Effects of weak vacuum on triboelectric charging and x-ray emissions of colliding particles.

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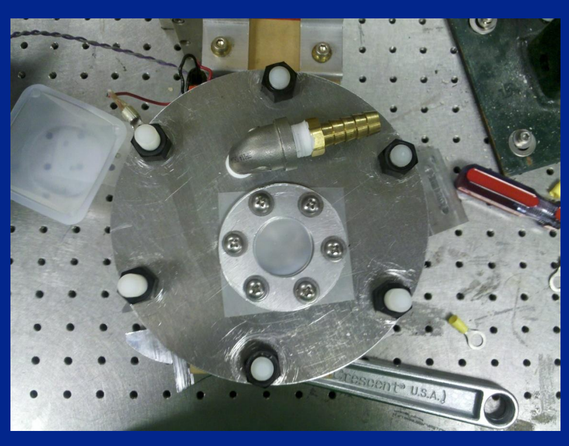
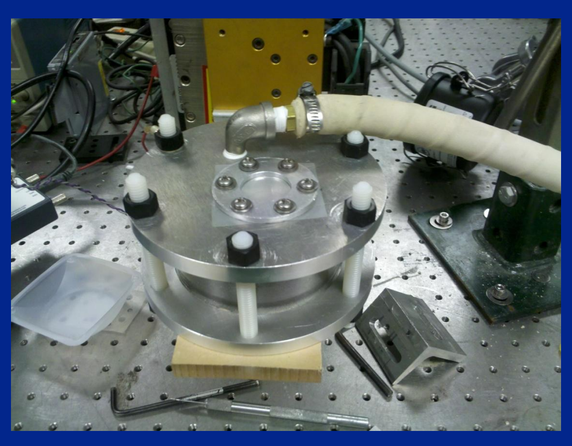
Background

The triboelectric effect occurs when small particles collide with each other and become oppositely charged. Triboelectricity is a poorly-understood phenomenon, and scientists do not even know whether the exchange of electrons or ions causes the charging.[1] Another puzzling aspect of the tribolectric effect is that colliding particles have been seen to release x-rays when under a vacuum.[2]

Apparatus

•Two 15.24cm diameter by 0.9525cm thickness aluminum plates, electrically insulated from each other and 6.0325 cm apart.
•One Oscilloscope to measure voltage, attached to the top and bottom aluminum plates.
•One 9 cm ID by 10 cm OD by 5.08cm height glass cylinder, f/p
•0.5mm Mylar window for viewing x-rays
•34g of 400-600 micrometer diameter glass beads to shake, forming a .35 cm layer in the cell.





Objectives

•Attempt to understand more about the triboelectric effect
•Design and create a container which will hold a milli-torr vacuum and has conductive top and bottom plates which are insulated from each other.
•Measure the voltage difference in the plates after shaking particles in various pressures and compare the effect.
•Measure the x-rays resulting from the collisions between the glass beads and the aluminum plates.
•This experiment expands the recent studies on the effect of mass, particle size, and shaking frequency done by Zack Lasner and Julia Salevan, trend and UMD undergraduate students.

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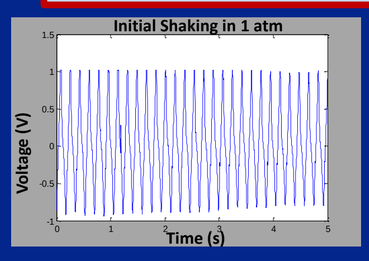
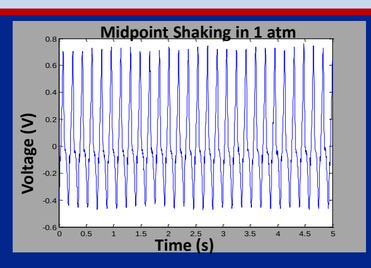
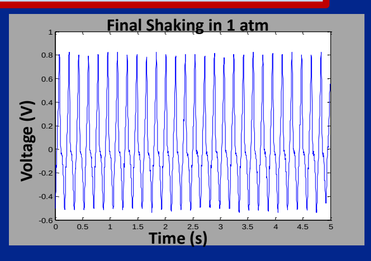
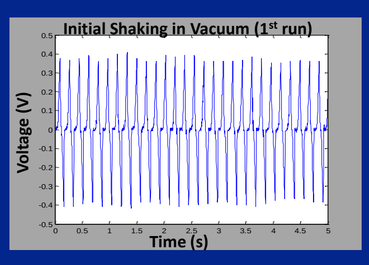
Experiment

