ECARS:

A study of dissociative attachment and the technology produced

A Thesis Submitted in Partial Satisfaction

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By

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Dedication

I would like to dedicate this thesis to my mother Susann and my father Ned, for pushing me to be better and for never giving up on me.

Acknowledgements

I would like to acknowledge my thesis advisor Professor Fred Kuttner, my co workers Ranjit Pradhan, Leonid Bukshpun, John Mathews, and Physical Optics Corporation. I would also like to acknowledge my colleague Josh Ford as well as the rest of the staff at the University of California Santa Cruz that aided in my education. I would lastly like to acknowledge my professors at El Camino College.

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0.0.0 Abstract

Electron reversal is for the use in a new device that will detect explosives, chemical weapons, and radiological weapons. After a discussion of the theory of dissociative attachment is a discussion of the experimental setup, because the actual experiment has yet to be finished there are no results to report as of yet. The experiment, which needed to be under high vacuum conditions, will eventually be turned into a sensor. This sensor will eventually be used for the United States military in the field of battle to detect improvised explosive devices as well as other forms of bombs.

1.0.0 Introduction

In 1948 Wigner describes the behavior of low energy electrons and how they can become "sticky" at low energy thresholds [1]. When these slow electrons have become "sticky" they can be easily attached to various different materials. Wigner uses an arbitrary wave function to start his derivation.

$$\varphi = \sum_{\lambda} \frac{\int \mathrm{X}_{\lambda} (grad\varphi)_n ds}{E_{\lambda} - E} \chi_{\lambda} \tag{1}$$

Wigner points out that ψ and grad ψ both depend on E. There are a few conditions that are to be imposed on the system, one of which is that χ_{λ} and E_{λ} are characteristic values. The wave function may also be written to have 's', which corresponds to the particle, and 'l', which corresponds to angular momentum.

$$\varphi_{s,l} = P_l(\Omega_s)\psi_s \tag{2}$$

With the condition that:

$$\int \psi_{s,l}\psi_{s',l'} dS = \delta_{ss'}\delta_{ll'} \tag{3}$$

Meaning that any two wave functions on the same surface S will be orthogonal and can normalized. Then our equation (1) can represent a potential (V).

$$V_{s,l} = R_{s,l:s',l'} D_{s',l'} \tag{4}$$

With:

$$R_{s,l:s',l'} = \sum_{\lambda} \frac{\gamma_{\lambda,s,l}\gamma_{\lambda s',l'}}{E_{\lambda}-E} \quad \text{and} \quad \gamma_{\lambda,s,l} = \hbar^{1/2} \int X_{\lambda}\psi_{s,l}\, dS \tag{5) \& (6}$$

Then plugging into the spherical Schrödinger equation and solving for the energy of interest ($E_{s,l}$) one arrives at the solutions.

$$i\left(E_{s,l}e^{*}_{s,l} - E^{*}_{s,l}e_{s,l}\right) = \frac{a_s^2}{r_s^2} \quad \text{where} \quad e_{s,l} = \left(\frac{\hbar}{2M_s}\right)\frac{dE_{s,l}}{dr_s} \tag{7) \& (8}$$

From here Wigner solves the Schrödinger equation to get the most general form of the wave function using the Ricatti differential method to yield the following wave function.

$$\varphi = \sum_{s,l} \psi_{s,l}\left(\alpha_{s,l}E_{s,l} + \beta_{s,l}\, E^{*}_{s,l}\right) \tag{9}$$

This wave function can be compared to equation (1) to solve for the coefficients of the Schrödinger equation in the region outside of the atom. It appears that the coefficients α and ß are interdependent. They can be related through a diagonalized matrix defined as Ū (See Eq. (11)). The coefficients are written as.

$$\alpha_{s,l} = -\sum_{s',l'} U_{s,l:s',l'}\beta_{s',l'} \tag{10}$$

The matrix Ū can be written as the following matrix.

$$\bar{U} = \begin{Vmatrix} U & 0 \\ 0 & 1 \end{Vmatrix} \quad \text{With} \quad U = \omega\left(1 + ij(q-R)^{-1}j\right)\omega \tag{11) \& (12}$$

Then Wigner uses this interaction matrix (11 & 12) to calculate the different levels of angular momentum for different types of interactions. Wigner places the angular momentum values ("l" in tables 1, 2, & 3) into classifications based on how the electron interacts. The theory described by Wigner had huge implications. What Wigner basically did was describe how it was that particles interact with certain cross sections based on whether the particles are interacting with a coulomb attraction, coulomb repulsion, or neutral.

Table 1: No interaction in eternal region and asymptotic values of E, q, j, and ω for small $k_s a_s$

	$E_{s,l}(r_s)$	$q_{s,l}(a_s)$	$j_{s,l}(a_s)$	$1 + i^l\omega_{s,l}(a_s)$
$l = 0$	$\left[\left(\frac{M}{\hbar k}\right)^{\frac{1}{2}}\right] a/r$	$-\frac{2Ma}{\hbar}$	$2ka(\frac{M}{\hbar k})^{\frac{1}{2}}$	$\frac{[i(ka)^3]}{3}$
$l = 1$	$\frac{\left[i\left(\frac{M}{\hbar k}\right)^{\frac{1}{2}}\right] a}{kr^2}$	$-\frac{Ma}{\hbar}$	$[\frac{(ka)^2}{3}]\left(\frac{M}{\hbar k}\right)^{\frac{1}{2}}$	$-\frac{[i(ka)^3]}{6}$
$l \geq 1$	$\frac{i^l 1 * 3 * \cdots (2l-1)}{\left(\frac{\hbar k}{M}\right)^{\frac{1}{2}}(\frac{r}{a})(kr)^l}$	$-\frac{2ma}{(l+1)\hbar}$	$\frac{2(ka)^{l+1}\left(\frac{M}{\hbar k}\right)^{\frac{1}{2}}}{(l+1)1 * 3 \cdots (2l-1)}$	$-\frac{il(ka)^{2l+1}}{(l+1)(2l+1)\left(1 * 3 \cdots (2l-1)\right)^2}$

