SHERWOOD SCIENTIFIC
MAGNETIC SUSCEPTIBILITY BALANCES

FOR THE STUDY OF DIAMAGNETIC AND PARAMAGNETIC PROPERTIES OF MATERIALS

t. +44 (0) 1223 243444
f. +44 (0) 1223 243300
e. enquiries@sherwood-scientific.com
w. www.sherwood-scientific.com

Sherwood

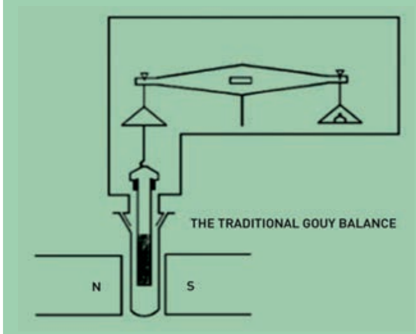
SHERWOOD SCIENTIFIC
MSB MK1 & AUTO

SHERWOOD SCIENTIFIC'S MAGNETIC SUSCEPTIBILITY BALANCES

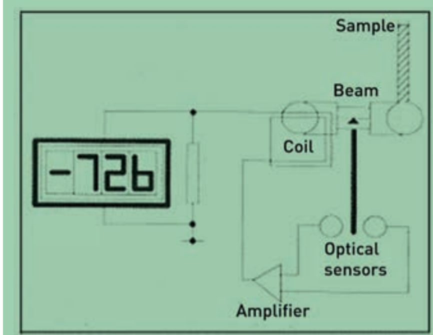
are recognised in hundreds of teaching and research laboratories throughout the world. Based on a design by the Late Professor Evans of Imperial College London, they offer a number of significant advantages over traditional methods. The Mk 1 balance adheres closely to Evans' original design. The MSB AUTO is a micro-processor controlled state of the art balance for detecting the magnetic properties of gases, liquids and solids. The improved sensitivity, versatility and overall performance make it ideally suited for new analytical applications in the research laboratory and industrial quality control. Both balances are exclusively manufactured by Sherwood Scientific in Cambridge UK.

Magnetic Susceptibility is defined as "The ratio of the intensity of magnetism induced in a substance to the magnetising force or intensity of field to which it is subject."

BASIC DESIGN PRINCIPLE



The traditional technique, developed by Gouy, employs a conventional balance and a large permanent magnet. The magnet remains stationary while the sample is caused to move, giving apparent gain or loss in sample weight



Moving Magnetic Field and Null Point Detection

Both MK1 and the AUTO work on the basis of stationary sample and moving magnets. Two pairs of magnets are placed at opposite ends of a beam making a balanced system having a magnetic field at each end. Introduction of the sample into the magnetic field attempts to deflect the beam and the movement is optically detected. A compensating force is applied by introducing a current through a coil between the other pair of magnets. The current required to maintain the original balance beam position is proportional to the force created by the sample and the direction in which the beam (magnetic field) moves indicates whether the sample is paramagnetic or diamagnetic; shown by a plus or minus indication on the display.

BASIC PRINCIPLES OF MAGNETIC BEHAVIOUR

Based on their magnetic properties, all substances can be classified into one of three groups, those attracted by a strong magnetic field; known as paramagnetic, those repelled; designated diamagnetic and finally, the most recognised class, ferromagnetic, unique in their ability to retain their own magnetic field. Ferromagnets are able to retain a permanent magnetic field since their free electrons are in close proximity and remain aligned even after the external magnetic field is removed. Unlike the ferromagnets, the magnetic properties of the diamagnetic or paramagnetic materials may only be observed and measured when they are held within a magnetic field applied externally.

MAGNETIC SUSCEPTIBILITY AT THE MOLECULAR LEVEL

The nature of the electrons within a sample determine its magnetic properties. The magnetic forces that are generated are more or less neutralised when two electrons become paired. Free, unpaired, electrons give rise to magnetic forces which are attracted to a strong magnetic field and the strength of these attractive forces are in direct proportion to the number of free electrons. The presence of free electrons results in materials being classified as paramagnetic and the lack of them results in a compound being diamagnetic. Crystallinity, chemical reactions, oxidation states, and virtually anything that can alter the electronic configuration of a compound, may also change its magnetic properties. Analogous to spectral measurements, magnetic susceptibility measurements are both qualitative and quantitative in nature.

