Zeitschrift: Archives des sciences et compte rendu des séances de la Société
Band: 42 (1989)
Heft: 1: Archives des Sciences

Artikel: Polarity : from dipoles to biopolarizations. II. Addenda and indexes
Kapitel: Atomic polarizations
Autor: Turian, Gilbert
DOI: https://doi.org/10.5169/seals-740081

I. ATOMIC POLARIZATIONS

A. ORIGINS

A fourth state of matter is the plasma state which is formed when a gas is heated to such high temperatures that it becomes partly or fully ionized: ''electrons are torn off the atoms in the gas, leaving a stream of negatively charged free electrons and positively charged ions''(Peratt, 1990). Suggestively, the term plasma proposed in 1932 by Langmuir evokes ''the unstable almost lifelike behavior of the ionized material''. According to plasma cosmology, ''the universe has been and remains a veritable sea of charged particles interlaced with complex magnetic fields and electric currents. Many among the cosmologists therefore conclude with Peratt (1990) that ''the universe may have evolved not with the Big Bang but from a vast sea of plasma''. However, the theory of primordial explosion and of the shaping of the universe by gravitational rather than by electromagnetic forces keeps strong proponents (Rees, 1990).

In the evolutive perspective from the inert to the living matter, the atom of hydrogen (H) could be viewed as forming ''le couple divin''(Turian, 1990) displaying the electron, mobile as a male cell around the passively ''courted'' proton, as female cell, a most fertile association indeed concretized in the bioenergetics through the ATP-generating redox scale ($2H^+ + 2e^- + O = H_2O$, see **I**, IV.B.2.c).

B. SYMMETRY – POLARITY

The whole world appears to be chirally asymmetric from the scale of elementary particles upward. This leads Hegstrom and Kondepudi (1990) to ask the questions, as we did (**I**) for related polarities ''How do the asymmetries arise? Are chiral symmetries at one level linked to those at another, or are they independent?''

Chiral asymmetry must therefore be first studied at the scale of elementary particles. Indeed, there is symmetry within an atom only when it is regarded as governed by the electromagnetic force and its associated property of conservation of parity. The additional weak force (involving W^+ and W^- gauge bosons) gives rise to a violation of parity and consequently an asymmetry between the electrons and the nucleus in the atom (Bouchiat and Pottier, 1984). Chiral asymmetry at the subatomic level is thus fundamentally connected to parity nonconservation. One result of this asymmetry is that nuclear β decay, which is governed by the W force, produces mostly left-handed electrons. Consequently, electrons of matter are polarized with a left helicoidal coil while positrons of antimatter are right-directed. However, such chiral effects of the electroweak W and Z charges leading to a distinction between left and right chirals are strictly valid only when the electrons are travelling at the high energies near the speed of light (Hegstrom and Kondepudi, 1990).

An important consequence of chiral asymmetry at the *subatomic* level is that it causes a chiral asymmetry at the higher level of *atoms*: under the influence of the Z weak force, the electron orbit becomes a right-handed helix in the vicinity of the nucleus. However, the asymmetric Z force is so small that its effects on the chemical properties of *molecules* has not (yet) been observed (Hegstrom and Kondepudi, 1990). That such a mechanism affecting the production rate of L- and D-amino acids can indeed exist in nonequilibrium chemical systems was shown theoretically by Kondepudi and Nelson (1985, see **I**).

The problem of equivalence which has been upheld about left and right (see II.D) also arises ''with respect to positive and negative electricity'' as commented by Weyl (1952) in his book entitled ''Symmetry'' in which he also discussed relationships between quantum mechanics and symmetry. This author also assumed that ''the primary polarity as well as the subsequent *bilateral* symmetry come about by external factors actualizing potentialities inherent in the genetic constitution'' (see VII-VIII in **I**).

As already expressed by Pierre Curie ''symmetric systems behave in a symmetric fashion''. However, such Curie's principle is contradicted by the occurrence of spontaneous symmetry breaking which occurs when a perfectly symmetric system takes up a state with less symmetry (Field and Richardson, 1989). An example of the phenomenon is the change of form produced by compression of a cylindrical shell initially endowed with a perfectly *circular* symmetry.

The principle of ''cosmologie symétrique'' has been further discussed by Brack *et al.* (1989) in relationship with the equivalence between matter (proton + electron) and antimatter (antiproton + antielectron). Among previous books concerned with the principle of symmetry there are those cited by Weyl (1935), namely Jaeger (1917) and Hambidge (Dynamic Symmetry, 1920), completed by Jaeger (1925) and, more recently, those by Nicolle (1950) and Caillois (1973) as well as Hargittai and Hargittai (1986).

C. ELECTRIC BIPOLARIZATION

2) *Electric dipoles*

The hydrogen atom (H) can be considered as the primordial electric dipole when we consider that its electron or unit of negative charge is probabilistically positioned on a peripheral orbit around the positive proton according to the classical image of a planet circling the sun (Fig. 1B, in **I**). However, when the atom is placed under strong stimuli such as a constant magnetic field or exposed to electromagnetic radiation in the form of microwaves, either of these strong stimuli disturbs the orbit of the electron and pushes it into chaotic, unpredictable motion. Eventually, the electron atom is ionized, i.e. its electron has so much energy that the pull of the proton can no longer hold it, and the electron is torn away. According to quantum mechanics, the electron is not considered as a particle orbiting the proton, but as a rather nebulous ''wave packet''. Ionization high energy will delocalize the wave packet, namely ''the electron will become ''spread out'' over several energy levels'', an event corresponding to ''the chaos in the classical motion of the electron'' (Pool, 1989).

