In the case of the Bethe–Salpeter equation, a relation concerning the kernel Q of the equation follows from the invariance of the field equations with respect to the scale transformation (1). We write the Bethe–Salpeter equation in the form

$$D(x, M_a)\, D(y, M_b)\, f(x, y) = \int Q(x, y;\ x', y';\ M_a, M_b, m)\, f(x', y')\, dx'\, dy',$$

where M_a and M_b are the experimental masses of the particles, and the kernel Q can be regarded as already normalized.

The relation in question is then of the form

$$Q(x, y;\ x', y';\ \lambda m, \lambda M_a, \lambda M_b) = \lambda^{10} Q(\lambda x, \lambda y;\ \lambda x', \lambda y';\ m, M_a, M_b). \tag{7}$$

The Virial Theorem. The invariance of the field equations (2) with respect to the scale transformations (1) is disturbed in the presence of external fields. The variation of the scattering matrix δS_{12} does not vanish in the presence of an external field. In order to find its value we shall make use of the action principle (5). It is evident that, in the absence of an external nucleon field, the variation of a matrix element of the scattering matrix

$$\delta S_{12} = i\left(\Psi'^{(2)}_{\text{out}},\ \delta W_e \Psi'^{(1)}_{\text{in}}\right)$$

will be determined by the variation of the part of the action operation W_e, depending on the external meson field φe:

$$W_e = -ig \int \overline{\psi}(x)\, \gamma_5 \varphi_e(x)\, \psi(x)\, dx.$$

The varied action W_e' is obtained from W_e by putting $x = \lambda y$ and the introduction of variated operators $\psi'(y) = \lambda^{3/2} \psi(\lambda y)$ and $\psi(y) = \lambda^{3/2} \psi(\lambda y)$, which yield

$$W_e' = -ig\lambda \int \overline{\psi'}(y)\, \gamma_5 \varphi_e(\lambda y)\, \psi'(y)\, dy.$$

Putting $\lambda = 1 + \epsilon$, where ϵ is infinitesimally small, we find the relation

$$\sum_i^n p_i \frac{\partial S_{12}}{\partial p_i} + \sum_j^{n'} p_j' \frac{\partial S_{12}}{\partial p_j'} + m \frac{\partial S_{12}}{\partial m} + M \frac{\partial S_{12}}{\partial M} + \frac{3}{2}(n + n')\, S_{12} = \left(\Psi'^{(2)}_{\text{out}}, -g \int \varphi\, \gamma_5\, \psi \left[\varphi_e + x_\mu \frac{\partial \varphi_e}{\partial x_\mu}\right] dx\, \Psi'^{(1)}_{\text{in}}\right), \tag{8}$$

where the summation is extended on the incident particles (total number n) and the scattered particles (total number n'). The expression under the sign of the integral in the right–hand side of Eq. (8) is of the form typical for the virial theorem. The relation (8) can be therefore regarded as the virial theorem of the quantum field theory.

If we consider the case when we have an external nucleon field $\psi_e(x)$ instead of the external meson field, the nucleon field being characterized by the current

$$j_e = -ig\, \overline{\psi}_e(x)\, \gamma_5 \psi_e(x),$$

we find in an analogous manner that the right–hand side of the equation (8) will be equal to

$$i\left(\Psi'^{(2)}_{\text{out}},\ \int \varphi(x) \left[3 j_e(x) + x_\mu \frac{\partial j_e(x)}{\partial x_\mu}\right] dx\, \Psi'^{(1)}_{\text{in}}\right). \tag{9}$$

The generalization of the above ideas for the case of other fields is straightforward.

Note added in proof: After the paper had been submitted to the editor, I. M. Shmushkevitch drew the attention of the author to the fact that the scale invariance of the equations of quantum electrodynamics is mentioned in the book of Jauch and Rohrlich.[4] The consequences of this fact and the virial theorem are not, however, studied there.

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Translated by H. Kasha
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Some New Electrets from Inorganic Dielectrics

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IT is known that the electret represents an electric analog of the magnet. It is a dielectric characterized by a "constant" electrification with opposite charges at its ends. Usually electrets are obtained by cooling a heated dielectric in an electric field.

