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Workplace air quality — Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography —

Part 1:
Pumped sampling method

Qualité de l'air des lieux de travail — Échantillonnage et analyse des composés organiques volatils par désorption au solvant/chromatographie en phase gazeuse —

Partie 1: Méthode d'échantillonnage par pompage

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 16200 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 16200-1 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 2, *Workplace atmospheres*.

ISO 16200 consists of the following parts, under the general title *Workplace air quality — Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography*:

- *Part 1: Pumped sampling method*
- *Part 2: Diffusive sampling method*

Annexes A, B and C of this part of ISO 16200 are for information only.

Workplace air quality — Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography —

Part 1:
Pumped sampling method

1 Scope

This part of ISO 16200 gives general guidance for the sampling and analysis of volatile organic compounds (VOCs) in air by solvent desorption/gas chromatography using pumped sampling.

This part of ISO 16200 is applicable to a wide range of VOCs, including hydrocarbons, halogenated hydrocarbons, esters, glycol ethers, ketones and alcohols. A number of sorbents are recommended for the sampling of these VOCs, each sorbent having a different range of applicability. However, activated coconut shell charcoal is frequently used. Very polar compounds may require derivatization; very low boiling compounds will only be partially retained by the sorbents and can only be estimated qualitatively. Semi-volatile compounds will be fully retained by the sorbents, but may only be partially recovered.

The upper limit of the useful range is set by the sorptive capacity of the sorbent used and by the linear dynamic range of the gas chromatograph column and detector or by the sample-splitting capability of the analytical instrumentation used. The lower limit of the useful range depends on the noise level of the detector and on blank levels of analyte and/or interfering artefacts on the sorbent tubes or in the desorption solvent. Artefacts are typically subnanogram for activated charcoal, but higher levels of aromatic hydrocarbons have been noted in some batches.

The concentration range for which this part of ISO 16200 is valid for the measurement of airborne vapours of VOCs is dependent on the volume sampled. For example, for a 10-litre sample of air, the range is approximately 1 mg/m^3 to 1000 mg/m^3 individual organic compound. For a 1-litre sample of air, the range is approximately 10 mg/m^3 to 10 000 mg/m^3 individual organic compound, and *pro rata*.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 16200. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 16200 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

EN 1232, *Workplace atmospheres — Pumps for personal sampling of chemical agents — Requirements and test methods*

EN 1540, *Workplace atmospheres — Terminology*

3 Principle

A measured volume of sample air is drawn through one (or more) sorbent tubes in series; an appropriate sorbent (or sorbents) being selected for the compound or mixture to be sampled. Provided suitable sorbents are chosen, volatile organic components are retained by the sorbent tube and thus are removed from the flowing air stream. The collected vapour is desorbed by a solvent, typically carbon disulfide, and the solution is analysed with a gas chromatograph equipped with a flame ionization detector, mass spectrometer or other selective detector.

4 Reagents and materials

During the analysis, use only reagents of analytical reagent grade.

4.1 Volatile organic compounds

A wide range of VOCs are required as reagents for calibration purposes.

4.2 Desorption solvent

The desorption or elution solvent, commonly carbon disulfide, should be of chromatographic quality. It shall be free from compounds co-eluting with the substances of interest. Tables 1 and 2 give recommended desorption solvents for particular vapours (see 7.5).

Where necessary (see Note 2), a desorption solvent modifier should be added at a sufficient concentration to result in a homogeneous solution in desorbed samples. Dimethylformamide may be suitable for this purpose.

NOTE 1 Carbon disulfide is normally recommended for the desorption of non-polar compounds from activated carbon. For polar compounds and mixtures of polar and non-polar compounds there is no ideal universal desorption solvent. Dichloromethane, methanol, higher alcohols, dimethylformamide and acetonitrile have been used as eluents, either singly or mixed with each other or carbon disulfide. OSHA methods 07 and 100 [1] and the NIOSH methods 1301, 1400, 1401, 1402, 1403 for ketones and alcohols [2] give examples of suitable desorption solvents other than pure carbon disulfide.

NOTE 2 The use of carbon disulfide desorption solvent can result in problems when polar analytes are collected from humid atmospheres. Polar analytes may be soluble in a water phase which forms following desorption with carbon disulfide when sufficient water is collected with the sample.

4.3 Sorbents

4.3.1 Activated charcoal

Tubes prepacked by the manufacturer with preconditioned charcoal are available and do not require further conditioning. Alternatively, tubes may be prepared by the user. A particle size of 0,35 mm to 0,85 mm is recommended. Before packing the tubes, the charcoal shall be heated in an inert atmosphere, e.g. high-purity nitrogen, at approximately 600 °C for 1 h. To prevent recontamination of the charcoal, it shall be kept in a clean atmosphere during cooling to room temperature, storage, and loading into the tubes.

The sorptive capacity and desorption efficiency of different batches of activated charcoal may vary. Commercial tubes, if used, should be purchased from the same batch and in sufficient number to provide consistent performance for a definite period of time.

NOTE Activated charcoal is usually processed from coconut shells. For some applications, petroleum-based charcoal is preferred (see Tables 1 and 2). Some manufacturers recommend synthetic carbons as alternatives to charcoal of biological origin.

4.3.2 Other sorbents

Sorbents other than charcoal may be used for certain applications (see Tables 1 and 2).

NOTE A description of sorbent types is given in annex A. Equivalent sorbents may be used.

4.4 Calibration standards

Calibration blend solutions are required in order to compare the concentrations of desorbed solutions (7.3) with those calibration standards in the gas chromatographic analysis. Such solutions should be prepared in a way that is traceable to national standards.

An internal standard is optional. If used, it should not interfere with the compounds of interest and it should not be removed from the elution solvent by the sorbent. In the context of this method, the purpose of the internal standard is to correct for small variations in the injection volume. The use of an internal standard as a surrogate to correct for desorption efficiency (e.g. *n*-propyl acetate in the analysis of *n*-butyl acetate) is not recommended. Desorption efficiency should be determined directly with the compounds of interest (7.5).