Table 2: $V = \frac{Ze^2}{r} > 0$. Asymptotic values of E, q, and j for small kr or ka

	$E_{(r)}$	$q_{(a)}$	$j_{(a)}$
$l = 0$	$-\frac{e^{(\pi\alpha + i\alpha ln2kR)H_1(i\beta)}}{\left(\frac{\hbar r}{\pi Ma^2}\right)^{\frac{1}{2}} arg}$	$\frac{\left(\frac{4Ma}{\hbar}\right)H_1(i\beta)}{i\beta H_0(i\beta) - 2H_1(i\beta)}$	$\frac{4\left(\frac{Ma}{\pi\hbar}\right)^{\frac{1}{2}} e^{(-\pi a)}}{i\beta H_0(i\beta) - 2H_1(i\beta)}$
$General$	$\frac{(-)^{l+1} e^{(\pi\alpha + i\alpha ln2kR)} H_{2l+1}(i\beta)}{(\frac{\hbar r}{Ma^2})^{\frac{1}{2}} arg}$	$\frac{\left(\frac{4Ma}{\hbar}\right)H_{2l+1}(i\beta)}{i\beta H_{2l}(i\beta) - (2l+2)H_{2l+1}(i\beta)}$	$\frac{4\left(\frac{Ma}{\pi\hbar}\right)^{\frac{1}{2}} e^{(-\pi\alpha)}}{\lvert i\beta H_{2l}(i\beta) - (2l+2)H_{2l+1}(i\beta)\rvert}$

Table 3: $V = \frac{Ze^2}{r} > 0$. Asymptotic values of E, q, and j for small $k_a a_s$ or kr

	$E_{s,l}(r)$	$q_{s,l}(a_s)$	$j_{s,l}(a_s)$
$l = 0$	$\frac{e^{[i\alpha \ln(2kR)]} i H_1(\bar{\beta})}{(\frac{\hbar r}{\pi M a^2})^{\frac{1}{2}} arg}$	$\frac{\left(\frac{4Ma}{\hbar}\right) H_1(\bar{\beta})}{\bar{\beta} H_0(\bar{\beta}) - 2H_1(\bar{\beta})}$	$\frac{4\left(\frac{Ma}{\pi\hbar}\right)^{\frac{1}{2}}}{\left\|\bar{\beta} H_0(\bar{\beta}) - 2H_1(\bar{\beta})\right\|}$
$General$	$\frac{(-)^l e^{[i\alpha \ln(2kR)]} i H_{2l+1}(\bar{\beta})}{(\frac{\hbar r}{Ma^2})^{\frac{1}{2}} arg}$	$\frac{\left(\frac{4Ma}{\hbar}\right) H_{2l+1}(\bar{\beta})}{\bar{\beta} H_{2l}(\bar{\beta}) - (2l+2) H_{2l+1}(\bar{\beta})}$	$\frac{4\left(\frac{Ma}{\pi\hbar}\right)^{\frac{1}{2}}}{\left\|\bar{\beta} H_{2l}(\bar{\beta}) - (2l+2) H_{2l+1}(\bar{\beta})\right\|}$

Once Wigner had successfully derived the angular momentum values for different potentials, he then compared them to the scattering cross section for different types of particles. Wigner broke it down into three types of reactions that come out of the different natures of the particles. Particles can have no charges, the same charges, or opposite charges. Particles can also be created from the matching of different values of angular momentum.

The first discussion was about the production of new types of particles with the use of the angular momentum of old types of particles. First they can form neutral particles with a cross section (σ) that are proportional to k by the following proportionality.

$$\delta \sim k_n^{2l+1} \tag{13}$$

The second thing that can happen is that the particles created can be the same charge and thus create a coulomb repulsion. The cross section is then dependent on the exponent of M, Z, and k in the following way.

$$\delta \sim e^{\left(-\frac{2\pi M_n Z_n e^2}{\hbar k_n}\right)} \tag{14}$$

The third thing that can happen is the particles formed are opposite charges and thus create a coulomb attraction. The cross section is oddly different and can be written as follows.

$$\delta \sim 1 \tag{15}$$

The cross section is proportional to a constant. This case will present a finite value for high angular momentum at the low energy threshold. This result has huge consequences. The constant proportionality in the cross section reviles that particles can interact with others even if they have large differences in angular momentum.

