



BET SPECIFIC SURFACE AREA & PORE SIZE ANALYZER

BELSORP MAX G

Quick, Easy Characterization of Powder Materials with the Highest Accuracy

The BELSORP MAX G is a powerful, compact, and economical model in Microtrac's BELSORP MAX series of BET specific surface area and pore size analyzers. It allows the measurement of gas adsorption isotherms starting from extremely low pressures for the evaluation of micro-, meso- and macroporous materials, as well as non-porous materials.

The analyzer is equipped with one measurement port, one dedicated port for saturated vapor pressure measurement, and one port for free space (dead volume) analysis. Each port is equipped with a dedicated pressure sensor for high-precision analyses.

The BELSORP MAX G surface area & pore size distribution analyzer is capable of analyzing a wide range of materials, including pellets, molded bodies, substrates, and finely dispersed samples thanks to specially designed sample tubes.

The unit also supports a wide range of adsorbates and measurement conditions. The instrument is available in two different versions, making it suitable for a wide range of applications: BELSORP MAX G LP (Low Pressure) and BELSORP MAX G MP (Medium Pressure). Either version is equipped with a specific pressure transducer to best suit your needs.



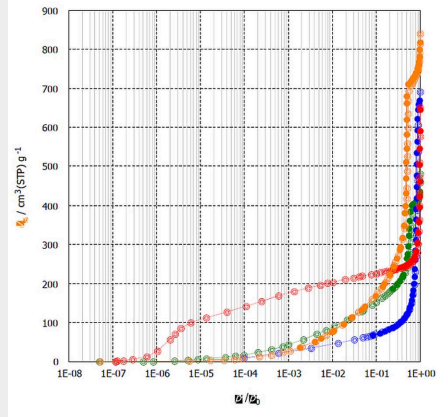
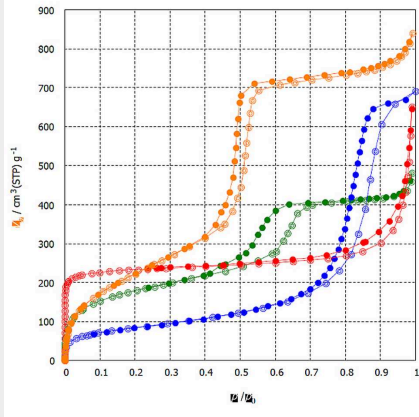
| | BELSORP MAX G LP | BELSORP MAX G MP |
|--------------------------------|---------------------------------|-------------------------------|
| Port 1 | 1,000 Torr, +10 Torr, +0.1 Torr | 1,000 Torr, +10 Torr, +1 Torr |
| Port 2 | | 1,000 Torr |
| Saturation vapor pressure port | | 1,000 Torr |
| Turbomolecular pump | | yes |

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KEY FEATURES

Ultra-Low Pressure Measurement

The BELSORP MAX G allows for high-accuracy measurement of adsorption isotherms in a wide range, starting from the ultra-low pressure region ($P/P_0 = 10^{-8}$, N_2 @ 77 K) to atmospheric pressure. The BET surface area and pore size distribution analyzer includes a turbo molecular vacuum pump and low-voltage pressure transducer.



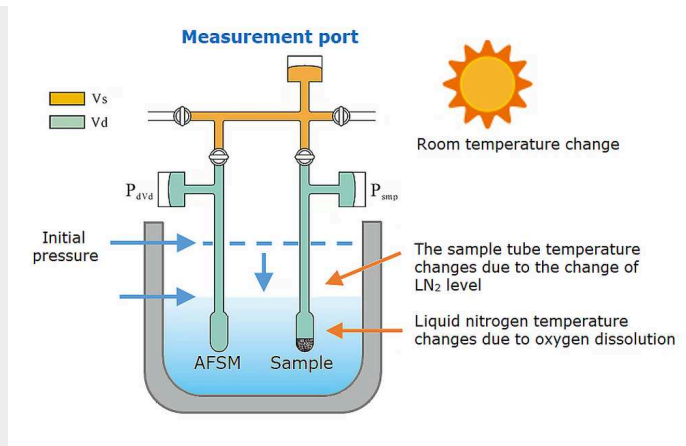
Innovative Free Space Measurement for Highest Accuracy (AFSM™)

Strictly controlling the level of liquid coolants (e.g. liquid nitrogen or argon) is no longer required with the BELSORP MAX G. Instead, we have implemented our groundbreaking, continuous free space measurement method: the patented Advanced Free Space Measurement (AFSM™). This method achieves the highest level of reproducibility by using a reference cell to follow the second-to-second changes of free space. First, the instrument determines the free space of the sample cell and reference cell. Then, as the analysis proceeds any changes to the system that might alter the measured Free Space are concurrent in both cells. Therefore, alterations in the measured free space can be continuously accounted for through the reference cell.

