interest, summer resorts, fishing places, &c., in Eastern Ontario, the Muskoka district, the St. Lawrence region, the Lake St. John country, the maritime provinces, Prince Edward Island, and Newfoundland. In an appendix are given fish and game laws, and official lists of trout and salmon rivers and their lessees. The author generally compresses his information into as small a space as possible, but in dealing with the more interesting Canadian scenes has sought to make his descriptions lively and attractive. The volume is prettily printed, and is well supplied with maps and illustrations.

LETTERS TO THE EDITOR

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A Question in Physics.

CAN there be a crowding of the particles of a gas to a much smaller compass without its being markedly heated? Can a gas expand without being cooled? It is probable that nearly every physicist will give negative answers to these questions, and yet the fact that such conditions may occur sometimes seems well established. The present writer, in 1889, attempted to determine the actual heating of air when compressed by a pump connected with the cylinder by a long tube, and found that the temperature was raised about 4° F. for a compression of 10 inches above atmospheric pressure. In like manner, on expanding this compressed air into the free atmosphere, it was found that the cooling was about 4°. These results were published in *Science*, vol. xv. p. 387, and were strongly combated by Prof. Ferrel and Prof. Marvin. Prof. Ferrel advanced, as applicable in this case, the well-known thermodynamic formula for the computation of the heat developed in a gas when compressed, as follows:—

$$\frac{t}{t'} = \left(\frac{p}{p'}\right)^{.291}$$

in which t and t' are the absolute temperatures corresponding to the pressures p and p' . Sir Wm. Thomson has given this formula in slightly different form, and with a larger exponent (see "Encyclopædia Britannica," vol. vii. p. 814). Prof. Ferrel found that, under the experimental conditions above, the heating should have been 43°, and the cooling 45°? (38°) (see *American Meteorological Journal*, vol. xii. pp. 339 and 340).

It seems very evident, however, that this formula can be used only when all the heat due to the work of compression is concentrated in the compressed air, and conversely when the air expands against an external resistance. An experiment by Joule will serve to elucidate this point. He determined the mechanical equivalent of heat by immersing the cylinder into which the air was to be compressed and the compressing pump in the same water-bath, and then determining the amount of compression and the total heat developed. This enables us to advance the proposition: *If air when compressed is to be raised to the temperature indicated by theory, it is very essential that all the heat developed in the work of compression should enter the air.* This seems self-evident; nevertheless, nearly all the errors that have entered the various discussions of this question have arisen from a neglect of this very obvious consideration.

In Joule's experiment let us suppose that the compressing pump had been in one bath, and the cylinder into which the air was compressed in another. Under these conditions, if no heat were lost, the first bath would have received very much the greater amount of heat. Now, if the compressed air in passing from the pump to the cylinder became cooled to the outside temperature, it is evident that all the heat due to the work of compression would have been disposed of outside the cylinder, and would not have been available for raising the temperature of the compressed air.

Instead of connecting the pump directly with the cylinder, let us take two cylinders of the same size, and connected by a tube. Compress the air in the first cylinder (A), to three atmospheres, the air in the other (B) being at atmospheric pressure. If we cool the air in A to the outside temperature,

and then open the connection with B, the compressed air will rush from A to B, and an equilibrium will be established very quickly, the pressure in each cylinder being at two atmospheres. The air in A will be slightly chilled because of the work of imparting a certain velocity to the particles entering B, and the air in B will be slightly warmed from the impact of the particles rushing from A, but there will be no heating due to the work of an external force making the compression.

Instead of allowing the air in A to rush into B, suppose we open communication with the outside air. The resistance to the rush of air will be much less than before, and the chilling in A, due to the work of imparting a certain velocity to the air, would be slightly greater than in the previous case, but it is obvious that this will be vastly less than that given by the formula. We may say, then, that the conditions suggested by the questions above may be very easily brought about.

The compressed air in a cylinder has a potential energy or capacity to do work, and this energy may be transmitted to another cylinder having air at atmospheric pressure without loss, and plainly without imparting or losing any heat. We might compare it to the head of water in a pond. This water has a certain capacity to do work depending upon its head. We may enlarge the pond somewhat, and the capacity for doing work will remain almost unchanged. The extremely important bearing of these views upon problems in meteorology is very apparent. The convection theory of storms demands a cooling from the work of expansion in an ascending column of moist warm air; it would appear, however, that the cooling must be vastly less than has generally been considered probable.

H. A. HAZEN.

Aurora.

PERHAPS it may interest some of your readers to see a short abstract of the observations of aurora made here during the last months, this winter having been by far the richest in well-developed northern lights since the winter 1870-71. Beginning with the magnificent display of February 13, which lasted almost the whole night, sometimes with vivid red and green tints (it was first noted at 6h. 45m., and faded away in the moonlight between 15h. and 16h. astronomical time), and whose beams converged several times from a large part of the horizon towards the magnetic zenith (formation of corona was noted at 7h. 2m., 10h., and 13h.), we have had aurora on February 14, 15, 24, 25, March 1 (at 7h. high arch, with the highest part through α and β Cephei, 7h. 55m. corona, between 8h. and 10h. pulsating and flashing light, sometimes with apparently screw-formed motion), March 2, 3, 6 (at 10h. curtains and corona, yellow-green colours), March 24, 25, 26, 27, April 23, 24 (at 10h. 10m. curtains, yellow-green) April 25 (strong light visible through small openings in cumulo-stratus in the north). The last display was on May 1, with corona at 9h. 40m., after 10h. flashes, curtains, and beams, at 13h. beams. About 11h. there was a peculiar downward motion of reddish light near the north horizon.

The magnetic disturbances of February 13 were also the greatest we have had for some years. The magnetometers, of the Gaussian construction, are generally observed at 2h. and 21h., but on February 13 observations were made every hour from 11 p.m., in correspondence with Bosekop in Finmarken, where the German observers, MM. Brendel and Baschin, were taking magnetical observations and photographs of the aurora during February and part of January. In Christiania the perturbations were comparatively small in declination (westerly maximum 12° 35' noted at 12h. 10m., minimum 11° 42' at 15h. 18m., but neither of them absolute, the observations not being continuous); but the horizontal intensity, which had already begun to increase a little at 21h., February 12, varied by more than 0.03 C.G.S. units, a maximum of 0.171 having been noted at 2h. 30m., and a minimum of about 0.140 from 12h. 0m. to 13h. 20m.; as the mirror of the magnet was in both cases outside the scale, the values could only be roughly measured. At 16h. 0m. the bifilar had returned to the small end of the scale, but a nearly constant value of the horizontal intensity was only attained after 5h., February 14. The inclination had a maximum of 73° 18' at 13h. 10m., from which it gradually diminished, with some fluctuations, towards the normal value, about 71° 0'.

With reference to Mr. Backhouse's observation of nacreous