Storage times for calibration solutions vary according to application. Typically, carbon disulfide dilutions should be prepared fresh weekly, or more frequently if evidence is noted of decomposition or evaporation.

NOTE In the analysis of complex mixtures, calibration blends of the pure compounds may be prepared before dilution with the elution solvent. Examples of three calibration blends are listed here. These have been used in the analysis of mixed solvents in paints, thinners, adhesives, cleaning fluids and miscellaneous commercial products. The components are arranged to give resolved peaks on both BP-1 and BP-10 phases[1]. Other blends may be more appropriate on different columns or in other applications. In the examples below, calibration blends 1-3 are stable for at least one year when stored in dark glass bottles with PTFE-lined screw-caps at less than 4 °C.

a) Blend 1 consists of: *n*-hexane, *n*-heptane, *n*-octane, *n*-decane, *n*-undecane, *n*-dodecane, benzene, toluene, *o*-xylene, *p*-xylene, *n*-propylbenzene, isopropylbenzene, *o*-ethyltoluene, *m*-ethyltoluene, *p*-ethyltoluene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, *n*-propyl acetate, *n*-butyl acetate, isobutyl acetate, butoxyethyl acetate.

b) Blend 2 consists of: isopropanol, isobutanol, *n*-butanol, 1-methoxy-2-propanol, butoxyethanol, toluene, ethylbenzene, 1,2,3-trimethylbenzene, ethyl acetate, ethoxyethyl acetate.

c) Blend 3 consists of: acetone, 2-butanone, 4-methylpentan-2-one, cyclohexanone, 2-methylcyclohexanone, 3-methylcyclohexanone, 4-methylcyclohexanone, isopropyl acetate, *n*-nonane, toluene.

4.4.1 Solution containing approximately 10 mg/ml of each liquid component

Weigh 1 g of the substance or substances of interest into a 100 ml volumetric flask, starting with the least volatile substance. Make up to 100 ml with desorption solvent (4.2), stopper and shake to mix.

4.4.2 Solutions containing approximately 1 mg/ml of liquid components

Introduce 50 ml of desorption solvent into a 100 ml volumetric flask. Add 10 ml of solution 4.4.1 Make up to 100 ml with desorption solvent, stopper and shake to mix.

4.4.3 Solution containing approximately 100 µg/ml of each liquid component.

Weigh 10 mg of the substance or substances of interest into a 100 ml volumetric flask, starting with the least volatile substance. Make up to 100 ml with desorption solvent (4.2), stopper and shake to mix.

4.4.4 Solution containing approximately 10 µg/ml of liquid components

Introduce 50 ml of desorption solvent into a 100 ml volumetric flask. Add 10 ml of solution 4.4.3. Make up to 100 ml with desorption solvent, stopper and shake to mix.

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[1] BP-1 and BP-10 are examples of suitable products available commercially. This information is given for the convenience of users of this part of ISO 16200 and does not constitute endorsement by ISO of these products. Equivalent products may be used if they can be shown to lead to the same results. Annex B gives a non-exclusive list of products that are believed to be equivalent.

4.4.5 Solution containing approximately 1 mg/ml of gas components

For gases, e.g. ethylene oxide, a high-level calibration solution may be prepared as follows. Obtain pure gas at atmospheric pressure by filling a small plastic gas bag from a gas cylinder. Fill a precision 1-ml gas-tight syringe (5.8) with 1 ml of the pure gas and close the valve of the syringe. Using a septum vial of suitable capacity, add 2 ml desorption solvent and close with the septum cap. Insert the tip of the syringe needle through the septum cap into the desorption solvent. Open the valve and withdraw the plunger slightly to allow the desorption solvent to enter the syringe. The action of the gas dissolving in the desorption solvent creates a vacuum, and the syringe fills with solvent. Return the solution to the flask. Flush the syringe twice with the solution and return the washings to the flask. Calculate the mass of gas added using the gas laws, i.e. 1 mole of gas at STP occupies 22,4 litres.

4.4.6 Solution containing approximately 10 µg/ml of gas components

For gases, e.g. ethylene oxide, a low-level calibration solution may be prepared as follows. Obtain pure gas at atmospheric pressure by filling a small plastic (or other inert material) gas bag from a gas cylinder. Fill a precision 10-µl gas-tight syringe (5.8) with 10 µl of the pure gas and close the valve of the syringe. Using a septum vial of suitable capacity, add 2 ml desorption solvent and close with the septum cap. Insert the tip of the syringe needle through the septum cap into the desorption solvent. Open the valve and withdraw the plunger slightly to allow the desorption solvent to enter the syringe. The action of the gas dissolving in the desorption solvent creates a vacuum, and the syringe fills with solvent. Return the solution to the flask. Flush the syringe twice with the solution and return the washings to the flask. Calculate the mass of gas added using the gas laws, i.e. 1 mole of gas at STP occupies 22,4 litres.

4.5 Calibration blend atmosphere (for 4.6 and annex B)

Prepare standard atmospheres of known concentrations of the compound(s) of interest by a recognized method. Methods described in ISO 6141, ISO 6145 and ISO 6349 are suitable. If the procedure is not applied under conditions that allow the establishment of full traceability of the generated concentrations to primary standards, confirm the delivered concentrations using an independent procedure.

4.6 Standards for desorption efficiency (for 7.5)

Prepare loaded sorbent tubes by passing an accurately known volume of the standard atmosphere through the sorbent tube, e.g. by means of a pump or mass flow controller. The volume of atmosphere sampled shall not exceed the breakthrough volume of the analyte-sorbent combination (annex B). After loading, the tube is disconnected and sealed.

