Magnetic Monopoles in Theory and Experiment

W.D. Bauer, talk at Göde-Institut, Waldaschaff, 22.11.02
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1) Introduction current opinion today on magnetic monopoles

2) Ehrenhaft's Experiments

- historical
- the Ehrenhaft - Millikan disput
- basic experimental setup & particle production
- exp. methods:
  - Stokes-Cunningham
  - optical methods
  - mechanical methods
- "light pressure" phenomena:
  - positive photophoresis
  - negative photophoresis
  - gravitophoresis
  - photophoretic figures
- electrophoresis: proof, v-E- diagram
- electronic charge: "Millikan's proof"
- magnetophoresis:
  - definition, proof
  - mixed effects
  - does the electronic charge exists?
- magnetic charge:
  - experiments on
  - particles
  - in gas discharges
  - in liquids
  - in radioactive decay

3) Magnetic Monopoles in Classical Electrodynamics

4) Conclusion

1. Introduction

The current scientific opinion says:

experimentally:

there exist no significant proofs on magnetic monopole charges

theoretically:

1) magnetic monopoles behave acc. to Dirac's prediction, i.e.

$$\frac{ge}{\hbar c} = \frac{n}{2}$$

2) electric and magnetic fields have the following symmetries:

x --> -x	E	-1
	D	-1
	H	1
	B	1
t --> -t	E	1
	D	1
	H	-1
	B	-1

<u>de facto:</u>

experimentally:

magnetic monopoles were found and seem to follow Dirac's prediction

theoretically:

therefore, electromagnetic fields do not have any symmetric preferences generally

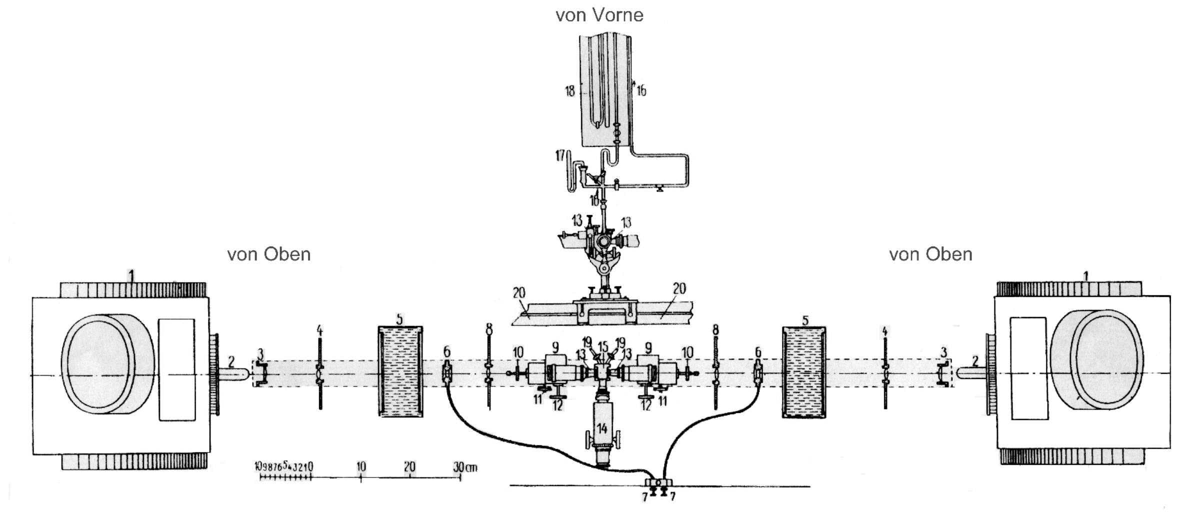
practically and economically:

relevant with respect to calculation and design of anisotropic magnetic materials and antennas

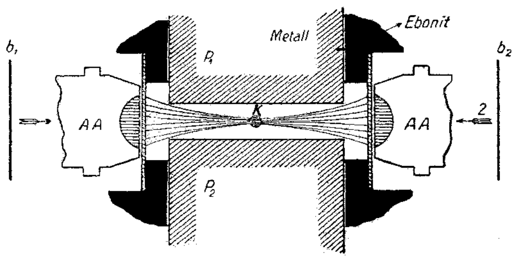
2. The Experiments of Felix Ehrenhaft

historical problem: how to measure forces on little particles ?
to test the theories of
light pressure
electronic or magnetic charges

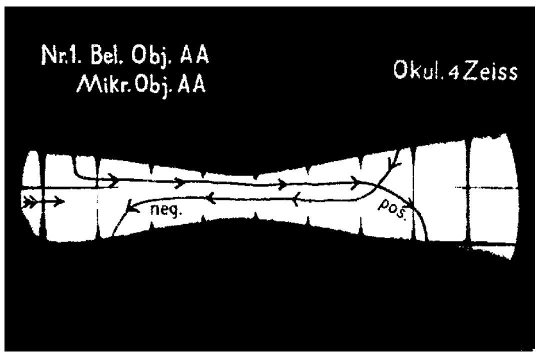
typical experimental setup:



Ehrenhaft's basic setup to observe aerosols
1) DC-current lampe 20-25 A, 2) iris tube, 3) convex lens ⌀36mm, f=50mm, 4) projective objektiv f=80mm, 5) water filter, 6) shutter, 7) wire release, 8) projective lens f=55mm, 9) stative for illuminatig objektive, 10) micrometer screw for horizontal movement in beam direction, 11) micrometer screw for horizontal movement perpendicular to the beam direction, 12) micrometer screw for adjustement in height, 13) illuminating objective f= 17mm num apert. 0,3, 14) microskope for observation; objektive; f= 17mm num apert. 0,3, compensatin okular 12 Zeiss , 15) probe chamber (as Kondensator) comp. Abb.2, 16) to pump 17) +18) to pump, 19) taps to gas inlet and outlet 20) rails of optical bank



cross section of the chamber of Ehrenhaft's setup, vgl. fig. above



view of the chamber under the microscope
arrow shows the direction od the light beam, the lines represent light-positive and light-negative particles

production of particles: by electrical sparking of the wanted material

Measuring Forces on Microscopic Particles

method is indirect and needs

1) a measurement of the velocity of the particle
2) a measurement of the diameter of the particle

formulas:

$$v = \mu . F \quad \text{with} \quad \begin{array}{l} v := \text{velocity} \\ \mu := \text{mobility} \\ F := \text{force} \end{array}$$

and

$$F = 6\pi\eta v \Bigg/ \left[1 + \frac{1.63\, l/r}{f + 2(1-f)}\right] \quad \text{with} \quad \begin{array}{l} \eta := \text{viscosity} \\ f := 0 \ \ \text{(elastic recoils)} \\ l := \text{free mean path} \\ r := \text{radius} \end{array}$$

measurement of velocity :

with microscope scale und stop watch

measurement of diameter (selection!):

using Mie-light diffraction
by a mechanic method
by fotography

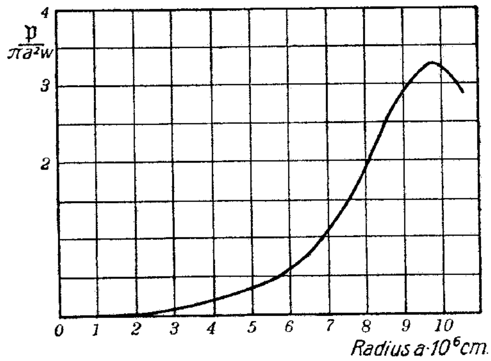
Results of Experiments with Light Pressure