No. in order	Material	Dielectric constant and conductivity at room temperature		Maximum current during polarization in Amp.	Surface charge density $\sigma\cdot10^9$ coul/cm^2					Remarks
		ε	γ, в Ω^{-1} см$^{-1}$		30 min. after polarization	10 days after polarization	30 days after polarization	3 months after polarization	7 months after polarization	
1	$MgTiO_3$	16	10^{-13}—10^{-14}	$4.0\cdot10^{-8}$	1.9	1.4	0.5	0.5	0.5	
2	$ZnTiO_3$	22	10^{-12}—10^{-13}	$3.4\cdot10^{-6}$	0,3	0.2	0,3	0.4	нет	
3	$BaO\cdot4TiO_2$	28	10^{-13}—10^{-14}	$1.6\cdot10^{-7}$	1.1	2.8	0.2	1.6	1.4	
4	Bismuth titanate	80	10^{-12}—10^{-13}	$1.2\cdot10^{-4}$	10.0	6.8	3.9	4.2	1.8	Samples were polarized at 10 kv/cm*
5	$CaTiO_3$	150	10^{-12}—10^{-13}	$5.0\cdot10^{-8}$	5.3	10.5	5.8	9.6	4.2	
6	$SrTiO_3$	175	10^{-10}—10^{-12}	$3.4\cdot10^{-7}$	1.7	2.2	0.1	0.7	0.65	
7	Strontium-bismuth titanate	750	10^{-13}—10^{-15}	$7.0\cdot10^{-7}$	3,4	0.2	0,8	**	**	Thickness of samples 3.55 mm.
8	$BaTiO_3$	1200	10^{-10}—10^{-12}	$5.9\cdot10^{-4}$	15,4	2.0	0.04	1,2	1.1	Samples were polarized at 10 kv/cm
9	Steatite	4—5	10^{-14}—10^{-15}	$3.5\cdot10^{-7}$	0,3	2,1	1.5	**	**	
10	Ceramic	4—6	10^{-12}—10^{-13}	$5.0\cdot10^{-4}$	none	none	none	**	**	Samples polarized at 10 kv/cm2
11	Ordinary glass	7—8	10^{-10}—10^{-11}	$1,5\cdot10^{-6}$	none	none	none	**	**	Temperature held at 175°C.*
12	Pyrex glass	5,8	10^{-14}	$1,0\cdot10^{-4}$	0.07	none	none	none	none	Temperature held at 50°C.*
13	Fused quartz	3,7	$<10^{-15}$	$3.5\cdot10^{-9}$	none	none	none	none	**	
14	KBr crystals	4,7	10^{-14}	$1,5\cdot10^{-5}$	none	none	none	none	**	Sampes polarized at 10 kv/cm

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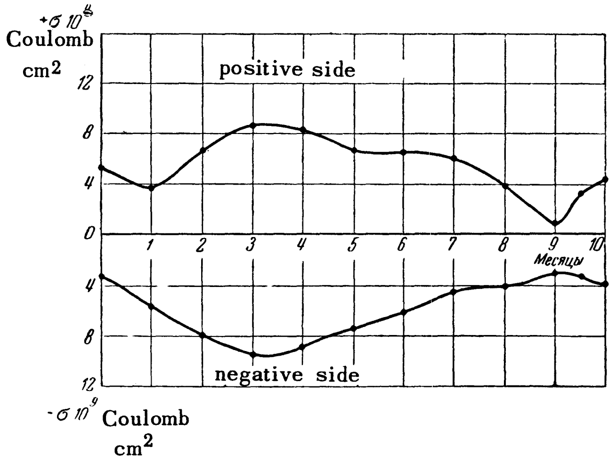
*The values of field intensity and temperature maintained during polarization for a group of materials were limited by their dielectric strength an relation to their thermal conductivity.

**Data have not yet been obtained.

There is a series of published works on the investigation of properties of electrets, obtained from different organic substances.[1,2]

Inorganic substances have been studied very little in this respect, and available information about them is very contradictory. In general electrets of polycrystalline inorganic dielectrics have not been studied, although mention was made of the electret-like behavior of field polarized barium titanate samples[3] in the program of the American Physical Society meeting of 1953.



We have first shown that stable electrets, the properties of which are not connected with pyroelectricity, can be obtained from polycrystalline inorganic dielectrics, such as titanates of magnesium, calcium, bismuth, strontium, zinc, strontium-bismuth, from metatitanate of barium, tetratitanate of barium and from steatite.

The following polarization procedure was used to obtain electrets in all cases; the sample was placed in a field of 20 kv/cm, maintained at room temperature for 30 min, raised to 200° C in 2 hours, maintained at this temperature for 2 hours and reduced to 65–90° C in 2 hours. The samples were 5 mm thick and about 60 mm in diamter. The electrodes were brass discs 30 mm in diameter. The surfaces of the samples and electrodes were thoroughly polished. The current was measured during polarization. The polarized samples were wrapped in lead foil and kept in a desicator with $CaCl_2$. Effective surface charge density σ of some electrets was measured by the electrostatic induction method and the signs of the surface charges were determined.

