# Experiment E-4

## Stern-Gerlach Experiment

The present apparatus for the Stem-Gerlach experiment was developed by Daybell at New Mexico State University and modified and substantialiy improved by P. Hartman and N. Szabo at Comell.

The objective is to observe the splitting of a neutral. potassium atomic beam after passing through an inhomogeneous magnetic field and the subsequent profile when the beam experiences a dH/dz.

The beam profiles should be analyzed by taking into account the expected Maxwellian velocity distribution of the neutral atomic beam. Should the profile be corrected for broadening due to the detector slit?

For the final analysis assume that the field gradient is 104 gauss/cm. How would you measure dH/dz absolutely to ultimately determine the electron's magnetic moment?

References:

I. Daybell, Manual of the Apparatus

2. Ram say, *Molecular Beams,* App. F, pp. 361-417, and Chapter I, 2, 14.
3. Esterman, *Rev. Mod. Phys.l8.,* 300 (1946).
4. Kellogg & Millman,Rev. *Mod. Phys.* 18, 323 (1946)
5. Smith, *Molecular Beams,* Methuen Monographs (Reading Room)

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STERN-GERLACH

**DO NOT DISTURB ALIGNMENTS**
** NO LOOSENING OR TIGHTENING OF BOL TS**

## Tvpical ODeratin2: Conditions

1) Turn "ON" Cooling H2O (Located on South wall. Open fully.)
2) Turn "ON" Diffusion Pump (Gray Box mounted above apparatus)
3) Fill up Cold Traps with LN2 (3 Traps. Diff.Pump, Sac.Aperture, and Detector) 4) Wait -15 minutes
5) Refill Cold Traps
6) Turn "ON" ION Gauge (Set to 10-5 Torr Range. Depress Green "ON" switch.)
7) Turn "ON" Detector Supply and set to lA (Bias set to 17 if batteries are OK) 8) Turn "ON" Picoammeter (Set to lnA scale) 9) Turn Oven Heater Current to 3A ~ 10) Wait -15 minutes 11) Refill Cold Traps
12) Turn Detector Current to 1.5A *slowlv.*
13) Turn Oven Heater Current to 4A *slowlv. 14) Wait -15 minutes 15) Refill Cold Traps*
16) Turn Detector Current to 1.8A~
17) Turn Oven Heater Current to 5A ~
18) Keep Refilling or "Topping Oft" the Cold Traps every 30min!

*PLEASE BE PATIENT.* IT WILL TAKE ANOTHER GOOD HOUR FOR YOUR EXPERIMENT TO WARM UP AND STABILIZE. PLEASE UNDERSTAND THAT YOU *CANNOT* RUSH THIS PERIOD OF TIME WITHOUT SERIOUS EQUIP~NT FAILURE.

## Su22estions. During!! Your Warm Up Period

I) Set the detector micrometer to -250 Mils
2) Let the oven come up to 375~. At this point lower the oven current to 55v @ 4.5A. This will take into account the temperature "overshoot" and will give you a final temperature of about 425~ which is your normal operational temperature.
3) Open the shutter carefully with the hand held magnet. Now watch the picoammeter. You should see some digits come "alive" and slowly start rising upward on the picoammeter as the temperature rises toward operational temperature.

A temperature of approx. *425F* is needed to break the Potassium down to liquid. Please note that a .1 00-.150nA reading should appear on the picoammeter. Now you can scan with the detector and take data. (If this is not true. ..check shutter, micrometer, and raise oven temp by another *IO-20OP.* This should raise your current reading into the appropriate range.) Should this NOT be the case, please contact Nick.

When using the magnet latter in the exp. Please make sure that the variable output is turned fully to zero before turning on the line power. When finished please turn the output back down to zero first, then turn off the main power switch.

