable, all may be safely assumed to be known; while the factors involved in the non-geologic estimates — surface and sub-surface temperatures, thickness of the earth-crust, properties and conditions of rocks, etc. — must be furnished by the geologist, so that, at the best, such estimates represent nothing more than the grist ground from a mathematical mill; and, moreover, it usually happens that unknown factors are introduced to give texture to the product, but which, at the same time, so far adulterate the grist as seriously to affect its value. The geologic estimates concerning the age of the earth are based on real processes and actually observed conditions in such manner as practically to eliminate inaccuracies growing out of complex and unknown factors, and are thus strictly pertinent to the case; while the non-geologic estimates are based on ideal conditions immeasurably simpler than those actually attending a planet, and thus, interesting and instructive as they are in the abstract way, have very little to do with the concrete case.

It is significant that the discussion of geologic process by students who are not geologists is commonly trammeled in two diametrically opposite ways. The student of the "exact" sciences is seldom willing to grant so high a degree of mobility in the terrestrial crust as is required by the geologist to explain current continent movements, and is given to rejecting or ignoring the evidence of such movements; while, on the other hand, he is the first to reject as excessive the time-estimates of the geologist based in part on, and in complete harmony with, these observed movements. This mental habit, growing out of the methods and postulates employed in certain lines of study, is constantly to be borne in mind in weighing non-geologic opinion concerning the rate of geologic process, just as the opposite tendency on the part of geologic study is to be guarded against.

THE STANDARD COLOR SCHEME.

BY J. H. PILLSBURY, NORTHAMPTON, MASS.

IN *Science* for Feb. 26, 1892, I gave a brief account of a colo scheme, first proposed by myself in 1880, and set forth in mor elaborate form in a paper read before a meeting of the Society o American Naturalists held in Boston, Dec. 31, 1890. During th present year, through the courtesy of the Department of Physic of Wesleyan University, of whose laboratory and apparatus I wa allowed free use, the standards previously selected by the con sensus of a number of color experts have been located by wave lengths and, as far as possible, also by the prominent absorptio lines of the solar spectrum. Since there are vibrations of an ir finite variety of wave-length, any number of standards might b selected, but it is not, of course, desirable to select a larger num ber than the eye can readily distinguish. Six colors are clearl recognized by every normal eye in the solar spectrum, and th number has been chosen for the scheme of standard colors, a being both convenient and practical. These colors are red, orang yellow, green, blue, and violet. For the area of the solar spe trum taken for measurement, which we will call the unit of the color, a patch of the spectrum obtained by a diffraction grating, representing a range of fifty ten-millionths of a millimetre in wave-length, was selected. This gives an area of color of convenient size for comparison, and one which appears quite homogeneous to the eye, even in those parts of the spectrum where the change is most rapid. The wave-lengths here given represent the centre of the area selected. The location of the standards with relation to the absorption lines of the spectrum, where such a location was possible, will give a convenient means of ascertaining the position of the standards I have selected without recourse to the elaborate method required in the use of the goniometer.

The Standard Spectrum Colors.

Color.	Wave Length.	Location by Prominent Solar Lines.
Red	6587	Above the "C" line.
Orange	6085	Between lines 6123 and 6066.
Yellow	5793	Between lines 5816 and 5763.
Green	5164	Between lines 5189 and 5139.
Blue	4695	No prominent lines.
Violet	4210	No prominent lines.

To obtain the intermediate hues, which it may seem desirable to introduce between these standards, these should be combined in inverse proportion to what the artists call the "value" of the colors. This is not, perhaps, easily determined, yet its approximate measure can be ascertained with sufficient accuracy for this purpose. These, however, are of much less consequence than the standards. Using Maxwell discs in these standards, the following formulæ will serve to illustrate, viz.:—

Orange Red *R* 70, *O* 30, Red Orange *R* 41, *O* 59.

Here the orange, having what the artist calls a higher "value," is used in a smaller proportion than the red. The same will be true in producing the tints and shades of any color. The amount of white or black to be used must be determined by the value of the color.

It has been urged in objection to the spectrum colors that they are not the colors of nature. In reply to this objection, it should be said that nature has no other colors than those of the spectrum. With these, however, are combined more or less of white light and shadow, producing the beautiful effects which so charm us in the landscape as it is spread out before us. For purposes of instruction, a series of what we may call "broken" colors is valuable. These are mixtures of the standards with both white and black, in given proportions. The amount of white and black must be determined, as in the case of tints and shades, by the value of the color. For advanced educational purposes, these broken colors are valuable, but should not be used until the student is well grounded in the knowledge and use of the standards.

