student requires to know. For how can the action of the steam-engine be properly understood without a knowledge of the principles of fluid and gaseous pressure, and of the relation between heat and work? Yet under the present arrangement the former of these constitutes a neglected part of Subject VI., while the latter comes under Subject VIII., and is associated with matter totally irrelevant.

All these considerations seem to point to the desirability of a change in the official syllabus somewhat as follows:—

(a) To cut out Heat from Subject VIII., making the latter consist of Sound and Light only.

(b) To cut out Hydrostatics and Pneumatics from Subject VI., making the latter consist of Statics and Dynamics only.

(c) To combine Heat, Hydrostatics, and Pneumatics into a new subject having its appropriate number. These three could then be more effectively studied than under the present system, and there would be ample matter therein to form one of the courses from September to May. The syllabus of the new subject would naturally include all the points specified by the Department as necessary preliminaries to the study of Steam (*vide* Steam syllabus, Subject XXII.), and would thus supply a specific want to all engineering students.

On the whole, it is respectfully submitted to the authorities of the Department, and others interested in the education of the people, that the proposed alteration would conduce to a more thorough and systematic study of all the subjects referred to, and be attended with benefit to students both of physics and mechanics. VOLO LEGES MUTARI.

On Last-place Errors in Vlacq.

M. M. F. LEFORT, in his account of the great Cadastre tables, contained in the fourth volume of the *Annales de l'Observatoire Impérial de Paris*, gives a list of errors in Adrian Vlacq's ten-place table of logarithms. As this one by Vlacq, or its copy by Georg Vega, is the only complete table of ten-place logarithms yet in existence, we naturally desire to make it thoroughly accurate, and therefore proceed to correct it by aid of this new information.

M. Lefort tells us that Prony, in his instructions, was expressly enjoined "not only to compute tables which shall leave nothing to be desired as to exactitude, but to make them the most vast and imposing monument of calculation that had ever been made or even conceived," and, adds M. Lefort, "this programme, so widely sketched, has been faithfully carried out." Yet, on the very same page, we are told "that Prony fixed the general limit of precision for his logarithmic tables at 12 decimals"; this although the original work by Henry Briggs had been carried to 14 places.

Thus it seems that the Cadastre tables cannot be trusted to determine the absolute accuracy of those of Vlacq whenever the figures to be rejected are between the limits 4900 and 5100, and that in no case can they serve to check the final figures in Briggs.

Having scrupulously examined, by help of my fifteen-place table, all the corrections given by M. Lefort, I here give the results, in order that the possessors of Briggs, Vlacq, or Vega may make note of them.

Among 282 last-place corrections given, I find seven to be erroneous, the logarithms in Vlacq and in Vega being right. In order to make doubly sure, I have also used my 28-place table, and here give the exact figures from the 8th to the 20th place—

Number.		Logarithm.
26188	...	322 49959 00920
29163	...	978 49968 31667
30499	...	999 50010 73882
31735	...	026 49975 27403
34182	...	883 50038 92375
34358	...	753 50011 99957
60096	...	662 49998 09339

From this we see that the Cadastre tables are inadequate to the thorough checking of ten-place logarithms; in the case of the last of these miscorrections, even the fifteen-place table is barely sufficient, and needs to be fortified by an extended calculation.

Among the 275 remaining errors, five have been imported from Briggs, and I have therefore examined them to greater length; the logarithms to the 20th place are—

Number.		Logarithm.
7559	...	453 41468 90981
8006	...	857 69086 31797
8009	...	936 63054 38960
10033	...	122 46398 29224
99926	...	031 14867 68936

Thus there are left 270 errors to be charged against Vlacq; of these no less than 96 are within the limits of inaccuracy allowed by Prony.

Near the end of the list there occurs a group of 21 (from the number 98336 to 98367) which seem to have resulted from some single running error. Now this part of the table was copied from Briggs, and we should expect these errors there; but, on turning to the original work, we find that none of his logarithms differs by more than unit in the 14th place from that of the fifteen-place table, and thus the source of the errors in Vlacq becomes mysterious.