The next discussion that Wigner went over was the reaction of new types of particles with use of angular momentum to from old types of particles. It is again broken up into three different categories based on the cross sectional interactions. The first of which is the interaction between neutral particles.

$$\delta \sim k_n^{2l-1} \tag{16}$$

This interaction is similar to the interaction given in equation (13). The only difference is that equation (16) is a subtraction instead of a plus sign. While this is notable it is only a minor difference because it means that when the cross section is smaller there is a more likely chance that the particles will interact, and when the cross section is large then the particles just pass each other by without interacting. The second interaction was between equal charges and it has the following proportionality with the cross section.

$$\delta \sim e^{\left(-\frac{2\pi M_n Z_n e^2}{\hbar k_n}\right)} \tag{17}$$

Here it is evident that (14) and (17) are exactly the same equation. This is not a surprising result because it simply states that if particles have a coulomb repulsion they will repulse themselves, which is dependent on the mass (M), the

atomic number (Z), indirectly the energy (k), and the charge (e). The last interaction that was presented was the interaction between opposite charges.

$$\delta \sim k_n^{-2} \tag{18}$$

This was a very significant discovery because the particles no longer have that independence of angular momentum. The cross section will still be a constant but only with respect to the amount of energy that the two particles have, and thus the two particles have a more likely chance of interaction at low energies.

The last thing that Wigner covers is the reaction of the new particles with new particles. This process is also known as depolarization at low energies. Again it was split into the types of particles interaction, and the neutral particles were related to the cross section by (here we allow $n \to l \; and \; l \to l'$).

$$\delta \sim k_n^{2l+2l'} \tag{19}$$

The interactions between particles that have the same charge, and thus follow the coulomb repulsion, at low energies are as follows.

$$\delta \sim k_n^{-2} e^{\left(\frac{4\pi M_n Z_n e^2}{\hbar^2 k_n}\right)} \tag{20}$$

Again this is not a surprise. The interaction proves to be exactly the same as the previous two classifications. The final category that was derived was the interaction of particles with the opposite charge, thus a coulomb attraction. The cross section was proportional to the following.

$$\delta \sim k_n^{-2} \tag{21}$$

Again the result is the same as the reaction of new particles to old particles. Recurrently it suggests that the interaction of particles is dependent on the energy and also is strongest when the particles are at low energies. Here Wigner has given a mathematical basis for the interaction of particles for a few different interaction

types and all of them suggest that particles of opposite charge become energetically favorable when the particles in question are at low energies. The idea of dissociative attachment that Wigner discovered as looked at again in 1966 by a man named T.F. O'Malley [2]. O'Malley wrote about a fairly comprehensive theoretical treatment of the dissociative attachment of electrons and diatomic molecules.

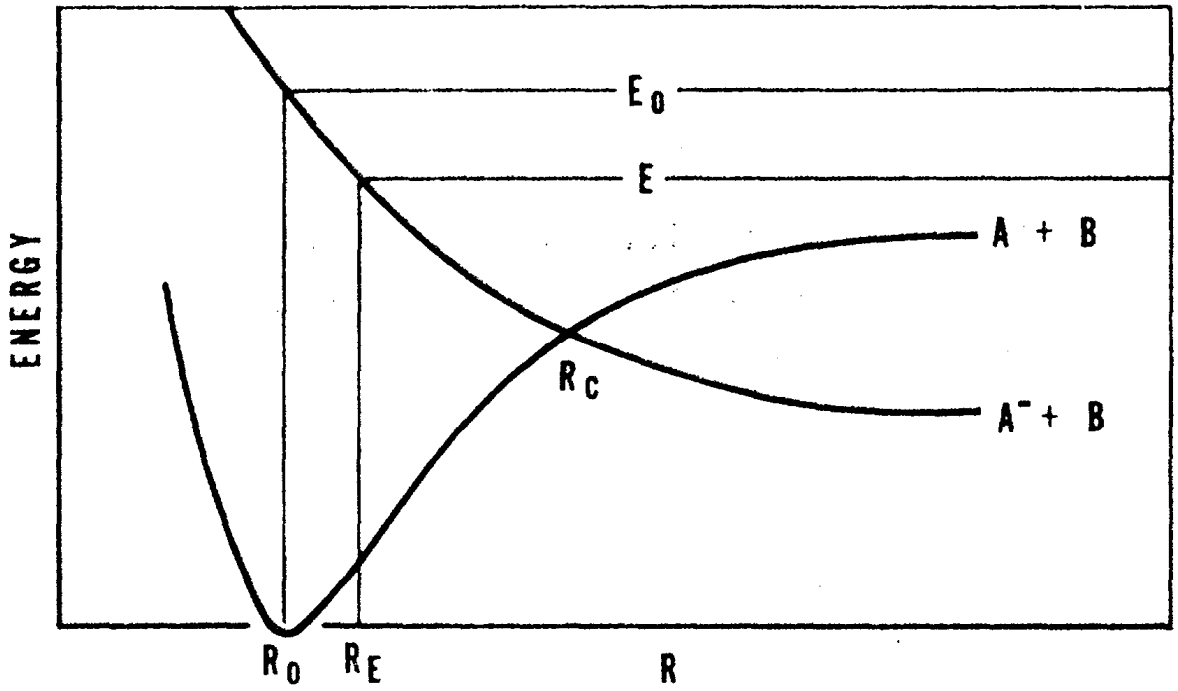
$$AB + e^{-} \xrightarrow{yields} A^{-} + B \tag{22}$$

Equation (22) describes the interaction between a diatomic molecule (AB) and an electron (e-) at low energy. It builds off the interactions that Wigner laid out by taking his equations and solving them using the Born—Oppenheimer approximation. The Born—Oppenheimer approximation is an approximation that allows one to take the total wave function and break it down into a cross product of the electronic and nuclear components.

$$\Psi_{Total} = \psi_{electrical} \times \psi_{nuclear} \tag{23}$$

This is extraordinarily useful because the separation allows for scientists to focus on the electrical interaction of the wave function. O'Malley compares the energy curves that arise from the solution of the potential energy to the radius (R) from the atom. O'Malley puts the two curves on the same graph to compare. The graph (figure 1) clearly shows how diatomic molecules can disassociate with the introduction of an electron.