If the generation of standard atmospheres is not practicable, the standards may be prepared by a liquid spiking procedure, provided that the accuracy of the spiking technique is established by using procedures giving spiking levels traceable to primary standards of mass and/or volume, or is confirmed by an independent procedure.

Load the sorbent tubes by injecting aliquots of standard solutions (4.4) of accurately known mass or volume onto clean sorbent tubes as follows: a sorbent tube is fitted to a T-piece of which one end is fitted with a septum, or injection facility of a gas chromatograph, through which inert purge gas is passed at 100 ml/min. Inject a 1 µl to 4 µl aliquot through the septum and purge for 5 min. Disconnect the tube and seal.

5 Apparatus

Ordinary laboratory apparatus and the following.

5.1 Sorbent tube

A sampling tube, typically consisting of a glass tube with both ends flame-sealed, 70 mm long with an outside diameter of 6 mm and an inside diameter of 4 mm, containing two sections of sorbent. In the case of charcoal, the sorbing section contains 100 mg of charcoal and the back-up section, 50 mg. The sections are separated and their contents are held in place with an inert material, e.g. glass wool plugs (preferably silanized).

Glass tubes shall be held in protective holders to prevent breakage.

The desorption efficiency (D) for each batch of tubes shall be checked by one of the methods described in 4.6. If D is lower than 0,75 (75 %), the tubes shall not be used (but see below).

Tubes meeting these requirements are commercially available; however, they may also be made by the user. Metal tubes may also be used with appropriate end caps. Self-packed samplers should not be used unless they can be shown to have reproducible and constant sorption properties.

Where mixtures of non-polar analytes are desorbed with pure carbon disulfide, the mutual concentration effect on D is generally negligible. If the composition of a mixture of polar and non-polar analytes is known approximately, D values should be established with a similar mixture. It may not be possible to achieve greater than 75 % D for all components of such a mixture with a single desorption solvent. Provided that it can be established that the D is consistent and that no better solvent has been found, then a compromise is acceptable, although where possible, the taking of a second sample and optimizing desorption conditions for both polar and non-polar analytes is preferred.

NOTE 1 Instead of commercial two-section tubes, two single section tubes in series may be used. This arrangement has the advantage that it is not necessary to store tubes at subambient temperatures after sampling, to prevent migration of the sorbed compounds from one section to the other.

NOTE 2 Polyurethane plugs may be used in place of silanized glass wool; however, they are known to sorb certain pesticides [3] for which this part of ISO 16200 is inapplicable.

NOTE 3 When it is desirable to sample highly volatile compounds for extended periods, or at a high volume flowrate, a larger sampling device may 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 flowrate and contact time with the charcoal bed.

5.2 End caps, made to fit snugly over the sorbent tubes (5.1) to prevent leakage or contamination and made of inert material such as polyethylene.

5.3 Sampling pump, fulfilling the requirements of EN 1232 or equivalent.

The sampling pump should be in accordance with local safety regulations.

5.4 Tubing, plastic or rubber, about 90 cm long of appropriate diameter to ensure a leak-proof fit to both pump and sample tube or tube holder, if used. Clips shall be provided to hold the sorbent tube and connecting tubing to the wearer's lapel area.

It is not recommended to use tubes with any tubing upstream of the sorbent, as sample losses may occur.

5.5 Gas chromatograph, fitted with a flame ionization, photo-ionization detector, mass spectrometric or other suitable detector, capable of detecting an injection of 0,5 ng toluene with a signal-to-noise ratio of at least 5 to 1.

A gas chromatograph column capable of separating the analytes of interest from other components. Examples of suitable choices are 50 m × 0,22 mm fused silica columns with BP-1 or BP-10 stationary phase. A typical film thickness is in the range 0,5 µm to 2,0 µm. Typical operating conditions for these columns might be temperature programming from 50 °C to 200 °C at 5 °C/min with a helium carrier gas flowrate of 0,7-0,8 ml/min. Annex B gives a list of equivalent phases.

5.6 Autosampler

These are commercially available with liquid-chilled sample trays, suitable for the analysis of volatile solvents.

5.7 Precision volumetric flasks, of accurately known volumes, to be used for the preparation of calibration blend solutions (4.4).

5.8 Precision gas-tight syringes, of accurately known volumes of 1,0 ml and 10 µl, readable to 0,1 ml and 1,0 µl, respectively.

5.9 Flow meter, soap bubble type, or other suitable device for calibrating the flowrate of sampling pumps. The flow meter readout should be traceably calibrated or checked to a primary flow standard.

NOTE The use of uncalibrated rotameter readouts for the calibration of pump flowrates may result in systematic errors of several tens of percent.

6 Sampling

6.1 Calibration of pump

Adjust the flowrate with a representative sorbent tube assembly in line, such that the recommended sample volume will be taken in the available time, using the internal meter. The flowrate should not exceed 200 ml/min (see annex C and EN 1076). The sample volume shall be less than the breakthrough volume (6.2, annex C). Calibrate the pump using an appropriate external calibrated meter (5.9). One end of the calibrated flow meter should be at atmospheric pressure to ensure proper operation. Additional information about pump calibration is given in [4].

6.2 General

Select a sampler appropriate for the compound or mixture to be sampled. Guidance on suitable sorbents is given in annex A. Published methods that give further information on sampling and analysis details for specific VOCs are referenced in Tables 2 and 3. The source references give details of suitable flowrates and recommended sampling times for particular VOCs. For most VOCs, a sample volume of at least 10 litres can be taken without breakthrough occurring on a standard-sized tube (5.1). For some more volatile VOCs, the safe sampling volume may be much less than this, and a standard tube may not have the capacity to sample for a full 8 h. An 8-h time-weighted average concentration can be derived from the results of two or more consecutive samples, or a larger sample tube may be used.