The basic results are shown in the Table. Values of σ in the Table are given only for one side of the electret, namely the one which was facing the minus side* during polarization (the negative side of the electret, the opposite side being positive). The signs of charges at the ends of the studied samples shown in the table coincide with polarity of the voltage applied to the samples during polarization (it is customary to refer to such a charge as "homocharge"), with the exception of pyrex glass. which has charges of opposite polarity (such a charge is called "heterocharge")**

The Figure shows the variation of σ with time for the $CaTiO_3$ electret. Similar curves were obtained for other investigated electrets. Preliminary experiments with $MgTiO_3$ samples indicate that the "life time" of electrets of this dielectric exceeds 1.5 years.

It follows from the data in the Table and the Figure that the surface charge density of the new electrets in all cases reaches the value for electrets made of carnubian wax ($1–2 \times 10^{-9}$ cm); and in some cases considerably exceeds this value (electrets of $CaTiO_3$ and others).

It is characteristic that in polarization without heating the dielectric also acquires homocharges, but they fall off with time much faster than those which were obtained with supplementary heating. Thus values of σ of $CaTiO_3$ samples, obtained without heating were, one month after polarization, 10 times smaller than the corresponding values of σ obtained for samples heated to 200° C. When electrets of magnesium titanate and of steatite are polarized in a 5 kv/cm field a heterocharge is observed, which after a few days is changed to a homocharge and then remains practically constant for a long time. At intensities of less than 5 kv/cm the samples of $MgTiO_3$ samples only a homocharge which slowly drops to zero. If the electrodes are formed by evaporation of silver (there is no layer of air between the electrode and the surface of the electret), then, in the absence of corona discharge from the conducting wires and from the electrodes, there are obtained insignificant charges (exhibit of $ZnTiO_3$) which drop to zero very quickly. An analogous situation is also obtained by the polarizations in a silicon organic liquid.

The work on the study of properties of electrets from inorganic delectrics is continuing at the present time.

The following persons participate in this work: junior scientific assistant V. S. Mitronina, senior laboratory techncian A. N. Kalganova and also, in the early phase of this work, P. Ch. Muchamedieva.

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*It should be noted that the absolute values of σ on the opposite sides of the electret are nearly equal.

**On the surface of dielectrics of high specific resistance (for example on quartz) there frequently appear, as a result of working the material, friction, etc., surface charges. However, these charges, as a rule, are of relatively small magnitude and are of the same sign at the two ends. Therefore, the error introduced by these changes into the measurements is small.

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Translated by J. L. Herson
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Dependence of Dielectric Strength of Alkali Halide Crystals on Temperature

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IT has been considered until not so long ago that the dielectric strength at puncture does not depend on temperature. Investigations of recent years[2–6] have shown that the dielectric strength of alkali halides in the region of puncture does not remain constant, and, as reported in all cited references, the temperature dependence of the dielectric strength at constant intensity exhibits a maximum. The results of these investigations do not agree, however, so far as the puncture values for pulsed voltages are concerned. There is also no agreement in the values of the temperature maximum.

In order to refine the existing experimental data, we have investigated the temperature dependence of dielectric strength for puncture KBr and KCl in the temperature interval from –170° to + 200° C. Investigations were conducted at constant voltage and with pulses of 10^{-2}, 10^{-4} and 10^{-6} sec duration with the voltage increasing linearly. For constant voltages and 10^{-2} sec pulses, measurements of the voltage applied to the sample were made with an electrostatic voltmeter whose error does not exceed 5%. The cathode ray oscillograph KO–20 was used for recording of the 10^{-4} and 10^{-6} sec pulse amplitudes with the sample voltage applied to the plates of the oscilloscope through a divider. The measurement error in this case did not exceed 10%.

Samples for crystals were prepared from monocrystals KBr and KCl grown by the method of Kiropulos . A cavity was bored in the crystal plates after which, in order to remove mechanical strains, the samples were subjected to a temperature 50 to 70° below the melting point and then to slow cooling at a rate of 1° per minute. After annealing the thickness of the sample in the region of the cavity was reduced, by polishing of the plane surface, to from 0.1 to 0.2 mm and silver electrodes were formed on the surface of the cavity and on the plane surface by evaporation in a vacuum. To guard against cracking the rate of heating and cooling before puncture was made not to exceed 1° per minute.

Figure 1 shows the temperature dependence for KBr. Each point on the curve corresponds to the mean value of dielectric strength based on measurements of 12 to 20 samples. The mean square error did not exceed 8% for constant voltages and 12% for pulses. As shown in Fig. 1, the temperature dependence of the dielectric strength E_{st} at constant voltage exhibits a maximum at 50° C which is smoothed out with decrease of the voltage duration. For pulses of 10^{-6} sec duration there is no maximum, and a gradual increase of the dielectric strength with temperature is observed. In the region below 50° C, the dielectric strength does not depend on temperature for constant voltages and pulses of 10^{-2} and 10^{-4} sec. Figure 2 shows the results of E_{st} temperature dependence measurements for KCl.

The following conclusions can be made on the basis of the present work.

1. It is established that the temperature depen-