## SHUTDOWN

I) Close shutter (hand held magnet)
2) Slowly lower detector current to zero and turn power off (toggle switch)
3) Picoammeter power off (push switch)
4) Diffusion power off (toggle switch)
5) Magnet output to Zero. Power OFF (toggle switch)
6) Ion Gauge Off (Depress "yellow" OFF switch until filament goes out. Visually Look )
7) Oven heater set to I OV AC @ .5A (DO NOT TURN OFF)
8) Turn cooling H2O " off' AFTER W AITING 15 Minutes

PLEASE DO NOT TURN OFF THE MECHANICAL VACUUM PUMP

N. Szabo 01-31-2001

# General Notes on the Stern-Gerlach Apparatus

This is one of the great experiments of modern physics. This version, designed by Daybell at New Mexico Las Cruces, and modified by us, has given very nice peaks. It has not, however, been studied enough to understand in all details, but at least we know how to get a good vacuum, a beam through the apparatus, and a reasonably sensitive detector.

The apparatus is fairly well described in the manual which, incidentally, Mr. Nick Szabo had to put together. The detector is not quite as described in the manual, however. It has a 5 mil tungsten wire at the center of a small cylindrical enclosure with a slot through it to let a neutral beam of alkali atoms in. The tungsten must be hot so that the potassium is ionized. The electrometer measures the ion current flowing between filament and cylinder. There are two difficulties with the filament: As supplied, it was rigidly mounted and fastened to the support rods by tiny sleeves. We made little stainless steel springs to allow some tensioning even while the filament expands under heat. It is not easy to change filaments. Great care must be exercised in loosening the screws to avoid twisting the spring. Since the filament runs.at quite low temperatures in the experiment, we expected it to last forever--but it didn't. When a new filament is first heated, an ion current of nearly a microampere is observed without any beam. It is necessary to cook the detector for a long time before background current drops to acceptable values. If one keeps a heating current of say 2.0 or 2.1 amperes through it for a day, there will still be a current observed; but when the filament current is dropped to the operating value of about 1.7 amperes, this current drops down into the 10-11 range. Some of this residual is due to alkali vapor floating around in the detector region. This can be dropped by about an order of magnitude (eight was observed) by cooling the detector parts (except filament itself) with a flexible copper finger connecting the detector mounting block with a small liquid nitrogen trap at the end.

n case it becomes necessary to change filament, the finger can be unscrewed from the block support and the liquid nitrogen trap by reaching in with a screw- grabbing screw driver. Don't lean too hard on the liquid nitrogen trap in getting the screw undone; the trap is a thin stainless steel tube capped at the bottom end. To get at the filament, the spring support is undone from the brass plate, and then unscrewed from the block supporting the anode and filament. The block can go back in either of two positions but one gives an overall alignment of filament and anode slot with the

shield slot that is better than the other way around. When things are open, it will be seen that three soft solder joints have to be undone at the brass plate seals--even before the spring shield is unscrewed. Then the anode can be taken off revealing the filament support structure. The anode comes off by loosening two set screws and carefully wiggling the anode off the support rods. The bushings are now hard soldered to the anode. (Originally it was soft solder) In putting in a new filament wire, clamp one end with the screw and pull on the other end of the wire while it is clamped under the screw at the other end. It doesn't take much pull. You are only trying to insure that the filament is under some tension at all times so it stays straight and parallel to the length of the beam it is to detect. After it is clamped up, deflecting it at one end by leaning slightly on the spring will cause the other spring to deflect a bit. Too much tension will cause the filament to break when it is hot. When it is clamped, it should not be necessary to deflect the springs more than a few mils to do what is needed. After assembly, the filament should be straight and be seen through the two front slots more or less parallel and approximately centered. Slop in .the screw holes in the leaf spring shield allows some latitude and one orientation is better than the other. The anode is best in one orientation also.

In assembly, things go back in the reverse order. One minor matter that can stand improvement: the wire to the anode is fed through some spaghetti tubing through the leaf spring shield rig; the insulation there should be good. The wire is a bit stiff, however, so that when the whole business is deflected by the micrometer, the relative position of the wire to the shield shifts a little causing the electrometer to deflect because of the changing capacitance. It's slightly annoying when first searching for the beam. You think you have it and instead it is just a deflection resulting from the wire movement. It is not clear if a tiny coax cable with the shield at ground potential would provide adequate insulation or not. Currents to be detected go down in the 10-12 range but when a beam is coming through to the detector, the currents have gone as high as a few times 10-10 range.