Break open both ends of the sample tube, ensuring that each opening is at least one half the inside diameter of the tube. Insert the tube into its protective holder and attach to the sampling pump (switched off) with the connecting tubing such that the back-up (50 mg) section is nearest the pump.

When used for personal sampling, mount the sampler in the breathing zone (as defined in EN 1540). When used for fixed location sampling, choose a suitable sampling site. In either case, the sampler should be mounted in a vertical position to minimize channelling of air through the sorbent sections.

Turn the pump on at the start of sampling. Record the time and the flowrate, or register reading if appropriate, when the pump was turned on. At the end of the sampling period, record the time and flowrate, or register reading, and turn the pump off. Normally, the sampled volume is calculated from the mean value of the initial and final flowrates, multiplied by the elapsed time, or from the register reading for a pump with automatic flow control, multiplied by the stroke volume. However, if the difference between the initial and final flowrates is greater than 10 %, the sample should be discarded.

Disconnect the sample tube assembly and seal both ends of each tube with end caps (5.2). Tighten these seals securely. The tubes should be uniquely labelled, e.g. by engraving. Solvent-containing paints and markers or adhesive labels should not be used to label the tubes.

Record air temperature and barometric pressure periodically during sampling if it is desired either to express concentrations reduced to specific conditions (8.1, Note) or to express concentrations in volume fractions (8.2).

NOTE 1 The sampling efficiency will be 100 %, provided that the sampling capacity of the sorbent has not been exceeded. If this capacity is exceeded, breakthrough of vapour from the front section to the back-up section will occur. The source references in Tables 1 and 2 give indicative values for breakthrough volumes for single components. The breakthrough volume is defined and may be determined as specified in annex C.

NOTE 2 The breakthrough volume varies with ambient air temperature, relative humidity, concentration of sampled vapour and of other contaminants, and with the sampling flowrate. An increase in any of these parameters causes a reduction in the breakthrough volume. The back-up section may be used as a check on breakthrough under practical conditions. Alternatively, two or more tubes can be run in parallel using different sample volumes (“distributed sample volumes”).

Field blanks should be prepared by using tubes identical to those used for sampling and subjecting them to the same handling procedure as the samples except for the actual period of sampling. Label these as blanks.

7 Procedure

7.1 Safety precautions

This part of ISO 16200 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 part of ISO 16200 to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.

7.2 Storage

If samples are not to be analysed within 8 h, they shall be placed in a clean, uncoated, sealed metal or glass container.

Samples of very volatile materials, such as vinyl chloride, should be stored in dry ice or in a freezer, depending on their volatility. For less volatile materials, refrigeration at < 5 °C is sufficient.

7.3 Desorption

Analyse the samples as soon as possible.

In each case, carry out the desorption in a clean atmosphere in a fume hood. Desorb the sample blanks in the same way as the samples.

Pipette 1,0 ml of desorption solvent (4.2) into a septum vial of suitable capacity and cap the vial immediately. Score the sorbent tube containing the sample in the front (largest) section and break open the tube. Remove the glass wool and discard it. Open the vial and transfer the front section of sorbent into the desorption solvent and recap it. Agitate the vial occasionally over a period of 30 min to ensure maximal desorption. Repeat the same procedure for the second, back-up section, using a different vial.

When using sorbent tubes containing more than 100 mg + 50 mg sorbent, use a larger vial and a larger volume of desorption solvent *pro rata*. Other volumes of desorption solvent may be used for special applications.

For the desorption of samples of very volatile materials, such as vinyl chloride, the vial containing desorption solvent should be pre-chilled before addition of the sorbent.

7.4 Analysis

Set up the gas chromatograph for the analysis of volatile organic compounds. A variety of chromatographic columns may be used for the analysis of these compounds (see 5.5). The choice will depend largely on which compounds, if any, are present that might interfere in the chromatographic analysis.

Inject a known fixed volume (1 µl to 5 µl) of each standard solution (4.4) into the gas chromatograph. An injection technique should be used so that repeatable peak heights or areas are obtained.

NOTE Typically, for a series of replicate injections, the relative standard deviation should be better than ± 2 %. Autosamplers normally achieve better than ± 1 %.

Inject the same fixed volume of solution from the desorbed sample into the gas chromatograph. Read from the calibration graph the concentration of the analyte in the desorbed sample. Analyse the sample blank and the samples used to determine desorption efficiency in the same way.

Correspondence of retention time on a single column should not be regarded as proof of identity. The retention indices of about 160 VOCs on BP-1 and BP-10 phases are given in Table 3. They are a useful guide to elution order on these phases or their near equivalent, but are not definitive, since exact values depend on temperature programme, carrier flowrate and other factors.

If the back-up section contains more than 10 % of the sample, or of any component VOC, discard the sample as unreliable [2].

7.5 Determination of desorption efficiency

The desorption efficiencies (D) of VOCs can vary with the type and batch of sorbent used. Thus it is necessary for each type of sorbent and for each analyte to determine D over the sample concentration range. Samples are prepared as described in 4.6, desorbed as described in 7.3 and analysed as described in 7.4. D is then the amount recovered divided by the amount applied.

Alternatively to the liquid spiking procedure (4.6, 7.3, 7.4), the phase-equilibrium method may be applied, in which accurately known volumes of standard solutions are added to the sorbent from unused blank samplers (or blank sorbent in desorption solvent) with the difference in concentration before and after addition being determined.

If the desorption efficiency data can be shown to be a homogeneous set, then D is given by the pooled mean. Otherwise the data should be examined to determine whether it can be modelled using a smooth non-linear equation, with D increasing with the ratio of analyte mass to sorbent mass. In such cases, D can be estimated using this curve. Indicative values of D for single compounds are given in the source references for Table 2. Actual values should always be determined at the time of analysis.

NOTE 1 The desorption efficiency will vary with the mass loading of compound on the sorbent tube; the variation is usually significant where the average value is below 90 %.

