so that the total number of forms of this period in our country must now exceed three hundred. A number of species "are scarcely distinguishable from English and Swedish forms," and this is all the more remarkable in these very intricately plated animals. Out of the sixty-three genera, thirty-three are common to Europe and America. The reviewer is further surprised to see no fewer than nine species (seven are of *Pisocrinus*) common to the southern and northern Silurian seas of the United States, showing that these waterways must have been in open connection.

The monograph also describes those most anomalous of all crinoids, the Calceocrinidæ, some of which have been called "dead men's fingers." Here the crown, starting with the normal number of radii (five), gradually eliminates two of them, and the head is reversed or recumbent upon the stem, a peculiar evolution which the author thinks was due to the stalk or stem being prostrate on the ground, with the crown in the horizontal attitude when feeding. Springer brings together all that is known of these highly specialized American and European crinoids (four genera and twenty-eight species), ranging from the middle Ordovician to the Mississippian (Keokuk), and successfully traces and illustrates their trends of evolution. The Calceocrinidæ are, he says, "an example of evolutionary modification with the process clearly visible, that is without precedent among the crinoids" (p. 71). Their singular modification out of normally developed Heterocrinidæ is due to the fact that "the base is united to the radials by a hinged muscular articulation, allowing motion of the crown above the base up and down in the plane of its bilateral symmetry" (p. 88).

Would that the human world had more men like Frank Springer!

CHARLES SCHUCHERT

SPECIAL ARTICLES

PROPERTIES OF SUBSTANCES IN THE CONDENSED STATE AT THE ABSOLUTE ZERO OF TEMPERATURE

IN a paper read at the Philadelphia meeting of the American Association for the Advancement of Science the writer deduced from results of an axiomatic character a result which may be stated in the form that the controllable internal energy and entropy of a substance or mixture in the condensed state at the absolute zero of temperature are zero, and that this zero corresponds to the mathematical definition of a minimum in the Calculus.[1] The result includes the third law of thermodynamics and Nernst's heat theorems. A number of deductions may be made from it which are of considerable interest and importance. These can not be deduced, it may be mentioned, from the third law of thermodynamics or from Nernst's heat theorems. The deductions of some of these results are given in a paper read at the February meeting of the Physical Society held in New York City, of which a few will be given here because they open up a new field of experimental research.

It is shown that besides

$$C_v = 0 \qquad (1)$$

for any substance or mixture in the condensed state at the absolute zero of temperature, we also have

$$\left(\frac{\partial' C_v}{\partial' T}\right)\frac{1}{v} = 0 \qquad (2)$$

where C_v denotes the specific heat at the constant volume v, and T the absolute temperature. Experimental evidence of the truth of these two equations already exists. According to Debye's formula for the specific heat of a monatomic solid, which is found to agree well with the facts, the specific heat near the absolute zero of temperature is given by

$$C_v = a_1 T^3 \qquad (3)$$

where a_1 is a constant. This equation has been specially investigated by Kammerlingh Onnes and found to agree well with the facts.[2] Equations (1) and (2) evidently agree with it. Experiments on the specific heat of mixtures near the absolute zero of temperature besides on monatomic solids would be very desirable.

If U denotes the internal energy of the substance or mixture, and it may be expressed as a series of integral powers of T by Taylor's theorem,

$$U = a_2 T^3 \qquad (4)$$

near the absolute zero of temperature, according to equations (1) and (2), where a_2 is a constant.

It is also shown that besides

$$p = 0 \qquad (5)$$

we have

$$\frac{dp}{dT} = 0 \qquad (6)$$

and

$$\frac{d^2p}{dT^2} = 0 \qquad (7)$$

where p denotes the vapor pressure of the substance or mixture. Therefore, if p may be expressed in integral powers of T by Taylor's theorem

$$p = a_3 T^3 \qquad (8)$$

near the absolute zero of temperature, where a_3 is a

[1] See SCIENCE, Feb. 25, 1927.