The oven end of the apparatus has also been modified--and this was a great improvement. We have provided the region with a series of liquid nitrogen cooled baffles and a sliding shutter. It is not too difficult to take apart or put into place. The trap and long vertical baffle are screwed together on the bench. The baffle over the pump opening is not yet screwed to it. The horizontal baffling nearest the magnet is slid into position with the two sector apertures cut from the outermost baffles put in up position. The vertical baffle (and trap) is then fed down part way so the lower end of the baffle is in the region of the cross over of the side arms of the glass enclosure.

A screw grabbing screw driver is then used to put the little pump baffle on the end of the vertical baffle. The screw is trapped in its socket so when the screw is grabbed, the pump baffle is also supported. It is then simply moved in and the screw turned into the end of the vertical baffle. The thing can then be lowered into position. The oven baffling is then slid into its position. A slender-rod can be used for orienting the flanges of the two baffle systems so the screw holes through the vertical baffle all align. Then again with a screw grabbing screw driver firmly onto a screw one reaches in and clamps the three pieces together. Clearance holes for the screw driver are provided in the two oven baffles--that nearest the oven has its clearance hole in the up position. When all is clamped to the vertical baffle then the O-ring seal at the liquid nitrogen trap flange is tightened down--more or less evenly. The shutter is simply slid back and forth with the little external horseshoe magnet.

T he oven itself is a stainless steel block with an adjustable slit over an orifice connecting to a cavity filled with potassium. This is loaded through a threaded hole in the top, which is then covered with a screw. Heating is with a pair of heaters embedded in the slit region. The block is supported on three pointed pins to reduce heat loss to the flange. The oven is removed by undoing two screws fastening the plate carrying four glass seals for leads. In no case change the tightening of the bolts clamping the whole business to the glass cross piece. This involves an O-ring seal and changing the clamping will change the alignment of the system. The oven slit is about ten mils wide. The slit at the magnet (mid slit) is six mils and is positioned about as in the Daybell Manual (Fig. 5, p. 9).

Daybell says the time delay in getting a beam-is the result of having to get the walls of the cavity and orifice all well coated with potassium. Or it may be that the thermocouple does not measure the temperature of the bulk potassium. The slit region should be the hottest part of the block since the heaters are embedded in the block up near the front. Anyway, it seems to take some time after operating temperature is attained before any beam is observed.

A word of precaution on the magnet--it is best to reduce the current by not turning the switch to OFF; rather bring the current to zero with the Variac and then switch the supply to OFF. L di/dt can raise Cain with some electronics. The magnet current required for nice splitting into the two components is only about 2 to 3 amperes, say 2.5 for a starter.

Plots should be made of the undeflected peak and the deflected peaks--i.e. , current vs. micrometer position. Note that micrometer reading and slit movement are not 1: I. See p.12 of the" , construction notes. n Daybell suggests it may be possible to

say something about the distribution of atomic velocities as they sail out of the oven. Perhaps so. It would be lovely if we could think of a way to measure the field gradient in the space between the pole pieces. That would allow us to measure the spin absolutely. The space is small, however, and tough to reach. Perhaps someone will come up with a cute trick for doing it.

One switch controls both the bias and the filament. On shut down please remember to turn off the detector supply. Bring that current down with the V ariac control--don't just turn it off. It pays to heat filaments reasonably gradually. Turn off the diffusion pump, the oven, the magnet, and the vacuum gauge. After the pump has cooled a bit, then cut off the water .

The alignment has not been carried out quite as Daybell outlined, nor probably as well. The mid-slit, at the oven side of the magnet, was positioned carefully and adjusted before the apparatus was closed up and installed. Then the lab laser was positioned looking centrally down the long glass section.