NOTE 2 The liquid spiking and phase-equilibrium methods may not take account of high humidity at the time of sampling. Adsorbed water vapour is a factor which can be simulated by addition of water to the sorbent. This should be investigated when sampling water-soluble compounds from atmospheres of high humidity.

NOTE 3 The phase-equilibrium method may give rise to incorrect values for D [5-8].

8 Calculations

8.1 General

Prepare a log-transformed calibration graph by plotting the base-ten logarithm of the heights or areas of the analyte peaks corrected for blank levels on the vertical scale against the base-ten logarithm of the concentration of the analyte, in micrograms per millilitre, in the injected aliquot of the calibration blend solutions.

NOTE Other methods of weighting calibration points, such as linear, exponential or polynomial plots, may be more or less suitable, depending on the linearity of the detector response and the software available.

8.2 Mass concentration of analyte

Calculate the concentration of the analyte in the sampled air, in milligrams per cubic metre, by means of the following equation:

$$c_\mathrm{m} = \frac{m_\mathrm{F} + m_\mathrm{R} - m_\mathrm{B}}{D \cdot V} \times 1\,000$$

where

c_m is the concentration of analyte in the air sampled, in milligrams per cubic metre;

D is the desorption efficiency at the sample tube load level corresponding to m_F;

m_F is the mass of analyte present in the actual sample (front section) as found in 7.3, in milligrams;

m_R is the mass of analyte present in the actual sample (rear or back-up section) as found in 7.3, in milligrams;

m_B is the mass of analyte present in the blank tube, in milligrams;

V is the volume of sample taken in litres.

NOTE If it is desired to express concentrations reduced to specified conditions, e.g. 25°C and 101 kPa, then;

$$c_{\mathrm{c}} = c_{\mathrm{m}} \cdot \frac{101}{p} \cdot \frac{T+273}{298}$$

where

c_{c} is the concentration of analyte in the air sampled, reduced to specified conditions, in milligrams per cubic metre;

p is the actual pressure of the air sampled, in kilopascals;

T is the actual temperature of the air sampled, in degrees Celsius.

8.3 Volume concentration of analyte

Calculate the volume fraction of the analyte in air, in millilitres per cubic metre, by means of the following equation:

$$c_{\mathrm{v}} = c_{\mathrm{m}} \cdot \frac{24{,}5}{M} \cdot \frac{101}{p} \cdot \frac{T+273}{298}$$

where

c_{v} is the volume fraction of the analyte in air, in millilitres per cubic metre;

M is the molecular mass of the analyte of interest, in grams per mole;

24,5 is the molar volume at 25 °C and 101 kPa.

9 Interferences

Organic components which have the same or nearly the same retention time as the analyte of interest during the gas chromatographic analysis will interfere. Interferences can be minimized by proper selection of gas chromatographic columns and conditions.

High humidity may affect the recovery of some compounds from samplers, particularly for those using activated charcoal. The method description should be consulted for specific advice.

10 Precision and bias

The precision and bias of the method have been examined as part of the NIOSH Standards Completion Programme [9]. This gives values of between approximately 5 % and 10 % for the combined pump and analytical precision (as a coefficient of variation) over the range 0,1 to 2,0 the US Permissible Exposure Limit (PEL). In most cases, the PEL is equivalent to Exposure Limits in other countries. Allowing 5 % for the maximum bias expected, the overall uncertainty (see EN 482) will always be within 30 %. However, biases greater than 5 % may be introduced through the use of incorrect desorption efficiencies (see 7.5, Notes).

11 Storage and transport

The long-term stability of hydrocarbons and some chloroalkanes on charcoal is good. The long-term stability of many polar compounds on charcoal is unknown. Storage and transport in a refrigerator or freezer will generally improve storage stability.

12 Test report

The test report shall contain at least the following information:

a) complete identification of the sample;

b) reference to this part of ISO 16200 or any supplementary standard;

c) the sampling location, sampling time period, volume of air pumped and any difference between the initial and final flowrate;

d) the barometric pressure and temperature, if required in 6.2;

e) the test result, including units of measurement and date of analysis;

f) any unusual features noted during the determination;

g) any operation not included in this part of ISO 16200 or in the International Standard to which reference is made or regarded as optional.

13 Quality control

An appropriate level of quality control should be employed (see [10], [11] or equivalent).

The field tube blank is acceptable if artefact peaks are no greater than 10 % of the typical areas of the analytes of interest.

Table 1 — Published methods that give further information on sampling and analysis details for specific VOCs — HSE methods

Method name	Test compounds	Sorbent [a]	Desorption solvent	MDHS Method Number [12]
Acrylonitrile	Acrylonitrile	C	CS_2	1
Benzene	Benzene	C	CS_2	17
Carbon disulfide	Carbon disulfide	C	Toluene	15
Chlorinated hydrocarbons	Dichloromethane [b] Chloroform Carbon tetrachloride 1,1-Dichloroethane 1,2-Dichloroethane 1,1-Dichloroethylene 1,2-Dichloroethylene [b] 1,1,1-Trichloroethane 1,1,2-Trichloroethane Trichloroethylene 1,1,2,2-Tetrachloroethane [c] Tetrachloroethylene Chlorobenzene *o*-Dichlorobenzene	C	CS_2	28
	1,2-Dichloropropane [b, c]	C	85:15 Cyclohexane: acetone	28
Dioctyl phthalates	Di(2-ethylhexyl)phthalate 'Diisooctyl' phthalate	T [d]	Cyclohexane	32
Ethylene dibromide	Ethylene dibromide	T	Hexane	45 [e]
Ethylene oxide	Ethylene oxide	C [f]	CS_2	26
Glycol ether and glycol ether acetates	2-Butoxyethanol 2-Ethoxyethanol 2-Methoxyethanol 2-Butoxyethyl acetate 2-Ethoxyethyl acetate 2-Methoxyethyl acetate	C	95:5 CH_2Cl_2: methanol	21
Styrene	Styrene	C	CS_2	20
Toluene	Toluene	C	CS_2	36
Vinyl chloride	Vinyl chloride	C [g]	CS_2	24

[a] Abbreviations are as follows: C = charcoal (100 mg + 50 mg tube), T = Tenax (100 mg + 50 mg tube).

