INTERNATIONAL

Designation: D3686 – 13

Standard Practice for Sampling Atmospheres to Collect Organic Compound Vapors (Activated Charcoal Tube Adsorption Method)[1]

This standard is issued under the fixed designation D3686; 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 practice covers a method for the sampling of atmospheres to determine the presence of certain organic vapors by means of adsorption on activated charcoal using a charcoal tube and a small portable sampling pump worn by a worker. A list of some of the organic chemical vapors that can be sampled by this practice is provided in Annex A1. This list is presented as an information guide and should not be considered as absolute or complete.

1.2 This practice does not cover any method of sampling that requires special impregnation of activated charcoal or other adsorption media.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *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 and health practices and determine the applicability of regulatory limitations prior to use.* A specific safety precaution is given in 9.4.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D3687 Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method

D5337 Practice for Flow Rate Adjustment of Personal Sampling Pumps

2.2 *NIOSH Standards:*

CDC-99-74-45 Documentation of NIOSH Validation Tests[3]

HSM-99-71-31 Personal Sampler Pump for Charcoal Tubes; Final Report[3]

NIOSH Manual of Analytical Methods, Fourth Edition[4]

2.3 *OSHA Standards:*

29 CFR 1910 Code of Federal Regulations Relating to Labor, Occupational Safety and Health Administration, Department of Labor[5]

OSHA Chemical Sampling Information [6]

OSHA Sampling and Analytical Methods [7]

2.4 *UK Health and Safety Executive:*[8]

Methods for Determination of Hazardous Substances (MDHS)

2.5 *Berufsgenossenschaftliches Institut für Arbeitsschulz (BGIA)*[9]

GESTIS Analytical Methods

3. Terminology

3.1 For definitions of terms used in this method, refer to Terminology D1356.

3.2 Activated charcoal refers to properly conditioned charcoal.

4. Summary of Practice

4.1 Air samples are collected for organic vapor analysis by aspirating air at a known rate and for an appropriate time through sampling tubes containing activated charcoal.

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[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.04 on Workplace Air Quality.

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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] Available from National Technical Information Service (NTIS), 5285 Port Royal Rd., Springfield, VA 22161, http://www.ntis.gov.

[4] NIOSH Manual of Analytical Methods. http://www.cdc.gov/niosh/nmam/

[5] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[6] OSHA Chemical Sampling Information. http://osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html

[7] OSHA Sampling and Analytical Methods. http://osha.gov/dts/sltc/methods/toc.html

[8] Health Safety Executive. Methods for the Determination of Hazardous Substances (MDHS) guidance. http://www.hse.gov.uk/pubns/mdhs/index.htm#

[9] Berufsgenossenschaftliches Institut für Arbeitsschutz. GESTIS Analytical methods. http://www.hvbg.de/e/bia/gestis/analytical_methods/index.html

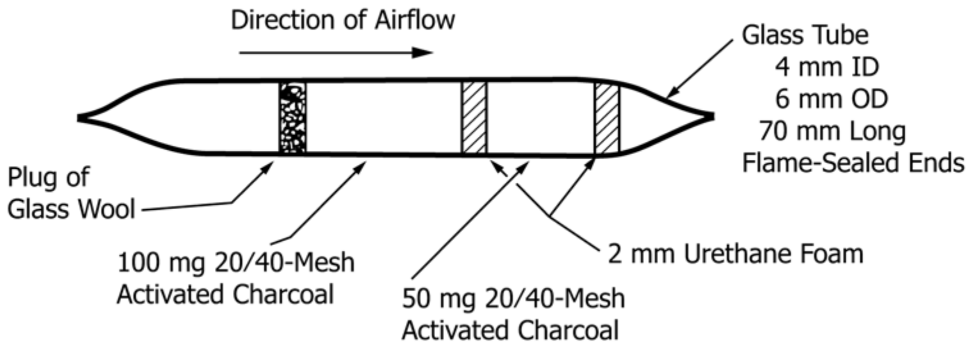

FIG. 1 Activated Charcoal Adsorption Sampling Tube

4.2 Instructions are given to enable assembly of charcoal tubes suitable for sampling purposes.

4.3 Information on the correct use of the charcoal tube sampling device is presented.

4.4 Practice D3687 describes a practice for the analysis of these samples.

5. Significance and Use

5.1 Promulgations by the U.S. Occupational Safety and Health Administration (OSHA) in 29 CFR 1910.1000 designate that certain organic compounds must not be present in workplace atmospheres at concentrations above specific values.