Figure 1: Typical initial state (AB) and final resonant state (AB-*) potential energy curves for the dissociated attachment of electrons (with energy E) to molecule AB. R_E is the turning point for motion on the upper curve, determined by E. R_0 is the initial equilibrium distance. The negative ion curve is considered relatively stable against auto-ionization for $R > R_c$.



Here O'Malley points out that the probability of an electron attaching to a diatomic molecule, and thus separating the molecule into its elemental components, be more favorable if the radius (R) is less than the critical radius (R_c). O'Malley describes how the electron will resonate with the molecule and this resonance will cause the electron to attach itself to the molecule.

Dissociative attachment has been a known and well studied physical phenomena, as developed by Wigner and O'Malley. It is really an amazing phenomenon because it can lead to the detection of materials from a distance. Dissociative attachment will allow for the detection of molecules by creating an ionic molecule that then can be analyzed using the mass spectrometry method [3].

The mass spectrometry method consists of a sample being turned into an ion. Then the ion source is sent to a mass analyzer, which separate particles based on their mass ion ratio. Then the ions are detected, by recording a charge induced of current produced event, and analyzed for chemical composition. An electron is a good ionizing particle because it has a well known and naturally common electric charge. Electrons are a bit finicky though. They only like to be energetically favorable, which means that the electron will mostly only attach to an atom or molecule if they have a positive charge of equal or larger strength as the electron. With dissociative attachment, an electron can be brought into the low energy threshold which will cause it to attach to the nearest molecule or atom. This will effectively make the electron "sticky" and able to attach to a wider range of molecules and atoms.

One of the challenges that came about in the research of dissociative attachment was how to get a free electron to slow down enough to reach the low energy threshold. This problem has been solved and the technology is owned by Physical Optics Corp. This technology will be used to make a sensor that will aid the United States troops, at first, and potentially many others. This sensor, entitled **ECARS**, will detect **e**xplosive, **c**hemical, and **r**adiological weapons from a safe distance (the '**s**' is for sensor).

1.1.0 Explosives

There are many different types of explosive materials. An explosive material, as defined by the military, is a material that either is chemically or otherwise energetically unstable or produces a sudden expansion of the material usually accompanied by the production of heat and large changes in pressure upon ignition [4]. They are classified into low explosives and high explosives. Low explosives are usually a mixture of a combustible substance and an oxidant. They are most commonly used in propellants such as gun powder, pyrotechnics and flares. High explosives differ in that they are a singular compound of substance. They are classified into three different sub categories.

1.1.1 Primary explosives

Primary explosives are explosives that are extremely sensitive to stimuli such as impact, friction, heat, or electrostatic sources of ignition [5]. This classification holds a key component of dynamite, nitroglycerin (see Fig. 1) as well as acetone peroxide, lead picrate, silver fulminate, and tetrazoles to name a few [5-6]. Primary explosives are commonly used in blasting caps because of their volatility.

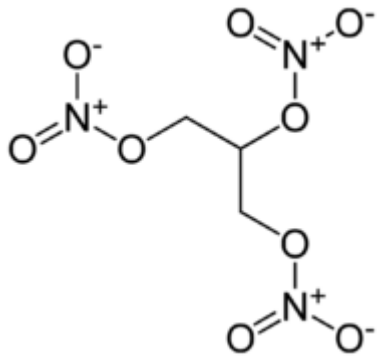


Figure 2: Nitroglycerin

1.1.2 Secondary explosives

Secondary explosives are the same as primary with the exception that secondary explosives are much less sensitive to stimuli [5]. Secondary explosives are used as the fuel in common explosive devices set off by the blasting cap. Some common secondary explosives are TNT (Fig. 3) and RDX (Fig. 4), also known as trinitrotoluene and cyclotrimethylenetrinitramine respectively.

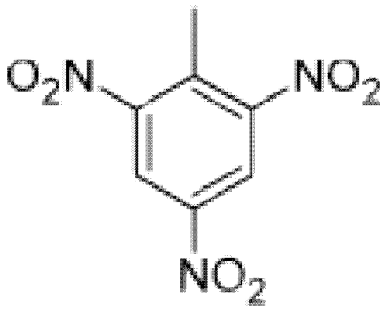


Figure 3: Trinitrotoluene (TNT)

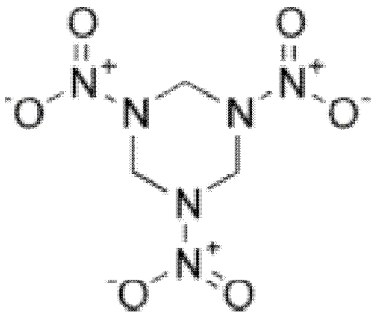


Figure 4: RDX

1.1.3 Tertiary explosives

Tertiary explosives are even more insensitive to stimuli, so much so that it cannot be detonated by practical amounts of primary explosives. These explosives are commonly detonated by secondary explosives. Tertiary explosives are most commonly used in mining and construction, as well as terrorist attacks [7].

1.2.0 Chemical Weapons

Chemical weapons are a very real threat in combat situations. One of the reasons chemical weapons are so dangerous is that they can vary in vast number of ways. They can be as simple as a single element, in the case of chlorine [8]. Or they can be a complex molecule that is so secret it requires a United States security clearance to even see the formula, such as certain Novichok agents [9]. Chemical agents are listed into three different categories: 1) harassing agents, 2) incapacitating agents, and 3) lethal agents [8]. Harassing agents are chemical agents that are designed to simply irritate the body. Examples include tear gasses and vomiting agents [8]. The lethal agents are split up into four main categories based on how they affect the human body.

