molecules quickly find their way to the surface of every pore in the solid (the adsorbent). These molecules can either bounce off or stick to the surface. Gas molecules that stick to the surface are said to be adsorbed. The strength with which adsorbed molecules interact with the surface determines if the adsorption process is to be considered physical (weak) or chemical (strong) in nature.

Physical adsorption (physisorption) is the most common type of adsorption. Physisorbed molecules are fairly free to move around the surface of the sample. As more gas molecules are introduced into the system, the adsorbate molecules tend to form a thin layer that covers the entire adsorbent surface. Based on the well-known Brunauer, Emmett and Teller (BET) theory, one can estimate the number of molecules required to cover the adsorbent surface with a monolayer of adsorbed molecules.
Gas Sorption Process

Solid materials determine the manner in which their surfaces interact with gas molecules. Quantifying gas–solid interactions through the generation of gas sorption isotherms permits the evaluation of properties that control the performance of solids, such as surface area, size and shape of pores, chemically active sites, and many others.

Molecules, $N_m$, (see Figure 2). Multiplying $N_m$ by the cross-sectional area of an adsorbate molecule yields the sample’s surface area.

Continued addition of gas molecules beyond monolayer formation leads to the gradual stacking of multiple layers (or multilayers) on top of each other. The formation of multilayers occurs in parallel to capillary condensation (see Figure 3). The latter process is adequately described by the Kelvin equation, which quantifies the proportionality between residual (or equilibrium) gas pressure and the size of capillaries capable of condensing gas within them. Computational methods such as the one by Barrett, Joyner and Halenda (BJH) allow the computation of pore sizes from equilibrium gas pressures. One can therefore generate experimental curves (or isotherms) linking adsorbed gas volumes with relative saturation pressures at equilibrium, and convert them to cumulative or differential pore size distributions.

As the equilibrium adsorbate pressures approach saturation, the pores become completely filled with adsorbate (see Figure 4). Knowing the density of the adsorbate, one can calculate the volume it occupies and, consequently, the total pore volume of the sample. If at this stage one reverses the adsorption process by withdrawing known amounts of gas from the system in steps, one can also generate desorption isotherms. Since adsorption and desorption mechanisms differ, adsorption and desorption isotherms rarely overlay each other. The resulting hysteresis leads to isotherm shapes that can be mechanistically related to those expected from particular pore-shapes.

In contrast to physisorption, chemical adsorption (chemisorption) involves the formation of strong chemical bonds between adsorbate molecules and specific surface locations known as chemically active sites. Chemisorption is thus used primarily to count the number of surface active sites which are likely to promote chemical and catalytic reactions.

Quantachrome’s pioneering development of gas sorption instruments worldwide R&D and quality control efforts for decades.
**Windows® based performance**

The AUTOSORB-1 analyzer is microprocessor controlled, and communicates with a Windows 95, 98, 2000 based PC utilizing Quantachrome’s state-of-the-art, data acquisition and data reduction software.

**Comprehensive software to meet modern needs**

Whether a laboratory’s need is for wide ranging physisorption studies or complete automation of the catalyst treatment and multiple pass chemisorption process, the AUTOSORB software serves admirably. It also serves two or more analyzers... and two or more users connected via a network. And, after the accumulation of many data files, a built-in database engine quickly locates desired files by searching for a specific ID, description, operator, comment or range of dates. The user-friendly software guides you through sample preparation, preprogrammed parameter recall or making settings for operations, data reduction, graphs and report printouts.

During operation one can view the accumulated data, the isotherm and all associated graphs and analytical results up to that point.

After a run, reports and graphs are printed automatically or the operator can use the software to determine the best fitting method, to compare data by overlaying curves or to adjust graph, size, scaling, titles, plot markers and line colors for best printouts.

**Data presentation**

A comprehensive range of surface area and pore size methods is available:

- Adsorption and desorption isotherms.
- Multi and single point BET surface area (including C constant and correlation coefficient).
- Langmuir surface area
- Mesopore volume and area distribution (BJH and DH methods).
- Standard micropore size distribution (MP method) and t-method by deBoer, Halsey or carbon black (STSA).
- Total pore volume, average pore size and sample density.
- Dubinin-Radushkevich micropore surface area
- Horvath-Kawazoe, Dubinin-Astakhov and Saito-Foley micropore distribution.
- Full Density Functional Theory library for unified micro- and mesopore analysis using N₂, Ar and CO₂ on materials such as zeolites, MCM-41, carbons and silicas.
- Monte Carlo based pore size model.

