*r* the specific resistance. The “ thermoelectric constant,” *θ,* of Kohlrausch, is evidently the same as the thermoelectric power, *p,* in Thomson's theory. In order to explain the Peltier effect, Kohl- rausch further assumes that an electric current, *C,* carries a heat-flow, *Q = AΘC,* with it, where “ *A* is a constant which can be made equal to unity by a proper choice of units.” If *A* and 0 are constant, the Peltier effects at the hot and cold junctions are equal and opposite, and may therefore be neglected. The combination of the two postulates leads to a complication. By the second postu­late the flow of the current increases the heat-flow, and this by the first postulate increases the E.M.F., or the resistance, which therefore depends on the current. It is difficult to sec how this complication can be avoided, unless the first postulate is abandoned, and the heat-flow due to conduction is assumed to be independent of the thermoelectric phenomena. By applying the first law of thermodynamics, Kohlrausch deduces that a quantity of heat, *CθdT,* is absorbed in the element *dT* per second by the current *C.* He wrongly identifies this with the Thomson effect, by omitting to allow for the heat carried. He does not make any application of the second law to the theory. If we apply Thomson’s condition *P = TdE∣dT=Tp,* we have A = *T*. If we also assume the ratio of the current to the heat-flow to be the same in both postulates, we have α = ι∕T0, whence *θ2=kr∣T.* This condition was applied' in 1899 by C. H. J. B. Liebenow (*Wied. Ann.,* 68, p. 316). It simplifies the theory, and gives a possible relation between the constants, but it does not appear to remove the complication above referred to, which seems to be inseparable from any conduction theory.

L. Boltzmann (*Sitz. Wien. Akad.,* 1887, vol. 96, p. 1258) gives a theoretical discussion of all possible forms of expression for thermo­electric phenomena. Neglecting conduction, all the expressions which he gives are equivalent to the equations of Thomson. Taking conduction into account in the application of the second law of thermodynamics, he proposes to substitute the inequality, *Td∣dET-P^2d T{dk'r'* + √⅛\* r\*), instead of the equation given by Thomson, namely, *P = TdE∣dT.* Since, however, Thomson's equation has been so closely verified by Jahn, it is probable that Boltzmann would now consider that the reversible effects might be treated independently of conduction.

23. *Thermoelectric Relations.—*A number of suggestions have been made as to the possible relations between heat and electri­city, and the mechanism by which an electric current might also be a carrier of heat. The simplest is probably that of W. E. Weber (*Wied. Ann.,* 1875), who regarded electricity as consisting of atoms much smaller than those of matter, and supposed that heat was the kinetic energy of these electric atoms. If we suppose that an electric current in a metal is a flow of negative electric atoms in one direction, the positive electricity associated with the far heavier material atoms remaining practically stationary, and if the atomic heat of electricity is of the same order as that of an equivalent quantity of hydrogen or any other element, the heat carried per ampere-second at 0° C., namely *P,* would be of the order of ∙030 of a joule, which would be ample to account for all the observed effects on the convection theory. Others have considered conduction in a metal to be analogous to electrolytic conduction, and the observed effects to be due to “ migration of the ions.” The majority of these theories are too vague to be profitably discussed in an article like the present, but there can be little doubt that the study of thermo­electricity affords one of the most promising roads to the dis­covery of the true relations between heat and electricity.

*Alphabetical Index of Symbols.*

*a, b, c =* Numerical constants in formulae.

*C =* Electric Current.

E = E.M.F. = Electromotive Force.

*k* = Thermal Conductivity.

*P =* Coefficient of Peltier Effect.

*p =dE)dt-* Thermoelectric Power.

*Q =* Heat-flow due to Conduction.

*R =* Electrical Resistance; *r,* Specific Resistance.

s = Specific Heat, or Coefficient of Thomson Effect.

*t* = Temperature on the Centigrade Scale.

*T* = Temperature on the Absolute Scale.

(H. L. C.)

**THERMOMETRY** (Gr. *θepμos,* warm; *μeτpov,* a measure), the art of measuring temperature or degree of heat. The instru­ments used for this purpose are known as thermometers, or sometimes, when the temperatures to be measured are high, as pyrometers.

I. A brief sketch of the evolution of the thermometer is in­cluded in the article IIeat, §§ 2 and 3. The object of the present article is to discuss the general principles on which the accurate measurement of temperature depends, and to describe the application of these principles to the construction and use of the most important types of thermometer. Special attention will be devoted to more recent advances in scientific methods of testing thermometers and to the application of electrical and optical methods to the difficult problem of measuring high temperatures. In the article Pyrometer an account will be found of some of the thermoscopic methods employed in the arts for determining high temperatures.

2. *Zero: Fundamental Interval.—*In all systems of measuring temperature it is necessary (1) to choose a zero or starting-point from which to reckon, (2) to determine the size of the degree by subdividing the interval between two selected fixed points of the scale (called the “ fundamental interval ”) into a given number of equal parts. The fundamental interval selected is that between the temperature of melting ice and the tem­perature of condensing steam, under standard atmospheric pressure. On the Centigrade system the fundamental interval is divided into 100 parts, and the melting-point of ice is taken as the zero of the scale. We shall denote temperature reckoned on this system by the letter *t,* or by affixing the letter C. It is often convenient to reckon temperature, not from the melting- point of ice, but from a theoretical or absolute zero representing the lowest conceivable temperature. We shall denote tem­perature reckoned in this manner by the letter T, or *θ,* or by affixing the letters *Abs.* In practice, since the absolute zero is unattainable, the absolute temperature is deduced from the Centigrade temperature by adding a constant quantity, To, representing the interval between the absolute zero and the melting-point of ice; thus T=t+T0.

3. *Arbitrary Scales.—*An arbitrary scale can be constructed by selecting any physical property of a substance which varies regularly with the temperature, such as the volume of a liquid, or the pressure or density of a gas, or the electrical resistance of a metal. Thus if V denote the volume of a given mass at the temperature *t,* and if V0, V1 represent the volumes of the same mass at the temperatures 0o and 100° C., the size of 1° C. on the scale of this arbitrary thermometer is one hundredth part of the fundamental interval, namely (V1—V0)100, and the temperature *t* at volume V is the number of these degrees con­tained in the expansion V—V0 between 0° and *t*° C. We thus arrive at the formula

Z = ιoo (V-V0)∕(V1-V0) . . . (1),

which is the general expression for the temperature Centigrade on any such arbitrary scale, provided that we substitute for V the particular physical property selected as the basis of the scale. If we prefer to reckon temperature from an arbitrary zero defined by the vanishing of V, which may conveniently be called the *fundamental zero of* the scale considered, we have, putting V= 0 in equation (1), the numerical values of the funda­mental zero To, and of the temperature T reckoned from this zero

To=100Vo'(V1-Vo), and T=ToV∕Vc=Z-∣-To . . . (2).

It is frequently convenient to measure temperature in this manner when dealing with gases, or electrical resistance ther­mometers.

4. *Absolute Scale.—*It is necessary for theoretical purposes to reduce all experimental results as far as possible to the ab­solute scale, defined as explained in Heat, § 21, on the basis of Carnot’s principle, which is independent of the properties of any particular substance. Temperature on this scale measured from the absolute zero will be denoted by the letter *θ.* This scale can be most nearly realized in practice by observing the temperature T on the scale of a gas-thermometer, and making special experiments on the gas to determine how far its scale deviates from that of the thermodynamical engine. In the case of the gases hydrogen and helium, which can exist in the liquid state only at very low temperatures, the deviations from the absolute scale at ordinary temperatures are so small that