[2] *Comm. Phys. Lab.*, Leiden, No. 147 (1915).

constant. The writer is not aware of any experimental evidence of the truth of this equation. It affords an opportunity of putting to an important use the methods of measuring low pressures which are being perfected at present.

It is also shown that

$$\frac{dv}{dT} = 0 \qquad (9)$$

$$\frac{d^2v}{dT^2} = 0 \qquad (10)$$

Therefore, if the volume v of the substance or mixture in the condensed state may be expressed in a series of integral powers of T by Taylor's theorem,

$$v = v_0 + a_4 T^3 \qquad (11)$$

near the absolute zero of temperature according to equations (10) and (9), where v_0 denotes the volume of the substance or mixture in the condensed state at the absolute zero of temperature, and a_4 is a constant. The foregoing equation could be tested experimentally without encountering insuperable difficulties, probably best by an optical method.

It will be of interest to point out that if equations (1) and (2) can be proved experimentally for a number of substances—Kammerlingh Onnes's experiments furnish the proof for some substances—equations (6), (7), (9) and (10) can be shown to hold for these substances by means of well-known thermodynamical formulae and the Calculus.

It may also be mentioned that it is shown that equation (1) holds for a mass of matter in the gaseous state at infinite volume at the absolute zero of temperature. The experiments of Scheele and Heuse[3] on the specific heat of helium at constant volume, who found that it decreased with decrease of temperature, support this deduction.

The foregoing results, since they were deduced by the help of thermodynamical formulae, will apply to a substance or mixture only if it is in a state that it can be passed through a thermodynamical cycle, *i.e.*, if it is in perfect thermodynamical equilibrium.

R. D. KLEEMAN

SCHENECTADY, N. Y.

PROFITS DERIVED FROM SEGREGATING COLLEGE STUDENTS ON THE BASIS OF ABILITY

TWO experiments, to determine both the qualitative and quantitative advantages that may be derived particularly by superior college students when segregated on the basis of ability, have recently been completed at the University of Michigan under the direction of Professor Henry W. Miller, head of the department of mechanism and engineering drawing, of the college of engineering. An exhaustive report has been prepared on these experiments by Professor Miller for the senate of the university, which began consideration several years ago of the question, "What can we do to further benefit our superior students?" A limited number of copies of this entire report are available for distribution to those interested in the more detailed discussions of the procedure in conducting the experiments, the incidental findings, and in the graphs showing the performance of the various classifications of students in all their college work, and in particular subjects. The complete report will be published soon in *School and Society*. A brief description of the experiments and the more pertinent findings are given herein.

The department of mechanism and drawing at Michigan is an independent department of the college of engineering and gives all the general courses in engineering drawing to some eight hundred freshmen and sophomores yearly. The department was in the process of revising all its courses, methods of teaching, etc., and felt that an effort should be made to determine the nature and extent of the benefits that might be derived by the students if they were taught in homogeneous groups made up on the basis of ability, rather than in the usual heterogeneous groups. Interest centered particularly in learning what benefits the superior students might derive therefrom and the extent.

Descriptive geometry was chosen as the best test medium for these experiments, for reasons which those having a knowledge of this subject can readily understand. This subject is given to the freshman class in its second semester. All students being tested had, therefore, completed one semester's work in college and a double test could be conducted, the one to determine the nature and extent of advantages from segregation on the basis of ability, and the other to learn whether the quality of work done on previous college courses can serve as a satisfactory basis of segregation

METHODS OF CONDUCTING THE EXPERIMENTS

At the end of the first semester and before the beginning of the second, the general averages made by the freshman engineers on all their first semester subjects were computed and the names of the men listed in the order of their averages. In computing these averages the mathematical value of the letter grade for each subject was multiplied by the number of credits for that subject and the sum of all the products divided by the sum of the credits. In general the grade "A" is given for a record of from 90 to 100 per cent., "B" for 80 to 90, "C" for 70 to 80, and "D" for 60 to 70. The university gives a value of 4 to the grade "A," 3 to "B," 2 to "C" and 1 to "D." In computing general averages, then, the four credits for any sub-

[3] *Ann. der Physik.*, 40, p. 484 (1913).