1.2.1 Blister Agents

Blister agents are chemical compounds that irritate and causes injury to the skin. Vesicants, a subgroup of blister agents, are substances that

produce fluid filled blisters on the skin. Most vesicants fall under three classifications. Sulfur mustard gas is a classification of different chemicals that are sulfur based vesicants, of which, commonly known mustard gas (1,5-dichloro-3-thiapentane) belongs to [11]. Nitrogen mustard gas is a classification of different chemicals that are similar to sulfur mustard gases except they are based on nitrogen instead of sulfur [12]. Arsenicals are a classification of vesicants that are organoarsenic compounds [8]. The other type of blister agent is called urticants. Urticants are blister agents that produce a painful wheal on the skin [8].

Figure 5: Mustard Gas

1.2.2 Blood Agents

Blood agents are compounds that prevent the normal transfer of oxygen from the blood to the body tissues, resulting in chemical asphyxiation [13]. Most blood agents contain the cyanide group, or more commonly just cyanide. Cyanide is an anion made from a carbon and nitrogen triple bonded together. One of the most famous blood agents is called hydrogen cyanide, or Zyklon B, made famous by the Nazi regime for use in their gas chambers to eradicate the Jews and enemies of the regime.

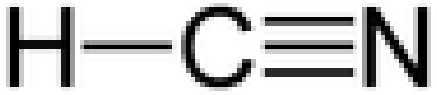


Figure 6: Hydrogen Cyanide (Zyklon B)

1.2.3 Pulmonary agents

Pulmonary agents, also known as choking agents or lung agents, are chemicals that attack the lungs. They operate by causing a build-up of fluid in

the lungs which lead to suffocation [14]. This classification tends to be corrosive and can burn skin and yield blurry vision. Chlorine gas is a pulmonary agent. The odd thing about chlorine gas is that is its simplicity, it is only two chlorine atoms that share a single bond. It is also the most common isotope of chlorine found naturally.

1.2.4 Nerve agents

Nerve agents, also referred to as nerve gases though these chemicals are liquid at room temperature, are a class of phosphorus-containing organic chemicals (organophosphates) that disrupt the mechanism by which nerves transfer messages to organs [15]. These are the most modern and deadly chemical weapons. Some of which are so dangerous that the military has made the exact chemical formula classified. There are three different classifications of nerve agents. G-series, named so because the German scientists were the first to discover the formulas, were all discovered during or at the end of the Second World War. They are named GA, or tabun, GB, or sarin, GD, or soman, and GF, or cyclosarin (see Figs. 7 to 10 respectively).

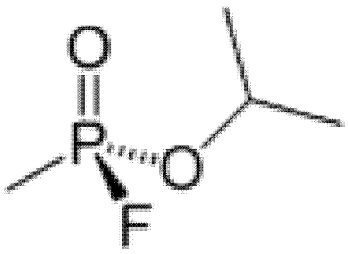


Figure 7: Sarin

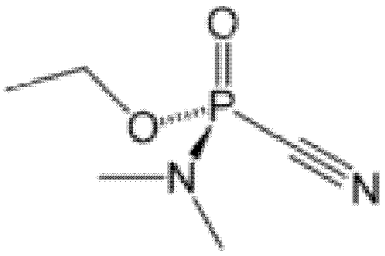


Figure 8: Tabun

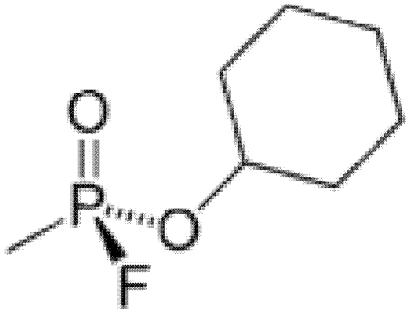


Figure 9: Cyclosarin

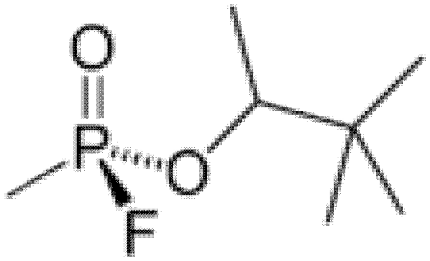


Figure 10: Soman

Sarin was the only G agent used by the United States as munitions. It was specifically manufactured into rockets, aerial bombs, howitzer rounds, and gun rounds. The second classification of nerve agents are the V-series. There are five well studied V-series agents and they are VE, VG, VM, VR, and VX (see Figs. 12 to 15 respectively). VX was the only V-series agents that the United States employed in munitions, consisting of rockets, artillery shells, airplane spray tanks, and landmines.

