dize the assumed AsH_3 developed by the cultures. The gas so obtained, when burned by oxide of copper, furnishes an abundance of CO_2; but it is not possible, thus far, to reach any positive conclusions on this point, nor even to exclude the suspicion that the formation of the CO_2 may depend on the admixture of some other hydrocarbon gas. This point will be made clearer by the special studies that I have undertaken together with Dr. Gorini, for which I am making use of a large culture material.

September, 1891.

A PROBLEM IN PHYSICS.

IN *Science* for Nov. 28, 1890, there was a short note on the experiment conducted by Joule, in which air compressed in one cylinder was allowed to expand into an exhausted cylinder. It was shown that the only work done by the compressed air was that of imparting a velocity to its own particles, i.e., it did not expand against a resistance, and hence the chilling produced was slight. This experiment has not received the attention it deserves, and, moreover, it seems to have been entirely misinterpreted. It has been suggested that, while at the first instant on opening communication between the two vessels, there is an expansion into a vacuum and no work done, yet at the very next instant there is air in the previously exhausted cylinder, and there is work done in compressing that. This is a serious fallacy, and lies at the bottom of the misinterpretation. It is very certain that no work against a resistance is done at any moment during the expansion This experiment is so far-reaching in its application, and is so extremely important, that I desire to discuss it a little farther, and I sincerely trust that some one in a suitably-equipped laboratory may be induced to try a few simple experiments in this line.

Tyndall has shown that mere rarefaction is not a source of cold, though this is somewhat of a popular fallacy. Let us take a cylinder with a piston fitted air-tight and moving without friction. Let us consider that there is no loss of heat from the interior nor accession from the outside. Suppose the piston is raised suddenly from bottom to top. A perfect vacuum will be formed; but, as no work has been done below the piston, there will be no cooling effect; all the work and consequent heating would be at the engine, which may communicate with the cylinder, though a hundred feet away. Now, suppose a very thin film of air .001 of an inch thick were at the bottom of the cylinder. When the vacuum was formed this thin film would impart a velocity to its particles in order that they might follow the piston, but this air certainly would not expand against a resistance, and hence the chilling would be exceedingly slight. Suppose the piston should be at a point half-way from top to bottom; when it was raised the air beneath would impart a certain velocity to its particles in following the piston, but here again there would be no expansion against a resistance, and hence the chilling would be slight.

Let us change the conditions slightly. Instead of having the air at atmospheric pressure beneath the piston, as in the last case, let it be at double that pressure. On lifting the piston as before we have taken off the pressure and the air beneath imparts a certain velocity to its particles in following the piston. At the first instant that the piston starts there may be a very slight expansion against a resistance, but that would be momentary. The bulk of the cooling would, as before, be due to the fact that a velocity is imparted to the particles beneath the piston, and, in this case, this velocity would be given to a greater number of particles than before. The cooling would be slightly greater, also, but it would not be due to the loss of heat consequent upon the work of expanding against a resistance.

In order to compute the cooling in such cases as these, a formula has been used which will be found in the *American Meteorological Journal* for November, 1890, p. 339, as follows:

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

In this T and T' are the absolute temperatures corresponding to p and p'. It seems to me, however, that this formula is not applicable in this case; for it gives a greater cooling, the less the work that is done. Suppose $\frac{p}{p'} = \frac{3}{4}$, the cooling by the formula would be 38°; if $\frac{p}{p'} = \frac{1}{3}$ the cooling would be 134°; and if $\frac{p}{p'} = 0$, or the expansion was in a vacuum, the cooling would be 490°. Now, by the principles already enunciated, if the expansion took place in a vacuum there would be no expansion against a resistance, and hence there would be no work done except in imparting a certain velocity to the particles. If the formula fails in the last case, it must also fail in all the others. It seems to me that the formula is only intended to be used in cases where there is an expansion against a resistance, and not in the cases here given.

A question has come up recently which may be partly answered by this discussion. It is this: What will be the cooling due to the expansion of gas in a balloon if it should ascend very suddenly to several thousand feet above the earth? Suppose the balloon were instantly put into a perfect vacuum, and the envelope had no resistance; there would be no expansion whatever against a resistance, as we have just seen, and the only work performed would be that of imparting a certain velocity to the particles of gas. As a result the gas would be slightly chilled, but vastly less than if it had expanded against a resistance. Now, if the balloon had been suddenly placed at a point where the pressure was ten inches, or one-third that at the earth, the same principles would apply; the only work done would be in imparting a certain velocity to the particles of gas, and in consequence there would be only a slight chilling.

I should be very glad if some physicist would kindly solve the following problems.

1. Given an exhausted cylinder of certain dimensions, how much would the air be heated if allowed to enter without noise, and until the pressure was the same as that outside?

2. What would be the cooling of a perfect gas in a balloon one-third full, if the pressure on the outside were suddenly reduced from thirty inches to ten inches, the temperature of the outside air remaining constant, the envelope of the balloon being without weight and infinitely flexible?

H. A. HAZEN.

THOMAS WHITTAKER announces a volume by Frederick Saunders (of the Astor Library), entitled "The Story of the Discovery of the New World by Columbus," the same being an abridgment from the latest authorities. It will be an illustrated quarto.