1) Einstein's formel is wrong for high light intensities; values of μ determined acc. to Einstein are to high if compared with other methods applied by Ehrenhaft

$$\mu_{Ehrenhaft} < \mu_{Einstein} = \frac{\Delta x^2}{2kT} \quad \text{with} \quad \begin{aligned} \Delta x^2 &= \text{mean square of deviation} \\ k &= \text{Boltzmann constant} \\ T &= \text{temperature} \end{aligned}$$

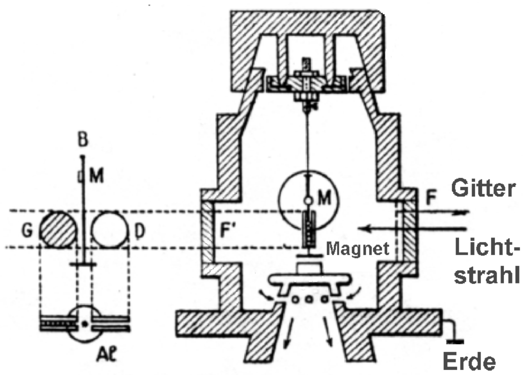
Δx^2-deviations between different methods are too big in the direction of light

2) the theory of light pressure of P. Debye is correct for the most particles, but not for all!



light pressure on a sphere dependent from its radius for a wavelenght of 700µm on Ehrenhaft's apparatus calculated acc. to P.Debye

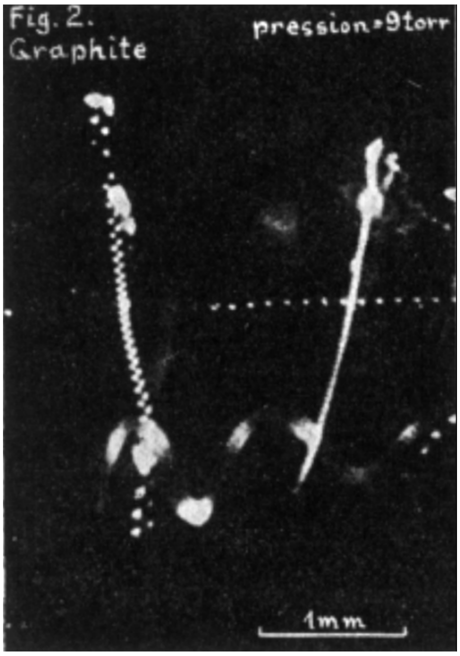
3) there exist "lightnegative" particles, which are attracted by light.
The working colour is mostly in the blue. Probably these colours correspond to excited spectral lines !

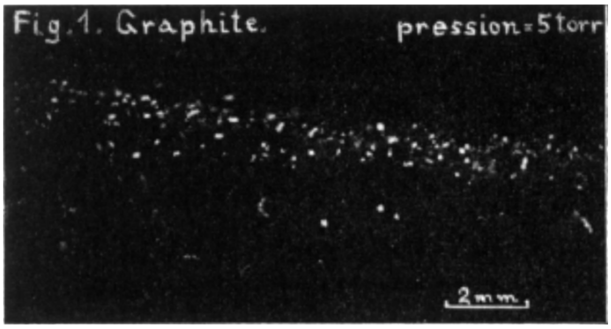


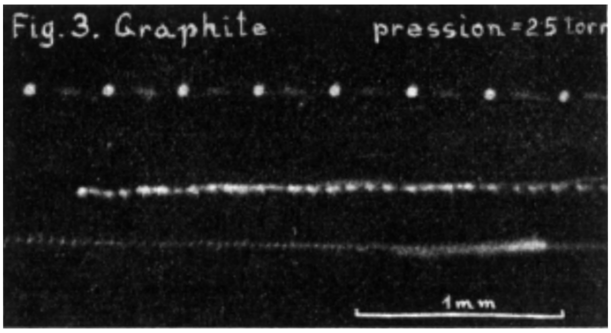
experimental setup of Ouang Te Tchao to prove macroscopic negativ-photophoretic force.
The wings of the torsion pendulum contain a liquid of china parfume. The chamber is evacuated to high vacuum. This excludes thermic radiometer forces

4) the path is spiraling, if
particle diameter ∅ > wavelenght λ

5) there exists “Gravitophoresis” i.e.
some particles move in the light beam against gravity



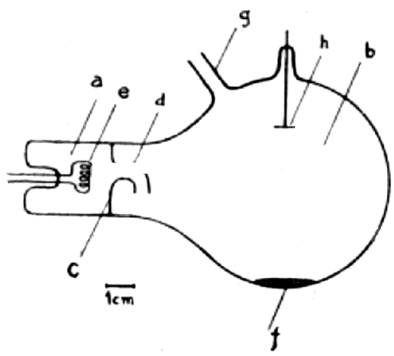




Gravitophoresis: the particles seem to loose their weight and are hanging at the upper border of the illuminating light beam.
sometimes they are moving up and down periodically; comp. left fig.

