EXPERIMENT 4
Electron Spin Resonance

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january 31, 2017

Contents

1 AIM

To determine the Lande g-factor using Electron Spin Resonance

2 Apparatus Used

ESR setup which includes Helmholtz coils, R.F. oscillator and the test sample, and in addition, a cathode ray oscilloscope (CRO).

3 Nomenclature

g=lande g- factor
$\mu = magneticmoment$
H_o=magnetic field on the sample at resonance in Gauss
ω_o=larmor frequency
e=charge of electron, C
m=mass of electron, kg
c=speed of light, m/s
ν_0=resonance frequency, cycle/sec
ΔE= energy difference
μ_o= bohr magneton, $0.927 * 10^{-20}$ erg/gauss
h= plancks constant, $6.625 * 10^{27}$ erg.sec
$H_p p$= peak to peak magnetic field, gauss/amp
p=total X- plate deflection in oscilloscope
n= is the number of turns in each coil
a= is the radius of the coil, cm
I= is current in amperes
QI= slope of the graph of Q Vs 1/I

4 Introduction

Electron Spin Resonance (ESR), also known as electron paramagnetic resonance (EPR) is a special technique used to investigate and determine the behavior of semi-free electrons in a paramagnetic material. ESR can be used to calculate the spin interactions of a substance and therefore give clues to the structure. The technique is closely related to Nuclear Magnetic Resonance the technique used in MRI machines. The fundamental difference being that ESR is concerned with the magnetically induced splitting of electronic spin states and electron has a much larger magnetic moment and larger energy gap for spin transition than the nuclei, while NMR describes the splitting of nuclear spin states. MRI machines however, use the magnetic moment of the atoms themselves instead of the electron only. Since few stable molecules have free electrons, the existence of those that do in a mixture can be detected by ESR precisely. This can be useful in determining the existence of free radicals in a material. Electrons have an intrinsic, quantized spin that results in a magnetic moment. When an external magnetic field is applied the magnetic moments of all the electrons align in parallel or antiparallel with the field. The difference in energy of these two states is proportional to the magnetic field and determined by Zeeman splitting. The electrons can be made to flip between the two energy states with the application of resonant electromagnetic radiation of the appropriate energy. A free electrons resonant frequency will be different from a bound electrons. The whole objective of ESR testing is to determine this difference known as the Lande g-factor. This study analyzes the almost free electron in Diphenyl Picryl Hydrazil also called DPPH in short. A nitrogen pair in the center of the molecule has a trapped electron with no orbital angular momentum. The magnetic moment of the molecule is determine only by the spin moment of the valence in the N- bridge. DPPH has been studied extensively with ESR because of its ability to absorb free radicals. A modulated frequency and a varying current flowing through the Helmholtz coil is used in this dissertation to determine the g-factor of DPPH as compared to the accepted theoretical value.

5 Experimental setup

The following figure shows the block diagram of the ESR setup.

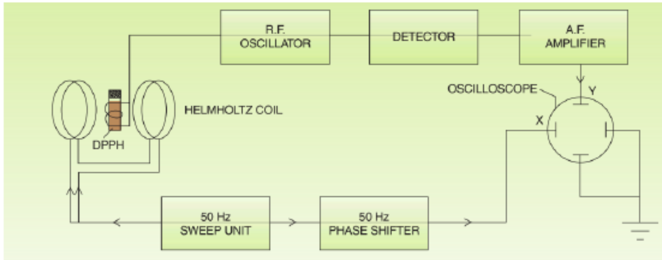


Fig1 Block Diagram of the ESR Setup

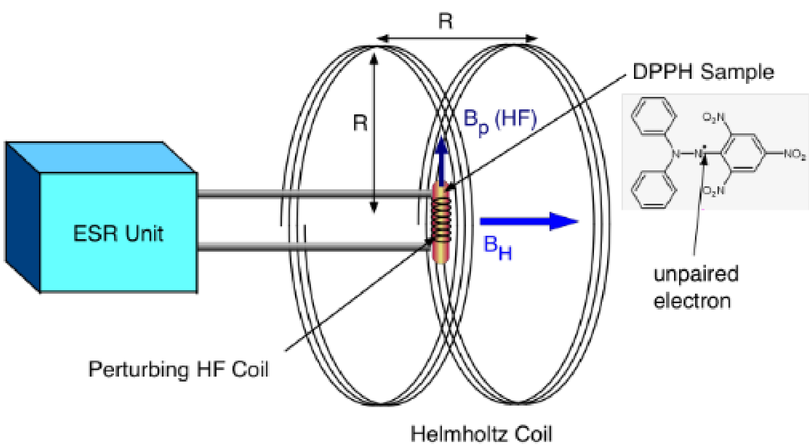


Fig2 ESR unit with DPPH sample, Helmholtz and signal (and perturbation) coils.

