1), größeren Adsorptionswärmen zu verstehen, wäre danach eine Zunahme der Adsorptionsvolumina gegenüber reinem Wasserstoff zu fordern, nämlich um jenen Anteil, der die Wärmeentwicklung bewirken soll. Die Isothermen in Abb. 2 widersprechen dem jedoch. Es ist deshalb zu folgern, daß der Wärmeeffekt nicht durch eine zusätzliche Adsorption, sondern durch eine Wechselwirkung der adsorbierten Spezies an der Katalysatorenoberfläche hervorgerufen wird, etwa durch Bildungsenthalpien von Oberflächenkomplexen oder definierten Oberflächenstrukturen.

Das Auftreten von Sorptionskomplexen kann somit auch aus energetischen Messungen gefolgert werden und steht im Einklang mit den in der Einleitung zitierten, durch andere Meßmethoden ermittelten Resultaten.

Betrachtet man abschließend den Einfluß der Zusammensetzung des zur Adsorption angebotenen Gasgemisches auf die Sorptionswärmen, so ist mit steigendem N_2Anteil eine Wärmezunahme festzustellen.

Auch dieses Ergebnis wird durch Adsorptionsmessungen von SASTRI und SRIKANT [13–14] bestätigt, die mit zunehmendem N_2-Partialdruck eine wachsende Komplexbildung postulieren.

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On the meaning of time-reversal invariance violation

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The possible effect of a cosmological background (such as proton-neutron preponderance) on the meaning of time-reversal violation is discussed in the context of the Dürr-Heisenberg degenerate vacuum theory of strangeness.

Introduction

The microscopic equations of motion do not define a sense of the direction of time. Developments in recent years in connection with the Fitch-Cronin effect [1] show that experiment supports the violation of time reversal invariance [2]. In view of the asymmetry of the environment (preponderance of matter over antimatter, proton-neutron preponderance etc.) it would seem natural to investigate the influence of the universe at large on the breakdown of invariance.

A number of papers have appeared in order to explain the observed CP violation (charge-parity) in terms of a cosmological origin [3]. However, cosmological models based on the assumption that the cosmological field couples with different signs to matter (K°) and antimatter ($\overline{K^\circ}$) implies, in addition to CP violation, a TCP violation for which no experimental evidence exists to date.

In this note a view of the question of time-reversal violation is outlined. The logical question at issue refers to the conceptual basis of the violation. The known temporal asymmetry associated with processes in the universe defines a direction of time. It is pro-

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posed in particular that the preponderance of isospin members over fellow members (proton-neutron preponderance for example) results in a degenerate vacuum state (cosmological prepared state) and that the rate of change of its isospin singles out an arrow of time.

The Model

In order to pursue this line of thought it is necessary to establish a connection between the arrow of time and microscopic attributes. The degenerate vacuum may manifest itself in a number of ways. The strangeness theory of DÜRR and HEISENBERG [4] is of particular interest. The theory proposes that isotopic spin of the degenerate vacuum state may be attached to particle states, forming new particles which are distinguished from the original particles by the acquired isospin. The relationship between the electric charge and the third component of isospin of the derived particle is influenced in such a manner that the acquired attribute associated with the new state plays a role similar to strangeness (isospin-spin decoupling) of the Gell-Mann-Nishijima proposal

$$Q = I_3 + \tfrac{1}{2}N + \tfrac{1}{2}S\ . \tag{1}$$

In view of the above, it follows that an arrow of time is furthermore associated with the rate of change of the isospin of the degenerate vacuum i. e. with strangeness changing processes. This implies that the strangeness changing contribution to the mass-shift consist of T-conserving and T-violating parts.

The $(K^\circ, \overline{K^\circ})$ System

The consequences for the $(K^\circ, \overline{K^\circ})$ system may briefly be stated as follows. The equation of motion in the Hilbert space corresponding to the strangeness coordinates of the K-meson is given by [5]

$$i\,\partial/\partial t\,\psi = \mathbf{M}\,\psi = (M - \tfrac{1}{2}i\,\Gamma)\,\psi\ ; \quad \psi = \begin{pmatrix} K^0 \\ \overline{K^0} \end{pmatrix} \tag{2}$$

where the mass matrix M may be represented in terms of the Pauli matrices by

$$M = \alpha\,I + \beta\,\sigma_x + \gamma\,\sigma_y + \delta\,\sigma_z \tag{3}$$

In terms of the phase convention

$$\mathrm{CP}\,|\,K^0\,\rangle = |\,\overline{K^0}\,\rangle \tag{4}$$

the representatives of the symmetry operators and the symmetry breaking terms in hyper-charge space is given in Table 1. Here K denotes the complex conjugate operation.

Table 1

Symmetry Operator	Representative	Symmetry breaking terms
CP	σ_x	σ_y and σ_z
T	K	σ_y
TCP	$K\sigma_x$	σ_z

The most general TCP conserving "mass"-matrix is therefore given by

$$\mathbf{M} = (m_0 + \tfrac{1}{2}i\,\Gamma_0)\,I + (H + \tfrac{1}{2}i\,\Gamma)\,\sigma_x + \gamma\,\sigma_y \tag{5}$$

where $m_0 = m(K^\circ) = m(\overline{K^\circ})$; $\Gamma = \Gamma(K^0) = \Gamma(\overline{K^0})$ and $(H + \frac{1}{2}\,i\,\Gamma)$, and γ are functions of the T-conserving and T-violating strangeness changing contributions to the mass-matrix respectively.

