periodically at the depressions but not at the ridges, then for a constant speed of the car body forward over the road, and thus presumably of the axle also (neglecting any vibration lengthwise of the road, of the wheels relative to the body) a constant rate of rotation of the wheels would be consistent with this explanation. For in ascending and descending the ridges the periphery of the tire at the point of contact would be moving at an angle with the direction of the forward motion of the axle, and if there were no slipping anywhere, would have to be moving circumferentially around the axle at a rate greater than that necessary in the depressions. But by the same argument there would be a tendency to spin on the peaks of the ridges also, which would tend to wear them down. This explanation by slippage uses, to be sure, the natural rate of vibration of the wheels relative to the approximately stationary body of the automobile. But on its face it does not appear so acceptable as that attributing the ridges entirely, or almost so, to the simple, periodic bumping of the road by the wheels, with negligible periodic slip.

The problem more generally, and in its simplest form, is that of a vibrating system of two masses, one much greater than the other, connected by an elastic spring, and affected by an elastic push corresponding to that of the rubber tire, and by gravity.

As to the transverse growth of the ridges, whose individual identity as they lie across the road, can be recognized often over a length of ten or twelve feet, possibly more, suppose a second car, similar to the first, follows it and strikes the first humps formed, which will be necessarily short transversely to the road. The chances are that the wheel of the second car will not strike the humps squarely if at all, but at one end of them or the other. But this is sufficient to give an initial bounce, and the result is a slight lengthening, transverse to the road, of the initial humps. It is rather remarkable that the two series of humps, one at either side of the first car to pass, should eventually join up into continuous ridges across the road, but this is the actual effect from the passing of many cars. Perhaps this joining up is the result mainly of a sympathetic action, mentioned above, of the wheel on the opposite side of the machine.

Alternate grooves and ridges, roughly parallel, can be formed by water flowing across the road, but this type is likely to lie obliquely rather than perpendicularly with respect to the road, and at any rate will hardly be so uniformly spaced over a considerable distance. The opinion may be ventured that where ridges of the particular washboard type are found on solid road surface devoid of loose material, they were formed by the vibration process at a time when the ground, due probably to moisture, was in a more pliable condition.

The frequency of vibration of the wheels of a car relative to a stationary body is a quantity much greater than the frequency of the heavier body relative to stationary wheels. Assuming one and one half feet as the approximately uniform interval between the ridges of the "washboard," and further assuming 30 miles per hour as the speed of the "average" car, the average vibration rate of the wheels relative to the body of the car, comes out about 30 v.p.s. ($v = \lambda$. The value of one and one half feet as the distance between ridges in a group makes the vibration rate about 2 per cent. less than the speed of the automobile in miles per hour.) A certain driver, who has driven much on these desert roads, mentioned 25 miles as an average value for all machines, which would give approximately 25 v.p.s. for an average value.

The question might be raised whether the "average" car, or a particular class of cars, heavy or light, is in the main responsible for the ridges. Also, is the vibration chiefly that of the balloon tires? Heavier cars with balloon tires were observed to travel in the straight stretches at 40 miles and better. Riders in the heavier machines traveling at the higher speeds are probably little disturbed by these corrugations on the road. The bumping effect in a lighter car at a speed of 12 or 15 miles would become at times monotonous, to say the least. A certain other driver living in the desert stated he found the bumping effect least at a speed of about 35 miles. This should vary with the type of automobile, but theoretically for each car there is one best speed for maximum comfort of riding, and that is the speed at which the wheels "resonate" with the ridges.

The writer has taken no actual measurements on these ridges. Moreover, it would be interesting to check the vibration rates of automobile wheels in the laboratory, with the values calculated on the basis of the physical explanation offered. Such matters are properly subjects for consideration in the fields of road and automobile engineering.

