charge of the Observatory, that the instruments in use are a Clark equitorial telescope, focal length 10½ feet, aperture 8¼ inches; a portable equatorial made by John Byrne, of New York, aperture 4.3 inches; a Howard sideral clock; a Howard mean-time clock, a Bond sideral chronometer, a Fauth transit instrument with telescope of 3 inches aperture, a Clark chronograph; meteorological apparatus, and a complete set of Johnson's large astronomical maps, recently imported. By courtesy of Lieut. Edw. Maguire, Chief Engineer of the Department of Dakota, the Observatory has also the use of an excellent zenith telescope for special work.

The time of the Observatory is the standard for the State of Minnesota and parts of those States adjoining, and given to the railroad companies daily by telegraph. The distribution of the time of the Northfield meridian by the aid of excellent instruments, is said to be easy, exact and reliable.

The object of erecting this Astronomical Observatory appears to have been three-fold. 1. To give instruction to undergraduate students. 2. To offer opportunities for a complete course of study in Theoretical and Practical Astronomy. 3. To aid in useful investigations.

ON THE LIMIT OF PLANETARY STABILITY.

By Professor Daniel Kirkwood.

Laplace, in his *Système du Monde*, pointed out the limit at which, according to his estimate, the moon's attraction could have retained an elastic atmosphere.* The question of a satellite's stability was also considered by the late Professor Vaughan, of Cincinnati.† I have seen no attempt, however, to obtain for the different members of our system any definite numerical results. In the present paper it is proposed to find the approximate limits of stability in the cases of the eight major planets and certain of the satellites, on the hypothesis that their primitive condition was either liquid or gaseous.

Let M = the mass of the larger or central body,
m = that of the dependent planet or satellite,
x = the distance from the centre of the former to the limit of stability of the latter,
a = the distance between their centres; then, since the disturbing or separating force of the larger upon the smaller mass is the difference between the attraction of the former on the nearest point of the surface of the latter and that on its centre of gravity, we have

$$\frac{M}{x^2} - \frac{M}{a^2} = \frac{m}{(a-x)^2} \qquad (1)‡$$

or putting $a = 1$ and reducing,

$$x^4 - 2x^3 + \frac{m}{M}x^2 + 2x = 1. \qquad (2)$$

If we adopt the masses and distances given in Newcomb's Popular Astronomy and solve equation (2) for each of the eight principal planets we shall obtain the distance from the centre of each to its limit of stability, as given in the second column of the following table. If, moreover, the planets, with their present masses, be reduced to the sun's mean density their radii as stated in the third column are found by the formula

$$r^n = 430{,}000 \left(\frac{m_n}{M}\right)^{1/3},$$

and the respective ratios of the limits of stability to these radii are seen in column fourth.

* Syst. du Monde, B. IV., Ch. X.

† Pop. Sci. Monthly for Sept. 1878. See also the Proc. of the A. A. A. S. for 1856.

‡ We neglect the centrifugal force due to the planet's rotation, as the modification would be slight and we propose to obtain merely approximate results.

Table.

Planet.	R_n	r_n	$\frac{R_n}{r^n}$
Mercury	165,165 ms	2,514 6 ms	65.7
Venus	701,746	5,719.2	122.7
Earth	1,059,386	6,242.7	169.7
Mars	764,900	2,951.1	259.2
Jupiter	37,354,287	42,335	882.35
Saturn	45,859,381	28,317	1619.48
Uranus	49,512,900	15,209	3255.51
Neptune	81,663,510	16,009	5101.10

On the assumption that in each case the mean density of the separated mass was equal to that of the central body, the sun's present radius multiplied by the respective numbers in column fourth will give the radii of the solar nebula when the planets extended to their respective limits of stability. These radii are less than the mean distances of the planets in the ratio of 1 to 1.265. This fact may have some significance in regard to the former oblateness of the solar nebula or the law of its density.

The Earth and the Moon.—For the moon, which in perigee approaches within 221,500 miles of the earth, the limit of stability is about 38,000 miles. Were the moon's density reduced to that of the earth its radius would be 916 miles, the ratio of which to the limit of stability is 1 : 41.6. The moon's least distance diminished by 38,000 miles is 183,500 miles. If our satellite originally extended to the limit, and if the moon and the earth had the same form and density, the radius of the latter was 165,000 miles.