The mass-matrix (5) is diagonalized by the transformation

$$U = 1/\sqrt{2}\begin{pmatrix} 1 & \exp i\,\varphi \\ 1 & -\exp i\,\varphi \end{pmatrix} \tag{6}$$

where the complex phase, Φ, is given by

$$\tan\varphi = \gamma\,[H^2 + \tfrac{1}{4}\,\Gamma^2]^{-1}\,[H - \tfrac{1}{2}i\,\Gamma]\ . \tag{7}$$

The eigenstates and eigenvalues are given by

$$K_S{}^0(t) = \exp\,[-iM_S t]\ [1 + |\exp i\varphi\,|^2]^{-\frac{1}{2}}\ [K^0 + \exp\,(i\varphi)\,\overline{K^0}]\ , \tag{8a}$$

$$K_L{}^0(t) = \exp\,[-iM_L t]\ [1 + |\exp i\varphi\,|^2]^{-\frac{1}{2}}\ [K^0 - \exp\,(i\varphi)\,\overline{K^0}] \tag{8b}$$

and

$$M_S = m_0 + \tfrac{1}{2}i\,\Gamma_0 + \cos\varphi\,(H + \tfrac{1}{2}i\,\Gamma) + \gamma\sin\varphi\ , \tag{9a}$$

$$M_L = m_0 + \tfrac{1}{2}i\,\Gamma_0 - \cos\varphi\,(H + \tfrac{1}{2}i\,\Gamma) - \gamma\sin\varphi \tag{9b}$$

respectively.

In the limit of vanishing T-violation ($\gamma = 0$, $\Phi = 0$) it follows that

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$$M_S = (m_0 + H) + \tfrac{1}{2}i\,(\Gamma_0 + \Gamma) = m_1 + \tfrac{1}{2}i\,\Gamma_1\,, \qquad (10a)$$

$$M_L = (m_0 - H) + \tfrac{1}{2}i\,(\Gamma_0 - \Gamma) = m_2 + \tfrac{1}{2}i\,\Gamma_2 \qquad (10b)$$

where m_1, m_2, Γ_1 and Γ_2 denote the experimentally known masses and lifetimes of the CP eigenstates

$$K_1 = (1/\sqrt{2})\,(K^0 + \overline{K^0})\,, \qquad (11a)$$

$$K_2 = (1/\sqrt{2})\,(K^0 - \overline{K^0})\,. \qquad (11b)$$

In the absence of T-violation the decay of the long-lived *kaon*, $K_2 \to 2\pi$, is prohibited. According to Eqs. (8) and (11) the ratio of the amplitudes for the decay

$$\eta_{\overset{+}{0}\overset{-}{0}} = \frac{A\,(K_L{}^0 \to \overset{+}{\pi^0}\,\overset{-}{\pi^0})}{A\,(K_S{}^0 \to \pi^0\,\pi^0)} = \frac{(1 - \exp i\,\varphi)}{(1 + \exp i\,\varphi)} \qquad (12)$$

serves as a measure of T-violation. Since the ratio η is small it follows that

$$\eta \simeq -\tfrac{1}{2}i\,\varphi = \gamma\,D^{-\frac{1}{2}}\exp i\,\psi\,, \qquad (13)$$

$$M_S = m_1 + 2\gamma^2 D^{-1}(m_1 - m_2) + \tfrac{1}{2}i\,[\Gamma_1 - 2\gamma^2 D^{-1}(\Gamma_1 - \Gamma_2)]\,, \qquad (14a)$$

$$M_L = m_2 + 2\gamma^2 D^{-1}(m_2 - m_1) + \tfrac{1}{2}i\,[\Gamma_2 - 2\gamma^2 D^{-1}(\Gamma_2 - \Gamma_1)] \qquad (14b)$$

where

$$D = (m_1 - m_2)^2 + \tfrac{1}{4}(\Gamma_1 - \Gamma_2)^2 \qquad (15)$$

and

$$\tan\psi = 2\,(m_2 - m_1)\,/\,(\Gamma_1 - \Gamma_2)\,. \qquad (16)$$

The last equation yields the phase of the CP- and T-violation defined by Eq. (13), $\Psi_{+-} = \Psi_{00} = 43°$ or 223°; to be compared with the experimental result [6] $\Psi_{+-} = (44 \pm 5)°$ and $\Psi_{00} = (51 \pm 30)°$. The result $\eta_{+-} = \eta_{00}$ is compatible with the experimental result $|\eta_{+-}| = (1.92 \pm 0.5)10^{-3}$ and $|\eta_{00}| = (2.5 \pm 0.8)10^{-3}$. Furthermore, the relation

$$\gamma \simeq |\eta_{+-}|\,\sqrt{2}\,(m_2 - m_1) \qquad (17)$$

and the fact that the mass difference $(m_2 - m_1)$ originates from $|\Delta s| = 1$, CP- and T-conserving process allow an evaluation of the CP- and T-violating coefficient γ. In particular, if the T-violating interaction possesses a $|\Delta s| = 1$ component it follows that the coupling is semi-weak (coupling of order 10^{-3} G); whereas if the T-violation originates from a $|\Delta s| = 2$ interaction, the coupling is superweak [7] (coupling of order 10^{-8} G).

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