[b] 400 mg + 200 mg tube.

[c] Petroleum-based charcoal.

[d] 200 mg or 30 mg + 15 mg tube.

[e] Analysis by CG/electron capture.

[f] Columbia JXC charcoal.

[g] 800 mg + 200 mg tube.

Table 2 — Published methods that give further information on sampling and analysis details for specific VOCs — NIOSH methods

Method name	Test compounds	Sorbent [a]	Desorption solvent	NIOSH Method Number [2]
Acetone cyanohydrin		QS	Ethyl acetate	2506 [b]
Acetic acid		C	Formic acid	1603
Acetonitrile		C [c]	85:15 Methylene chloride: methanol	1606
Acrylonitrile		C	98:2 CS_2:acetone	1604
Alcohols I	*t*-Butyl alcohol Isopropyl alcohol Ethanol	C	99:1 CS_2:2-butanol	1400
Alcohols II	*n*-Butyl alcohol Isobutyl alcohol *s*-Butyl alcohol *n*-Propyl alcohol	C	99:1 CS_2:2-propanol	1401
Alcohols III	Allyl alcohol Isoamyl alcohol Methyl isobutyl carbinol Cyclohexanol Diacetone alcohol	C	95:5 CS_2:2-propanol	1402
Alcohols IV	2-Butoxyethanol 2-Ethoxyethanol 2-Methoxyethanol	C	95:5 CH_2Cl_2:methanol	1403
Allyl chloride		C	Benzene	1000
Amines, aliphatic	Diethylamine Dimethylamine	S	Dil. H_2SO_4 in 10 % aq. methanol	2010
Amines, aromatic	Aniline *o*-Toluidine 2, 4-Xylidine *N*,*N*,-Dimethyl-*p*-toluidine *N*, *N*,-Dimethylaniline	S	95 % Ethanol	2002
Aminoethanol, compounds I	2-Aminoethanol 2, 2´-Iminodiethanol 2,2´,2´´-Nitrilotriethanol	S [d]	80 % Methanol	2007
Anisidine		XAD-2 [e]	Methanol	2514 [f]
Butadiene		C [c]	Methylene chloride	1024
Butyl glycidyl ether		C	CS_2	1616
Carbon disulfide		C [g]	Toluene	1600 [h]
β-Chloroprene		C	CS_2	1002
Cresols and phenol	*o*-Cresol *m*-Cresol *p*-Cresol Phenol	XAD-7	Methanol	2546

Table 2 (*continued*)

Method name	Test compounds	Sorbent[a]	Desorption solvent	NIOSH Method Number [2]
Dichlorodifluoro-methane, etc.	Dichlorodifluoromethane 1,2-Dichlorotetrafluoro-ethane Chlorodifluoromethane	C [i]	Methylene chloride	1018
Dichlorofluoro-methane		C [j]	CS_2	2516
1,1-Dichloro-1-nitroethane		C	CS_2	1601
Difluoro-dibromomethane		C [k]	2-Propanol	1012
Dimethylacetamide		S	Methanol	2004
Dimethyl sulfate		P	Diethyl ether	2524 [l]
Dioxane		C	CS_2	1602
Diphenyl		T [m]	Carbon tetrachloride	2530
Epichlorohydrin		C	CS_2	1010
Esters I	*n*-Amyl acetate *n*-Butyl acetate 2-Ethoxyethyl acetate Ethyl acrylate Methyl isoamyl acetate *n*-Propyl acetate Isobutyl acetate *s*-Amyl acetate *s*-Butyl acetate Isoamyl acetate	C	CS_2	1450
Ethyl acetate		C	CS_2	1457
Ethyl bromide		C	2-Propanol	1011
Ethyl chloride		C [c]	CS_2	2519
Ethylene chlorohydrin		C [n]	95:5 CS_2:2-propanol	2513
Ethylene dibromide		C	99:1 Benzene:methanol	1008
Ethyl ether		C	CS_2	1610
Ethyl formate		C	CS_2	1452
Fluorotrichloromethane		C [c]	CS_2	1006
Furfuryl alcohol		Q	Acetone	2505
Glycidol		C	Tetrahydrofuran	1608
Hexachlorobutadiene		XAD-2	Hexane	2543 [o]

Table 2 (*continued*)

Method name	**Test compounds**	**Sorbent** [a]	**Desorption solvent**	**NIOSH Method Number [2]**
Hexachloro-1,3-cyclopentadiene		T [p]	Hexane	2518 [o]
Hydrocarbons BP 36 °C to 126 °C	Benzene, toluene, pentane through octane Cyclohexane Methylcyclohexane	C	CS_2	1500
Hydrocarbons, aromatic	Benzene Cumene Naphthalene α-Methylstyrene Styrene Vinyltoluene *p*-*t*-Butyltoluene Ethylbenzene Toluene Xylene	C	CS_2	1501
Hydrocarbons, halogenated	Chloroform Tetrachloroethylene *o*- & *p*-Dichlorobenzene Bromoform Methyl chloroform Chlorobromomethane 1,2-Dichloroethane 1,1,1-Trichloroethane 1,1,2-Trichloroethane 1,2-Dichloroethylene Tetrachloroethylene Carbon tetrachloride Ethylene dichloride Chlorobenzene Hexachloroethane 1,2,3-Trichloropropane	C	CS_2	1003
Isophorone		C [n]	CS_2	2508
Isopropyl acetate		C	CS_2	1454
Isopropyl ether		C	CS_2	1618
Isopropyl glycidyl ether		C	CS_2	1620
Ketones I	Acetone Cyclohexanone Diisobutyl ketone 2-Hexanone Methyl isobutyl ketone 2-Pentanone	C	CS_2	1300
Ketones II	Camphor Ethyl butyl ketone Mesityl oxide 5-Methyl-3-heptanone Methyl *n*-amyl ketone	C	99:1 CS_2:methanol	1301

