Designation: E1194 – 17

Standard Test Method for Vapor Pressure[1]

1. Scope

1.1 This test method describes procedures for measuring the vapor pressure of pure liquid or solid compounds. No single technique is able to measure vapor pressures from 1×10^{-11} to 100 kPa (approximately 10^{-10} to 760 torr). The subject of this standard is gas saturation which is capable of measuring vapor pressures from 1×10^{-11} to 1 kPa (approximately 10^{-10} to 10 torr). Other methods, such as isoteniscope and differential scanning calorimetry (DSC) are suitable for measuring vapor pressures above 0.1 kPa An isoteniscope (standard) procedure for measuring vapor pressures of liquids from 1×10^{-1} to 100 kPa (approximately 1 to 760 torr) is available in Test Method D2879. A DSC (standard) procedure for measuring vapor pressures from 2×10^{-1} to 100 kPa (approximately 1 to 760 torr) is available in Test Method E1782. A gas-saturation procedure for measuring vapor pressures from 1×10^{-11} to 1 kPa (approximately 10^{-10} to 10 torr) is presented in this test method. All procedures are subjects of U.S. Environmental Protection Agency Test Guidelines.

1.2 The gas saturation method is very useful for providing vapor pressure data at normal environmental temperatures (–40 to +60°C). At least three temperature values should be studied to allow definition of a vapor pressure-temperature correlation. Values determined should be based on temperature selections such that a measurement is made at 25°C (as recommended by IUPAC) (1),[2] a value can be interpolated for 25°C, or a value can be reliably extrapolated for 25°C. Extrapolation to 25°C should be avoided if the temperature range tested includes a value at which a phase change occurs. Extrapolation to 25°C over a range larger than 10°C should also be avoided. If possible, the temperatures investigated should be above and below 25°C to avoid extrapolation altogether. The gas saturation method was selected because of its extended range, simplicity, and general applicability (2). Examples of results produced by the gas-saturation procedure during an interlaboratory evaluation are given in Table 1. These data have been taken from Reference (3).

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

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]
D2879 Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E1782 Test Method for Determining Vapor Pressure by Thermal Analysis

2.2 *U.S. Environmental Protection Agency Test Guidelines:*
Toxic Substances Control Act Test Guidelines; Final Rules, Vapor Pressure[4]

3. Terminology Definition

3.1 *vapor pressure*—a measure of the volatility in units of or equivalent to kg/m^2 (pascal) of a substance in equilibrium with the pure liquid or solid of that same substance at a given temperature (4).

4. Summary of Gas-Saturation Method

4.1 Pressures less than 1.33 kPa may be measured using the gas-saturation procedure (4).

4.2 In this test method, an inert carrier gas (for example N_2) is passed through a sufficient amount of compound to maintain saturation for the duration of the test. The compound may be coated onto an inert support (for example glass beads) or it may

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TABLE 1 Gas-Saturation Procedure Results Obtained During an Interlaboratory Evaluation

Test Compound	Temperature, °C	Mean Vapor Pressures, kPa	Standard Deviation Estimate, S_r [A]	Square Root, S_R [B]	Precision Estimate, S_R [C]
Naphthalene	25	1.3×10^{-2}	0.31	0.39	0.50
	35	3.5×10^{-2}	0.55	1.23	1.35
Benzaldehyde	25	1.8×10^{-1}	0.31	1.24	1.28
	35	2.8×10^{-1}	0.33	1.12	1.17
Aniline	25	7.9×10^{-2}	1.9	3.8	4.3
	35	1.5×10^{-1}	0.25	0.28	0.38
2-Nitrophenol	25	1.2×10^{-2}	0.33	0.41	0.53
	35	3.2×10^{-2}	0.53	1.57	1.66
Benzoic Acid	25	1.5×10^{-4}	0.32	1.69	1.72
	35	5.7×10^{-4}	2.3	5.2	5.7
Phenanthrene	25	1.6×10^{-5}	0.36	0.46	0.58
	35	4.7×10^{-5}	2.41	2.39	2.42
2,4-Dinitrotoluene	25	7.1×10^{-5}	1.9	6.3	6.6
	35	2.3×10^{-4}	1.0	3.2	3.4
Anthracene	25	6.0×10^{-6}	3.7	13.8	14.3
	35	1.1×10^{-5}	0.23	2.29	2.30
Dibutylphthalate	25	6.8×10^{-6}	4.4	8.8	9.8
	35	2.0×10^{-5}	0.49	2.28	2.33
p,p'-DDT	25	1.7×10^{-7}	0.55	1.66	1.75
	35	5.7×10^{-7}	11.1	4.7	12.1