5.2 This practice, when used in conjunction with Practice D3687, will provide the needed accuracy and precision for the determination of airborne time-weighted average concentrations of many of the organic chemicals cited in CDC-99-74-45, HSM-99-71-31, NIOSH Manual of Analytical Methods, 29 CFR 1910.1000, OSHA Chemical Sampling Information, OSHA Sampling and Analytical Methods, HSE Methods for the Determination of Hazardous Substances, and BGIA GETIS Analytical Methods.

5.3 A partial list of chemicals for which this method is applicable is given in Annex A1, along with their OSHA permissible exposure limits.

6. Interferences

6.1 Water mist and vapor can interfere with the collection of organic compound vapors. Humidity greater than 60 % can reduce the adsorptive capacity of activated charcoal up to 50 % for some chemicals **(1)**.[10] Presence of condensed water droplets in the sample tube will indicate a suspect sample.

6.2 High levels of organic vapors can interfere by reducing the amount of time a workplace can be sampled before the charcoal sampler becomes saturated.

7. Apparatus

7.1 *Charcoal Tube:*

7.1.1 A sampling tube consists of a length of glass tubing usually containing two sections of activated charcoal that are held in place and separated by nonadsorbent material. The tube is sealed at each end.

7.1.1.1 Sampling tubes are commercially available. The tubes are usually divided into two sections with the front section containing 100 to 800 mg of activated charcoal and the back section containing 50 to 400 mg of activated charcoal. The 100/50-mg tube (**(2-4)** and Fig. 1) is the one most frequently used, it consists of a glass tube that is 70-mm long, 6-mm outside diameter, 4-mm inside diameter, and contains two sections of 20/40 mesh-activated coconut-shell charcoal separated by a 2-mm section of urethane foam. The front section of 100 mg is retained by a plug of clean glass wool, and the back section of 50 mg is retained by either a second 2-mm portion of urethane foam or by a plug of clean glass wool. Both ends of the tube are usually flame-sealed.

NOTE 1—Urethane foam is known to adsorb certain pesticides (**5**). Contaminated urethane foam should not be used for this practice.

7.1.1.2 When it is desirable to sample highly volatile compounds for extended periods, or at a high volume flow rate, a larger device capable of efficient collection can be used, provided the proportions of the tube and its charcoal contents are scaled similarly to the base dimensions to provide nominally the same linear flow rate and contact time with the charcoal bed.

7.1.2 The back portion of the sampler tube usually contains 50 % of the mass of activated charcoal present in the front section. The back section adsorbs vapors that penetrate the front section and serves as a warning that breakthrough may have occurred. (Annex A1 gives recommended maximum tube loading information for many chemicals.)

7.1.3 The adsorptive capacity and extraction efficiency (also called desorption efficiency) of different batches of activated charcoal can vary. Commercial tubes, if used, should be purchased from the same batch and in sufficient number to provide sampling capability for an adequate period of time. *Care must be taken to have enough tubes from the same batch for a given study.*

7.1.4 Pressure drop across the sampling tube should be less than 25 mm Hg (3.3 kPa) at a flow rate of 1000 mL/min and less than 4.6 mm Hg (0.61 kPa) at a flow rate of 200 mL/min.

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[10] The boldface numbers in parentheses refer to the list of references at the end of this standard.

7.1.5 Charcoal sampling tubes prepared in accordance with this practice and with sealed glass ends can be stored indefinitely. Accrediting bodies, such as American Industrial Hygiene Association, may require that sampling media have an expiration date. Accredited facilities must abide by this date.

7.2 *Sampling Pumps:*

7.2.1 Any pump with a flow rate that can be accurately determined, that can be set at the desired sampling rate, and that can maintain the desired sampling rate for a sufficient time is suitable. Primarily though, this practice is intended for use with small personal sampling pumps.

7.2.2 Pumps having stable low flow rates (10 to 200 mL/min) are preferable for long period sampling (up to 8 h) or when the concentration of organic vapors is expected to be high. Reduced sample volumes will avoid exceeding the adsorptive capacity of the charcoal tubes. (Suggested flow rates and sampling times are given in Annex A1 for anticipated concentration ranges.) (Sample volumes are discussed in 9.5.)

7.2.3 Pumps are available that will provide stable flow rates between ±5 % of the desired flow rate. Pumps should be calibrated before and after sampling.