Examples of causes for free space fluctuations include:

- | Liquid nitrogen (LN₂) level changes
- | Atmospheric temperature and pressure changes
- | Coolant temperature changes due to dissolution of oxygen

With this superior technique, environmental factors can be taken into account that were not considered before. For more information, please visit our knowledge base.



Ease of use – Simple Setting of Measurement Conditions

The BELSORP MAX G has a fully automated system that enables the user to easily setup measurement conditions through 'Simple Mode'. This mode makes sample analysis a breeze by only requiring minimal user entry (e.g., sample information, pretreatment conditions and measurement range). This is particularly useful for unknown materials and for the application of standard operation procedures. Detailed measurement configurations can be set by experienced users by selecting the 'Professional Mode'.

Gas Dosing Optimization (GDO)

The Gas Dosing Optimization (GDO) function calculates the optimal gas dosing amount from previous measurement results. This function can reduce measurement times significantly.

Single mode

Measurement template: Last used method | Operator: _____

Sample info: Pre-treatment: Measurement pressure

Load an existing isotherm

Previous data: Use(GDO) | Load previous data (GDO)

Specify measurement pressure

| Target(PPO) | ADS | DES |
|-------------|----------|-------------------------------------|
| 15 | 6.00E-1 | <input checked="" type="checkbox"/> |
| 16 | 7.00E-1 | <input checked="" type="checkbox"/> |
| 17 | 8.00E-1 | <input checked="" type="checkbox"/> |
| 18 | 9.00E-1 | <input checked="" type="checkbox"/> |
| 19 | 9.50E-1 | <input checked="" type="checkbox"/> |
| 20 | 9.60E-1 | <input checked="" type="checkbox"/> |
| 21 | 9.70E-1 | <input checked="" type="checkbox"/> |
| 22 | 9.75E-1 | <input checked="" type="checkbox"/> |
| 23 | 9.80E-1 | <input checked="" type="checkbox"/> |
| 24 | 9.85E-1 | <input checked="" type="checkbox"/> |
| 25 | 9.875E-1 | <input checked="" type="checkbox"/> |
| 26 | 9.90E-1 | <input checked="" type="checkbox"/> |

Adsorption | Desorption

Display of expected isotherm

Automatic optimization of conditions such as gas introduction volume

Quick entry | Insert | Delete

Tolerance of equilibrium pressure: ± 0.1 %

Display update | Display setting

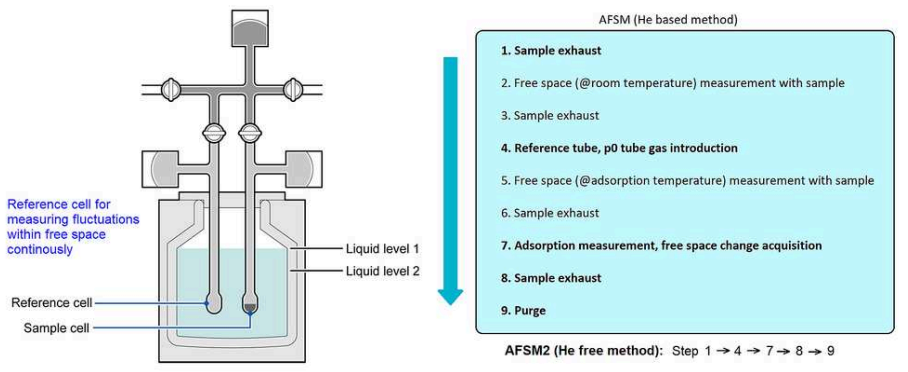
Port 1 | Port 2 | Port 3 | Port ref

Input of measurement range

Start | Close

Helium-Free Measurements (AFSM^{TM2})

By measuring the free space of a 'blank' sample tube in advance, measurements can be achieved without the need for helium gas. Using the same sample tube, in the same analysis conditions, the free space can be easily calculated using your sample's mass and density. This method also reduces sample analysis time by cutting out the free space determination at the beginning of every sample measurement. With AFSM^{TM2}, there is no need to match the liquid level of the coolant between the blank measurement and sample analysis.