6) There exist highly complex “photophoretic” patterns of movements

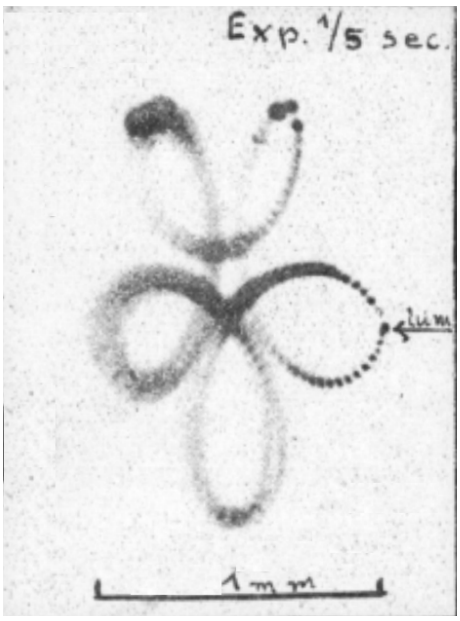
Setup:

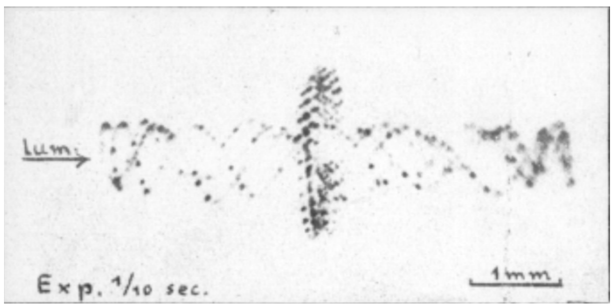


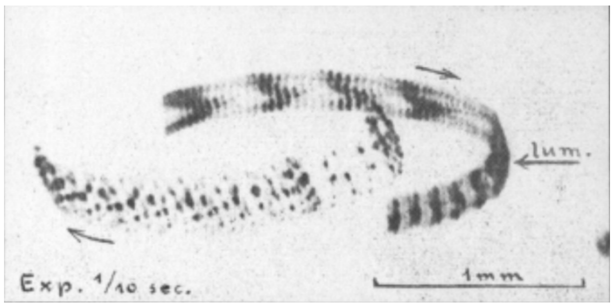
vacuum bulb to observe photophoresis
a filamentl b vacuum c anode f dust material
g to pumping line h deflection electrode

Conditions: 10^{-5} -> 50 mg Hg pressure ,
intensive (sun)-light has to be focused by a big lens
(∅=10-20cm) in the inner of the vacuum bulb
A fine dust matrial (∅=10^{-3} cm) has to be used

typical “nice” pictures:

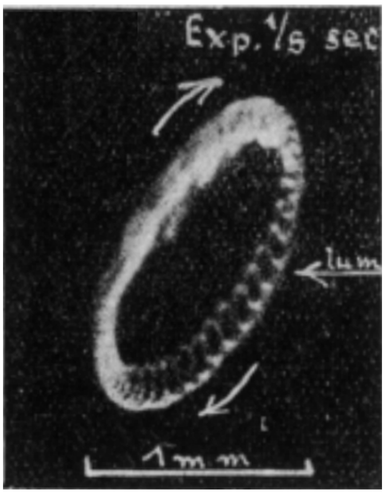




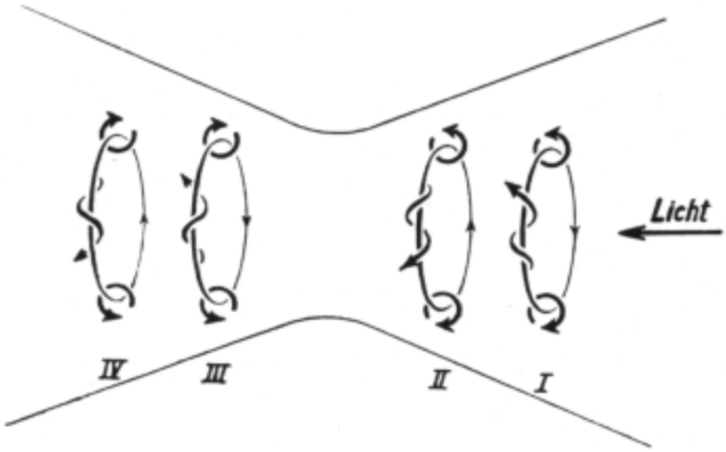


complex patterns of movement in photophoresis as taken as snapshots with stroboboscobe illumination (positives)

The most important patterns of photophoresis

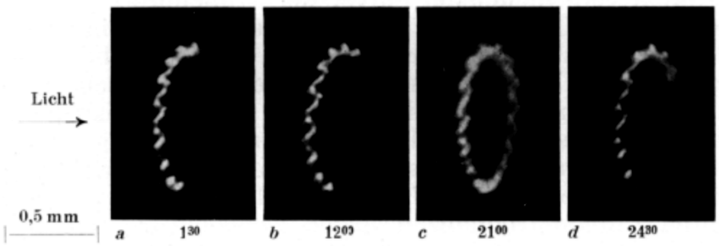


photophoretic toroidal path

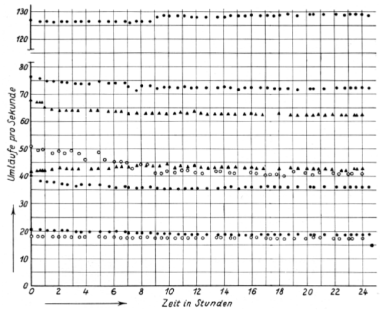


the most important toroids of photophoresis, comp. text

the particles are captured in the gradient of the light focus and move on a stable and closed path!



photophoretic toroid during a day



frequency measurement of photophoretic toroids during a day

Electrophoresis

Definition: movement of charged particles in a electric field. the charge is generated by intense light. it dissapears instantaneously if the light is switched off

Observations:

1) the movement of the particle commutes with the field (in the most cases !)

2) the stronger the light, the bigger the effect

3) electrophoretic charges go down to 1/10 e.

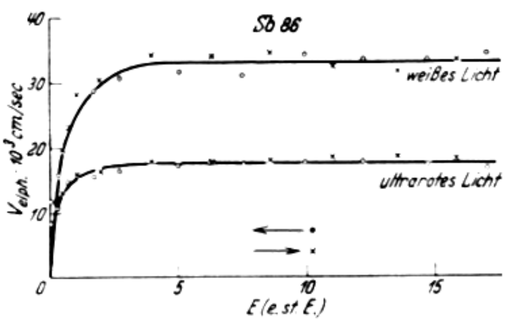
4) Electrophoresis shifts the position of photophoretic toroids in a light focus

5) the effects are not influenced by ionising radiation (γ- oder UV-Strahlung)

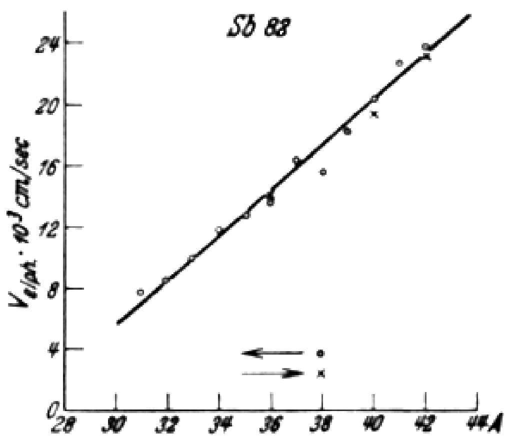
6) useful materials ordered : Te, Sb, J > Ni, Fe, Se, Bi