For chemisorption analysis, standard calculations include:

- Combined, strong and weak, (reversible and irreversible) isotherms.
- Monolayer coverage by extrapolation or bracketing of isotherm data and Temkin or Freundlich plots.

- Active metal area, degree of metal dispersion and average crystallite size.
- Heats of adsorption.
- Fractal dimension.

**Sample preparation**

Sample surface contaminants are removed by heating under vacuum. Two automated degassing stations may operate concurrently with the analysis station. PASS/FAIL degas test with digital display of degas pressure permits user to set and monitor sample preparation more precisely.
AUTOSORB-1 Series

AUTOSORB-1 Series Benefits

Superior engineering delivers years of trouble-free operation. All process control features are self-contained, enabling the instrument to function independently without operator intervention or external computer support.

**Designed for operator convenience and ease of use**

With minimal operator training, the AUTOSORB-1 produces the results you need.

- Store a limitless number of user-defined analyses for fast and simple measurement initialization.
- Automatic error checking ensures reliable data.
- Front panel LED display of valve and dewar status provides “at-a-glance” confirmation of system operation.
- Easy-fill dewar flasks offer safe and simple handling of cryogenic liquids.
- Benchtop and floor standing units satisfy any laboratory space requirement.
- Excellent graphical interface offers manual control of all instrument functions. It also aids in maintenance and system diagnostics.

**Meets the most rigorous technical demands**

- Separate sample cell transducers monitor equilibration in the smallest possible volume. This gives maximum sensitivity while a sample cell is isolated from the dosing manifold.
- Dedicated P<sub>2</sub> transducer updates each data point for maximum accuracy of surface area and pore size measurements.
- Sample preparation under high vacuum of turbomolecular pump offers a more complete degassing.

- Welded, stainless steel dosing manifold ensures compatibility with a wide range of gases and contamination-free operation.
- Thermistor sensor coolant level control with TempComp™ for improved void volume accuracy and sensitivity.
- Built-in, automated calibration maintains optimum performance consistent with ISO 9000 requirements.
- Onboard computer continuously monitors the dosing manifold temperature and automatically compensates for environmental temperature changes.

**Feature-rich, extra touches define quality**

- Oil-free turbomolecular drag pump eliminates oil backstreaming (-MP and -C models).
- Cold trap eliminates degas byproducts.
- Tandem manifolds for low maintenance, high efficiency single vacuum system.

**Comprehensive, advanced chemisorption capabilities**

- Fully integrated chemisorption option with small bench-space requirements.
- PC programmable temperature controller with auto-tuning functions offers limitless number of preparation routines with guaranteed temperature accuracy.
- Automatic repeat measurement of isotherm following evacuation provides complete weak and strong chemisorption data without operator intervention.
- Multiple, sequential unattended measurements at operator selected temperatures.

AUTOSORB-1-MP and -C models provide sample preparation in an oil-free vacuum at the same high vacuum as required for analysis. The special needs of chemisorption preparation are achieved with multiple gas inputs featuring automatic switching. Flow rates for preparation are user selectable for each gas using the built-in flow meter. A programmable temperature controller provides linear heating rates for the furnace.
### Pressure Transducers (per manufacturer’s specifications)

<table>
<thead>
<tr>
<th>Range</th>
<th>AUTOSORB-1</th>
<th>AUTOSORB-1-MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1,000 torr</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Accuracy: ±0.11% full scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum resolvable pressure: 2.5 x 10^-4 torr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum resolvable relative pressure (P/P_o): 3 x 10^-7 (nitrogen)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>AUTOSORB-1</th>
<th>AUTOSORB-1-MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10 torr [Optional 0 -1 torr]</td>
<td>no</td>
<td>yes [yes]</td>
</tr>
<tr>
<td>Accuracy: ±0.15 % reading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum resolvable pressure: 2.5 x 10^-6 torr [2.5 x 10^-7 torr]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum resolvable relative pressure (P/P_o): 3 x 10^-9 [3 x 10^-10] (nitrogen), 7.6 x 10^-6 (krypton)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Ultimate Vacuum (per manufacturer’s specifications)