Compact & Lightweight

By optimizing the component materials, we have managed to provide a unit with a small footprint and low weight.

In-Situ Pretreatment (Optional)

For an accurate adsorption measurement, a pretreatment of the samples is required. The pretreatment process (also called activation process) is usually performed by applying vacuum under heat, which removes adsorbed gas and / or water molecules from the surface of the material without affecting the sample structure (avoiding denaturation).

Microtrac offers two options for sample pretreatment. First, it can be performed externally using our BELPREP equipment, which is usually preferred to increase sample throughput. Alternatively, the activation process can be performed directly at the measurement port of the BELSORP MAX G using a heater (see accessories list). This way, a transfer from the external pretreatment device to the measuring port can be avoided, which is an important option for sensitive samples (e.g. hydrophilic material).



Data Analysis

Our BELMASTER analysis software is provided with the BELSORP MAX G, and enables the user to perform a wide variety of data analysis, including evaluating specific surface areas using the Langmuir or BET method, evaluating pore volumes by applying the t-plot method, conducting mesopore analyses with the DH or BJH method, micropore analyses via HK or SF method, or GCMC / NLDFT analyses, and much more.

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TOEBEHOREN EN OPTIES

**STANDARD
CONSUMABLE GOODS**



Our standard consumables consist of sample cells, filler rods, filters, O-rings, caps and weighing platforms that are required for adsorption measurements. NSD capsules, a variety of sample cells, quick seals, and much more are part of the consumable goods.

WATER BATH



Easily swap the Dewar with a water bath for measurement temperatures ranging from -10°C to 70°C. A refrigerated / heated circulator is required.

HEATER



In-situ pretreatment of the sample from 50°C to 450°C. With this option, samples can be pretreated directly at the measurement port, without the need to transfer the sample cell before analysis. Particularly useful for sensitive samples.

GAS SELECTOR



The gas selector enables the connection of up to 4 adsorptives simultaneously (1 x Helium + 4 x adsorptive).

BET SPECIFIC SURFACE AREA & PORE SIZE ANALYZER BELSORP MAX G

BELCONTROL: NEW OPERATION SOFTWARE

The versatility of BELSORP equipment is truly world leading. The numerous features and capabilities are complemented by BELCONTROL the intuitive and user-friendly operation software. It guides the user step-by-step through the analysis process. This includes the setup of analysis conditions, executing the measurements, when to fill and setup the liquid nitrogen or other bath, when to replace the gas cylinder, the degassing steps, and much more. The software is designed to make the instrument accessible and operable to everyone, including inexperienced users.

For inexperienced users or for measurements of unknown samples, BELCONTROL only requires basic sample information (name, mass, etc.), pre-treatment conditions (if not performed externally) and the measurement range.

Detailed control of the configuration and measurement settings is possible to optimize the measurement conditions (e.g. dosing settings, equilibrium criteria, leak test option, etc.). This allows the user to fully customize the sample analysis to his needs.

| BELCONTROL | | |
|-------------------------|-----------|--|
| Quick BET | ja | Multi-point BET surface area in less than 20 minutes |
| Helium-Free Measurement | ja | AFSM™ 2 enables He-free measurements with unmatched accuracy |
| Adsorption Kinetics | optioneel | Rate of adsorption measurements for diffusion analysis |

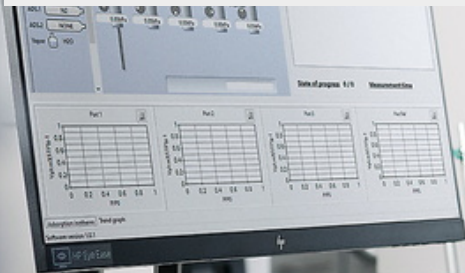
MORE BELCONTROL FEATURES

- | Overlaying adsorption / desorption isotherms and comparing the measured data between the various ports during measurement
- | All pressures, temperatures, valve actuations, etc. are stored in trend data, allowing for immediate examination
- | A system check function is available for



diagnosing the instrument status

- | E-mail notification automatically transmits measurement status and results
- | Interactive program in Japanese or English ensures easy, reliable operation
- | Extensive help functions, including step-by-step instructions during operation



