winds in a cyclone, it may be an important aid to central warmth.

Water-spouts are closely allied to tornadoes: but when seen in small form they approach the character of simple desert-whirls; that is, they then depend merely on air warmed at the place where they occur, and not on the running together of warm and cold winds from other regions. A probable cause for the excess of their strength above that of the sand-whirls lies in the smoothness of the water-surface on which they spring up, which will allow a long time of preparation; and in the moisture in the air, which will cause the warming of a greater thickness than if the air were very dry. The greater the thickness, the more their action will resemble that of a typical tornado. The appearance of the downward extension of the funnel-shaped cloud to meet the rising column of water is almost certainly only an appearance, and has the explanation already quoted from Franklin's ingenious writings.

We have relied largely, in the preceding explanations, on deductions from general principles, checked by the results of observation. The writings of many investigators have been examined, and in a few cases their names have been given; but the literature of the subject is now so extensive that full reference has been deemed unadvisable. Little attention has been paid to the older theories, in which conflicting winds and electricity were looked on as the chief causes of storms. The latter is regarded as an effect rather than a cause; and, while the former has much importance when rightly considered in connection with the earth's rotation, it is of small value as originally stated, and is then limited to the production of short-lived storms in mountainous districts. The more important factors of the modern theory of storms are the consideration of the conditions of stable and unstable equilibrium of the atmosphere, the true measure of the action of condensing water-vapor, the full estimation of the effect of the earth's rotation, and the recognition of the necessary increase in the wind's velocity as it is drawn in toward the storm-centre. W. M. DAVIS.

THE CRITICAL STATE OF GASES.

THE *Philosophical magazine* for August, 1883, contains a letter from Dr. William Ramsay which refers to observations upon the critical state of gases, published in the Proceedings of the London royal society, 1879–80. The chief observations that had previously been made upon this interesting subject are those of Cagniard de la Tour (*Annales de chimie*, 2ème série, xxi. et xxii.), Faraday (*Phil. trans.*, 1823 and 1845), Thilorier (*Annales de chimie*, 2ème série, lx.), Natterer (*Pogg. ann.*, xciv.), Andrews (*Phil. trans.*, 1869). Andrews found that when a gas was compressed in a closed space, and was maintained at a temperature below a certain limit, the pressure of the gas increased up to a fixed point, beyond which condensation occurred. The pressure at which condensation takes place increases rapidly with the temperature of the gas. At and beyond a certain temperature — the critical temperature — no amount of pressure can produce any of the usual phenomena of condensation. The isothermal lines below the critical temperature are apparently discontinuous, one portion representing no change of pressure corresponding to a change of volume. Above the critical temperature the isothermals are continuous.

The experiments of Dr. Ramsay were made upon benzine and ether, and a mixture of equal weights of benzine and ether. In one experiment a closed glass tube, somewhat in the shape of an hourglass, was used. One end of the tube was partly filled with ether, and was heated in an inclined position. The liquid expanded until, at the moment the meniscus disappeared, it nearly filled the lower half of the tube. On cooling, the liquid all condensed in the lower half.

The experiment was varied by inverting the tube after the meniscus had disappeared. On cooling, the liquid condensed in the upper half of the tube. The tube was next maintained for some time at a temperature above that at which the meniscus disappeared. On cooling, an equal quantity condensed in each division of the tube. It was observed, that, after the meniscus had disappeared, the part of the tube containing liquid had a different index of refraction from the other part.

The conclusion to be drawn from these results is, that, at and above the critical point, the density of the liquid is the same as that of its saturated vapor: consequently, after a sufficient time, the liquid and its vapor will become mixed. Above the critical point, the surface tension of a liquid disappears.

This conclusion is confirmed by the experiments of M. Cailletet (*Comptes rendus*, Feb. 2, 1880). He found that when the lower part of his experimental tube was filled with liquid carbonic anhydride at a temperature of 5°.5, and the upper part was filled with air and gaseous carbonic anhydride, a pressure of a hundred and fifty to two hundred atmospheres was necessary to cause the liquid to mix with the gas. At the suggestion of Mr. Jamin (*Comptes rendus*, May 21, 1883), hydrogen was substituted for the air in the upper part of the tube, and it was then found that a greater pressure was necessary to produce the mixture. This result would necessarily follow if we suppose that the mixture takes place when the densities of the liquid and the gas become equal. We cannot say that the liquid is converted into gas by pressure.

Though the densities of a liquid and its saturated vapor are equal, above the critical point, the two states of matter are still distinguished by other physical properties. Their indices of refraction are different: the liquid is capable of dissolving solids which are insoluble in the vapor. The latter fact is proved by the experiments of Hannay and Hogarth (*Proc. roy. soc.*, Oct., 1879), and also by similar experiments of Dr. Ramsay. A small piece of potassium iodide was placed in the lower part of the experimental tube, which was partly filled with anhydrous alcohol. The upper part of the tube was free from alcohol, but its sides were covered with a film of crystalline potassium iodide. When the tube was heated and the meniscus disappeared, the salt in the lower part of the tube was dissolved, while that in the upper part remained unchanged. Similar observations were made on eosine.