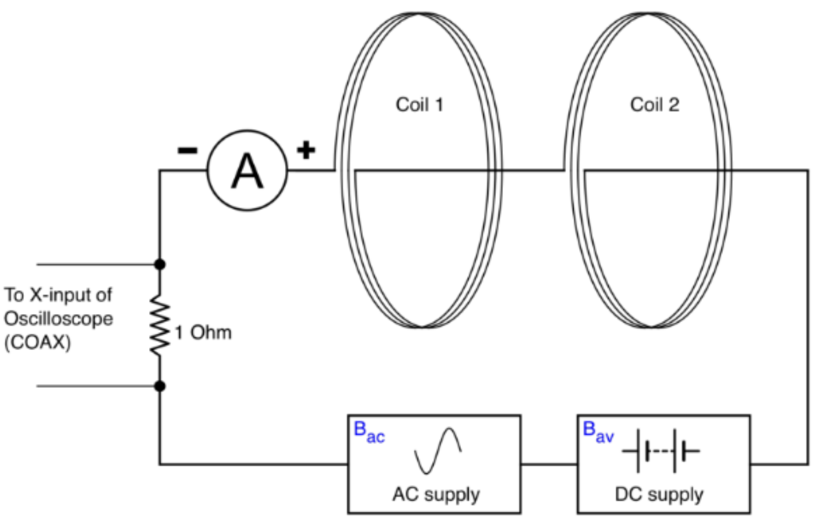


Fig3 Wiring of the Helmholtz coils using an AC and a DC power supply in series. The 1Ω resistor is used to determine the instantaneous coil current..

6 Theory and formula used

In terms of simple classical concept, let us consider a particle having a magnetic moment μ which is placed in a uniform magnetic field of intensity H_0 . Then the moment μ will precess around H_0 with an angular larmor frequency,

$$\omega = g\frac{e}{2mc}H_o$$

g being the lande g- factor(g=1for pure orbital momentum and g=2 for a free electron spin). Let us proceed to the quantum picture of elementary magnetic resonance. Suppose that the intrinsic angular momentum of the electron S couples with the orbital angular momentum of the electron L to give a resultant J . We know, that J+1 magnetic sublevels labelled by the magnetic field H_o by equal energy difference, Between adjacent sublevels where μ_o is the Bohr magneton ($\mu_o = \frac{eh}{2m}$) and g is the lande factor whose correct quantum mechanical value is given as,

$$\boxed{g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}}$$

Also, if a particle is subjected to perturbation by an alternate magnetic field with a frequency ν_1 such that the quantum h is exactly the same as the difference between the levels ΔE, and if the direction of the alternating field is perpendicular to the direction of the static magnetic field, then there will be induced transition between neighbouring sublevels according to the selection rules $\Delta m = \pm 1$ for magnetic dipole radiation.
Therefore the resonance condition is

$$\Delta E = g\mu_o H_0 = h\nu_o = h\nu_1$$

Where ν_1 is the resonance frequency. This requirement is identical with classical condition $\omega_1 = \omega_o$ Therefore, to find the landes g factor we use equation

$$g = \frac{h\nu_o}{H_o\mu_0}$$

The magnetic field at the center of Helmholtz coil is

$$\boxed{H = \frac{32\pi n}{10\sqrt{125}a}I}$$

Since the current measured is in rms, the magntic field is also rms. The peak to peak magnetic field will be,

$$H_{pp} = 2\sqrt{2}H = 168 * I gauss/amp$$

So the magnetic resonance frequency is $H_o = 168 * \frac{QI}{p}$
therefore

$$\boxed{g = \frac{h\nu_o}{\mu_o} * \frac{p}{QI * 168}}$$

For better results, i.e. to remove any random errors it is better to plot a 1/I versus Q graph, get the slope and from that we can use the QI relation to get the value of g.