7) it exists a optimal gas pressure

8) the saturation field of a particle is independent from pressure



velocity v vs. electrical field E of a electrophoretic charged particle. the saturation depends from the intensity



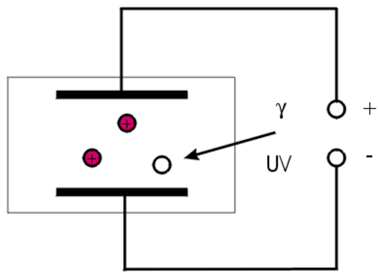
velocity v vs. lamp current for a Sb -Particle under electrophoresis

The electric Charge

Historical background: Ehrenhaft-Millikan disput:
Millikan stated to have seen e
Ehrenhaft said that this is not possible !

today we know : Ehrenhaft was right - Millikan tuned his data !

Experimental setup:

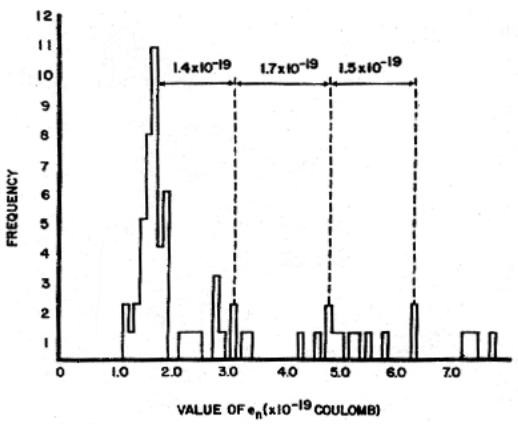


Measurements:

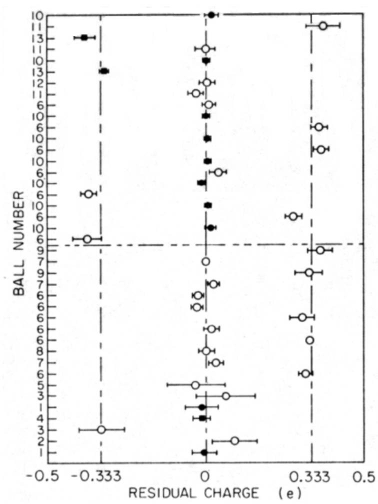
without field:	$mg = v_1/\mu$
with negative field:	$-eE + mg = v_2/\mu$
with positive field:	$+eE + mg = v_3/\mu$

after measurement the equations are solved for μ, m und e

Conclusion: the single electronic charge cannot be proved at this pressures with this method.



histogramm of 74 charged oildrops from a student lab.
From:.American Journal of Physics 40 (May 1972), 769

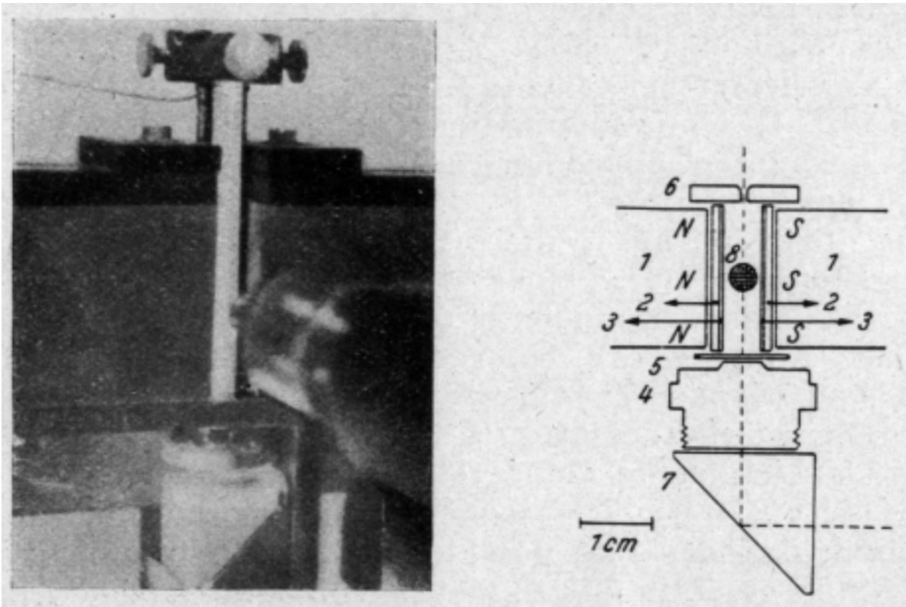


1/3-electronic charges on little supraconductive Niob spheres measured acc. to Fairbank's method

Magnetophoresis

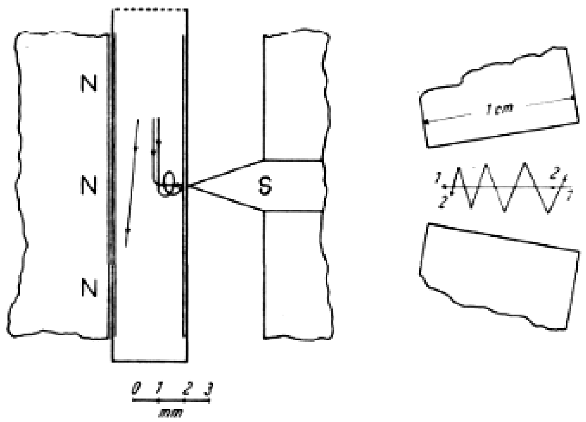
Definition: movement of magnetic charged particles in a magnetic field. The magnetic charge is induced by the light and disappears instantaneously , if the light is swichted off.

Experimental setup:



Observations:

1) magnetophoresis adds to photophoresis in the light
2) the particle follow the outer field acc. to unipolar charge
   They can be deviated by a homogeneous magnetic field.



experimental setups to observe magnetophoresis The path on the left represents a monopol

Observations:

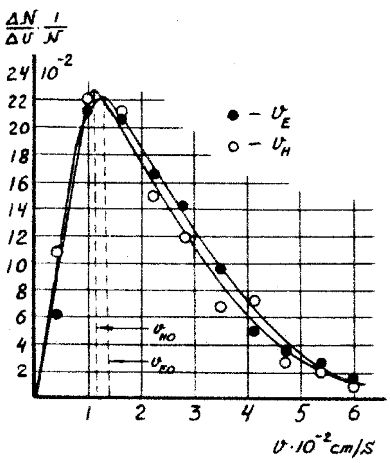
1) linear or weak spiraling movements enlarge to full spiral in field. kinetic energy or velocity remains conserved.

