



Designation: **D4365 – 13 D4365 – 19**

Standard Test Method for Determining Micropore Volume and Zeolite Area of a Catalyst¹

This standard is issued under the fixed designation D4365; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of total surface area and mesopore area. From these results are calculated the zeolite area and micropore volume of a zeolite containing catalyst. The micropore volume is related to the percent zeolite in the catalyst. The zeolite area, a number related to the surface area within the zeolite pores, may also be calculated. Zeolite area, however, is difficult to ~~interpret~~ interpret in physical terms because of the manner in which nitrogen molecules pack within the zeolite.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and ~~health~~ environmental practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see **Note 3**.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

D3663 Test Method for Surface Area of Catalysts and Catalyst Carriers

D3906 Test Method for Determination of Relative X-ray Diffraction Intensities of Faujasite-Type Zeolite-Containing Materials

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E456 Terminology Relating to Quality and Statistics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 ~~mesopore (matrix) area of a catalyst—the area determined from the slope of the t-plot.~~

3.1.1 ~~micropore volume of the catalyst—catalyst, n—the pore volume in pores having radii less than 1 nm, usually associated with the zeolite portion of the catalyst, and determined from the intercept of the t-plot.~~

3.1.2 ~~surface area of a catalyst—catalyst, n—the total surface of the catalyst pores. It is expressed in square metres per gram, obtained from the BET method.~~

¹ This test method is under the jurisdiction of ASTM Committee **D32** on Catalysts and is the direct responsibility of Subcommittee **D32.01** on Physical-Chemical Properties.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.2.1 Discussion—

Surface area may be used interchangeably with BET area. It is expressed in square meters per gram.

3.1.3 t-area of the catalyst, n—the area determined from the slope of the t-plot.

3.1.3.1 Discussion—

t-area may be used interchangeably with matrix area or external surface area. It is expressed in square meters per gram.

3.1.4 *zeolite area of a catalyst—catalyst, n*—the difference between total surface area and mesopore area.

3.1.4.1 Discussion—

The zeolite area may be used interchangeably with micropore area. It is expressed in square meters per gram.

3.2 Symbols:

P_{H_1}	= initial helium pressure, torr
P_{H_2}	= helium pressure after equilibration, torr
S_B	= slope of BET plot, 11.7
I_B	= intercept of BET plot, 11.7
A_B	= BET area, 11.9
N	= Avogadro's number
A_{CS}	= Cross-sectional area of adsorbed nitrogen molecule
S_t	= slope of t-plot, 11.13
I_t	= intercept of t-plot, 11.13
A_t	= t-area
T_{H1}	= temperature of manifold at initial helium pressure, °C
T_{H2}	= temperature of manifold after equilibration, °C
$T_x(i)$	= extra volume bulb temperature, °C
$T_x(i)$	= extra volume bulb temperature, K
$P_1(i)$	= initial N_2 pressure, torr
$T_1(i)$	= manifold temperature at initial N_2 pressure, K
$T_1'(i)$	= manifold temperature at initial N_2 pressure, °C
$P_2(i)$	= pressure after equilibration, torr
$T_2(i)$	= manifold temperature after equilibration, K
$T_2'(i)$	= manifold temperature after equilibration, °C
$P_0(i)$	= liquid nitrogen vapor pressure, torr
$T_s(i)$	= liquid nitrogen temperature, K
P_c	= nitrogen critical pressure
T_c	= nitrogen critical temperature
X	= relative pressure, P_2/P_0
V_d	= volume of manifold, cm^3
V_x	= extra volume bulb, cm^3
V_s	= effective void volume, cm^3
W_s	= weight of sample, g
W_1	= tare weight of sample tube, g
W_2	= weight of sample + tare weight of tube, g
V_{ds}	= volume of nitrogen in the dead-space, cm^3
V_1	= see 11.4.3
V_2	= see 11.4.4
V_f	= see 11.4.5
V_a	= see 11.4.7
V_m	= see 11.8
BET(i)	= see 11.4.8
$t(i)$	= see 11.10

4. Summary of Test Method

4.1 The volume of nitrogen gas adsorbed by the catalyst at liquid nitrogen temperature is measured at various low-pressure levels by the catalyst sample at liquid nitrogen temperature. This is done by measuring pressure differentials resulting from introducing a fixed volume of nitrogen to the degassed catalyst in the test apparatus. This procedure is the same as Test Method D3663, that gives total surface area, but extends the pressure range to permit calculation of micropore volume and matrix surface area, by the t-plot method. Zeolite area is the difference between total area and matrix area.