BET SPECIFIC SURFACE AREA & PORE SIZE ANALYZER BELSORP MAX G

OPERATION SOFTWARE

The versatility of the BELSORP instruments, with their many features and possibilities, is complemented by our intuitive and user-friendly operation software. It guides the user step-by-step through the analysis process including setting up the analysis conditions, executing the measurements, when to fill and setup the liquid nitrogen or other bath, when to replace the gas cylinder, the degassing steps, and much more. The software has been crafted to make the instrument accessible to everyone, even inexperienced users.

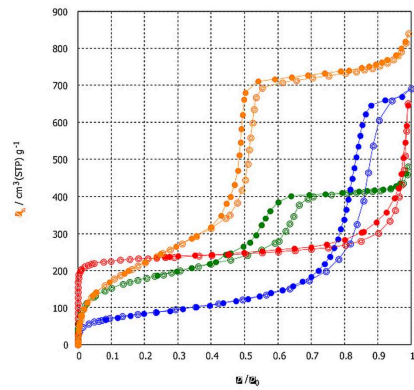
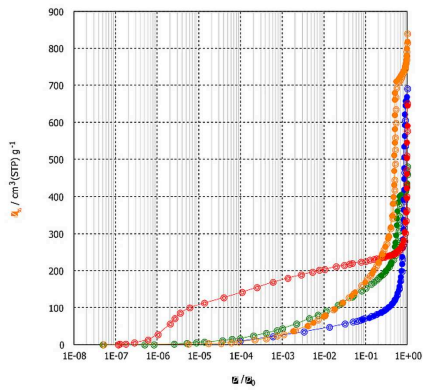
Two measurement modes are offered: 'Simple Mode' and 'Professional Mode'. Simple Mode enables easy operation, requiring minimal setup. You only need to enter the basic sample information (name, mass, etc.) and then select your pretreatment conditions and analysis conditions from a list of preset options. This is ideal for inexperienced users or measurements of unknown samples. If a prior measurement with comparable sorption behavior has been performed, GDO can be used to reduce the measurement time. Professional Mode allows detailed control of the configuration and measurement settings (e.g., dosing settings, equilibrium criteria, leak-check option, etc.), allowing the user to completely customize sample analysis.



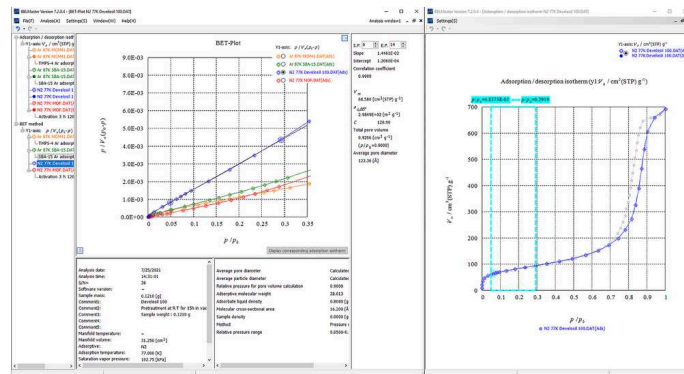
GAS ADSORPTION MEASUREMENTS OF POROUS & NON-POROUS MATERIALS: MOFS, ZEOLITES, CARBONS,
AND MORE

EVALUATION SOFTWARE BELMASTER

A sorption isotherm is defined as the relationship between the adsorbed amount onto an adsorbent and the equilibrium pressure of the adsorptive gas – commonly related to the saturation vapor pressure – at constant temperature. The gas sorption isotherm (e.g. nitrogen) delivers information about the specific surface area, pore size distribution and pore volume of measured material. In the following graph some exemplary sorption isotherms are shown.