Table 2 (*continued*)

Method name	Test compounds	Sorbent [a]	Desorption solvent	NIOSH Method Number [2]
Methanol		S [q]	5 % 2-Propanol in water	2000
Methyl acetate		C	CS_2	1458
Methyl acrylate		C	CS_2	1459
Methylal		C	Hexane	1611
Methyl cellosolve acetate	2-Methoxyethyl acetate	C	CS_2	1451
Methyl chloride		C [i]	Methylene chloride	1001
Methyl cyclohexanol		C	Methylene chloride	1404
Methyl cyclohexanone		Q	Acetone	2521
Methylene chloride	Dichloromethane	C [r]	CS_2	1005
Methyl methacrylate		XAD-2 [c]	CS_2	2537
Methyl *t*-butyl ether		C [c]	CS_2	1615
Methyl iodide		C	Toluene	1014
Naphthas	Kerosine Petroleum ether Rubber solvent Stoddard solvent, etc.	C	CS_2	1550
Nicotine		XAD-2	Ethyl acetate	2544 [b]
Nicotine		XAD-4	Ethyl acetate + 0,01 % triethylamine	2551 [b]
Nitro-aromatic compounds	Nitrobenzene Nitrotoluene(s) 4-Chloronitrotoluene	S	Methanol	2005
Nitroethane		XAD-2 [s]	Ethyl acetate	2526
2-Nitropropane		106	Ethyl acetate	2528
Nitroglycerin and ethylene glycol dinitrate		T	Ethanol	2507
N-Methyl-2-pyrrolidone		C	95:5 Methylene chloride/methanol	1302
Octane-1-thiol		T	Acetone	2510 [b]
Pentachloroethane		R	Hexane	2517 [o]
Phenyl ether		C	CS_2	1617
Phenyl ether/diphenyl mixture		S	Benzene	2013
Phenyl glycidyl ether		C	CS_2	1619

Table 2 (*continued*)

Method name	Test compounds	Sorbent [a]	Desorption solvent	NIOSH Method Number [2]
Propylene dichloride	1,2-Dichloropropane	C [n]	85:15 Cyclohexane: acetone	1013 [l]
Propylene oxide		C	CS_2	1612
Pyridine		C	Methylene chloride	1613
Terpenes	Limonene α-Pinene β-Pinene 3-Carene	C	CS_2	1552
1,1,2,2-Tetrabromoethane		S	Tetrahydrofuran	2003
1,1,1,2-Tetrachloro-2,2-difluoroethane, etc.	1,1,1,2-Tetrachloro-2,2-difluoroethane 1,1,2,2-Tetrachloro-1,2-difluoroethane	C	CS_2	1016
1,1,2,2-Tetrachloroethane		C [n]	CS_2	1019
Tetrahydrofuran		C	CS_2	1609
Trichloroethylene		C	CS_2	1022
1,1,2-Trichloro-1,2,2-trifluoroethane		C	CS_2	1020
Trifluorobromomethane		C [i]	Methylene chloride	1017
Turpentine		C	CS_2	1551
Vinyl acetate		CMS	95:5 Methylene chloride:methanol	1453
Vinyl bromide		C [c]	Ethanol	1009
Vinyl chloride		C [k]	CS_2	1007
Vinylidine chloride	1,1-Dichloroethene	C	CS_2	1015

[a] Abbreviations are as follows: C = charcoal (100 mg + 50 mg tube); CMS = carbon molecular sieve (160 mg + 80 mg tube); P = Porapak P (100 mg + 50 mg tube); Q = Porapak Q (150 mg + 75 mg tube); QS = Porapak QS (100 mg + 50 mg tube); R = Porapak R (70 mg + 35 mg tube); S = Silica gel (150 mg + 75 mg tube); T = Tenax (100 mg + 50 mg tube); 106 = Chromosorb 106 (100 mg + 50 mg tube), XAD-2 = (100 mg + 50 mg tube), XAD-4 = (80 mg + 40 mg tube), XAD-7 = (100 mg + 50 mg tube).

[b] Analysis by GC/NPD.

[c] 400 mg + 200 mg tube.

[d] 300 mg + 150 mg tube.

[e] 150 mg + 75 mg tube.

[f] Analysis by HPLC/UV.

[g] Used a sodium sulfate drying tube in front.

Table 2 (*continued*)

[h] Analysis by GC/FPD.

[i] Two tubes 400/200 mg + 100/50 mg.

[j] Two tubes 400/200 mg + 400/200 mg.

[k] Two tubes, 150 mg + 150 mg.

[l] Analysis by GC/conductivity (Hall).

[m] 20 mg + 10 mg tube.

[n] Petroleum-based carbon.

[o] Analysis by GC/ECD.

[p] Two tubes 75 mg + 25 mg.

[q] 100 mg + 50 mg tube

[r] Two tubes 100/50 mg + 100/50 mg.

[s] 600 mg + 400 mg tube.