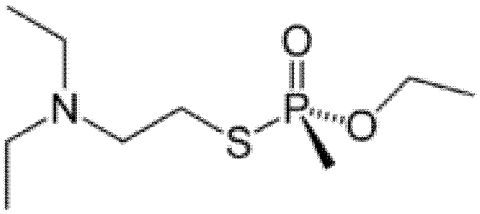


Figure 11: VM

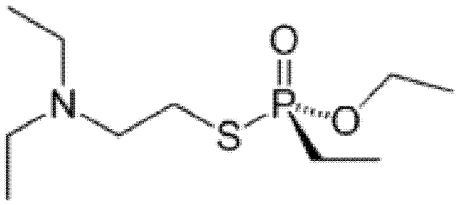


Figure 12: VE

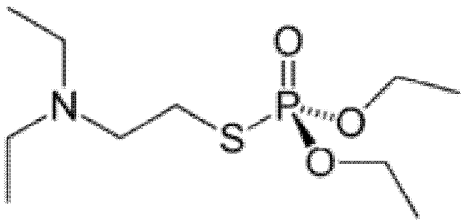


Figure 13: VG

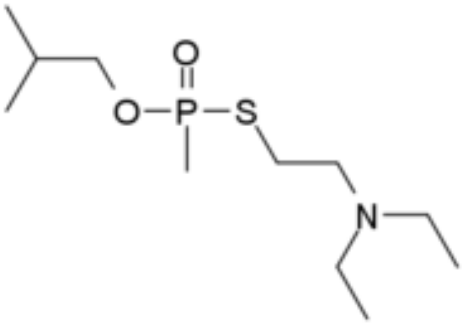


Figure 14: VR

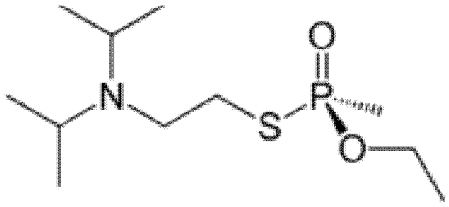


Figure 15: VX

The last classifications of nerve agents, and allegedly the most deadly, are the novichok agents. The novichok family of nerve agents is very heavily regulated by the military and the exact formulas are not open to the public, most notably novichok 5. The generic formula is, however, open to the public (see Fig. 16).

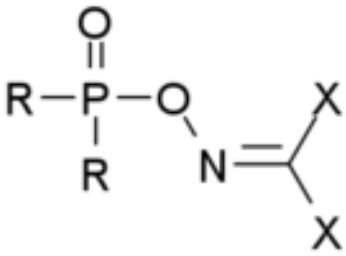


Figure 16: Novichok (General), where R is alkyl, alkoxy, alkylamino, or floruine and X is halogen or pseudohalogen.

1.3.0 Radiological weapons

Radiological weapons are any weapons designed to spread radioactive material with the intent to kill [16]. The term radiation can refer to either electromagnetic radiation, light, or it can refer to particles that are ejected from the nucleus of an atom. There are three types of radioactive decay. Alpha decay is the radioactive decay, usually made from heavy elements, which produces a helium nucleus. Alpha particles are heavy decay elements and tend to lose their kinetic energy and are relatively easy to shield from. Beta decay is the radioactive decay that produces beta particles. Beta particles are positrons or electrons. Since beta particles have significantly less mass then the alpha particles, as well as a much smaller cross sectional area, it is harder to shield form this type of radiation. The last type of radiation is the most general, it is known as gamma radiation. Gamma radiation is so general because it is not particulate radiation. Gamma radiation is high energy electromagnetic radiation, which can be created by the nucleus of an atom [17]. Gamma radiation can contaminate other materials casing them to change at the atomic level. All three categories of radiation can cause harm in humans and therefore must be detectable the sensor.

2.0.0 Materials and Methods

The experiment was designed to test electron reversal. It was designed to test and detect the reversal region of an electron that is at the low energy threshold. The first thing to do is research. The device must eventually be able to detect chemical, explosive, and radiological threats from a safe distance for troops in the field. In order to help construct the device it is necessary to have a clear idea of what each of the categories signature traits are because this will give a clearer focus of study. The place to start the research would be a general search over the internet or at the local library for what types of chemicals can be classified as weapons as well as the chemical makeup of the most common explosives and what characteristic helps to classify the explosive in the particular categories. A review

of radiological decay would also be beneficial to the creation of the device. One of the main issues with this experiment was that it all had to be done in a vacuum environment. The vacuum had to be as low as 10^{-3} torr to 10^{-9} torr, or high vacuum region.