The specific surface area (SSA) refers to the accessible surface area of the sample and is of great importance in adsorption, homogeneous and heterogeneous catalytic reactions. The specific surface area can be calculated according to ISO 9277 with the BET method (BET: Brunauer, Emmett and Teller) or Langmuir method. The following graph shows an exemplary evaluation of the specific surface area according to the BET method in our BELMASTER software:



Select the right pressure range (multi point BET) or a measurement point (single point BET) and the surface area will be calculated automatically. Further, our BELMASTER software also provides the BET surface area calculation according to ISO 9277 Annex C (also known as Rouquerol-plot), which is recommended for microporous materials.

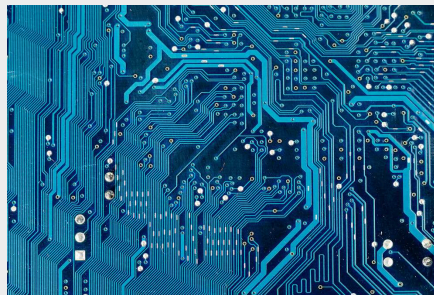
The outstanding feature of the BELSORP MAX G is the availability of three different transducers (1000, 10 and 1 / 0.1 torr), enabling very low pressure adsorption isotherms, starting from $p/p_0 = 10^{-8}$ ($N_2 @ 77K$) up to atmospheric pressure. As a result, pore size distributions from 0.35 up to 500 nm can be obtained. Further, low surface area measurements down to $0.0005 \text{ m}^2/\text{g}$ by using krypton gas are possible.

The characterization of low specific surface area materials such as non-porous metallic materials, glass substrates, and films can be difficult or impossible with traditional gases like nitrogen (77 K) and argon (77 K or 87 K) due to detection limits. Instead, krypton gas adsorption can be used at liquid nitrogen temperature to determine the BET specific surface area down to $0.0005 \text{ m}^2/\text{g}$.

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TYPISCHE TOEPASSINGEN

Microtrac's gas adsorption analyzers are used in a variety of fields. These include catalysts, batteries, fibers, polymer materials, zeolite, fuel cells, chemicals, pigments, cosmetics, MOF / PCP, magnetic powders, separation membranes, filters, toners, cement, ceramics, semi-conductors, and many more.



- | batterij materialen
- | Katalysatoren
- | zeoliet
- | keramiek
- | koolstof

- | elektronische componenten
- | Brandstofcellen
- | toner
- | cement
- | geneesmiddel / medicijnen

- | Silicium
- | MOF / PCP
- | pigmenten
- | cosmetica

... en meer!

Om de beste oplossing te vinden voor uw deeltjes-karakterisatie behoeften, kunt u onze toepassingsdatabase consulteren

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TECHNISCHE GEGEVENS

| | |
|--|--|
| Meetprincipe | Volumetric method + AFSM™ |
| Adsorption gas | N ₂ , Ar, Kr, CO ₂ , H ₂ , O ₂ , CH ₄ , NH ₃ , NO, CO, butane, and various other (non-)corrosive gases |
| Gas ports | 2 ports (5 ports max.) |
| Number of measurements (High Accuracy mode) | 1 port in High Accuracy mode |
| Measurement range (specific surface) | 0.01 m ² /g and above (N ₂) 0.0005 m ² /g and above (Kr) (depending on sample density) |
| Pore size distribution (Diameter) | 0.35 - 500 nm |
| Low pressure isotherm | p/p ₀ = 10 ⁻⁸ (N ₂ @77K, Ar @87K) |
| Pressure transducer | 133 kPa (1000 Torr) x 3 units 1.33 kPa (10 Torr) x 1 unit 0.133 kPa (MP) or 0.0133 kPa (LP) x 1 unit |
| Vacuum gage / pump | Turbo molecular pump + rotary pump Cold cathode gauge (optional) |
| Sample tube | Standard tube, approx. 1.8 cm ³ (optional: 5 cm ³) |
| Dewar vessel | Volume: 2.6 L Holding time: 80 h |
| Pretreatment heater | 50 - 450 °C |
| Water bath | -10 - 70 °C |
| Analysis software BELMaster™ 7 | Adsorption isotherm, BET specific surface area I type (ISO9277), BET automatic analysis, Langmuir specific surface area, BJH, DH, CI, INNES method, t-plot, Alpha-s plot |
| Analysis software BELMaster™ 7 cont. | HK, SF, CY method, NLDFT / GCMC, MP method, Dubinin-Astakhov method, Difference adsorption isotherm, Molecular probe, Adsorption rate analysis (opt.) |
| Afmetingen (B x H x D) | 320 x 740 x 465 mm |
| Weight (main body) | 36 kg |
| Utility - Gas | He, adsorption gas: 0.1MPa (G), purity: more than 99.999% Joint: 1/8" Swagelok joint |
| Utility - Power | Main unit: AC 100 - 240 V / 850 W, 50 / 60 Hz (including vacuum pump) |