2) the v-H diagrams are point-symmetric. The form of the Diagrams varies very strongly

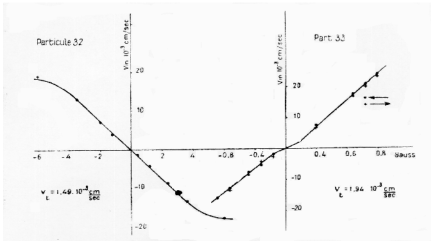
3) it exists a fixed ratio q_H/q_E which is empirical

$$\frac{q_H}{q_E} = \frac{E}{H}\frac{v_H}{v_E} \approx \text{Dirac-value}$$

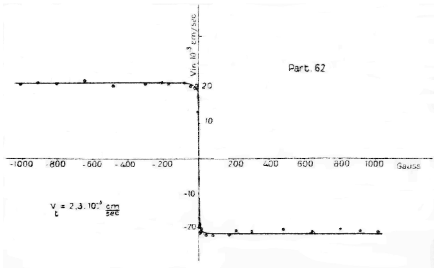
experiment of V.F. Mikhailov



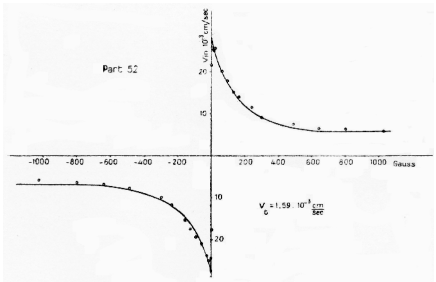
parallel velocity distribution of elektrophoretic (E) and magnetophoretic (M) charged particles



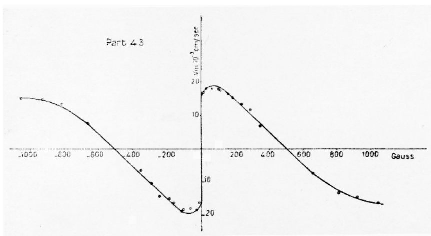
different v-H- diagrams of magnetophoresis;
linear v-H -diagram at weak H-field



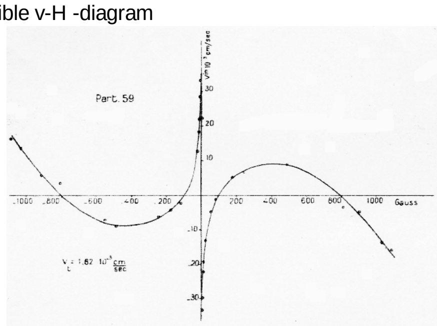
different v-H- diagrams of magnetophoresis;
saturation at high H-field



different v-H- diagrams of magnetophoresis;
a possible v-H -diagram



different v-H- diagrams of magnetophoresis;
a possible v-H -diagram



different v-H- diagrams of magnetophoresis;
a possible v-H -diagram

The magnetic Charge

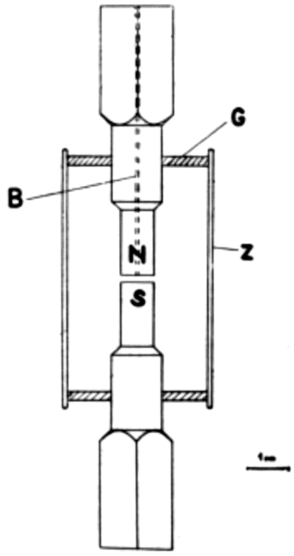
Setup:

Fall experiment under strobos-cobe illumination

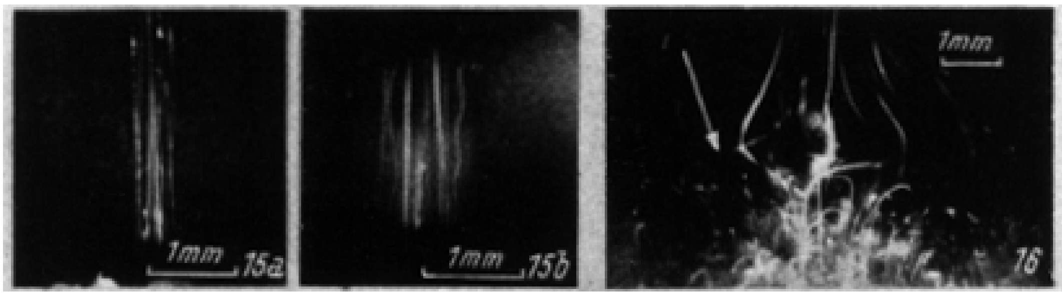
Observations:

1) particles fall with a screw movement without any electric charge

2) after switching on the field the particles jump around some seconds.
–> Barkhausen - noise ????

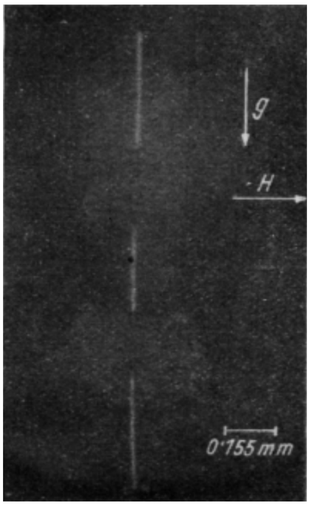


Setup to observe falling particles in magnetic fields;
B channel, Z chamber of glass G rubber tightenings

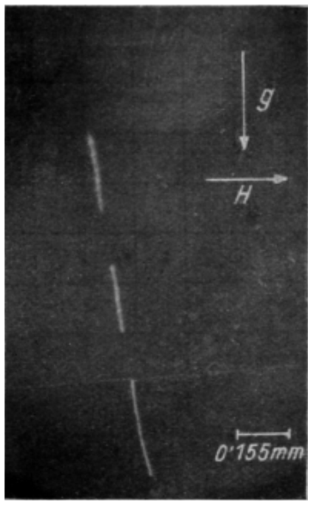


left fig.15a and b falling copper paticles in the magnetic field (7000 G) in 15b screwing path with ⌀=1/8mm and slope per tread 1.4 oder 0.6mm; fig.16 right side: explosion of Nickel particles on switching in 7000 Gauss under stroboscobic Illumination .