7.2.4 All sampling pumps must be carefully calibrated with the charcoal tube device in the proper sampling position.

7.2.5 A sampling tube holder with flexible tubing is used to connect the sampling tube to the sampling pump. The sampling tube holder is used to protect the worker from the sharp end of the samping tube.

8. Reagents

8.1 *Activated Charcoal*—Prior to being used to make sampling devices the charcoal should be heated in an inert gas at an appropriate temperature for a sufficient time. Commercially available coconut-shell charcoal (20/40 mesh) has been found to have adequate adsorption capacity for many volatile chemicals. Other charcoals, such as petroleum-based charcoal and proprietary charcoals, can be used for appropriate applications.

9. Sampling with Activated Charcoal Samplers

9.1 *Calibration of the Sampling System*—Calibrate the sampling system, including pump, flow regulator, tubing to be used, and a representative charcoal tube (or an equivalent induced resistance) with a primary flow-rate standard or with a calibrated secondary standard to within ±5 % of the desired flow rate as described in Practice D5337. Calibrate the sampling pump in a clean location with similar temperature and barometric pressure as the sampling site. Normally, calibrated pump flow rates or sample air volumes are not corrected for temperature or barometric pressure.

9.2 Break open both ends of the charcoal tube to be used for sampling, ensuring that each opening is at least one half the inside diameter of the tube.

9.3 Insert the charcoal tube into the connective flexible tubing, placing the back-up section nearest to the pump. At no time should there be any tubing ahead of the sampling tubes. Use a sampling tube holder to protect the worker from the sharp end of the sampling tube.

9.4 For a breathing zone sample, fasten the sampling pump to the worker, and attach the sampling tube as close to the worker's breathing zone as possible. Position the tube in a vertical position to avoid channeling of air through the charcoal sections. (**Warning—**Assure that the presence of the sampling equipment is not a safety hazard to the worker and that the equipment will not interfere with the worker's duties.)

9.4.1 Turn on the pump.

9.4.2 Record the flow rate, the starting time, and depending on the make of pump used, the register reading.

9.5 *Sampling Volumes*—The minimum sample volume will be governed by the detection limit of the analytical method, and the maximum sample volume will be determined by either the adsorptive capacity of the charcoal or limitations of the pump battery.

9.5.1 One method of calculating required sample volumes is to determine first the concentration range, over which it is important to report an exact number, for example from 0.2 to 2 times the permissible exposure concentration, and then calculate the sample volumes as follows:

$$\text{Minimum sample volume, m}^3 = \frac{\text{minimum detection limit, mg}}{0.2 \times \text{permissible exposure limit, mg/m}^3} \tag{1}$$

$$\text{Maximum sample volume, m}^3 = \frac{\text{tube capacity for vapors, mg}}{2 \times \text{permissible exposure limit, mg/m}^3} \tag{2}$$

9.5.2 Select a sampling rate that, in the sampling time desired, will result in a sample volume between the minimum and maximum calculated in 9.5.1.

9.5.2.1 Generally a long sampling time at a low flow rate is preferable to short-term, high-volume sampling. This is consistent with the fact that most health standards are based on 8-h/day time-weighted averages of exposure concentrations. Often, two 4-h samples are preferable to a single 8-h sample so that if one is lost then the other can be used to partially document exposure. Work practices may change during the day and be better documented with two samples.

9.5.2.2 A sample flow rate of less than 10 mL/min, however, should not be used. Calculations based upon diffusion coefficients for several representative compounds indicate that sampling at less than 10 mL/min may not give accurate results.[11]

9.5.2.3 Sampling information for a large number of organic chemicals is given in Annex A1, in the NIOSH Manual of Analytical Methods, OSHA Chemical Sampling Information file and methods, UK HSE MDHS database, and German BGIA GESTIS Analytical Methods database. Other appropriate sources of information and guidance, including Annex A1, can also be used.

9.5.3 When spot checks are being made of an environment, a sample volume of 10 L is adequate for determining vapor concentrations in accordance with exposure guidelines. Particularly volatile organic chemicals may require a lesser sample

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[11] Heitbrink, W. A., "Diffusion Effects Under Low Flow Conditions," American Industrial Hygiene Association Journal, Vol 44, No. 6, 1983, pp. 453–462.

volume to prevent sampler saturation. Consult the above sources for sampling information before sampling.

