

## EXPERIMENT PROCEDURE

- Observe the resonance curve of DPPH.
- Determine the resonant frequency as a function of the magnetic field.
- Determine the Landé  $g$ -factor for free electrons.

## OBJECTIVE

Demonstrate electron spin resonance in DPPH.

## SUMMARY

Electron spin resonance (ESR) is based on the energy absorption by substances with unpaired electrons, which are inside an external magnetic field produced by a DC source. The energy is absorbed from a high-frequency AC-generated field which is fed in perpendicular to the field from the DC source. If the frequency of the alternating field is equal to the resonant frequency, the impedance of the transmitting coil filled with the test material changes in accordance with a resonance curve and a peak will be visible on an oscilloscope screen. One suitable material for this is diphenyl-picryl-hydrazyl (DPPH).

## REQUIRED APPARATUS

Quantity	Product	Number
1	ESR/NMR Basic Set (230 V, 50/60 Hz)	1000638 or
	ESR/NMR Basic Set (115 V, 50/60 Hz)	1000637
1	ESR Supplementary Set	1000640
1	Analogue Oscilloscope, 2x30 MHz	1002727
2	HF Patch Cord	1002746

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## GENERAL PRINCIPLES

Electron spin resonance (ESR) is based on the energy absorption by substances with unpaired electrons, which are inside an external magnetic field produced by a DC source. The energy is absorbed from a high-frequency AC-generated field which is fed in perpendicular to the field from the DC source. If the frequency of the alternating field is equal to the resonant frequency, the impedance of the transmitting coil filled with the test material changes in accordance with a resonance curve and a peak will be visible on an oscilloscope screen. The cause of resonance absorption is the „tipping over“ of the magnetic moments between spin states of a free electron. The resonant frequency depends on the strength of the DC-generated field and the width of the resonance signal is related to the uniformity of the field.

The magnetic moment of an electron with purely spinrelated magnetism assumes discrete values in a magnetic field  $B$ :

$$(1) \quad E_m = -g_j \cdot \mu_B \cdot m \cdot B, \quad m = -\frac{1}{2}, \frac{1}{2}$$

$$\mu_B = 9,274 \cdot 10^{-24} \frac{\text{J}}{\text{T}} : \text{Bohr magneton}$$

$$g_j = 2.0023: \text{Landé } g\text{-factor}$$

The interval between the two levels is therefore

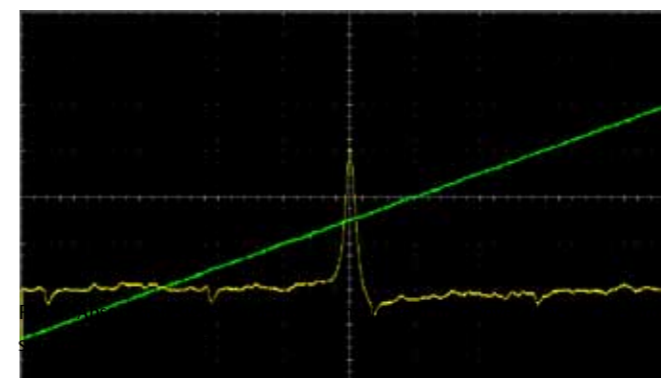
$$(2) \quad \Delta E = g_j \cdot \mu_B \cdot B$$

Resonance occurs when the frequency  $f$  of the alternating field being fed in meets the following condition:

$$(3) \quad h \cdot f = \Delta E,$$

$$h = 6.626 \cdot 10^{-34} \text{ Js: Planck's constant}$$

In this experiment, electron spin resonance will be demonstrated in diphenyl-picrylhydrazyl (DPPH), an organic compound, the molecules of which include an unpaired electron. The basic magnetic field is generated inside a pair of Helmholtz coils and is moved between zero and a maximum value of  $B_{\text{max}} = 3.5 \text{ mT}$  using a saw-tooth wave-form. Now it is possible to look for a frequency  $f$ , at which resonance absorption takes place at a distinct position along the saw-tooth curve, i.e. for a pre-selected magnetic field.



## EVALUATION

The following relationship between the resonance frequency  $f$  and the magnetic field  $B$  can be derived from (2) and (3).

$$f = g_j \cdot \frac{\mu_B}{h} \cdot B$$

The measurements therefore lie along a straight line through the origin to within the measurement tolerances. The Landé  $g$ -factor can be determined from the slope of this graph.

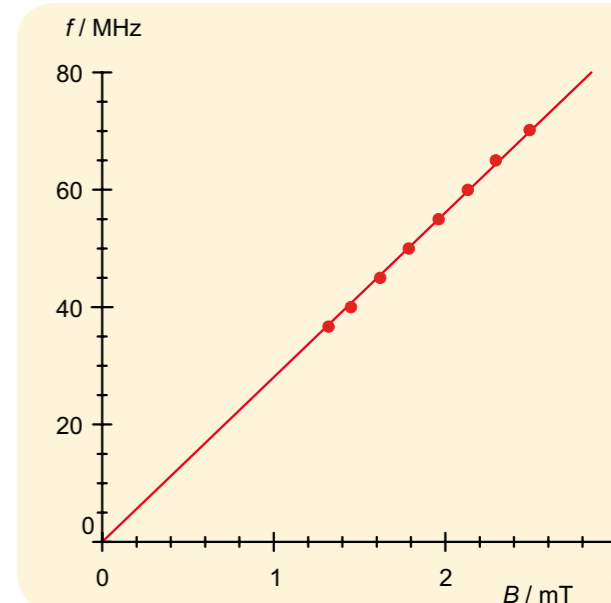


Fig. 2: Resonant frequency  $f$  as a function of the magnetic field  $B$

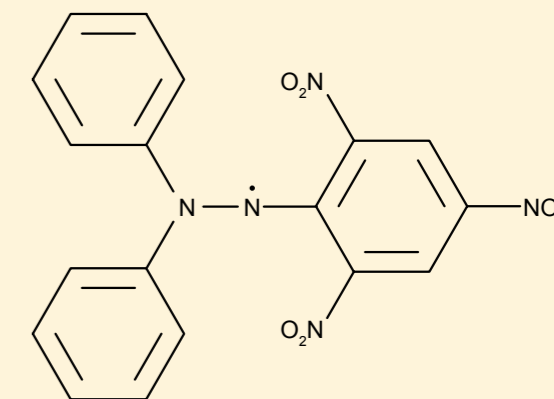


Fig.3: Molecular structure of DPPH