3) “classical” monopoles under stroboscobe illumination



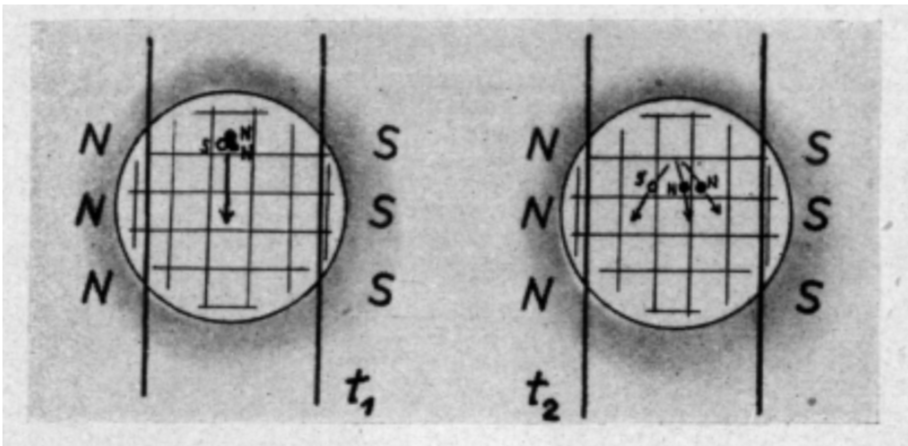
free fall of a particle (Fe or Cr) in the field without monopole charge under stroboscobe illumination



free fall of a particle (Fe or Cr) in the field with monopole charge under stroboscobe illumination

4) bursting of particle into magnetic monopoles

with conservation of momentum and charge



Magnetic burst of a particle with magnetic charge; left hand before, right hand after the burst

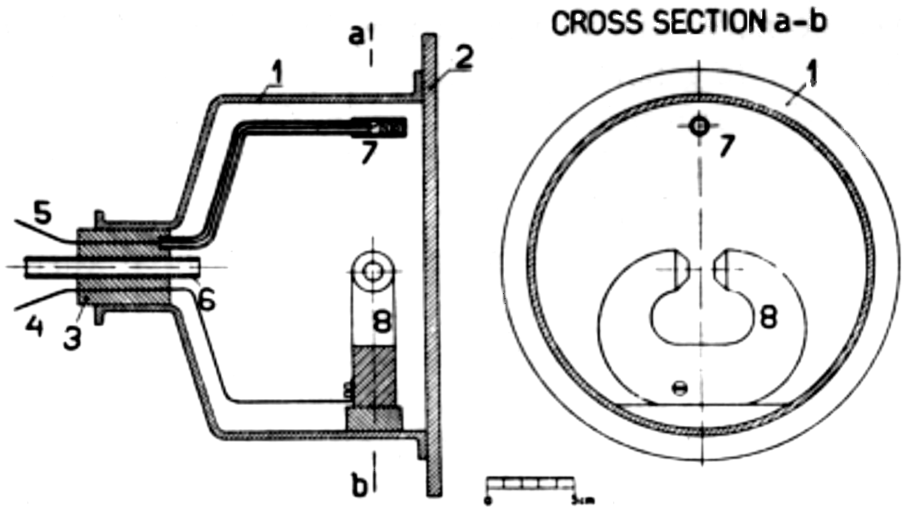
Monopoles in different environments

1) in light: magnetisation of iron by light is observed!
magnetisation explained by charging up with monopoles ?

2) in gas discharges: all magnetic charge particles are produced in sparks !

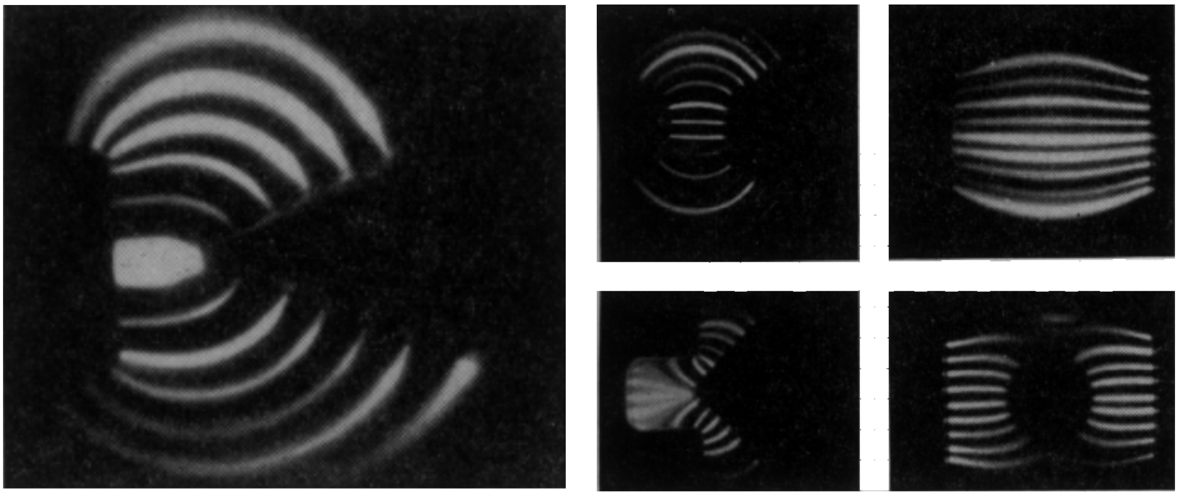
3) in vacuum tubes: a) Righi's magnetic rays

setup: magnet in vacuum as cathode
surface covered by with apiezon grease
anode in space, 800V, 40mA, R=50000Ω



setup for observation "magnetic" rays
1 glass vessel, 2 glass window, 3 stopper, 5+7 anode, 4 cathode, 6 to pumping lines 8 magnetic cathode

Observations: 1) el. fields do not influence the radiation
2) light intensity ~ magnetic field
3) rays go through Alu if in magnetic field
4) rays originate from apiezon grease



magnetic rays in different field geometries of the magnetic field

5) plasma can be decomposed, however no exact results were available.
6) magn. rays not present in high vacuum