5. Significance and Use

5.1 This gas adsorption method complements the X-ray procedure of Test Method D3906. This test method will be useful to laboratories that do not have X-ray diffractometers. Each test method can be calibrated by use of an appropriate series of

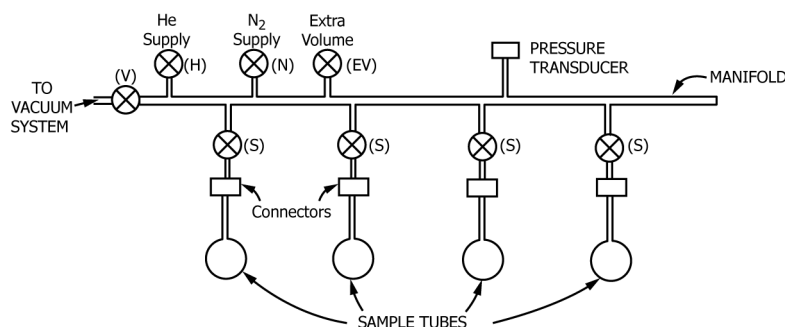


FIG. 1 Schematic Diagram of Surface Area Apparatus

mechanical mixtures to provide what may be termed percent zeolite. If there is disorder in the zeolite, the adsorption method will yield higher values than the X-ray method. The reverse will be true if some zeolite pores (micropores) are blocked or filled.

6. Apparatus

6.1 A schematic diagram of the apparatus is shown in Fig. 1. It may be constructed of glass or of metal. It has the following features:

6.1.1 *Distribution or Dosing Manifold*, having a volume between 2018 cm³ and 3540 cm³, (V_d), known to the nearest 0.05 cm³. This volume is defined as the volume between the stopcocks or valves and includes the pressure gage. It is preferred that this volume be thermostatted gage.

6.1.2 *Vacuum System*, with a pump capable of attaining pressures below 4×10^{-4} torr (1 torr = 133.3 hPa (3×10^{-3} Pa) torr). This will can include a vacuum gage (not shown in Fig. 1). Access to the distribution manifold is through the valve V.

6.1.3 *Pressure Sensing Devices or Pressure Transducer*, capable of measurements to the nearest 0.1 torr sensitivity in the range from 00 torr to 1000 torr (1 torr = 133.3 Pa).

NOTE 1—See, for example, the article by Joy for a description of a constant-volume manometer.³

6.1.4 *Valve (H)*, from the helium supply to the distribution manifold.

6.1.5 *Valve (N)*, from the nitrogen supply to the distribution manifold.

6.1.6 The connection between the sample tube and the S valve can be a standard-taper glass joint, a glass-to-glass seal, or a compression fitting.

6.1.7 *Extra Volume (EV) Bulb*, if employed, may be attached through valve EV. Its volume (V_x) should be 100100 cm³ to 150 cm³, known to the nearest 0.05 cm³. V_x includes the volume of the stopcock bore in the glass apparatus. It is preferred that this volume be held at the same temperature as that of the distribution manifold.

NOTE 1—Modern commercial instruments automatically adjust the amounts dosed in order to produce data points at user-selected target pressures. Hence, the use of an EV bulb is optional. Some instruments can analyze multiple samples simultaneously and may use sample tubes with volumes outside of the range specified. They may also include additional Pressure Transducers in addition to the one shown in Fig. 1 this test method.

6.2 *Sample Tubes*, with volumes from 5 cm³ to 25 cm³ depending on the application. Markings should be placed on the sample tubes about 30 mm to 50 mm below the connectors to indicate the desired liquid nitrogen level if automatic control of liquid nitrogen level is not available.

NOTE 2—Some instruments can analyze multiple samples simultaneously and may use sample tubes with volumes outside of the range specified in this test method.

6.3 *Heating Mantles or Small Furnaces*.

6.4 *Dewar Flasks*.

6.5 *Laboratory Balance*, with 0.1 mg (10^{-7} kg) sensitivity.

6.6 *Thermometer or Thermocouple*, for measuring the temperature of the distribution manifold, $T_1'(i)$ or $T_2'(i)$, in degrees Celsius or $T_1(i)$ or $T_2(i)$ in kelvin.