9.6 At the end of the sampling period, turn off the pump, and record all pertinent information: time, register reading, and if pertinent, sampling site temperature, barometric pressure, and relative humidity.

9.6.1 Seal the charcoal tube with the plastic caps provided.

9.6.2 Label the tube with the appropriate information to identify it.

9.7 At least one charcoal sampling tube should be presented for analysis as a field blank with every 10 or 15 samples, or for each specific inspection or field study.

9.7.1 Break the sealed ends off the field blank tube and cap it with the plastic caps. Do not draw air through the blank tube, but in all other ways treat it as an air sample.

9.7.2 The purpose of the field blank is to assure that if the sampling tubes adsorb vapors extraneous to the sampling atmosphere, the presence of the contaminant will be detected on the field blank.

9.8 *Calculation of Sample Volume:*

9.8.1

$$\text{Sample volume, mL} = \textit{calibrated pump flow rate}\ (\textit{mL/min}) \times \textit{sampling time}\ (\textit{min}) \quad (3)$$

Typically, sampling pumps should be calibrated at or near the sampling site. Sample air volumes should not be corrected for sampling site temperature or barometric pressure.

10. Handling and Shipping of Samples Collected on Charcoal Sampling Tubes

10.1 There is a lack of information on the stability of the many different chemical species that can be collected on activated charcoal and the variety of conditions to which these samples may be exposed. Good practice suggests the following:[12]

10.1.1 Use validated NIOSH and OSHA methods (or other validated methods) whenever possible.

10.1.2 Samples should be securely capped and clearly identified.

10.1.3 Samples collected in charcoal tubes should not be kept in warm places or exposed to direct sunlight.

10.1.4 Samples of highly vaporous or low-boiling materials, such as vinyl chloride, should be stored and transported in dry ice or in another acceptable material. These samples should be shipped using an overnight delivery service.

10.1.5 At present there are no published test data on the effect of conditions in aircraft cargo holds on capped samples. However, it is generally advisable to avoid shipping in unpressurized aircraft cargo compartments.

10.1.6 Samples should be shipped to the analytical laboratory as soon as possible, stored under refrigeration until they are analyzed, and analyzed if possible within five working days.

10.1.7 Migration or equilibration of the sampled material within the sampling tube during prolonged or adverse storage or handling could be interpreted as break-through.

10.1.8 Bulk solvent samples should never be shipped or stored with air samples or with sampling media.

11. Keywords

11.1 activated charcoal tube; air monitoring; charcoal tube; organic vapors; sampling and analysis; workplace atmospheres

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[12] Two studies that present information pertinent to this section are:
Saalwaechter, A. T., et al, "Performance Testing of the NIOSH Charcoal Tube Technique for the Determination of Air Concentrations of Organic Vapors," *American Industrial Hygiene Association Journal,* Vol 38, No. 9, September 1977, pp. 476–486.
Hill, R. H., Jr., et al, "Gas Chromatographic Determination of Vinyl Chloride in Air Samples Collected on Charcoal," *Analytical Chemistry,* Vol 48, No. 9, August 1976, pp. 1395–1398.

ANNEX

(Mandatory Information)

A1. INFORMATION OF SOME ORGANIC COMPOUND VAPORS THAT CAN BE COLLECTED ON COCONUT-SHELL CHARCOAL (100/50 mg tubes)

TABLE A1.1 INFORMATION OF SOME ORGANIC COMPOUND VAPORS THAT CAN BE COLLECTED ON COCONUT-SHELL CHARCOAL (100/50 mg tubes)