<table>
<thead>
<tr>
<th>Component</th>
<th>AUTOSORB-1</th>
<th>AUTOSORB-1-MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum Pump</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Turbo Molecular Pump</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Pressure</td>
<td>1.1 x 10^-3 torr</td>
<td>yes</td>
</tr>
<tr>
<td>Pressure</td>
<td>&lt;5 x 10^-9 torr</td>
<td>no</td>
</tr>
</tbody>
</table>

### Adsorbates

<table>
<thead>
<tr>
<th>Type</th>
<th>AUTOSORB-1</th>
<th>AUTOSORB-1-MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-corrosive gas (N_2, Ar, CO_2, C_2H_10, etc.)</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Krypton gas</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Corrosive vapors (NH_3, cyclohexane, etc.)</td>
<td>no</td>
<td>optional</td>
</tr>
<tr>
<td>Programmable 5-gas switching</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

### Temperature Capabilities

<table>
<thead>
<tr>
<th>Component</th>
<th>AUTOSORB-1</th>
<th>AUTOSORB-1-MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degas Heating Mantles (2 stations)</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Heating up to 400°C in steps of 1°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy within 5°C of set point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optional quartz mantles for higher temperatures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis Heating Furnace</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Heating to 1,100°C with automatic calibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programmed ramp rates from 1 to 50°C/min.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unlimited number of heating/cooling programs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto-Leveling Cooling Bath</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Two liter standard (60 hours)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One liter, wide mouth (optional)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Physical

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature</td>
<td>10°C to 38°C, non-condensing</td>
</tr>
<tr>
<td>Electrical</td>
<td>100 to 240 V, 50/60 Hz</td>
</tr>
<tr>
<td>Weight</td>
<td>335 lbs. (161 kg)</td>
</tr>
<tr>
<td>Includes internal vacuum pump(s)</td>
<td></td>
</tr>
<tr>
<td>Steel Construction</td>
<td>Cabinet and optional rolling cart</td>
</tr>
</tbody>
</table>

### Performance

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Area Analysis</td>
<td>Nitrogen range: 0.01 m^2/g to no known upper limit</td>
</tr>
<tr>
<td>Krypton range: 0.0005 m^2/g to no known upper limit</td>
<td></td>
</tr>
<tr>
<td>Pore Analysis</td>
<td>Detectable volume limit: &lt;0.0001 cc/g</td>
</tr>
<tr>
<td>Pore size range: 3.5 to &gt;4000 ångströms</td>
<td></td>
</tr>
</tbody>
</table>

### Analysis Station Components

- 1 Sample cell with dedicated pressure transducer(s)
- 1 Saturated vapor pressure (P_o) cell with dedicated transducer
- 1 Dewar bath level sensor for liquid coolant or slurries

### Sample Cell Volumes

<table>
<thead>
<tr>
<th>Stem OD</th>
<th>Small Pellet cm^3</th>
<th>Large Pellet cm^3</th>
<th>Micro-</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mm</td>
<td>1.40 cm^3</td>
<td>5.50 cm^3</td>
<td></td>
</tr>
<tr>
<td>9 mm</td>
<td>1.80 cm^3</td>
<td>5.50 cm^3</td>
<td></td>
</tr>
<tr>
<td>12 mm</td>
<td>2.40 cm^3</td>
<td>5.50 cm^3</td>
<td></td>
</tr>
</tbody>
</table>

Special cells available upon request.
Pressure Transducers

- 0 to 1,000 torr
- Accuracy: ±0.11% full scale
- Minimum resolvable pressure: 2.5 x 10^{-4} torr
- Minimum resolvable relative pressure (P/P_o): 3 x 10^{-7} (nitrogen)