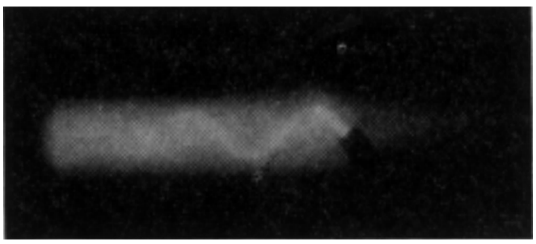
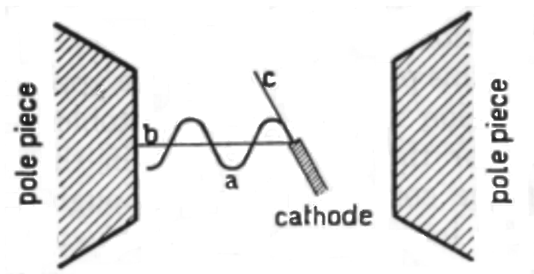


foto of magnetic rays with a separated cathode in setup (right side)

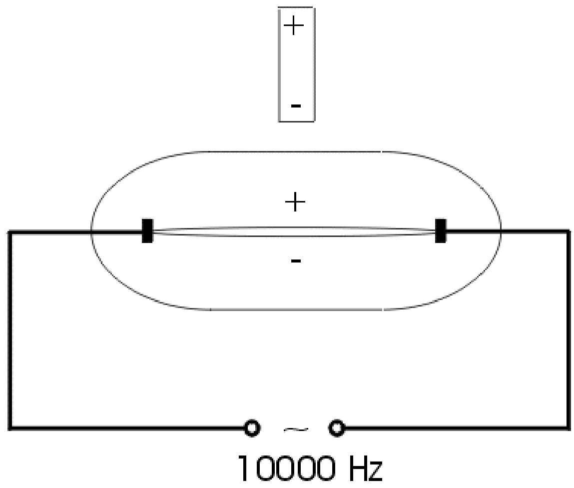


sceme to clarify the left foto
a) spiral wave b) diffuse rays c) “neutral beaml”

3) in vacuum tubes: b) Tesla's oscillating plasma files

Observations:

at 10000Hz, and high voltage in a gas discharge - 1 plasma file
with additional magnetic field - splitting up in 2 files,
Oscillation after disturbance by magnetic fields or by approach of a hand



Interpretation(acc. to Freeman Cope): plasma file consists of monopoles

4) charged solid bodies with monopoles ? (experiment of Freeman Cope)

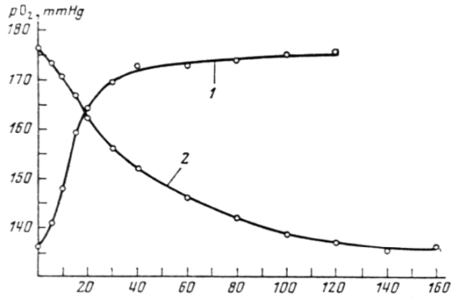
Measurement of the (superweak) magnetic fields of hairs

	white hair	black hair
at	protonresonanzmagnetometer	
	2	2
at	SQUID	
	8	2

5) Monopoles in Liquids ?

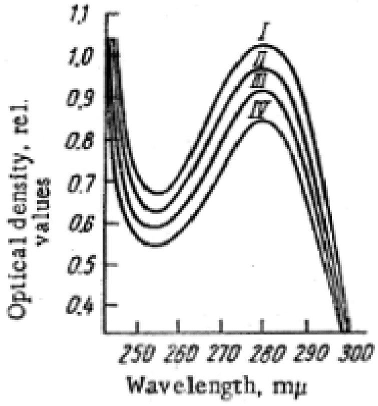
“Charging” experiments or only
slowly changes of chemical substances in a magnetic field ???

solution von Oxygen in water
in a magnetic field



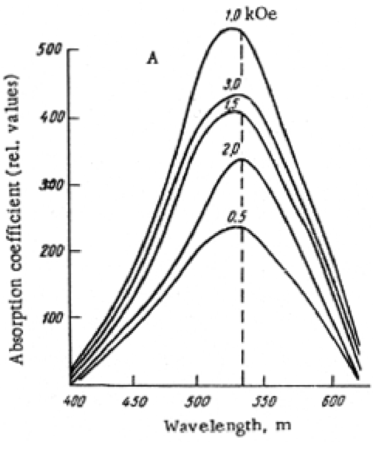
solution of O_2 in H_20 in a magnetic field; 1 near to the magnetic pole after switching on; 2 dito after switching off the field

change of the spectrum of absorption
of Trypsin a magnetic-field

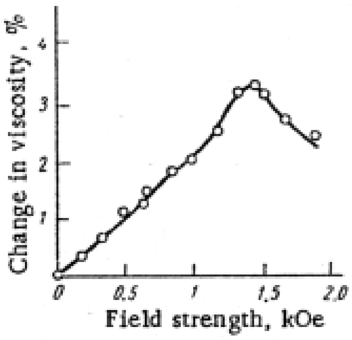


absorption of Trypsin vs. wavelenght after a “treatment” of 8000 Oe; I control; II 2h; III 5h; IV 7h

change of the spectrum of absorptions
of water under a magnetic field

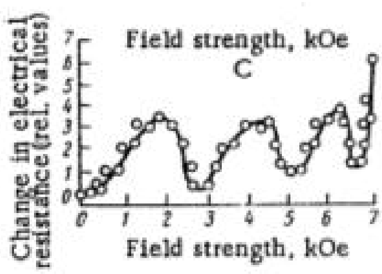


absorption of flowing H_2O vs. wavelenght at different magnetic fields change of viscosity of water in magnetic field



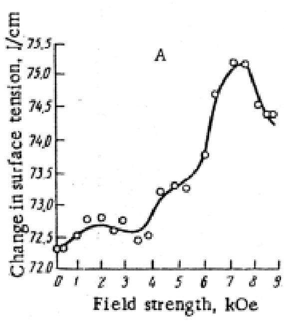
viskosity of H2O in a magnetic field

change of electric resistance of water in a magnetic field



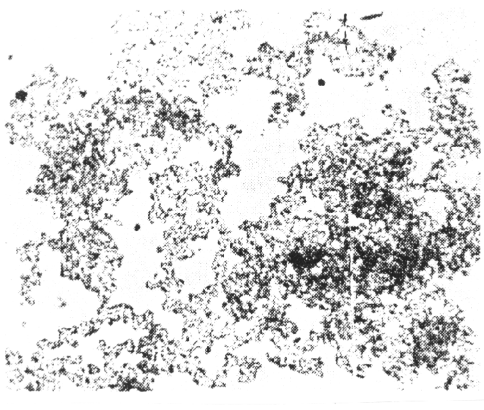
electric resistance of water in a magnetic field