Protons and neutrons, the two types of nucleons, can be examined ''by observing electron or muon scattered off them with a large transfer of momentum to one of their constituent particles or partons'' (Roberts, 1990). As for the proton, its simplest properties are dependent on the three valence quarks, two ''up'' (u^+) and one ''down'' (d^-) (see **I**, I.C.2), each of which carries a spin of 1/2. These are polarized so that the u^+ quarks contribute 4/3 of the proton's total angular momentum (also 1/2), and the d quark $-1/3$. The distribution of polarized quarks can never exceed the distribution of unpolarized quarks (further discussion in Roberts, 1990).

The neutron (1 quark u^+ and 2 quarks d^-, see Cline, 1988) has also an electric-dipole moment, the upper limit of which has been recently measured (Smith *et al.,* 1990). The interest of neutron's electric-dipole moment is that ''it would violate the combination of charge conjugation invariance and parity known as CP symmetry. As such, any electric-dipole moment would take the opposite sign for the antineutron, and thus discriminate between matter and antimatter'' (Ellis, 1990).

Quantum theory holds that two photons emitted by a particular light source share their similarly oriented polarization. According to Clauser and Freedman's experiments recently recorded by Linden (1990), ''a change in one photon did alter the polarization of the other'' as if they were not separate objects and thereby obeying to the laws of quantum mechanics also applied to other ''wave particles'' such as leptons (electrons, etc).

In a search for understanding the charging of storm clouds, and contrarily to previous conclusions from Wilson and Simpson (see Williams, 1988) that electrical structures of thunderclouds were either a positive dipole (Wilson) or a negative dipole (Simpson), their actual structure is tripolar rather than dipolar. The correct explanation for this tripolar structure of thunderclouds is now known to lie in the microphysics of charge transfer between graupel particles (soft hail) and ice crystals (Williams, 1988).

3) *Polarized conductivity*

In a semiconductor the electrons move through an array of constituent atoms arranged in a crystalline lattice. Electrons move with great ease through gallium arsenide circuits. This compound is made into bipolar transistor devices by depositing it in three layers: electrons n-type doping, holes p-type base and n-type collector. These compose light-emitting diode of gallium arsenide alloyed with aluminium. Gallium arsenide photodetectors respond faster than silicon ones. They can also detect light by reversing the reaction and the resulting photodetector converts the flash signal to electronic pulses. Such optoelectronic computing systems can be linked by optical fibers which greatly increase the efficiency of the digital computing circuitry (Brodsky, 1990).

D. MAGNETIC POLARIZATION

1) *Cosmological level*

The sun's magnetic field can affect many aspects of the sun's surface and atmosphere. It oscillates along a 11-year variation of sunspot number. Measurements of sunspot spectra (Zeeman effect's analysis) showed that the strength of the magnetic fields around sunspots is thousands of time stronger than the earth's field. Most spots occurred in paired groupings that resemble giant magnetic dipoles roughly parallel to the solar equator. According to Foukal (1990), the great astronomer Hale already announced in 1924 that this switch in polarity occurred at each activity minimum, in the midst of a 22-year solar magnetic cycle and was a basic feature of the sunspot cycle. The largest areas of single magnetic polarity are the sites of spot formation. These solar magnetic changes may have their effects on the earth's periodic climate changes.

2) *Magnetic fields*

The discovery of ferroelectric crystals such as barium titanate ($BaTiO_3$) offered an electrically switchable, two-state device with which one could encode the 1 and 0 states required for the Boolean algebra of binary computer memories. A tetragonal ferroelectric crystal has two polarization states in which the centrally located Ti^{4+} ions are involved through their displacement up or down with respect to the other ions (Ba^{2+} or Pb^{2+}, O^{2-}). In a crystal of $PbTiO^3$, for example, there would then occur regions in which the polarization is up and regions it is down, called "ferroelectric domains" (Scott and Paz de Araujo, 1989). Most important for memory applications, the polarization of the entire crystal can be switched from up (+1) to down (0) by reversing the applied field. This ferroelectric memory progressively fades when the amount of switched charge decreases with use or by retention failure when the stored charge decreases to a level where the + or − state of polarization cannot be sensed.

All ferroelectric materials display a hysteretic behavior relating polarization and applied field, so that there is a nominal threshold (coercive field) above which the polarization changes sign.

4) *Spin polarizations*

Dipolar interaction between two nuclear spins depends on size and orientation of the magnetic moment as well as on the distance. In NMR spectroscopy which is based on the Zeeman phenomenon (Ernst *et al.,* 1987), nuclei with a kinetic moment of spin I higher than 1/2 have a quadrupolar (Q) electric moment. The nuclear quadrupolar resonance (NQR) is bound to a nonspherical symmetry in the distribution of electric charges on the nuclear volume. This NQR can only be observed on a limited number of nuclei but is helpful in the study of the electric structures of chemical bonds (Lucken, 1969).

E. LIGHT POLARIZATION

A light ray can be polarized by reflection on a polarizer and the intensity of the reflected ray received on an analyzer varies with its incident angle. The proportion of polarized light in the light ray or the rotation of the polarization plane of light are measured with a polarimeter (Pariselle, 1936).