The most feasible explanation is that the errors had been observed and corrected while the sheet was at press, and that thus all the copies of Briggs are not alike. It is probable that the very copy used by Vlacq may be preserved in some one of the libraries in the Netherlands; in such case, an inspection would set the matter at rest. EDWARD SANG.

September 27.

On the Soaring of Birds.

IN answer to Mr. C. O. Bartrum's objections in *NATURE* of September 4 (p. 457), I beg to refer to an article in the *Skand. Archiv. für Physiologie*, ii. 2, in which I have given a detailed account of the weighty reasons which have led me to suppose that soaring birds are able to undertake successive alterations of direction with very little loss of *vis viva*. This loss is of the same kind as that caused by the resistance of the air to the rectilinear translation.

There is, however, one fact which, in the article in the *Skand. Archiv.*, I have thought it superfluous to point out—namely, that the manœuvre of the bird is the same, and the loss of energy thereby equally the same, whether the bird turns in a calm or in a uniform wind. If Mr. Bartrum has been led to another opinion, it may be that he has not quite made out how these turnings are executed. MAGNUS BLIX.

Lund, Sverige, October 10.

Earthquake Tremors.

IF those of your readers who are interested in this subject will turn to p. 84 of the "Report on the East Anglian Earthquake of April 2, 1884," by R. Meldola and W. White (Essex Field Club special memoirs, vol. i.), they will see that at Wivenhoe a man who felt the shock of the earth movement found to his own satisfaction, by careful measurement and calculation, that the vertical displacement where he stood amounted to no less than *six feet*. How it was that any building in Wivenhoe remained standing after so tremendous an upheaval the observer did not appear to think worth considering.

ALFRED P. WIRE.

THE PROPERTIES OF LIQUID CHLORINE.

ALTHOUGH chlorine was shown by Faraday so long ago as the year 1823 to be one of the more easily condensable gases, yet, no doubt owing in a large measure to its very disagreeable nature, comparatively little has hitherto been known concerning its properties when in a liquefied state. In view of the fact that chlorine is now stored in the liquid state for the use of manufacturing chemists in a similar manner to carbon dioxide, sulphur dioxide, and ammonia, it is imperative that something more definite should be known as to the relations of liquefied chlorine to temperature and pressure. Consequently, a very complete investigation of the subject has been made by Dr. Knietsch at the request of the directors of the "Badischen Anilin- und Sodafabrik," of Ludwigshafen; and his results, of which the following is a brief account, are published in an interesting communi-

cation to the current number of *Liebig's Annalen* (Band 259, Heft 1, p. 100).

The work includes the determination of the vapour-tension of liquid chlorine at temperatures from -88° C. to 146° C. (its critical point), a complete examination of its behaviour near the critical point and the determination of its specific gravity and coefficient of expansion for a range of temperature between -80° and $+80^{\circ}$.

Liquid chlorine generally appears to possess a yellow colour. When, however, the colour of a long column is examined, it is found to have a distinctly orange tint. The absorption spectrum does not exhibit any characteristic bands, but the blue and violet portions of the spectrum are completely absorbed, the transmitted spectrum thus consisting of the red, orange, yellow, and green.

Vapour-Tension of Liquid Chlorine below its Boiling-Point.

The apparatus used for this determination consisted of a kind of distilling flask, whose side tube was connected by means of a piece of strong-walled caoutchouc tubing with a wide manometer tube. The flask was about half filled with liquid chlorine, and was immersed in a bath also containing liquid chlorine whose temperature could at the same time be kept equal throughout, and be very finely regulated by means of a current of air driven in through a tube passing to near the bottom of the bath.