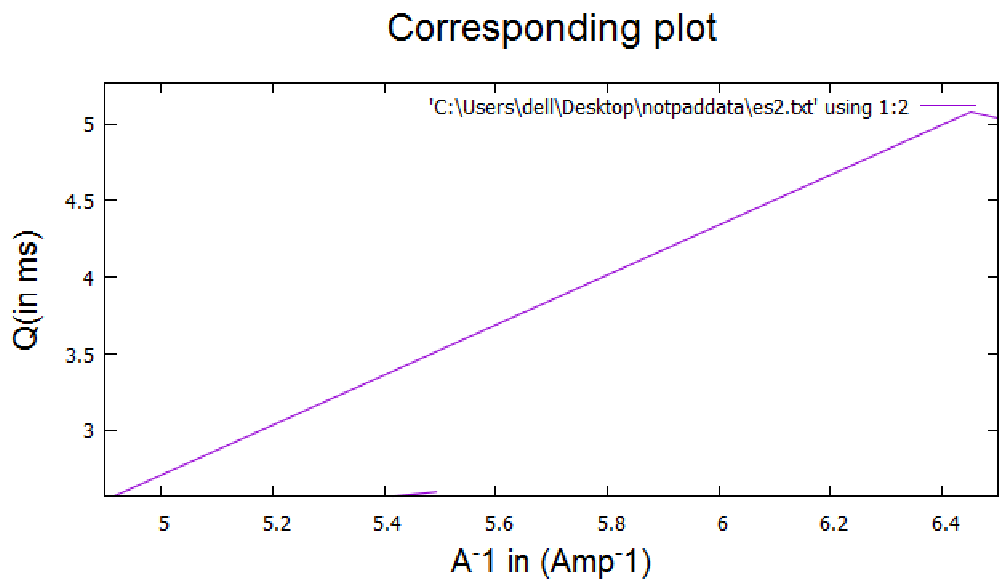
7 Observation

for $\nu_0 = 15.56 MHz$

Sl No.	I(mA)	1/I	P(ms)	Q(ms)
1	127	-6.08	6.040	3.86
2	155	-7.96	3.080	5.08
3	210	-9.71	3.320	2.32
4	182	-6.08	4.20	2.60
5	236	-7.96	3.32	2.0
6	263	-9.71	3.80	1.8
7	288	-6.08	3.12	1.64
8	314	-7.96	3.14	1.5

for $\nu_0 = 16.09MHz$

Sl No.	I(mA)	1/I	P(ms)	Q(ms)
1	126	-6.08	4.96	4.0
2	153	-7.96	5.160	3.16
3	208	-9.71	4.0	2.36
4	181	-6.08	4.0	2.64
5	234	-7.96	3.72	2.08
6	260	-9.71	3.08	1.84
7	286	-6.08	3.08	1.64
8	311	-7.96	2.64	1.64



8 Calculations

8.1 For ν_o=15.56MHz

we find the value from the table
$P_{mean} = 3.752ms$, $Q_{mean} = 2.5925ms$ and $I_{mean} = 221.87mA$ thus from the formula

$$g = \frac{h\nu_o}{\mu_o} * \frac{p}{QI*168} = \frac{6.625*10^{-27}*15.56*10^{6}*3.752}{0.927*10^{-20}*2.5925*221.87*10^{-3}*168} = 1.119$$

8.2 For ν_1=16.09MHz

we find the value from the table
$P_{mean} = 3.83ms$, $Q_{mean} = 2.42ms$ and $I_{mean} = 219.875mA$ thus from the formula

$$g = \frac{h\nu_1}{\mu_o} * \frac{p}{QI*168} = \frac{6.625*10^{-27}*16.09*10^6*3.83}{0.927*10^{-20}*2.42*219.875*10^{-3}*168} = 1.9713$$

thus we get g=1.9713 for ν_1 that is nearly the standard value

9 Error Analysis

So % of Error will be

$$\Delta = \frac{2.0038 - 1.9713}{2.0038} * 100 = 1.6\%$$

10 Results

The result for different frequencies was obtained and a graph of Q Vs 1/I was plotted to get the slope QI for the frequencies. This was used to calculate the Lande g-factor of DPPH.

11 Precautions

1. The direction of the Helmholtz coils should be preferable adjusted so that the field is perpendicular to earths magnetic field, which is about 0.3 Gauss.
2. Setup the experiment at a place free from electric and magnetic fields and mechanical disturbances.
3. Y-output from the ESR spectrometer should be through a good shielded cable

12 References

1. A Textbook on Electronics by Basudev Ghosh
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3.Lab manual
4.www.wikipedia.com