Substance PEL ppm-mg/m^{3A}	Recommended Sampling Rate, mL/min to Detect Approximately 15 to 200 % of PEL in Time Given^B			Recommended Maximum Tube Loading, mg^C	Approximate Desorption Efficiency %^{D}	Eluent	GC Column^E	CV_T^F
	2h	4h	8h					
Acetonitrile, 40–70	50	25	25	2.7				0.072
Allyl alcohol, 2–5	200	100	50	<0.4	89 ± 5	CS_2 + 5 % 2-propanol	2	0.11
n-Amyl acetate, 100–525	50	25	10	15	86 ± 5	CS_2	4	0.051
sec-Amyl acetate, 125–650	50	25	10	15.5	91 ± 10	CS_2	4	0.071
Isoamyl alcohol, 100–360	50	25	10	10		CS_2 + 5 % 2-propanol	2	0.077
Benzene, 10–31.3	100	100	50		96	CS_2	1	0.060
Benzyl chloride, 1–5	—	200	200	<0.4	90 ± 5	CS_2	2	0.096
2-Butoxy ethanol, 50–240	100	50	25		99 ± 5	methylene chloride + 5 % methanol	2	0.060
n-Butyl acetate, 150–710	50	25	10	15	95	CS_2	4	0.069
sec-Butyl acetate, 200–950	50	25	10	15	91 ± 5	CS_2	4	0.054
tert-Butyl acetate, 200–950	50	25	10	12.5	94 ± 5	CS_2	4	0.091
Butyl alcohol, 100–300	100	50	25	10.5	88 ± 5	CS_2 + 1 % 2-propanol	2	0.065
sec-Butyl alcohol, 150–450	50	25	10	6	93 ± 5	CS_2 + 1 % 2-propanol	2	0.066
tert-Butyl alcohol, 100–300	50	25	10	5	90 ± 5	CS_2 + 1 % 2-butanol	2	0.075
Butyl glycidyl ether, 50–270	100	50	25	11.5	86 ± 10	CS_2		0.074
p-tert-Butyl toluene, 10–60	100	50	25	2.5	100+	CS_2	2	0.067
Camphor, 0.32–2	200	100	50	13.4	98 ± 5	CS_2 + 1 % methanol	2	0.074
Carbon disulfide, 20–60	200	100	50		95	toluene	8	0.059
Carbon tetrachloride, 10–55	200	100	50	7.5	97 ± 5	CS_2	1	0.092
Chlorobenzene, 75–350	50	25	10	15.5	90 ± 5	CS_2	2	0.056
Chlorobromomethane 200–1050	25	10	^{G}	9.3	94 ± 5	CS_2	2	0.061
Chloroform, 50–240	100	50	25	11	96 ± 5	CS_2	1	0.057
Cumene, 50–245	50	25	10	11	100+	CS_2	2	0.059
Cyclohexane, 300–1050	25	10	^{G}	6.3	100+	CS_2	3	0.066
Cyclohexanol, 50–200	100	50	25	10	99 ± 5	CS_2 + 5 % 2-propanol	2	0.080
Cyclohexene, 300–1015	25	10	^{G}		100+	CS_2	3	0.073
Diacetone alcohol, 50–240	100	50	25	12	77 ± 10	CS_2 + 5 % 2-propanol	2	0.101
o-Dichlorobenzene 50–300	50	25	10	15	85 ± 5	CS_2	6	0.067
1,1-Dichloroethane, 100–400	50	25	10	7.5	100+	CS_2	2	0.057
1,2-Dichloroethylene, 200–790	25	10	^{G}	5.1	100+	CS_2	2	0.052
p-Dioxane, 100–360	100	50	25	13	91 ± 5	CS_2	1	0.054
Dipropylene glycol methyl ether, 100–600	25	10	^{G}		99 ± 5	methylene chloride +5 % methanol	2	0.064
2-Ethoxyethyl acetate, 100–540	50	25	10	19	99 ± 5	methylene chloride +5 % methanol	4	0.062
Ethyl acetate, 400–1400	25	10	^{G}	12.5	89 ± 5	CS_2	4	0.058
Ethyl alcohol, 1000–1900	^{G}	^{G}	^{G}	2.6	77 ± 10	CS_2 + 1 % 2-butanol	2	0.065
Ethyl benzene, 100–435	200	100	50	16	100+	CS_2	2	0.041
Ethyl bromide, 200–890	100	50	25	7.1	83 ± 5	isopropanol	2	0.054
Ethyl butyl ketone, 50–230	50	25	10	<5.5	93 ± 5	CS_2 + 1 % methanol	2	0.086
Ethyl ether 400–1200	10	^{G}	^{G}	7.5	98 ± 5	ethyl acetate	3	0.053
Ethyl formate, 100–300	50	25	10	4.8	80 ± 10	CS_2	1	0.074
Ethylene dibromide, 20–155	100	50	25	<10.7	86 ± 5	xylene	2	0.077
Ethylene dichloride, 50–200	100	50	25	12	95 ± 5	CS_2	6	0.079
Glycidol, 50–150	100	50	25	22.5	90 ± 5	tetrahydrofuran	2	0.080
Heptane, 500–2000	10	^{G}	^{G}	12.5	96 ± 5	CS_2	6	0.056
Hexane, 500–1800	10	^{G}	^{G}	11	94 ± 5	CS_2	1	0.062
Isoamyl acetate, 100–525	50	25	10	16.5	90 ± 5	CS_2	4	0.056
Isoamyl alcohol, 100–360	50	25	10	10	99 ± 5	CS_2 + 5 % 2-propanol	2	0.065
Isobutyl acetate, 150–700	50	25	10	14	92 ± 5	CS_2	4	0.065
Isobutyl alcohol, 100–300	50	25	10	10.5	84 ± 10	CS_2 + 1 % 2-propanol	2	0.073
Isopropyl acetate, 250–950	25	10	^{G}	13	85 ± 5	CS_2	4	0.067
Isopropyl alcohol 400–980	25	10	^{G}	5.6	94 ± 5	CS_2 + 1 % 2-butanol	2	0.064
Isopropyl glycidyl ether, 50–240	100	50	25	10.5	80 ± 10	CS_2	2	0.067
Mesityl oxide, 25–100	100	50	25	4.8	79 ± 5	CS_2 + 1 % methanol	2	0.071