In commencing a series of determinations the chlorine in the flask was first made to boil, thereby driving out the air remaining in the apparatus. The neck was then closed by means of a caoutchouc stopper well coated with glycerine, and the open end of the manometer was allowed to dip into a vessel containing concentrated sulphuric acid. As the flask became cooled by immersing it in the cold chlorine in the bath, sulphuric acid was drawn into the manometer until it attained a height of 3-5 cm., when the caoutchouc connection was momentarily pinched while the open end of the manometer was transferred to the mercury trough. The small column of sulphuric acid thus standing above the mercury column effectually protected it from the corroding action of the chlorine. The bath was then cooled gradually, and a series of readings taken of the temperature of the bath, by means of an alcohol thermometer, and of the position of the meniscus of the mercury in the manometer. The small column of sulphuric acid was of course calculated to its equivalent height of mercury, and added to the measured height of the mercurial column. By careful use of the current of dry air the liquid chlorine of the bath was found capable of being reduced in temperature as low as -60° C. The lower temperatures, down to -88° , were attained by mixing more or less solid carbon dioxide with the chlorine. The results obtained are given in the table at the end.

Determination of the Pressure of Liquid Chlorine from its Boiling-Point to 40° C.

The data at present existing upon this subject are very meagre and conflicting. Davy and Faraday found the pressure at 15° C. to be 4 atmospheres, whilst Niemann gives the pressure at 0° C. as 6 atmospheres, and at $12^{\circ}5$ C. as 8 atmospheres. As this is a most important point in regard to the storage of liquid chlorine in metallic bottles, great pains have been taken to arrive at unimpeachable results, and as the most certain method of measuring the pressure a high column of quicksilver was employed. The apparatus consisted of a U-tube, one limb of which was narrower than the other, and prolonged upwards to a height of over 8 metres. The other and wider limb was joined at the top by means of a capillary tube to a cup, serving the purpose of a funnel for introducing the liquid chlorine. In commencing an experiment, a convenient quantity of mercury was first poured in so as to stand in the wider limb at about a quarter its height.

A column of sulphuric acid was then introduced into the wider limb so as to protect the mercury, and finally the liquid chlorine was introduced through the funnel by a process of alternately warming and cooling; the cooling was effected by pouring a little liquid chlorine over a piece of cotton wrapped round the limb and evaporating it by a strong current of air. When the limb was quite full, the chlorine occupying the capillary tube was evaporated by the warmth of a small blowpipe flame, and the capillary fused up. The apparatus was then immersed, until the wider limb was covered, in a bath of liquid sulphur dioxide for temperatures up to 0° , in ice for the determination at 0° , and in water agitated by a current of air, and either cooled by ice or warmed by a small flame for temperatures up to 40° . For the comparatively higher of these temperatures it was of course necessary to pour mercury into the longer limb so as to prevent the mercury in the wider limb being driven round the bend. Complete results are given at the end, but it may be remarked in passing that the pressure at 0° is 3.66 atmospheres; and at 15° , 5.75 atmospheres.

Determination of the Pressure at Higher Temperatures.

For these yet more dangerous and difficult experiments a metal apparatus was employed, similar in principle to that just described, except that the pressures were measured by a metal gauge manometer, which had previously been completely tested and its readings verified. It was found important in these experiments not to employ too much chlorine, as owing to the immense coefficient of expansion the whole space might become full of liquid, and further heating would cause the generation of dangerously high pressures. For temperatures up to 100° a water-bath was employed, and for the higher temperatures up to the critical point 146° an oil-bath, both kept in circulation by a rapid current of air. The pressure at the critical temperature of 146° C. was found to be as high as 93.5 atmospheres.

Critical Point of Liquid Chlorine.