6.6.1 The manifold may be thermostated at a particular temperature, a few degrees above ambient, to obviate the necessity of recording this temperature at each reading.

6.7 *Pressure Saturation Tube* from which P_0 values may be measured directly, or *Thermometer or Thermocouple*, for measuring the temperature of the liquid nitrogen bath $T_s(i)$ in kelvins from which P_0 values may be derived. This will preferably be a nitrogen vapor-pressure-thermometer, often referred to in a commercial instrument as a pressure saturation tube, from which P_0 values may be measured directly with greater precision, or a resistance thermometer from which P_0 values may be derived.

³ Rouquerol, J., Llewellyn, P., and Rouquerol, F., *Stud. Surf. Sci. Catal.*, 160, 49, 2007.

6.8 *Thermometer or Thermocouple*, for measuring the temperature of the EV bulb, $T_x'(i)$, if different from $T_1'(i)$ or $T_2'(i)$.

6.9 *Sample Preparation Unit* (not shown) for degassing the sample(s) prior to analysis. Can be integral to the surface area apparatus or can be a separate external unit.

6.9.1 The Sample Preparation Unit may be equipped with a cold trap to improve elimination of evolved moisture from the vacuum system.

7. Reagents

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.³ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Helium Gas*—A cylinder of helium gas at least ~~99.9%~~99.99 % pure.

7.3 *Liquid Nitrogen*, of such purity that P_0 is not more than 20 torr above barometric pressure. A fresh daily supply is recommended.

7.4 *Nitrogen Gas*—A cylinder of nitrogen gas at least ~~99.9%~~99.99 % pure.

8. Procedure—Sample Preparation and Degassing

8.1 Select a sample tube of the desired size. A ~~5-cm~~5 cm³ sample tube is preferred for samples not exceeding about 1 g, to minimize the dead-space. However, a ~~25-cm~~25 cm³ sample tube may be preferred for finely powdered catalysts, to avoid “bumping” when degassing is started.

8.2 Fill the sample tube with nitrogen or helium, at barometric pressure, after removing air by evacuation. This may be done on the surface area unit, or on a separate piece of equipment.

8.3 Remove the sample tube from the system, cap, and weigh. Record the weight as W_1 .

8.4 Place the catalyst sample, of which the weight is known approximately, into the sample tube. Choose the sample size to provide an estimated total sample surface area of ~~20~~20 m² to ~~100~~100 m², or²; follow instrument manufacturer’s guidelines.

8.5 Attach the sample tube to the apparatus. If other samples are to be run, attach them at this time to the other ports.tube(s) to the Sample Preparation unit.

~~8.6 Open the S valves where there are samples.~~

8.6 Slowly ~~open~~evacuate the ~~V~~sample valve,tube(s), monitoring the rate of pressure decrease to avoid too high a rate, which could lead to excessive fluidization of powdered samples.

8.6.1 ~~It may be necessary to close the V valve system periodically to protect the vacuum pump from exposure to pressures above 0.1 torr for periods of more than 30 s. Close the valve off for 2 min each time.~~Follow pump manufacturer’s recommendations regarding maximum pressure and gas volume capacity to avoid any potential damage to the pump.

8.7 If provided, fill cold trap with liquid nitrogen.

8.8 Install a heating mantle or furnace around each sample and raise the temperature to about ~~300°C~~300 °C (573 K).

NOTE 3—Take special precautions if the moisture content exceeds approximately 5 % to avoid “bumping” of powdered catalyst, and to avoid surface area loss by self-steaming. It is recommended that the heating rate not exceed ~~100°C(K)/h~~100 °C(K)/h under these circumstances.

8.9 Continue degassing at about ~~300°C~~300 °C (573 K) for a minimum of 3 h, at a pressure not to exceed ~~10~~0.01⁻³ torr. Overnight degassing is permissible.

NOTE 4—Zeolite-containing catalysts may contain large quantities of water. Pretreatment of the sample in an oven at ~~400°C in flowing nitrogen~~150 °C for a couple of hours may be desirable.

8.10 Remove the heating mantles, and allow the samples to cool.

8.11 Close ~~off the EV vacuum valve, if open.~~

~~8.12 Close the S valve.~~

8.13 ~~It is recommended to exercise the option of preliminary degassing on an external unit. In such a case, follow the procedures of 8.4 – 8.11 and then optionally repeat on the surface area unit, except that the supplementary degassing time in 8.9 should not exceed 1 h.~~

³ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.