[A] S_r is the estimated standard deviation within laboratories, that is, an average of the repeatability found in the separate laboratories.
[B] S_R is the square root of the component of variance between laboratories.
[C] S_R is the between-laboratory estimate of precision.

be in a liquid or solid granular form. The compound is removed from the gas stream using a suitable agent (sorbent or cold trap). The amount of the test sample collected is then measured using gas chromatography or any other sensitive and specific technique capable of suitable mass detection limit for the intended purpose.

5. Significance and Use

5.1 Vapor pressure values can be used to predict volatilization rates (5). Vapor pressures, along with vapor-liquid partition coefficients (Henry's Law constant) are used to predict volatilization rates from liquids such as water. These values are thus particularly important for the prediction of the transport of a chemical in the environment (6).

6. Reagents and Materials

6.1 The purity of the substance being tested shall be determined and documented as part of the effort to define the vapor pressure. If available, all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society.[5]

6.2 Every reasonable effort should be made to purify the chemical to be tested. High sample purity is required for accurate evaluation of vapor pressure using direct mass loss measurement.

6.3 For the gas-saturation method, the results can be reported in terms of the partial pressure for each component of the mixture that is identified and quantified through the trapping procedure. However, unless the pure component vapor pressures and the vapor/liquid activity coefficients of the contaminants are known, the results cannot be interpreted any more clearly. If the activity coefficient of the major constituent is defined as one (= 1), the indicated partial pressure and analytical purity data can be converted to a pure component vapor pressure.

7. Gas-Saturation Procedure

7.1 The test sample can be (1) coated onto clean silica sand, glass beads, or other suitable inert support from solution; prior to data measurement, the solvent must be completely removed by application of heat and flow (2) in solid state, possibly using a method similar to the previous one or by melting the solid to maximize surface area prior to data measurement; or (3) a neat liquid. If using a coated-support procedure, the thickness of the coating must be sufficient to ensure that surface energy effects will not impact vapor pressure or vaporization rate. Following volatilization the surface must remain completely coated with the test compound.

7.2 Coat the support prior to column loading, to ensure the support is properly coated. Use sufficient quantity of material on the support to maintain gas saturation for the duration of the test.

7.3 Put the support into a suitable saturator container. The dimensions of the column and gas velocity through the column should allow complete saturation of the carrier gas and negligible back diffusion.

7.4 Connect the principal and back-up traps to the column discharge line downstream from the saturator column. Use the back-up trap to check for breakthrough of the compound from the principal trap. For an example of such a system, see Fig. 1.

7.5 Surround the saturator column and traps by a thermostated chamber controlled at the test temperature within ±0.05°C.

7.6 If test material is detected in the second trap, breakthrough has occurred and the measured vapor pressure will be too low. To eliminate breakthrough, take one or both of the following steps:

7.6.1 Increase trapping efficiency by using more efficient traps, such as a larger higher capacity or a different type of trap.

7.6.2 Decrease the quantity of material trapped by decreasing the flow rate of carrier gas or reduce the sampling period.

7.7 After temperature equilibration, the carrier gas contacts the specimen and the sorbent (or cold) traps and exits from the thermostated chamber. The thermostatically-controlled chamber should utilize liquid baths to facilitate heat transfer. Liquid (for example, ethylene-glycol-water or oil) baths are suggested because of the difficulty in controlling temperatures in accordance with the tight specifications required (7) using air baths. Variations in the ambient temperature in facilities designed for hazardous chemical work make this a critical requirement.