The Martian System.—The diameter of Phobos, according to Prof. Pickering, is 5.57 miles. If its density, therefore, be equal to that of Mars the limit of stability is about two miles exterior to the surface; or, if the density be to that of the primary in the same ratio as the density of the moon to that of the earth, the limit is less than a mile from the surface of the satellite; and finally if the density were no greater than that of water the satellite, if fluid, would be unstable, the limit being actually within the surface. Since, therefore, the satellite could never have existed at its present distance in a nebular state, it must follow, if any form of the nebular hypothesis is to be accepted, that its original distance was much greater than the present. Can we find a probable cause for this ancient disturbance?

If we suppose the former period of Mars to have been very nearly one-sixth that of Jupiter the close commensurability would render the orbit of Mars more and more eccentric. The planet in perihelion would thus pass through the sun's atmosphere, or rather through the outermost equatorial zone of the solar nebula. This resisting medium would not only accelerate the motion of Mars but also in a much greater degree that of his extremely small satellite. The solar mass contracting more rapidly than the orbit of Mars would finally leave the latter moving in an eccentric path without sensible resistance.

Other Secondary Systems.—For the first satellite of Jupiter the limit is 5250 miles, or 4½ times the radius of the satellite. For Mimas, the innermost satellite of Saturn, it is less than twice the radius. The rings of Saturn, in all probability, could not exist as three satellites, the limits of stability being interior to the surface.*

The effect of preturbation in the dismemberment of comets is known to all astronomers. The nucleus of the great comet of 1880, which approached within less than 100,000 miles of the sun's surface, must have had a den-

* It has been recently shown that Bessel's mass of the ring is much greater than the true value.

sity greater than that of granite, as well as a strong cohesive force between its parts, in order to withstand the tendency to disintegration during its perihelion passage. Had the nuclus been either liquid or gaseous, or even a cluster of solid meteorites, the difference between the sun's attraction on the central and the superficial parts would have pulled the comet asunder, spreading out the fragments into somewhat different orbits, like the meteoric streams of August and November.—*The Analyst.*

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. No notice is taken of anonymous communications.*]

To the Editor of "SCIENCE:"

I have much pleasure in enclosing you a copy of the particulars respecting the formation of our "Field Club," which I believe to be the third in England of similar pretentions, its original founders being Mr. Thomas Kiddie and myself, both being science students, and by profession analysts in manufactories on Coaly Tyne. We were at first inclined to restrict the Club to those of our own class, namely, Students in Chemistry, but knowing the intimate connection between all the other branches of Science and that of Chemistry, we determined to throw it open to all science students, and we are now pleased to find that our efforts have had such a successful issue so far, and met with such general approval throughout the whole district, as we have at present, after two months establishment, about 100 members, some living as far as fourteen miles from our centre; also having the countenance of fourteen gentlemen interested in scientific education as honorary members. The officers consist of students or teachers (under the Science and Art Department, London). Should you consider our club worthy a comment in your excellent journal, which latter must act as a valuable adjunct to the aims of scientific education, I shall be exceedingly obliged if you will forward me a copy to read at one of our excursions.

M. THEODORE DIXON, *Hon. Sec.*
5 BRANDLING PARK, Newcastle-on-Tyne, Eng.

[We print the above letter in the hope that it may suggest the formation of Field Clubs in the United States. The value of such organizations cannot be overrated, and we shall be glad to hear that some of our subscribers have taken the initiative in such an agreeable enterprise. We shall send information to those who desire it.—ED.]

CHEMICAL NOTES.

THE MARQUIS TOMMASSI has succeeded in sending a message across the Atlantic with two Minotto elements.

AN APPLICATION OF ACCIDENTAL IMAGES.—J. Plateau, from some experiments performed by his son, concludes that the *apparent* distance of the full moon is only 50 metres from the observer.

PROPAGATION OF LIGHT.—M. Gouy has shown that there is not, for a given homogeneous source, a determined speed of light independent of the manner in which the amplitude is caused to vary.

PHYLLOXERA IN FRANCE.—It appears that more than a third part of the vines in France have been already destroyed by the phylloxera. The departments of Haute Savoie and Jura are now attacked.