Dr. Ramsay's second paper contains the isothermal lines for benzine, ether, and a mixture of benzine and ether, below and above the critical temperatures. The apparatus used resembled that of Andrews. The most remarkable feature of these lines is, that, below the critical temperature for benzine, there appears to be a diminution of pressure corresponding to a diminution of volume, immediately before complete condensation takes place. This phenomenon appears very slightly in a mixture of benzine and ether, but is not apparent in ether alone. It has been suggested by James Thomson (*Proc. roy. soc.*, 1871) that the isothermals for all gases might have somewhat this form below the critical temperature. Dr. Ramsay explains the fact by supposing that the molecules, when the gas has been compressed to a certain extent, begin to exert mutual attraction and relieve the pressure. The fact may be connected with the observed phenomenon that the meniscus of benzine remains easily distinguishable until it vanishes, whereas the meniscus of ether soon becomes hazy. At the part of the isothermal under consideration the substance is evidently in a condition of unstable equilibrium, and it is difficult to see how this part of the curve could have been detected experimentally.

The critical temperature and pressure of a mixture of benzine and ether were found to be not far removed from the mean of the critical temperatures and pressures of the components.

No direct experiments have yet been made to ascertain whether heat is evolved when a gas is converted into liquid by pressure at temperatures above its critical temperature. Mr. Jamin concludes that at and beyond the critical point there is no latent heat. This conclusion, however, does not seem probable; since the molecular constitution of a liquid and its vapor are probably different, even above the critical temperature.

The conclusions which Ramsay draws from his experiments are summed up as follows: —

"1°. A gas may be defined as a body whose molecules are composed of a small number of atoms.

"2°. A liquid may be regarded as formed of aggregates of gaseous molecules, forming a more complex molecule.

"3°. Above the critical point, the matter may consist wholly of gas if a sufficient volume be allowed, wholly of liquid if the volume be sufficiently diminished, or of a mixture of both at intermediate volumes. That mixture is, physically speaking, homogeneous in the same sense as a mixture of oxygen and hydrogen gases may be termed homogeneous."

C. B. PENROSE.

COLORED SKIES AFTER AN ERUPTION OF COTOPAXI.[1]

THE remarkable sunsets which have been recently witnessed upon several occasions have brought to my recollection the still more remarkable effects which I witnessed in 1880 in South America, during an eruption of Cotopaxi; and a perusal of your highly interesting letter in the *Times* of the 8th inst. has caused me to turn to my notes, with the result of finding that in several points they appear to have some bearing upon the matter which you have brought before the public.

On July 3, 1880, I was engaged in an ascent of Chimborazo, and was encamped on its western side at 15,800 feet above the sea. The morning was fine, and all the surrounding country was free from mist. Before sunrise we saw to our north the great peak of Illiniza, and twenty miles to its east, the greater cone of Cotopaxi; both without a cloud around them, and the latter without any smoke issuing from its crater, — a most unusual circumstance: indeed, this was the only occasion on which we noticed the crater free from smoke during the whole of our stay in Ecuador. Cotopaxi, it should be said, lies about forty-five miles south of the equator, and was distant from us sixty-five miles.

We had left our camp, and had proceeded several hundred feet upwards, being then more than 16,000 feet above the sea, when we observed the commencement of an eruption of Cotopaxi. At 5.45 A.M. a column of smoke of inky blackness began to rise from the crater. It went up straight in the air, rapidly curling, with prodigious velocity, and in less than a minute had risen 20,000 feet above the rim of the crater. I had ascended Cotopaxi some months earlier, and had found that its height was 19,600 feet. We knew that we saw from our station the upper 10,000 feet of the volcano, and I estimated the height of the column of smoke at double the height of the portion seen of the mountain. The top of the column was therefore nearly 40,000 feet above the sea. At that elevation it encountered a powerful wind blowing from the east, and was rapidly borne for twenty miles towards the Pacific, seeming to spread very slightly, and remaining of inky blackness, presenting the appearance of a gigantic inverted ⌊ drawn upon an otherwise perfectly clear sky. It was then caught by a wind blowing from the north, and was borne towards us, and appeared to spread rapidly in all directions. As this cloud came nearer and nearer, so, of course, it seemed to rise higher and higher in the sky, although it was actually descending. Several hours passed before the ash commenced to intervene between the sun and ourselves; and, when it did so, we witnessed effects which simply amazed us. We saw a green sun, and

[1] From *Nature*, Dec. 27. A letter sent to Mr. Norman Lockyer.