The critical point was determined in a separate experiment, and some very interesting results were obtained, the yellowish green colour of chlorine perhaps assisting in rendering the appearance of what has sometimes been termed the fourth state of matter between the liquid and the gaseous more distinct than usual. A hard glass tube of 8 mm. diameter was about one-third filled with redistilled dry liquid chlorine and sealed. A small thermometer, whose readings commenced at 140° , was attached to it by platinum wire, and the whole very slowly heated in a bath of vaseline. The observations were made with the naked eye, the observer being protected from any possible explosion by a thick glass plate. At 140° extremely small bubbles began to be developed throughout the mass of liquid. At 144° the hitherto sharp meniscus began to disappear, and at 145° the presence of a liquid was only evident by the more intense yellow colour and higher refractive power of the lower portion of the tube. At 146° the contents of the tube were homogeneous throughout, the critical point being attained, and the liquid converted into gas. On allowing the tube to cool slowly, the condensation always commenced below 146° , with the formation of a cloud and a fine rain of minute yellow spheres of liquid chlorine. The rain was generally apparent throughout the whole of the upper portion of the tube. Sometimes, however, the liquid meniscus again appeared without any previous manifestation of precipitation.

Specific Gravity and Expansion of Liquid Chlorine.

It is a curious fact that many gases when compressed to the state of liquid expand enormously when heated as compared with ordinary liquids, the amount of expansion sometimes exceeding that of the gas itself. Liquid chlorine is no

exception to this rule, and it was absolutely essential that its rate of expansion should be thoroughly investigated, in order that storage bottles should not be filled to a dangerous extent. For temperatures up to 36° C. a closed dilatometer of glass was employed, the long cylindrical bulb of 60 c.c. capacity and part of the stem being filled with liquid chlorine, and the remainder of the stem with chlorine gas. The whole apparatus was immersed in a long cylindrical bath. For the lowest temperature, of -80°, the bath was filled with solid carbon dioxide. For the determination of the specific gravity at the boiling-point of chlorine, a bath of boiling liquid chlorine itself was employed, no less than three kilograms being required. Between the boiling-point and 0° the substance used in the bath was liquid sulphur dioxide. For the determination at zero powdered ice was employed, and for the higher temperatures a water-bath kept in motion by an air current. It was not possible to proceed higher than 36° with this apparatus, on account of the danger of explosion. The higher determinations were made by means of a hydrometer suspended in liquid chlorine enclosed in a tube of hard glass which was immersed in a glass water-bath heated to the required temperature.

It will be seen from the following table that liquid chlorine is indeed a very expansible substance. The coefficient of expansion at 80° is already 0.00346, nearly equal to that of gaseous chlorine, and is rapidly increasing, so that before the critical temperature of 146° is attained, the coefficient of expansion will be considerably higher than that of the gas.

Following is a table showing the pressure, specific gravity, and coefficient of expansion of liquid chlorine for every 5° of temperature from -80° C., calculated from the formulæ derived from the experimental data obtained.

Temperature.	Pressure.	Specific gravity.	Mean coefficient of expansion.
-102° C. ...	Solid (Olzewski).	...	—
- 88 ...	37.5 mm. Hg.	...	—
- 85 ...	45.0 "	...	—
- 80 ...	62.5 "	...	—
- 75 ...	88.0 "	1.6602	0.001409
- 70 ...	118 "	1.6490	
- 65 ...	159 "	1.6382	
- 60 ...	210 "	1.6273	
- 55 ...	275 "	1.6167	
- 50 ...	350 "	1.6055	0.001793
- 45 ...	445 "	1.5945	
- 40 ...	560 "	1.5830	
- 35 ...	705 "	1.5720	
- 33.6 ...	760 "	1.5589	
- 30 ...	1.20 atmospheres	1.5575	0.001978
- 25 ...	1.50 "	1.5485	
- 20 ...	1.84 "	1.5358	
- 15 ...	2.23 "	1.5230	
- 10 ...	2.63 "	1.5100	
- 5 ...	3.14 "	1.4965	0.002030
0 ...	3.66 "	1.4830	
+ 5 ...	4.25 "	1.4690	
+ 10 ...	4.95 "	1.4548	
+ 15 ...	5.75 "	1.4405	
+ 20 ...	6.62 "	1.4273	0.002190
+ 25 ...	7.63 "	1.4118	
+ 30 ...	8.75 "	1.3984	
+ 35 ...	9.95 "	1.3815	
+ 40 ...	11.50 "	1.3683	
+ 50 ...	14.70 "	1.3510	0.002260
+ 60 ...	18.60 "	1.3170	
+ 70 ...	23.00 "	1.2830	
+ 80 ...	28.40 "	1.2430	
+ 90 ...	34.50 "	1.2000	
+ 100 ...	41.70 "		0.003460
+ 110 ...	50.80 "		
+ 120 ...	60.40 "		
+ 130 ...	71.60 "		
+ 146 ...	93.50 "	Critical point.	