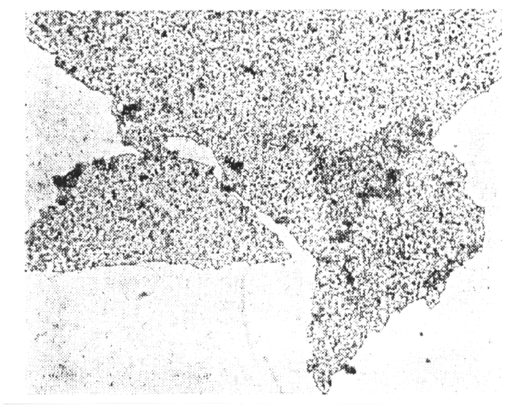
change of surface tension of water in magnetic field



electric surface tension of water in a magnetic field

change of cristallites in water in a magnetic field

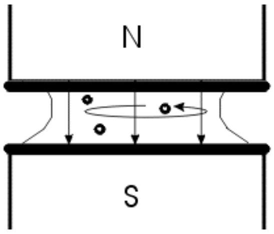




a similar phaenomen: different cristal modifications in water before and after a “vortex treatment”

6) fields of movement in liquids by magnetic field

FeCl - solution in a field of a magnet shows a rotation. the direction of rotation depends, whether the solution is acid or a base

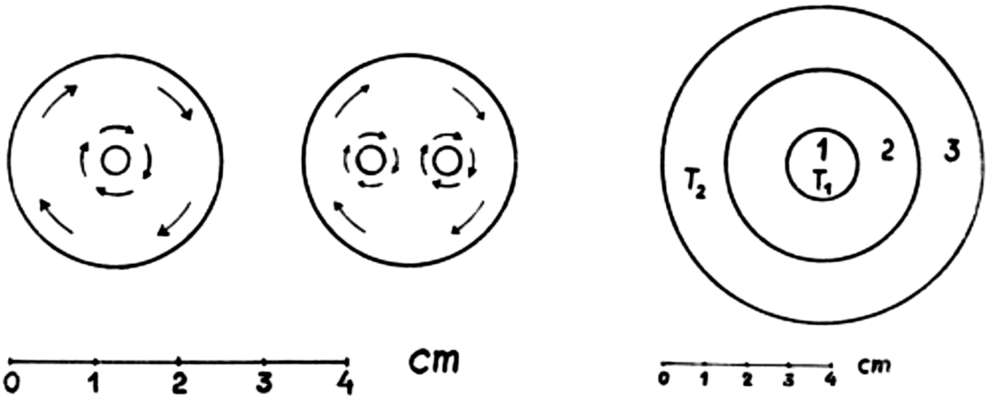


–> experiment (base over acid or reverse)

Reagents:

HCl(6n)	HCl(6n)	HCl(6n)	HNO_3(6n)	H_3PO_4(6n)
NaOH(6n)	NH_4OH(6n)	KOH(6n)	KOH(6n)	KOH(6n)
NH_4OH(6n)	NaOH(6n)	KOH(6n)	NH_4OH(6n)	NH_4OH(6n)
CH_3COOH	HJ(6.9n)	HJ(6.9n)	H_2SO_4(6n)	H_2SO_4(6n)

Setup:



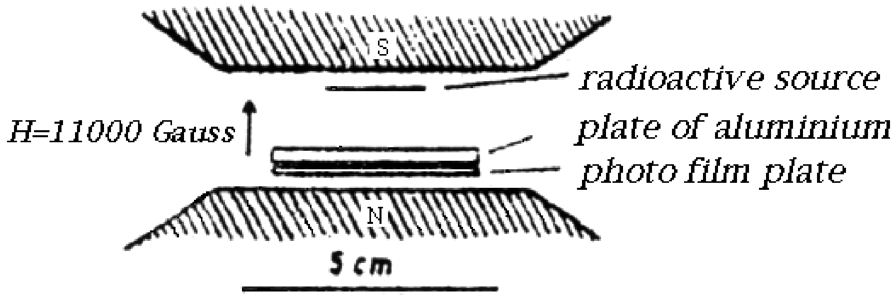
Petri disks are positioned over magnets !

Observations:

- if acid is positioned over the base there arise rotations of the liquid, whose direction of rotation depends from the pH locally present
- for a rotation is necessary:
  1) a vertical gradient in acidity 2) a magnetic field
- a temperature gradient can reverse the direction of rotation
- without magnetic field there exist no effect
- a semipermeable membran between base und acid does not prevent the effect!

7) magnetic monopoles in radioactive phaenomena ?

blackening of photoplates bei β-Strahlern is intensified,
if they are in a magnetic field .
Interpretation: particles carry magnetic charges
and are accelerated by the field



setup to prove the enhancement of radioactive radiation by magnetic fields

3.) Magnetic Monopoles in Classical Electrodynamics

Magnetic monopole charges are necessary,
because

$$\mathrm{div}\mathbf{B} = \mathrm{div}(\mu(\mathbf{x}).\mathbf{H}) = \mu\ \mathrm{div}\,\mathbf{H} + \mathbf{H}\ \mathrm{grad}\ \mu(\mathbf{x}) \neq 0$$

Consequences:

- magnetic fields are general fields without parity properties
- the causes of fields are always current <u>and</u> charges
- the magnetic boundary conditions have to be modified
- Constitutive relations are generally

$$\begin{pmatrix} \dot{\boldsymbol{\sigma}} \\ \dot{\mathbf{D}} \\ \dot{\mathbf{B}} \end{pmatrix} = \begin{pmatrix} f_1(\mathbf{E},\mathbf{D},\mathbf{H},\mathbf{B};T,\rho_i,x,\omega,...)(\mathbf{x},t) \\ f_2(\mathbf{E},\mathbf{D},\mathbf{H},\mathbf{B};T,\rho_i,x,\omega,...)(\mathbf{x},t) \\ f_3(\mathbf{E},\mathbf{D},\mathbf{H},\mathbf{B};T,\rho_i,x,\omega,....)(\mathbf{x},t) \end{pmatrix}$$

- --> In order to solve the problem the PDE-System of Maxwell equations has to be completed by thermodynamic, mechanic and other PDE -equations from the other areas of physics
- old magnetic vector potential **A** alone does not work generally !
  –> general magnetic fields have to be be derived from a vector potential <u>and</u> a magnetic potential due to magnetic charges
- practical applications: antenna with anisotropic cores
  simulation of and with permanent magnets

4.) Conclusion

Electromagnetic forces may have some interesting, unexploited features as

- negative photophoresis
- gravitophoresis
- photophoretic figures
- spiral movement
- magnetophoresis
- magnetic monopoles

magnetic monopoles seem to be necessary even in conventional electric engineering to cover all cases in magnetic field calculations

magnetic effects can play a big role in chemistry