CALCULATION OF MAGNETIC SUSCEPTIBILITY

The Volume Susceptibility (χv) is defined by

$$\chi_v = I \div H$$

Where I = Intensity of magnetism produced in a substance
H = Intensity of magnetic field applied externally

The Mass Susceptibility (Xg) is defined by

$$\chi_g = \chi_v \div d$$

Where d = density of substance

The calculation of χ_g from the readings on the MSB is simple:

$$\chi_g = C_{Bal^*} \frac{l}{m} \frac{(R-R_0)}{10^9}$$

Where C = calibration constant of the balance
L = length of sample in cm. (L >1 .5 cm)
m = mass of sample in grams
R = reading on MSB of sample in tube
R_0 = reading of empty tube

t. +44 (0) 1223 243444
f. +44 (0) 1223 243300
e. enquiries@sherwood-scientific.com
w. www.sherwood-scientific.com

Sherwood

SHERWOOD SCIENTIFIC
MSB MK1 & AUTO

THE SHERWOOD MK1 EXHIBITS MANY ADVANTAGES COMPARED WITH THE GOUY BALANCE:

- Ease and speed of use; place the sample tube in the balance and get an immediate digital read out.
- Measurements can be made on a wide range of diamagnetic and paramagnetic materials.
- The fixed sample tube allows susceptibility measurement of solids, liquids and gases.
- The technique has comparable sensitivity and is as accurate as traditional methods of measurement.
- The cost of the balance is significantly lower than a complete Gouy balance system.
- The instantaneous digital read-out can be used to calculate magnetic susceptibility using a simple equation. This gives significant time savings in both set-up and measurement.
- Small sample size; normally a sample weight of around 250mg is used but by using a narrow bore sample tube, as little as 50mg is required to give an accurate measurement.
- Analogue output: Using a flow cell allows a chemical reaction resulting in a change of susceptibility to be monitored dynamically. This allows new applications to be investigated, for example, redox reactions.
- External power supply: The MSB is a low voltage instrument enhancing the safety aspects by removing high voltage from the detection end in contact with the chemicals.
- The equipment is compact, lightweight and hence, easily portable.

APPLICATIONS OF MAGNETIC SUSCEPTIBILITY MEASUREMENTS

All substances exhibit magnetic properties so it is possible to use magnetic phenomena to identify, differentiate and quantitatively measure components and contaminants in mixtures non-destructively. Occasionally the magnetic susceptibility measurement offers a unique solution to a difficult analytical problem. We are happy to consider any new applications for the MSB.

Sherwood Scientific has been collecting and developing methods for many years and the following list illustrates the wide variety of possible applications:

- Wear particulate analysis directly on lubricating oils
- Pesticide and pharmaceutical analysis by generation of free radicals
- Examination of chemical reactions on a micro scale
- Characterisation of Ion exchange adsorption and desorption processes
- Measurement of concentration and size of magnetic beads
- Analysis of rare earth elements and their oxidation states
- Qualitative analysis of metal complexes
- QC of catalysts in the petrochemical and plastics industries
- QC of Industrial diamonds for trace metal contaminants
- Measurement of synthetic diamonds
- Archaeological studies of soil samples to indicate human occupation
- Measurement of the oxidation state of haemoglobin
- Quality control in the fabrication of superconductors

t. +44 (0) 1223 243444
f. +44 (0) 1223 243300
e. enquiries@sherwood-scientific.com
w. www.sherwood-scientific.com

Sherwood

SHERWOOD SCIENTIFIC
MSB MK1 & AUTO

MSB MK1

The MSB MK 1 displays results for the sample, R, and the blank tube, Ro, which are then computed using the formulae on page 2 (Bottom Right Corner). Matched magnets and a printed circuit construction for the coil, ensures balance to balance reproducibility is ensured.

The MK 1 has proven to be the ideal instrument for use in teaching laboratories throughout the world where the reduced amounts of chemicals required for an experiment saves on material costs and minimises waste product disposal.

MSB AUTO

The MSB AUTO weighs less than 2.2 kg and comes complete with rechargeable batteries for up to 8 hours of operation without a mains power supply. Supplied in a robust carry case, the instrument can be operational in minutes of arrival at the analysis site. Travel clamp removal and an adjustable level control are the only set-up procedures required.

The Auto shares all the advantages offered by the Mk 1, and also has many additional benefits to offer.

The Auto is most suited for materials research and development and quality control measurements where reproducibility and documentation of results are essential.

The MSB AUTO microprocessor has the balance calibration constant entered during manufacture. The digital display of the measurement is directly converted to **Volume Susceptibility** in c.g.s. units without need for calculation or manipulation.