TABLE A1.1 *Continued*

Substance PEL ppm-mg/m^{3A}	Recommended Sampling Rate, mL/min to Detect Approximately 15 to 200 % of PEL in Time Given^B			Recommended Maximum Tube Loading, mg^C	Approximate Desorption Efficiency %^{D}	Eluent	GC Column^E	CV_T^{F}
	2h	4h	8h					
Methyl acetate, 200–610	25	10	^{G}	7	88 ± 5	CS_2	1	0.055
Methylal, 1000–3100	10	^{G}	^{G}	11.5	78 ± 10	hexane	3	0.06
Methyl amyl ketone, 100–465	50	25	10	7.5	80 ± 10	CS_2 + 1 % methanol	2	0.061
Methyl butyl ketone, 100–410	50	25	10	2.0	79 ± 10	CS_2	2	0.053
Methyl cellosolve, 25–80	100	50	25	10	97 ± 5	methylene chloride + 5 % methanol	2	0.068
Methyl cellosolve acetate, 25–120	100	50	25	5	100 ± 5	methylene chloride + 5 % methanol	4	0.068
Methyl chloroform, 350–1900	25	10	^{G}	18	98+	CS_2	6	0.054
Methyl cyclohexane, 500–2000	10	^{G}	^{G}		95 ± 5	CS_2	1	0.052
Methyl isobutyl carbinol, 25–100	200	100	50	5.7	99 ± 5	CS_2 + 5 % 2-propanol	2	0.080
a-Methyl styrene, 100–480	100	50	25	21	91 ± 5	CS_2	2	0.054
Methylene chloride, 500–1740	10	^{G}	^{G}	9.3	95 ± 5	CS_2	1	0.073
Naphtha (coal tar), 100–400	100	50	25	14.8	88 ± 5	CS_2	7	0.051
n-octane, 500–2350	10	^{G}	^{G}	15	93 ± 5	CS_2	1	0.060
Pentane, 1000–2950	10	^{G}	^{G}	9	96 ± 5	CS_2	1	0.055
2-Pentanone, 200–700	25	10	^{G}		88 ± 5	CS_2	2	0.063
Perchloroethylene, 100–680	50	25	10	29	95 ± 5	CS_2	6	0.052
Petroleum distillates, 500–2000	10	^{G}	^{G}	12.3	96 ± 5	OS_2	6	0.052
Phenyl ether vapor, 1–7		200	200	0.6	90 ± 5	CS_2	2	0.070
Phenyl glycidyl ether, 10–60	100	50	25	12.5	97 ± 5	CS_2	2	0.057
n-Propyl acetate, 200–840	50	25	10	14.5	93 ± 5	CS_2	4	0.056
n-Propyl alcohol, 200–500	50	25	10	9	87 ± 5	CS_2 + 1 % 2-propanol	2	0.075
Propylene oxide, 100–240	25	10	^{G}	2	90 ± 5	CS_2	3	0.085
Pyridine, 5–15	200	100	50	<7.3	70 ± 10	methylene chloride		0.059
Stoddard solvent, 500–2900	10	^{G}	^{G}	13	96 ± 5	CS_2	7	0.052
Styrene (monomer), 100–425	100	50	25	18	87 ± 5	CS_2	2	0.057
1,1,1,2-Tetrachloro-2,2-difluoro ethane, 500–4170	10	^{G}	^{G}	19.5	100+	CS_2	2	0.069
1,1,1,2-Tetrachloro-1,2-difluoro ethane, 500–4170	10	^{G}	^{G}	26	96 ± 5	CS_2	2	0.054
Tetrahydrofuran, 200–590	25	10	^{G}	7.5	92 ± 5	CS_2	3	0.055
1,1,2-Trichloroethane, 10–55	100	50	25	5	96 ± 5	CS_2	6	0.057
Trichloroethylene, 100–535	100	50	25	21	96 ± 5	CS_2	6	0.082
1,1,2-Trichloro-1,2,2-trifluoro ethane, 1000–7660	10	^{G}	^{G}	20	100+	CS_2	5	0.07
Turpentine, 100–560	50	25	10	13	96 ± 5	CS_2	7	0.055
Vinyl toluene, 100–480	100	50	25	17	85 ± 10	CS_2	2	0.058