- 0 to 10 torr [Optional 0 -1 torr]
- Accuracy: ±0.15 % reading
- Minimum resolvable pressure: 2.5 x 10^{-6} torr [2.5 x 10^{-7} torr]
- Minimum resolvable relative pressure (P/P_o): 3 x 10^{-9} [3 x 10^{-10}] (nitrogen), 7.6 x 10^{-5} (krypton)

Ultimate Vacuum

- Vacuum Pump: 1.1 x 10^{-3} torr  yes yes yes
- Turbo Molecular Pump: <5 x 10^{-9} torr  no yes yes

Adsorbates

- Non-corrosive gas (N_2, Ar, CO_2, C_4H_{10}, etc.)  yes yes yes
- Krypton gas  no yes yes
- Corrosive vapors (NH_3, cyclohexane, etc.)  no optional yes
- Programmable 5-gas switching  no no yes

Temperature Capabilities

- Degas Heating Mantles (2 stations)  yes yes yes
- Heating up to 400 °C in steps of 1 °C
- Accuracy within 5 °C of set point
- Optional quartz mantles for higher temperatures

Analysis Heating Furnace

- no no yes
- Heating to 1,100 °C with automatic calibration
- Programmed ramp rates from 1 to 50 °C/min.
- Unlimited number of heating/cooling programs

Auto-Leveling Cooling Bath

- yes yes yes
- Two liter standard (60 hours)
- One liter, wide mouth (optional)

AUTOSORB-1-MP

**Detailed Micropore Characterization**

**Chemisorption and Physisorption Capability**

**System Requirements**

**Computer, Recommended:**
Pentium, 16Mb RAM, mouse, color printer

**Operating System:**
Standard Windows 3.1 or higher

**Agents**

**Sales Offices**

- AUTOSORB® 6B & 3B for automated, independent multiple sample sorption measurements.
- CHEMBET™-3000 TPR/TPD for chemisorption studies and catalyst characterization.
- NOVA® Series for simultaneous gas sorption analysis of 1, 2, 3 or 4 samples
- MONOSORB® for automated single point B.E.T. surface area determinations.
- HYDROSORB™ for water vapor sorption analysis.
- THERMOFLOW degassing-instruments.
- FLOW CONTROLLER for gas mixing.

**Other Fine Products from Quantachrome**

Quantachrome markets a-full range of particle technology characterization instruments, including:

- **POREMATER® Series** Mercury Porosimeters (60,000 psi and 33,000 psi) for a-full range of pore size distribution.
- **ULTRAPYCNOmeter 1000 & MICRO-ULTRAPYCNOmeter, PENTAPYCNOmeter, & ULTRAFOAM PYCNOMETER** for automatic volume and true density measurements.
- **MULTI & STEREOPYCNOMETERS®** for-manual volume and true density measurements.
- **AUTOTAP & DUAL AUTOTAP** for tap volume and tap density measurements.
- **SIEVING & ROTARY MICRO RIFFLERS** for accurate representative sampling.
- **REFERENCE MATERIALS** for surface area, metal dispersion, pore volume and pore size.

**Global Network of Distributors**

With more than 50 offices worldwide, Quantachrome’s distribution network delivers products and support on a global basis...truly a single source for all your particle characterization instruments.

**Prompt, Dependable Service... Worldwide**

At Quantachrome, reliability means more than product performance...it means responsiveness.

You can depend on our staff for on-site installation and service, prompt factory repairs, and telephone troubleshooting support.

The purchase of a Quantachrome product signifies the beginning of a long term relationship, with a-goal-to ensure the-maximum return-on your investment.

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The purchase of a Quantachrome product signifies the beginning of a long term relationship, with a-goal-to ensure the-maximum return-on your investment.
Applications for Quality Control and Research

The list of materials and products employing Quantachrome’s particle characterization technology is as diverse as industry itself:

**Carbon** for rubber, adsorbents (gas separation and water purification), gas masks, inks, laser printers and copiers

**Catalysts** for the automotive, fertilizer and petrochemical industries

**Organic materials** for adhesives, chromatography, cosmetics, detergents, foodstuffs, explosives, ion exchange resins, pharmaceuticals and plastics

**Minerals** such as alumina, clays, hydroxyapatite, pigments, phosphates, silicas, zirconia, etc., used for abrasives, adsorbents, biomaterials, ceramics, cements, desiccants, fillers, papers and paints

**Powdered metals and ferrites** for batteries, pressure formed/sintered products, electronics, magnets and magnetic tape

**Other** applications related to bone, composite materials, fibers, rigid foams, soil, sludge, slurries, suspensions and well cores

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**AUTOSORB-1 Series Product Overview**

Quantachrome’s AUTOSORB-1 Series offers a full line of high quality, high performance Surface Area and Pore Size Analyzers with three fully automatic models to meet the needs of any research or quality assurance laboratory.