By entering the sample weight and length in the separate keypad (internal sensors detect the diameter of sample tube) **Mass Susceptibility** can be read directly from the display. The AUTO automatically zeroes when the sample tube holder is empty. An empty sample tube can be tared and the value automatically subtracted from subsequent sample measurements. The AUTO reads in magnetic susceptibility (mass or volume) units **directly without requiring manual calculation.** The AUTO can measure values from 0.000 x to ± 1.999 in four ranges, namely x 10^{-7}, x 10^{-6}, x 10^{-5}, x 10^{-4} c.g.s. units. This is two orders of magnitude more sensitive than the MK 1, which is itself comparable in sensitivity to most traditional methods. The instrument includes both an RS232 computer interface and an analogue output for a chart recorder - particularly useful when using the **MSB AUTO as a detector.** The detector unit is separated from the read-out and controls which are housed in a hand-held unit. The operator can remain away from the sample when measuring hazardous substances or reactions.

t. +44 (0) 1223 243444
f. +44 (0) 1223 243300
e. enquiries@sherwood-scientific.com
w. www.sherwood-scientific.com

Sherwood

SHERWOOD SCIENTIFIC
MSB MK1 & AUTO

SPECIFICATIONS

	MSB MK1	AUTO
Size in cm (unpacked)	44w x 35d x 26h	54w x 40d x 30h
(packed)	34 x 26 x 45	25.5 x 51 x 41
Weight (unpacked)	3 kg (7 lbs)	1.2 kg (2.5 lbs)
(packed)	4.5 kg (9.9 lbs)	9 kg (19.8 lbs.)
Power Requirements	110V or 220V, works with PSU Uni. Multi-Plug Adapter, 12V DC, 001 53 313 supplied.	110V or 220V, works with PSU Uni. Multi-Head Adapter, 9V DC 001 53 343 supplied. Also provided with 4xAA rechargeable batteries for
Measurement Range	In the range of ±2 x 10^{-5} to ±5 x 10^{-8} arbitrary units	±1.999 x 10^{-4} to ± 5 x 10^{-10} cgs
Sample Tubes Available	Normal tubes (0.324 cm I.D.) Narrow tube (0.200 cm I.D.) Very narrow tube (0.100 cm I.D.) Gas sample tube (0.324cm I.D.)	All Mk I tubes (OD 0.400cm)plus: Wide bore tube (0.420 cm I.D.)
Amount of Sample Required for Accurate Determination of Magnetic Susceptibility	Volume 70µl (min.) 300µl (max) Weight (as solid) 40 milligrams (min) Weight (in solution) 2.5 milligrams (min.)	Volume 10µl (min.) 400µl (max) Weight (as solid) 40 milligrams (min) Weight (in solution) 2.5 milligrams (min.)
Outputs	Digital display	Digital display RS232 Analogue Output
Magnetic Field Strength	3.5 kGauss	4.5 kGauss

ORDERING INFORMATION

Model	Part Number	Including
Mk1	710 00 000	Main unit, Calibration standard tube, 2 normal bore sample tubes, Operator Manual, Software and Multi-head PSU
AUTO	700 00 109	Handheld Unit, Tube adapter - 4mm, Tube adapter - 5mm, PSU Uni. Multi-Head, 9Vdc, Software cd, 2 Sample tube Ø4mm, Sample tube Ø5mm, Stoppered tube Ø4mm, Flowcell, Tube stand, Pot. adjuster, Lead, Instrument to Printer/Computer, Carry case, Operators manual

SHERWOOD SCIENTIFIC
MSB MK1 & AUTO

THE RELATIONSHIP BETWEEN DIFFERENT TYPES OF SUSCEPTIBILITY

There are 3 commonly used types of susceptibility each with its own symbol. These types are shown below together with how they are related to each other in the cgs system:

Where: ρ is the substance density in g/cm^{-3} e.g. water 0.9982 g/cm^{-3} (20°C)
M is the relative molecular mass e.g. water 18g/mol
Literature values of susceptibility are often quoted as XM - Molar susceptibility, sometimes described as susceptibility per gram formula weight.

X_v	Volume susceptibility	$X_v = X_g * \rho$	and	$X_v = XM * \rho / M$
X_g	Mass susceptibility	$X_g = X_v / \rho$	and	$X_g = XM / M$
XM	Molar susceptibility	$XM = X_v * M / \rho$	and	$XM = X_g * M$

ARE THE MSBS ABLE TO MEASURE HIGH OR LOW TEMPERATURE SAMPLES?

Neither MK1 or AUTO Magnetic Susceptibility Balances have temperature control but it is possible to put hot or cold samples into either instrument and get readings. Measurements made on such samples will, however, be subject to errors for two reasons;

1) The sample temperature will not be constant so any temperature dependent magnetic property will be changing

2) There are magnets inside the balance, very close to the sample, whose strength varies as they are heated or cooled by the sample.

The user would have to make allowance for those effects. If any form of sensor is in the sample to measure its temperature and help with interpreting the readings, then any the effect of the sensor itself on the magnetic measurement must be understood.