An interesting result, which is not noticed by Dr. Knightsch in his paper, is obtained on calculating the specific volume of chlorine from the determination of specific gravity at the boiling-point, -33.6°. On dividing the atomic weight 35.5 by 1.5575, the specific gravity at the boiling-point, the number 22.8 is obtained for the atomic or specific volume of chlorine, a number practically identical with that derived by calculation from the numerous determinations of the specific volume of compounds containing chlorine.

In this respect chlorine resembles bromine and the compound radicles NO₂ and CN, which were shown by Prof. Thorpe (Journ. Chem. Soc., 1880, 382) to occupy the same volume in the free state as in combination.

A. E. TUTTON.

ELECTRICAL STORMS ON PIKE'S PEAK.

THE "Annals of the Astronomical Observatory of Harvard College," vol. xxii., contains the meteorological observations made at the summit of Pike's Peak, Colorado, at a height of 14,134 feet above sea-level. It is not remarkable that such an elevated station should be celebrated for its electrical storms, and the observers from 1874 to 1888 have recorded many interesting details in the journals respecting their physical and physiological actions.

The manifestation of atmospheric electricity by induced effects is often very strongly marked. During the passage of electrified clouds over the summit of the peak the well-known singing and buzzing noises described as an adjunct of St. Elmo's fire were heard to proceed from the telegraph wires, the exposed instruments, the instrument shelter, and the house. The sound is said to be very similar to the buzzing of bees and crackling of burning evergreens. At times the hair of the observers became upright and strongly repellent, and the same peculiar noise proceeded from it.

Some very remarkable effects are recorded on August 18, 1877:—"During the evening the most curiously beautiful phenomena ever seen by the observer were witnessed, in company with the assistant and four visitors. Mention has been made in journal of May 25 and July 13 of a peculiar 'singing' or rather 'sizzling' noise on the wire, but on these occasions it occurred in the day-time. To-night it was heard again, but the line for an eighth of a mile was distinctly outlined in brilliant light, which was thrown out from the wire in beautiful scintillations. Near us we could observe these little jets of flame very plainly. They were invariably in the shape of a quadrant, and the rays concentrated at the surface of the line in a small mass about the size of a currant, which had a bluish tinge. These little quadrants of light were constantly jumping from one point to another of the line—now pointing in one direction and again in another. There was no heat to the light, and when the wire was touched only the slightest tingling sensation was felt. Not only was the wire outlined in this manner, but every exposed metallic point and surface was similarly tipped or covered. The anemometer cups appeared as four balls of fire revolving slowly round a common centre: the wind-vane was outlined with the same phosphorescent light, and one of the visitors was very much alarmed by sparks which were plainly visible in his hair, though none appeared in the others'. At the time of the phenomenon snow was falling, and it has been previously noticed that the 'singing' noise is never heard except when the atmosphere is very damp, and rain, hail, or snow is falling."

These displays were described with the same minuteness on June 7, 1882. It was then noticed that when the finger was passed along the line the little jets of flame were successively puffed out, to be instantly relighted in the rear. An observer also found that when he approached