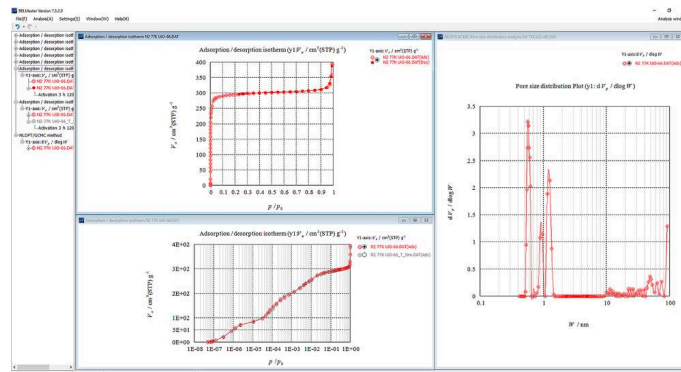
| | |
|----------------------------|---|
| Omgevingsfactoren | Temperature: 10 - 30 °C Humidity: 20 - 80% RH |
| ASTM compliance | B922, C110, C1069, C1240, C1274, D1993, D3663-20, D3908, D4222, D4365, D4641, D4780, D4842, D5604-96, D6556, D8325, E2864, WK61828, WK71859 |
| ISO compliance | 4652, 8008, 9277, 12800, 15901-2, 15901-3, 18757, 18852 |
| USP compliance | 268, 846 |
| DIN compliance | 66134 (1998-02), 66135-1 (2001-06), 66135-2 (2001-06), 66135-3 (2001-06), 66135-4 (2004-09) |
| CE certified | Ja |
| Recommended Monitor | Full HD monitors |

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PRINCIPE

Analysis of Pore Size Distribution via NLDFT & GCMC Method

The classical pore size distributions (PSD) are calculated by INNES method (slit shape) and BJH, DH, CI methods (cylinder shape), which evaluate mesopores based on the capillary condensation theory. HK (slit), SF (cylinder), and CY (cage) methods can also be used to evaluate micropores based on the adsorption potential theory. The DA method, as well as the DR method, are also commonly used for pore volume evaluation and pore structure evaluation. The new PSD and capacity evaluation methods, NLDFT and GCMC (optional for BELSORP MINI X), are used for wide range analyses (from micro- to meso and macropores) and more accurate methods, specified in ISO15901-2.



| Theory | Interaction Surface and Gas | Adsorbate | Applicable Pore Size Range |
|---------------------------|--|---------------------|-----------------------------------|
| BJH, CI, DH, INNES method | Kelvin equation (Surface tension and contact angle) | Bulk liquid density | > 2 nm Meso and macropore |
| HK, SF, CY method | Lennard-Jones potential (Interaction and repulsion force) | Bulk liquid density | 0.4 - 2 nm Micropore |
| NLDFT, GCMC | Statistical thermodynamic model | | 0.35 - 500 nm Whole pore range |

In recent years, attention has been focused on pore structure evaluation methods using computer simulations, such as the novel pore distribution analysis NLDFT (Non-localized Density Functional Theory) and GCMC (Grand Canonical Monte Carlo) method, which can analyze micropores to meso- and macropores using a unified theory. Pore size distributions obtained from the same adsorption isotherm are different between classical and novel PSD analyses, and even in between novel methods because the filling pressure obtained from each theory is different. Microtrac provides evaluation methods which cover a wide range of pore sizes and various adsorbates, such as N₂ (77.4 K), Ar (87.3 K), and CO₂ (298 K). It uses NLDFT / GCMC kernels of slit, cylinder, and cage pore models with carbon and metal oxide surface atoms, resulting in the most appropriate description of porous materials.

The BELMASTER software allows easy comparison between experimental and simulated isotherms, with the simulated isotherm serving as a basis for the PSD calculation.

www.microtrac.nl/belsorp-max-g