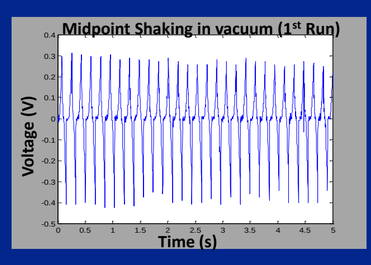
•After building the cell and pump connection tubing, a 20 milli-torr vacuum, which is to say 99.997% perfect vacuum, could be achieved in 5 minutes of pumping.
•The 9 graphs below are from shaking the container 2000 times at an acceleration of 1.34g for a distance of 2.515 cm. They graph voltage vs time. The peaks on the graph represent the voltage from the glass striking the top plate, and the troughs are from the glass striking the bottom plate.
•The first row is at 1 atm, the second row is in vacuum, and the third row is the fourth consecutive run of shaking in vacuum.
•The columns represent different times in the 2000-shake cycle: the beginning, middle, and end.
•The 2 pictures below show the cell after running in atmospheric pressure and in vacuum.

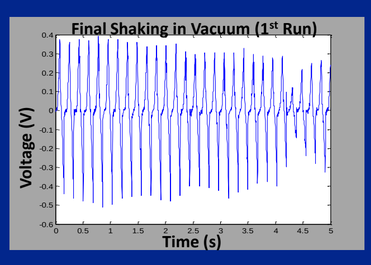


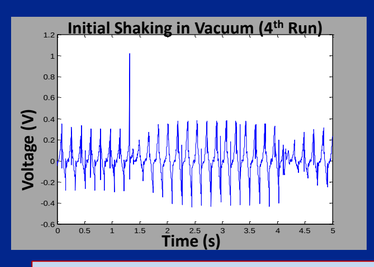


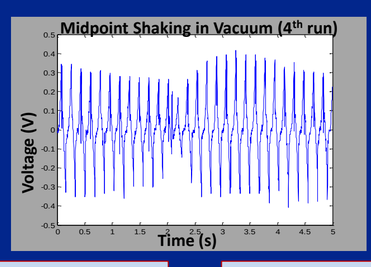


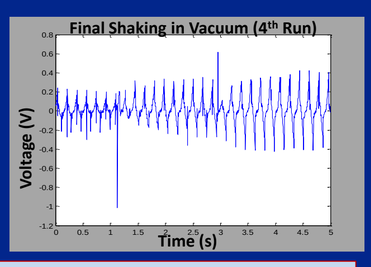












After shaking in atmospheric pressure

After shaking in 20 mtorr vacuum

Discussion

•Shaking particles in a vacuum appears to halve the charging of the particles. This is contrary to what we expected, as there is little to no humidity in a vacuum system, and humidity inversely affects triboelectric charging. One possible explanation for this is that there are fewer particles getting charged as almost no gas particles remain in the system.
•The charge difference between atmospheric pressure and milli-torr vacuum would also account for the lack of glass particles clinging to the walls during vacuum runs. The static charge isn't enough to overcome the other forces pulling the beads downward.
•The third row shows that the charging becomes more uneven the longer the system is shaken under vacuum. However, it still has many peaks at .4 V, the same voltage as beginning shakes had. This phenomenon is not understood at all.
•X-rays above 88 keV were not detected, but there is still a chance that the shaken particles emit lower level x-rays
•Further studies: Different levels of vacuum, whether going from 1 atm to vacuum has different effects than the opposite, testing for lower energy x-rays.

References

[1]K.M. Forward, D.J. Lacks, R.M. Sankaran, "Charge Segregation Depends on Particle Size in Triboelectrically Charged Granular Materials
[2]K.M. Forward, D.J. Lacks, R.M. Sankaran, "Methodology for studying particle–particle triboelectrification in granular materials," J. of Electrostatics 67 (2009) 178-183