MSB FAQ'S ON THE SHERWOOD WEBSITE

http://www.sherwood-scientific.com/msb/msbfaq.html

- Why does my MnCl2.4H2O solution filled tube that accompanied my MK1 MSB vary its reading?
- Why can't you tell me the concentration of MnCl2.4H2O in the solution in the tube?
- How can I use the MnCl2.4H2O tube to monitor the performance of the MK1 balance?
- How do I know if the reading I'm getting is right?
- How do I work out if two tubes are matched?
- How do I measure strong samples which are over range?
- How do I work out the concentration of the solute in the liquid sample?
- What about the 'air correction term'?
- Why do I need to add 1.5cm depth of sample?
- Is it ever possible to work with less than the 1.5cm depth?
- How do I work out the expected MSB reading of a known, solid substance?
- How do I work out the expected MSB reading of a solution of a known solid in a known solvent?

t. +44 (0) 1223 243444
f. +44 (0) 1223 243300
e. enquiries@sherwood-scientific.com
w. www.sherwood-scientific.com

SHERWOOD SCIENTIFIC
MSB MK1 & AUTO

ACCESSORIES

A varied selection of sample tubes and accessories are available
to accommodate a wide range of analytical applications

	Part Number	Description	For use with
A	700 04 126	Sample Tube Holder	AUTO and Mk1
B	700 86 003	Flow Cell	AUTO only
C	700 86 004	Sample Tube, wide bore (5mm OD, 4.2mm ID)	AUTO only
D	700 86 005	Adapter sleeve for use with wide bore tube (5mm OD)	AUTO only
E	700 86 010	Adapter sleeve for use with standard OD tubes (4mm OD)	AUTO only
F	710 86 002	Sample Tube, normal bore (4mm OD, 3.24 mm ID)	AUTO and Mk1
G	710 86 005	Sample Tube, gas tight top	AUTO and Mk1
H	710 86 006	Sample Tube, very narrow bore (4mm OD, 1 mm ID)	AUTO and Mk1
	710 86 007	Sample Tube, narrow bore (4mm OD, 2mm ID)	AUTO and Mk1

t. +44 (0) 1223 243444
f. +44 (0) 1223 243300
e. enquiries@sherwood-scientific.com
w. www.sherwood-scientific.com

Sherwood

INTRODUCTION AND HERITAGE

Sherwood Scientific Ltd., develops and manufactures a range of scientific instruments and apparatus with application in many industries, as well as in education and research. Known for high quality and reliability, Sherwood Scientific products are all manufactured at the company's base in Cambridge, UK and sold and supported through an extensive distributor network covering over 80 countries. Fully equipped training and laboratory facilities enable Sherwood Scientific to offer courses to our distributors on all products and to undertake consultancy projects in analytical measurement and process control. The history of Sherwood Scientific can be traced back more than 70 years to applications of the selenium photocell in early Flame Photometers – now the largest and most diverse of our product lines. The company's heritage also encompasses the Lab Scale Fluid Bed Dryer and Magnetic Susceptibility Balance developed under the auspices of Johnson Matthey, and the acquisition and further development of several Corning and CIBA Corning instruments: Colorimeters and Chloride Analysers.

PRODUCTS

FLAME PHOTOMETERS

Building upon the acclaimed Corning M410, we now manufacture the widest range of Instruments and Accessories: single and multi-channel, with analogue and digital outputs, free-standing and software controlled units and automated analysis packages for Sodium, Potassium, Lithium, Calcium, Barium, Cesium, Rubidium and Strontium analysis

MODEL 501 FLUID BED DRYER

This is a bench top, lab-scale, programmable Fluid Bed Dryer. The microprocessor controlled base unit accommodates the widest range of tub configurations and materials. We select inlet and outlet filters to complement a broad variety of sample types and particle sizes. With in-tub temperature and humidity feedback capability coupled to a software package providing real-time drying condition feedback. This unit allows rapid development of drying protocols and understanding of material drying behaviour.

CHLORIDE ANALYSERS

Our Chloride analysers use coulometric titration technology; offering the best available means of Chloride determination in food, pharmaceutical and industrial products etc. In addition sweat chloride measurement is also possible, (with samples as small as 20ul), as required for assistance with Cystic Fibrosis confirmation.

CHROMA COLORIMETERS

Our CHROMA Colorimeter range offers two fully open, programmable units; which may be utilised with any commercial test kits for water quality monitoring, clinical chemistry measurements and many other colorimetric determinations. We also have a digital equivalent to the renowned Corning 252, for instant, no frills, reliable Absorbance & %Transmission measurements.

MAGNETIC SUSCEPTIBILITY BALANCES

For those studying magnetic properties of materials, our Magnetic Susceptibility Balances offer unsurpassed sensitivity and reliability. We truly are world leaders in this field of analytical chemistry

Sherwood Scientific is represented by a worldwide network of distributors, details of whom can be found on our website.
Please contact us for further information or visit us at

www.sherwood-scientific.com

for full product information, application & technical advice and basic theory of principles of operation.

t. +44 (0) 1223 243444
f. +44 (0) 1223 243300
e. enquiries@sherwood-scientific.com
w. www.sherwood-scientific.com

Sherwood