**The AUTOSORB-1 for standard applications using a variety of adsorbates**
- Fully automated analyzer for surface area and pore size measurements.
- Simultaneous analysis and sample preparation.
- System supplied complete and ready for operation.
- Low maintenance, vacuum volumetric system with stainless steel manifold construction.
- Speed and precision ensured by MAXIDOSE™, a proprietary operating algorithm.
- DoseWizard™ learn mode and InitialFill™ for analysis time savings up to 60%.
- High sensitivity ensured by multiple pressure transducers, minimum void volume and accurate coolant-level control.
- Operates with any non-corrosive adsorbate and a wide variety of coolants, including slurries.

**AUTOSORB-1-MP for low surface area and micropore measurement**
- Allows adsorption data acquisition at relative pressures below 1x10⁻⁷ utilizing 1 torr transducers.
- Patented oil-free turbomolecular vacuum system eliminates any risk of oil backstreaming.
- Enhanced 22 bit A/D converter and micropore dosing algorithm allow precise data acquisition of up to 200 data points, sub-Ångström resolution and automatic correction for low pressure thermal transpiration.
- Ideal for detailed micropore-size measurements of zeolites, carbons, molecular sieves, etc.
- Many modern data reduction models and dosing algorithms for maximum flexibility.
- Well suited for low surface area analysis with krypton gas.

**AUTOSORB-1-C for total precise, chemisorption/physi- sorption measurement**
- Unattended chemisorption measurement with automatic transfer from *in-situ* sample preparation to analysis.
- Patented oil-free turbomolecular vacuum system eliminates any risk of oil backstreaming.
- Sample preparation with flow, vacuum or static conditions under programmable heating rates at temperatures up to 1,100°C. Prep gas flows through powder bed for thorough reduction.
- Built-in, five port gas input manifold with automatic gas switching.
- Applications include characterization of metal dispersion, acid site distribution, crystallite size, heats of adsorption and much more.
- Compatible with broad range of gases and vapors including hydrogen, carbon monoxide, ammonia, and cyclohexane (optional seals available).
- Optional interface for mass spec or GC.

**VAPOR SORPTION option for AUTOSORB-1-C and AUTOSORB-1-MP**
- Thermostatted dosing manifold to reduce vapor condensation.
- Built-in, heated vapor generator.
- Specially designed vapor dosing software for precise vapor isotherms.

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Photomicrograph: Natural zeolite

Photomicrograph: Coal ash

Vapor generation controls. (Vapor source visible through transparent cover)
Quantachrome®

Renowned innovator of ideas for today’s porous materials community.

For almost 40 years, Quantachrome’s scientists and engineers have revolutionized measurement techniques and designed instrumentation to enable the accurate, precise, and reliable characterization of powdered and porous materials:

- Adsorption/Desorption Isotherms
- Surface Area Measurement
- Pore Size Distribution
- Chemisorption Studies
- Water Sorption Behavior
- Mercury Porosimetry
- True Solid Density
- Tapped Density

Not only are Quantachrome products the instruments of choice in academia, but the technology conceived and developed by our expert staff is applied in industrial laboratories worldwide, where research and engineering of new and improved porous materials is ongoing. Manufacturers also rely on porous materials characterization technology to more precisely specify bulk materials, to control quality, and to isolate the source of production problems with greater efficiency.

Quantachrome is also recognized as an excellent resource for authoritative analysis of your samples in our fully equipped, state-of-the-art powder characterization laboratory.

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Quantachrome Instruments’ quality management system is certified to be in accordance with ISO9001:2000.