2.1.0 Apparatus

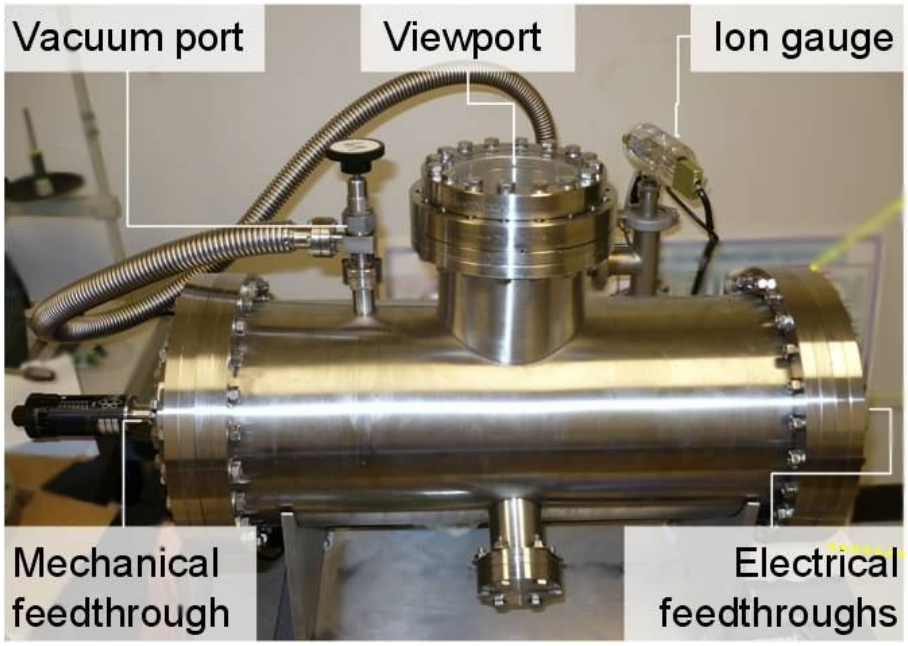


Figure 17: Experimental Setup

The next thing to do was to build the vacuum chamber that the ion optics and mirror were housed in. The vacuum chamber itself was custom built and was cylindrical in shape with a ten inch diameter tube that was twenty six inches long. It had four openings along the side, three approximately half way down the vacuum chamber, one approximately one third of the way down the chamber form one side. One of the three holes in the middle were 6 ¾ inches in diameter and the other two, 2 ¼ inches in diameter. The 2 ¼ inch openings were capped with a blank 2 ¼ inch flange. The 6 ¾ inch opening was a bit more challenging because it is a non-standard size of hole for vacuum chambers. A con-flat (CF) reducing flange was placed on the 6 ¾ opening to go from 6 ¾ inches to 6 inches. Then a 6 inch window flange was placed on the chamber so a view of the target area could be viewed while

the chamber was under vacuum. The last opening, the one a third of the way down the chamber, was 1 $\frac{1}{3}$ inch in diameter and was the attachment point for the pumping system to attach onto the chamber. At the ends of the chamber were placed more CF reducing flanges to get the appropriate size holes for the mechanical feed through and electrical feed throughs. At the mechanical end a 10 inch to 6 inch CF reducing flange was put on the chamber, using twenty four, ¼"-20 hex head machine screws. Then a 6 inch to 2 ¼ inch CF reducing flange was put on the chamber, using sixteen, ¼"-20 hex head machine screws. Finally a 2 ¼ inch to 1 $\frac{1}{3}$ inch CF reducer was put on the chamber, using six, 3/8"-16 hex head machine screws. After all of the aforementioned CF reducer flanges are placed on the same side of the chamber the mechanical feed through was attached.

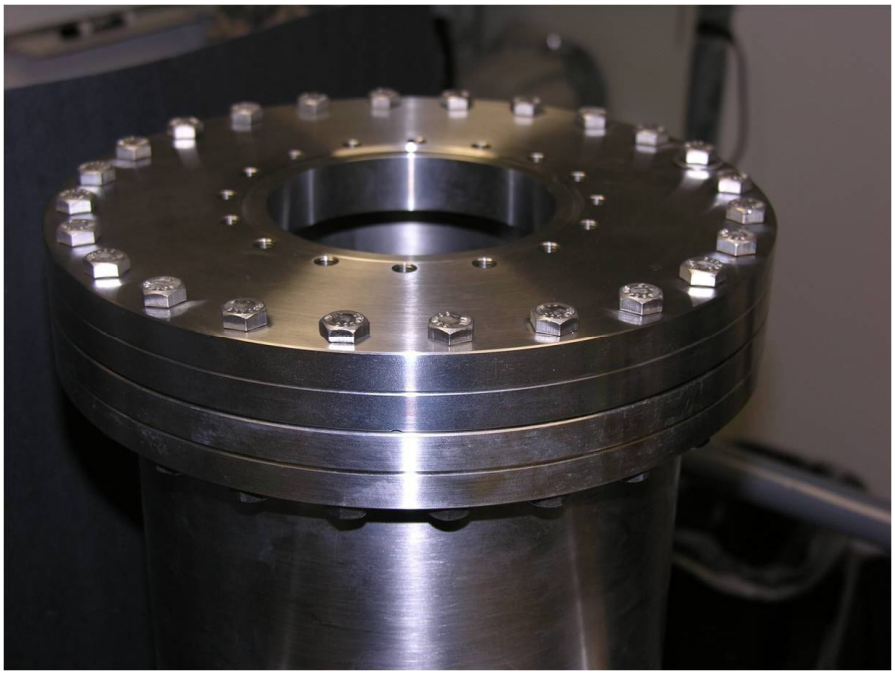


Figure 18: 10" to 6" CF Reducing Flange attached to the vacuum chamber.

The mechanical feed through was attached by six 8-32 screws. It has two rotatable knobs on one end and a steel bar with two holes at the other. Screws are placed through the holes to attach a hollow aluminum rod with matching holes. The hollow aluminum rod then had an 8-32 rubber self clenching standoff inserted

into the end so an aluminum mirror could be placed on the end. The mirror was a simple piece of aluminum sheet metal that was bent and biffed to a mirror shine. The other side of the vacuum chamber had attached to it two CF reducing flanges. The first is was a 10 inch to 6 inch, and the second was a 6 inch to a 2 ¾ inch reducer. The electrical feed through was a six pin electrical feed through. The ion optics was mounted onto specially designed standoffs that mounted the optics to the 6 to 2 ¾ inch CF reducer flange via four ¼-20 threaded rods that were cut to 8 inches.

