for the relation between the mass m of an electron and the number of particles in the universe at the present epoch. This should be compared with Eddington's equation[4]

$$m_0 = \frac{h}{2\pi c} \frac{\sqrt{\frac{3}{5}N}}{R},$$

where m_0 is the mass of a neutral particle of the comparison fluid. From Eddington's theory, $m_0 \sim 136\ m$.

Finally, the theory leads to the uncertainty relation in the form

$$\triangle p \triangle q \sim \frac{h}{4\pi},$$

and thus links quantum theory with cosmological theory.

It thus appears that a reasonable and self-consistent theory of cosmology can be built up from the initial assumption that a planetary or pendulum clock measures time at a different rate than does an atomic clock, the relationship between the two measures of a small interval of time being given by (1). The theory is based essentially upon this single assumption, together with the principle of the conservation of energy. An observer, measuring time by an atomic clock, concludes that, although the total energy of the universe remains constant, the number of elementary particles as defined above is increasing as the square of the epoch, and that there exists a definite epoch of creation. An observer, measuring time by a rotating planet, finds the usual laws of mechanics and the Newtonian and relativistic equations of motion to hold good. He concludes that the number of particles in the universe is constant, and that the universe has existed, though not necessarily in its present configuration, for an infinite time.

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[1] Milne, *Proc. Roy. Soc.*, A, **158**, 324 (1937) and earlier papers.
[2] Dirac, *Proc. Roy. Soc.*, A, **165**, 199 (1938).
[3] Dirac, NATURE, **139**, 323 (1937).
[4] Eddington, "Relativity Theory of Protons and Electrons", p. 272.

Thermal Expansion and 'Co-operative Phenomena'

A RECENT investigation[1] on the dielectric polarization of a ketone near the melting point shows a considerable difference between the temperature — polarization curves at constant volume and at constant pressure. The change of volume thus appears to have a considerable effect on the free rotation of molecules in the lattice, which is a 'co-operative phenomenon'.

It seems not unlikely that volume changes might be of importance in other 'co-operative phenomena'. The order-disorder transition of β-brass is experimentally investigated at constant pressure. The existing theories take no account of the experimentally observed change of volume. Actually, the theoretical maximum of specific heat is too small, and the slope of the temperature—specific heat curve at temperatures below the maximum is about 1/15 of the experimental value, which discrepancy may be due to the neglected expansion.

In order to test this view, I carried out a calculation of the specific heat at constant pressure. The energy of a zinc-copper pair is assumed to be proportional to the square of volume change. A similar assumption is made for the mean energy of copper-copper and zinc-zinc pairs, their minimum energy lying at higher volumes than the minimum of copper-zinc. In each of these parabolic energy curves a parameter is introduced. The method of calculation is similar to the theory of Bragg and Williams.

The specific heat—temperature curve obtained can be adjusted so as to give good agreement with experiment. It appears to be not very sensitive relative to variations of one parameter. The assumed dependence of copper-zinc energy on volume is compatible with the energy as calculated from the compressibility of brass and the observed expansion. By this calculation, the details of which are to be published shortly, it is shown that even a small expansion may have considerable effect on the specific heat.

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[1] Müller, A., *Proc. Roy. Soc.*, A, **166** (1938).

Occurrence of *Zelleriella*, an Opalinid Ciliate, in South Africa

THE fauna and flora of the southern extremity of Africa present a number of striking resemblances to those of South America on one hand and Australia on the other. I have recently come across an unexpected addition to this number in finding *Zelleriella* in the recta of two different species of *Rana* from the neighbourhood of Cape Town. According to Bigalke[1] there appear to be no records of the establishment of any exotic amphibia anywhere in the Union of South Africa and we must therefore assume that the Cape Zelleriellas are indigenous. The following zoogeographical data suggest their significance.

(1) *Zelleriella* is the dominant Opalinid of tropical America, its principal hosts being the toothed bufonids (Cystignathidæ or "Leptodactylids"). Elsewhere, except for one questionable record from a toad from "Asia", they have only been found in Australia, where their hosts are exclusively leptodactylids.

(2) The toothed bufonids also occur at the present day only in Central and South America and in Australia.

(3) From these facts Metcalf[2] concludes that the leptodactylids originated in Argentina–Patagonia and crossed to Australasia by an early Miocene land-bridge. *Zelleriella* was originally a parasite of these toads and migrated with them, but infected other amphibia as it spread northwards in America. The recent discovery in India of a Miocene Cystignathid closely resembling the present-day Australian genera, however, weakens this argument[3].

(4) The Cape Zelleriellas apparently do not extend far towards the north, for none were found by Fantham[4] in his extensive investigation of the parasites of amphibia in the Transvaal. In view of their ability to live in a variety of amphibian hosts, it is difficult to believe that these ciliates can have come from the north without leaving representatives in other parts of Africa. Their presence in the Cape consequently is most easily explicable on the hypothesis of former land connexions with the other southern continents, in which case their history must