The adoption of this scheme for practical purposes is also a subject of interest. By the use of the Maxwell discs, made in these standard colors, it is possible to determine the components of any color with which one may meet. The formula for such an analysis will enable anyone, by means of a similar set of discs, to reproduce the color with perfect ease. New combinations of color may also be produced with equal facility. In cases of experimentation, to ascertain what combinations of color would be harmonious, this is a great saving of time, labor, and cost.

The use of such terms as vermilion, emerald green, ultramarine, and other similar terms to express the results of analysis, is impracticable in the extreme, on account of the variability in the use of the terms.

Discs made in these standards are manufactured and can be furnished at a moderate price. These discs are at present made in pigments, which are excellent reproductions of the spectrum hues. Some of them, however, can be produced in the brilliancy required only by the use of analine colors, and these are not permanent when exposed to the light. For this reason they must be carefully protected when not in use and have to be frequently renewed.

MISSOURI OFFICIAL GEOLOGICAL REPORTS.

BY F. A. SAMPSON, SEDALIA, MO.

THE late publications of the geological survey of Missouri contain lists of the reports of the survey, which lists are not complete and give but a part of the official geological reports of the State; the four below mentioned should clearly be added to the list.

By an act of the legislature of the State approved Feb. 11, 1839, a Board of Internal Improvements was organized to have supervision and control over all State roads, railroads, slackwater navigation, or canals. The act provided for the appointment of a chief engineer, who should cause to be compiled "a large and correct map of the State" showing in "a correct and minute manner" the geographical, topographical, and geological features of the State. In his office should be kept "all reports of engineers, geologists, and other scientific persons, either contributed by individuals or ordered by the State." A supplemental act, dated two days later, provided for surveys of four rivers, the Osage, the North Grand, the Salt, and the Merrimac, and one railroad route, that from St. Louis to the Iron Mountain.

The members of the board were appointed by the Governor, and these were assigned as commissioners of the above five routes. A State engineer and a geologist of the Osage River survey were also appointed. The journal of the board and the reports of the chief-engineer and geologist are among the scarcest of the publications of the State. I know of no copy in the State except my own. It was published in the appendix to the Senate journal of the eleventh General Assembly, 1840-41, and probably in the House journal also, but I have never seen any copy of the latter, I know of no copy of either journal in any library in the State. The report I have I found in the tower of a court-house in Central Missouri, the journal part having been torn away, but leaving the appendix complete. The title of the report is "Report of a Geological Reconnoissance of that part of the State of Missouri adjacent to the Osage River, made to William H. Morrell, Chief-Engineer of the State, by order of the Board of Internal Improvement, by Henry King, M.D., Geologist, President of the Western Academy of Natural Sciences, etc., etc.," pp. 506-525.

Professor Swallow made a report on the southwestern branch, in obedience to the act of March 3, 1857, which required the State geologist to make a thorough survey along the lines of all railroads aided by the State, and to report in detail to the president and directors "all the mineral, agricultural, and other resources which may affect the value or income of the road under their direction." But one such report was published, but this is as much one of the official reports of the survey as any other of Swallow's reports. Its title is "Geological Report of the Country along the line of the Southwestern Branch of the Pacific Railroad, State of Missouri. By G. C. Swallow, State Geologist. To which is prefixed a Memoir of the Pacific Railroad. St. Louis: Printed by George Knapp & Co., 1859." 93 pp., plates and geological map of southwest Missouri.

Another edition of this report somewhat fuller was published in New York by the Pacific Railroad Company, but I have not seen a copy of it.

The third omitted report is a short one, but it could not have been omitted on account of that fact, as Swallow's third report is still shorter. It is entitled as follows: "Report to the Board of Curators concerning the Transfer of the Geological Survey to the School of Mines, and the work executed during the year. By Charles P. Williams, Ph.D., Director Missouri School of Mines and Acting State Geologist."

When preparing the bibliography of the geology of Missouri I found this report in the catalogue of the Missouri State University for 1876, pp. 213-216, a publication in which one would not look for a geological report, but for some years the catalogues of the university contained many papers of merit, as addresses and