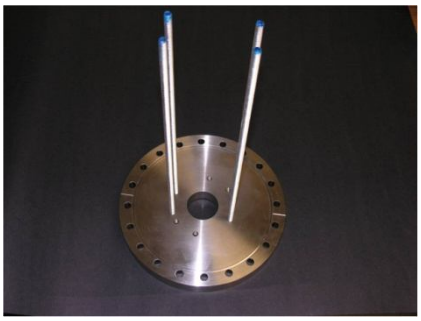


Figure 19: Four ¼-20 Threaded rods connected to the reducer flange

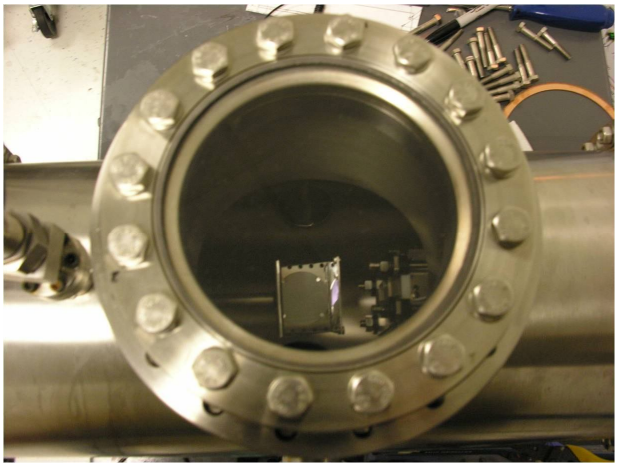


Figure 20: View through window of setup that gives a view of the mirror.

Great care must be taken to make sure that each material that is placed under vacuum is not fastened to a material of the same type because under the high vacuum region that in necessary for the experiment the materials will be virtually welded together. This is because there is much less air in between the two

surfaces. If someone places an aluminum box onto an aluminum table there is still a cushion of air that separates the two different objects. Once the box sitting on the table is placed under ultra high vacuum the cushion of air is removed and molecular forces are allowed to take over and the result is one solid piece of aluminum. It was also necessary to have the ion optics electrically isolated therefore Delron spacers were fabricated. Delron was chosen as the material because it has a low outgassing point. Outgassing is what happens when the surface pressure is taken off of a liquid in allowing the energy it contains to escape in the form of steam. If this happens inside a vacuum system it could potentially break the pump. The pumping system consisted of a roughing pump, which was used to pump down the vacuum system initially, then the main pump was turned on and the chamber was allowed to pump down to a sufficient vacuum to turn on the turbo pump. The turbo pump was left on over night to make sure there were no leaks in the system. All of the CF reducing flanges were purchased from either Kurt J Lesker company or from MDC Vacuum products. The mirror, standoffs and Delron spacers were all sent out to be manufactured by different privet manufactures and fabricators. The designing of the pieces were done in house by the technicians that worked on the experiment.

2.2.0 Experiment

Once the apparatus was set up it was time to start testing. First thing to do even before the experiment testing could start the inside needed to be cleaned. The cleaning process was very particular because of the order of the cleaning agents that needed to be applied in the correct order so to not leave any residue on the inside surface to outgas. The first chemical cleaner was acetone. This was applied to dissolve any organic residue because acetone is well known for its ability to dissolve organic materials. Latex is one such substance that acetone will eat through. Next was a cleaning with methanol. The methanol was used to dissolve any of the left over acetone as well as any other molecularly polar substances that might have been present. After the methanol was a nice cooling bath in 98% pure isopropyl alcohol to dissolve the methanol residue. And finally a bath in de-ionized

water to clear out the isopropyl alcohol and then just to make sure that there was no particulate matter left over it was necessary to use chemical towels. After everything that went inside the vacuum chamber was washed and dried it was time for assembly. Special latex powder free gloves were used to handle all of the parts while assembly of the apparatus was commencing. The gloves were necessary to keep all the pieces clean so the outgassing does not occur. If anything was left inside the chamber the vacuum pump would suck it into the intake and seriously damage the vacuum pump. In between each flange was placed an appropriate sized brass washer. After the assembly process was completed it was time to pump down the system and make sure that the vacuum system was completely air tight and that there were no leaks. Once cleaning and assembly was complete it was time to check the vacuum system by shutting the vacuum valve and pumping down all the vacuum parts that did not include the chamber itself, this was necessary to find if there were any leaks. First the roughing pump was turned on and let run for approximately five to ten minutes, as long as took to get to get to the upper limit of the medium vacuum region, 10^{-3} torr. Then the turbo pump was turned on to get to the target vacuum region, or more precisely $5.3 * 10^{-7}$ torr. Once the target region was hit it was time to re-pressurize the tubing and pumps, so the actual vacuum chamber could be attached and pumped down. Unfortunately the rest of the experiment has yet to be completed.

3.0.0 Discussion

The significance of the experiment was to demonstrate that the heart of ECARS, Wigner's electron reversal adaptation, was based in physical reality. The importance of this type of technology is vast. This technology allows for the detection of substances that in some cases are seemingly undetected from a distance. The intended use of the technology was for the troops of the United States of America. This technology will allow the American military to diminish the amount of solider casualties that are incurred form improvised explosive devices (IED) and road side bombs. IEDs can be made to simply explode to harm, or they

can be made do distribute chemical weapons and radiological weapons. The physics behind ECARS can be adapted for a wide range of different diagnostic tools. These tools could then be used in physics experiments to gain more knowledge about the physical world. ECARS technology can be used in a multitude of security fields, such as airports, stadiums, and anywhere that security is dependent on the control of substances coming in and out of an area. ECARS can also be adapted to the field of archeology. It can be used to find new archeological areas that would have previously been undetectable. The ECARS technology can also be adapted to the fields of biology, chemistry, and physics. ECARS will be a revolutionizing new technology that, once free from military control, can be very useful to the human race.

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