Acknowledgements: The information in this table comes from NIOSH Standards Completion Program (6). We gratefully acknowledge NIOSH's contribution to this table, by making available previously unpublished $CV—_T$ data.

[A] *Substances*—The list does not contain all compounds for which the method is applicable. It lists only those for which reliable data could be obtained. PEL-Federal OSHA Permissible Exposure Limits, as given in the *Federal Register,* June 1974, and updated May 1976. These values, which may be either ceiling limits or 8-h/day time weighted average exposure limits, depending on the compound, are presented to give guidance in selecting sampling rates and times. Some of the listed substances may presently have expanded OSHA standards. These values are subject to change by the Federal Occupational Safety and Health Administration. Check OSHA's website: http://www.osha.gov, for the most up-to-date information.

[B] *Recommended Sampling Rate*—The suggested sampling rates for the different sampling periods are sufficient to provide a tube loading of at least 0.01 mg when concentrations are 15 % of the listed PEL, but will not exceed the recommended tube loading when atmosphere are 200 % of the listed PEL. These figures are based on the 100-mg coconut-shell charcoal tubes described in this practice.

[C] *Recommended Maximum Tube Loading*—These values are conservative, to allow for high humidity or the presence of other substances which reduce the normal tube capacity.

[D] *Approximate Desorption Efficiency*—These figures are given only as guides and each laboratory must determine desorption efficiencies appropriate for its practices. Desorption efficiencies should always be confirmed at the time of analysis, and any significant deviation should be regarded as a possible indication of a systematic error in the analytical technique. The desorption efficiency for a compound may vary with the amount; in some cases, the desorption efficiency might be lower for reduced tube loadings.

[E] *Gas Chromatographic Columns*—The following columns are listed for information only and each laboratory is free to select which column to actually use. Many laboratories now exclusively use capillary gas chromatographic columns.

Key:

1—20-ft × ⅛-in.: ss packed with 10 % FFAP on Chromosorb W AW
2—10-ft × ⅛-in.: ss packed with 10 % FFAP on Chromosorb W AW
3—4-ft × ¼-in.: ss packed with 60/80 Porapak Q
4—10-ft × ⅛-in.: ss packed with 5 % FFAP on Supelcoport
5—6-ft × ¼-in.: ss packed with 60/80 Porapak Q
6—10-ft × ⅛-in.: ss packed with 10 % OV-101 on Supelcoport
7—6-ft × ⅛-in.: ss packed with 1.5 % OV-101 on Chromosorb W AW
8—6-ft × ¼-in.: Glass column packed with 5 % OV-17 on Supelcoport

[F] CV_T—Coefficient of variation (that is, relative standard deviation) of the total (net) error in the method (including variability of the pump). This data is for information only and each laboratory must develop its own precision and accuracy data.

$$\overline{CV}_T = \sqrt{\left(\overline{CV}_{A+DE}\right)^2 + \left(\overline{CV}_S\right)^2 + \left(\overline{CV}_P\right)^2}$$

where:

$\overline{CV}_{A+DE}$ = coefficient of variation of a single future assay including error in the desorption efficiency factor

$\overline{CV}_S$ = coefficient of variation due to sampling errors (not including variation of the pump) along with variability in true desorption efficiency from tube-to-tube, and

$\overline{CV}_P$ = coefficient of variation due to pump ($\overline{CV}_P = 0.05$ assumed).

[G] Sampling rates of less than 10 mL/min are not recommended. Shorter sampling periods are required.

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