

Chapter 3. Neutrality of Molecules by the Pulsed Gas Flow Method

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3.1 Introduction

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Determining whether the magnitude of the charge of a proton differs from that of an electron or whether neutrons, neutrinos, or photons are charged presents a significant and fundamental problem. Verifying the existence of these charge differences would be very important to our fundamental understanding of (1) electric charge quantization and conservation and (2) the standard model and grand unified theories.

Because these hypothetical small charges or differences in charges have no observable effect on the world, we could only verify them using specially designed experiments. Since there is no definite theoretical prediction for these hypothetical small charges, we simply carry out improved bench-top experiments that are feasible with our limited resources. (This is in contrast to studies of neutron dipole moment, proton lifetime, missing neutrinos, etc., which justified a large scale effort and commitment of resources.)

Experiments dating back 70 years have virtually guaranteed that these charges or charge differences are less in magnitude than 10^{-20} of the fundamental electron charge, 1.6×10^{-19} C. So far the results of our experiments have further reduced the limit of magnitude difference of proton-electron charge and the neutron charge by three orders of magnitude.

3.2 Project Description

The electric charge of any object, material, or system is measured by bringing a suitable sample near other charges or other charges near it so that electric forces would produce observable effects. The materials or systems that have been studied or are currently being studied by various groups around the world include: (1) beams of single atoms, which if not neutral, would experience a velocity change in an electric field and be deflected, change deBroglie wavelength, or interact with Doppler-shifted light; (2) small aggregates, like Millikan oil drops, which if not neutral, would be deflected by electric fields; (3) bulk fluids from which ordinary charges (ions or electrons) can be removed. This includes many gases and superfluid helium, which would transfer charge when moved by flow whether at low frequency, when simply let out of an electrically insulated container, or, in the case of liquid He II, sloshing in a U-tube, or at higher frequency such as in a standing sound wave; and (4) the inverse of the last method—an applied alternating electric field would induce sound waves in the material if it is not neutral.

While many of these methods suffer from difficulty with controlling, reversing, and otherwise characterizing applied electric fields, the gas efflux method we are using has problems with flow-induced charge separation, drift and noise problems of essentially dc charge measurements in the attoampere range, and comparatively small throughput of molecules (about 10^{21} /second). The pulsed flow method would raise the throughput by a factor of 500, and the fact that the signal sought is at 1 kHz, i.e., above the 1/f-noise range, should make long term correlation feasible to yield an additional factor of 100.

In the gas efflux method a siren-like chopper releases 0.5 ms gas pulses at a one kHz rate into a chamber where a background pressure of the same

gas is maintained by suitable pumps. This pressure must be such that the pulses travel a substantial distance with minimum diffusion neither stopping from viscous retardation nor coming apart by free molecule flow. We calculate that 0.5 kPa is approximately the correct pressure. These pulses, if charged, induce charge on cylindrical electrodes through which they travel. The resulting potential changes can be detected with a suitable electro-

meter, which might take the form of an array of parallel, cooled FETs to take advantage of Shannon's theorem.

At present, we are using a crude apparatus assembled from pipe fittings with a pneumatically operated shutter to investigate the dynamics of single pulses in background gas in order to design the pumping system needed to handle 1000 of these pulses per second.