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THE REVERSIBLE MIXING OF SUBSTANCES IN THE CONDENSED STATE AT THE ABSOLUTE ZERO OF TEMPERATURE

THE thermodynamical results established in a previous paper[1] and extended in a subsequent paper[2]

[1] Read at the Philadelphia meeting of the American Association; SCIENCE, Feb. 25.

were further extended and applied in a paper read at the Washington meeting of the Physical Society. An outline of a few of the more important results may be of interest to the readers of SCIENCE on account of their bearing on physico-chemical experiments frequently performed in a laboratory, and involving quantities often made the subject of accurate determinations.

It is shown that the internal heat of mixing h_m, or the increase in internal energy on mixing a number of substances, is zero, or

$$h_m = O$$

at the absolute zero of temperature, if the substances and resultant mixture are under the pressures of their vapors. It is also shown that

$$\frac{dh_m}{dT} = O$$

$$\text{and } \frac{d^2h_m}{dT^2} = O$$

where T denotes absolute temperature. Hence if h_m can be expanded in powers of T by Taylor's Theorem

$$h_m = aT^3$$

near the absolute zero of temperature, where a is a constant. This result could be investigated experimentally without great difficulty. It would involve measurements of the change in temperature on mixing a number of substances near the absolute zero of temperature, and a determination of the corresponding specific heats of the substances and the resultant mixture. The quantities H_m and A are shown to possess similar properties, where H_m denotes the heat absorbed on reversibly mixing the substances and A the maximum work done during the process.

In the first paper on the subject it was shown that the controllable internal energy and entropy, which are functions of the controllable variables v and T, are zero for any substance or mixture in the condensed state under their vapor pressures at the absolute zero of temperature. If several substances are simultaneously considered another controllable operation becomes possible, namely that of mixing some of them. From the way the foregoing result was established it does not follow directly that there will be no change in internal energy or entropy on mixing the substances under their vapor pressures at the absolute zero of temperature. It is now shown that no change takes place. With this result as basis it is further shown that the well-known formulae

$$\triangle U = h_m$$

$$T \triangle S = \triangle U + A = h_m + A = H_m$$

$$\triangle U = T\left(\frac{\partial A}{\partial T}\right)_v - A$$

hold also if U and S represent the controllable internal energy and entropy respectively. Since these quantities can be calculated from experimental data a method is afforded of testing the truth of the method of deduction of the various results obtained, and also of testing the truth of the first and second law of thermodynamics on which all the results are fundamentally based.

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[2] Read at the New York meeting of the Physical Society; SCIENCE, April 29.

DOUBLE COVEY OF CALIFORNIA VALLEY QUAIL

IT is common knowledge that the males of many species of birds assist in the protection and care of the young birds. During the week of June 12–18, the following interesting observations were made by Mr. R. A. Holley, of Fillmore, California, on what was apparently a double covey of California Valley quail or partridge (*Lophortyx californicus vallicola* (Ridgw.)). In the early part of the week he flushed a large flock of quail in an orchard. The covey consisted of twenty-three young quail of two distinct sizes and two adult males, one of which had a crippled leg, but no adult females. Approximately one half of the young quail were about one third grown, the rest were of uniform size but somewhat larger.

The following day the same covey was seen again. The crippled male was acting as sentinel while the other male was feeding with the young ones. When the sentinel was approached the covey flew a short distance away. It was then noted that the crippled male had taken his place with the young on the ground and that the other male was acting as the sentinel from the fence post. This same covey of two males, one a cripple, and the twenty-three young belonging to two size groups were seen on four successive days in the same orchard. Apparently the females of the two adult pairs had been killed and the two males with their respective broods had joined forces. This alliance had made it possible for the males to alternate as sentinels and warn the combined broods of any impending danger.

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SCIENTIFIC BOOKS

Man not a Machine. By E. RIGNANO. London. Kegan Paul, French, Trubner & Co., 1926. 77 pp.

IN this handy little volume Rignano discusses in a brief but suggestive way the mechanistic and the