SPONTANEOUS OXIDATION OF MERCURY AND OF METALS.—Mercury, as well as iron, zinc, cadmium, lead, copper, and tin, undergoes on exposure to the air a superficial oxidation, very slight, and restricted by the difficulty of renewing the surfaces and by the want of contact which results from the layer of oxide formed at the outset. For the oxidation to continue this layer must be constantly removed, as in the case with rust of iron formed in moist air, or for each hydrocarbonate produced in distilled water.—M. BERTHELOT.

WINES MIXED WITH GRAPE SUGAR.—The non-fermentable part of the grape sugar which is introduced into wines, if administered to dogs by way of subcutaneous injection produced vomiting and other morbid symptoms. A. Schmitz claims that these residues contain a poison similar to that present in potato-oil.

ACTION OF PHOSPHOROUS UPON HYDRIODIC AND HYDROBROMIC ACIDS.—With hydriodic acid and white phosphorous the latter melts and becomes covered with a reddish layer of biniodide, while phosphonium iodide sublimes. With red phosphorous even at 100°, there is produced merely a small quantity of phosphonium iodide. Upon dissolved hydrobromide acid, phosphorus does not react in the cold. At from 100° to 120°, phosphonium bromide sublimes, but no phosphorous bromide is produced.—A. DAMISEAU.

THE SOCIETE D'ENCOURAGEMENT POUR L'INDUSTRIE NATIONALE has awarded the Le Blanc prize of 1000 francs for the utilization of manufacturing refuse to M. Vincent, for his process for obtaining methyl chloride from the *vinasses* of the beet-root sugar manufacture. A sum of 1000 francs has also been awarded to M. J. A. Martin for his mixtures for rendering textile articles, paper, &c., uninflammable. His ordinary mixture for light goods is: Pure ammonium sulphate, 8 kilos; ammonium carbonate, 2 kilos, (5); boric acid, 3; pure borax, 2; starch 2 (for which may be substituted 0.400 kilo. dextrine, or the same weight of gelatine), and water 100 kilos. A silver medal has been awarded to M. Idrac for his process of drying timber.

A NEW ELECTRIC PROPERTY OF SELENIUM, AND THE EXISTENCE OF TRIBE-ELECTRIC CURRENTS PROPERLY SO-CALLED.—R. Blondlot has observed a new electric property of selenium which may be shown by the following experiment: To one of the poles of a capillary electrometer there is attached, by means of a platinum wire, a fragment of selenium which has been recently heated, and to the other pole a platinum foil. If the selenium is brought in contact with the platinum, holding it by means of an isolating handle, the electrometer remains at zero, as might be expected from the symmetry of the circuit; but if the selenium is rubbed against the surface of the metal the electrometer deviates strongly, the deviation obtained being equal to that produced by a sulphate of copper element.

ANALYSIS OF SUPERPHOSPHATES.—In acting upon a superphosphate made of bone-black or from the phosphate of Caceres with a solution of ammonium citrate of sp. gr. 1·09, there is no occasion to take into account the time of action or the fluctuations in the temperature of the laboratory. In the analyses of a bone-black superphosphate, an excess of citrate must be avoided—20 c.c. are sufficient for 2 grms. of the sample. An excess of the reagent dissolves part of the phosphoric acid of such tricalcic phosphate as has escaped the action of sulphuric acid in the manufacture of the superphosphate. The phosphate of Caceres is much less sensitive to the action of the citrate than the phosphate of bone-black, and here from 20 to 100 c.c. may be taken to 2 grms. of the sample.—L. CHEVRON.

DETERMINATION OF CHICORY IN GROUND COFFEE.—M. Prunier suggests the following method: Two grms. are weighed out and separated from the finer powder by sifting through fine silk. This powder which, as microscopic examination proves, is composed entirely of pure coffee, is set aside. That which remains on the sieve is macerated with a few grms. of water in a test glass. After some hours it is thrown upon a piece of cloth stretched out and crushed with the fingers. The grains of coffee resist the pressure, whilst those of chicory, reduced to a paste by soaking in water, penetrate into the cloth and adhere to it. On drying the cloth it is easy to detach the coffee, which, after dessication at 100° and addition of the fine powder separated at first, gives the weight of pure coffee. The chicory is calculated as loss.