Table 3 — Retention indices of selected VOCs on BP-1 and BP-10 phases

	BP-1		BP-10
Propane	300	Propane	300
Dichlorodifluoromethane (Freon 12)	311	Dichlorodifluoromethane (Freon 12)	318
Methyl chloride	348	1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)	353
1,2-Dichloro-1,1,2,2-Tetrafluoroethane (Freon 114)	359	Isobutane	359
Isobutane	364	Butane	400
Methanol	370	Methyl chloride	402
Chloroethene (vinyl chloride)	378	Chloroethene (vinyl chloride)	420
Butane	400	2-Methylbutane	478
Methyl bromide	421	Methyl bromide	482
Ethyl chloride	434	Ethyl chloride	492
Ethanol	450	Methanol	500
Acetonitrile	470	Pentane	500
Trichlorofluoromethane (Freon 11)	482	Trichlorofluoromethane (Freon 11)	503
Enflurane	486	2,2-Dimethylbutane	528
Acetone	487	1,1,2-Trichloro-1,2,2-trifluoroethane	528
2-Methylbutane	488	Dichlorofluoromethane (Freon 21)	532
Isopropanol	488	Dimethylethanolamine	553
Dichlorofluoromethane (Freon 21)	491	Propylene oxide	553
Pentane	500	1,1-Dichloroethene (vinylidene chloride)	555
Dimethoxymethane	511	Ethanol	559
Methyl acetate	511	2-Methylpentane	561
1,1-Dichloroethene (vinylidene chloride)	513	2,3-Dimethylbutane	561
Dichloromethane	514	3-Methylpentane	582
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	524	Acetone	589
2,2-Dimethylbutane	532	*n*-Hexane	600
n-Propanol	539	Isopropanol	601
Halothane	541	Methyl acetate	603
Vinyl acetate	560	Enflurane	607
Cyclopentane	562	Dichloromethane	608
2-Methylpentane	563	Acetonitrile	637
2,3-Dimethylbutane	563	Methylcyclopentane	642

Table 3 (*continued*)

	BP-1		BP-10
2-Butanone	571	Halothane	644
3-Methylpentane	579	Vinyl acetate	644
cis-1,2-Dichloroethene	592	2-Methylhexane	662
Ethyl acetate	596	*n*-Propanol	665
Chloroform	600	2,3-Dimethylpentane	669
n-Hexane	600	3-Methylhexane	673
Isobutanol	610	Cyclohexane	676
Methoxyethanol	616	Ethyl acetate	685
1,2-Dichloroethane	627	*cis*-1,2-Dichloroethene	685
Methylcyclopentane	627	2,2,4-Trimethylpentane	687
1,1,1-Trichloroethane	634	Methyl acrylate	690
n-Butanol	643	2-Butanone	693
Isopropyl acetate	643	1,1,1-Trichloroethane	693
Benzene	652	Carbon tetrachloride	697
1-Methoxy-2-propanol (PGME)	658	Chloroform	700
Cyclohexane	662	*n*-Heptane	700
Carbon Tetrachloride	663	Cyclohexene	712
2-Methylhexane	664	Benzene	723
2,3-Dimethylpentane	668	Isopropyl acetate	727
3-Methylhexane	674	Isobutanol	739
Cyclohexene	678	2,4-Dimethylhexane	736
1,2-Dichloropropane	684	Methylcyclohexane	736
t-Butyl acetate	687	1,2-Dichloroethane	745
2,2,4-Trimethylpentane	691	Methoxyethanol	755
Trichloroethene	691	Trichloroethene	755
Ethoxyethanol	695	*t*-Butyl acetate	763
n-Propyl acetate	695	2-Methylheptane	768
Methyl methacrylate	696	1-Methoxy-2-propanol	773
n-Heptane	700	3-Methylheptane	774
Methoxyflurane	706	*n*-Butanol	777
cis-1,2,Dichloropropene	720	1,2-Dichloropropane	778
Methyl isobutyl ketone	723	Methyl methacrylate	782
Methylcyclohexane	728	*n*-Propyl acetate	784
2,4-Dimethylhexane	735	*n*-Octane	800
1-Ethoxy-2-propanol	738	Methoxyflurane	806

Table 3 (*continued*)

	BP-1		**BP-10**
trans-1,2-Dichloropropene	739	2,4-Dimethylheptane	820
s-Butyl acetate	745	Ethoxyethanol	820
1,1,2-Trichloroethane	747	*cis*-1,2-Dichloropropene	821
2-Ethoxy-1-propanol	754	*s*-Butyl acetate	823
Isobutyl acetate	757	Toluene	825
Toluene	761	Methyl isobutyl ketone	831
2-Methylheptane	765	Isobutyl acetate	840
Hexanal	777	1-Ethoxy-2-propanol	843
Diethyleneglycol diethyl ether	783	Tetrachloroethene	846
1,2-Dibromoethane	787	Diethylene glycol diethyl ether	854
Propoxyethanol	790	*trans*-1,2-Dichloropropene	862
n-Butyl acetate	795	3-Methyloctane	872
n-Octane	800	1,1,2-Trichloroethane	876
Furfural	803	*n*-Butyl acetate	883
Methoxyethyl acetate	807	Hexanal	891
Tetrachloroethene	807	*n*-Nonane	900
2,4-Dimethylheptane	824	Di-*n*-butyl ether	905
Furfuryl alcohol	830	1,2-Dibromoethane	905
Chlorobenzene	837	Propoxyethanol	913
Diacetone alcohol	842	Ethylbenzene	922
1-Methoxy-2-propyl acetate	843	Chlorobenzene	922
Ethylbenzene	855	*p*-Xylene	929
Amyl acetate	859	*m*-Xylene	929
p-Xylene	864	Methoxyethyl acetate	940
m-Xylene	864	Amyl acetate isomer	948
4-Methyloctane	865	Amyl acetate isomer	951
Allyl glycidyl ether	868	*o*-Xylene	960
Cyclohexanone	871	α-Pinene	962
3-Methyloctane	873	Styrene	968
Tetrahydrofurfuryl alcohol	874	Isopropylbenzene (cumene)	983
Ethoxyethyl acetate	876	Furfural	987
Styrene	881	Allyl glycidyl ether	999
1,1,2,2-Tetrachloroethane	886	*n*-Decane	1000
o-Xylene	887	Ethoxyethyl acetate	1002
Butoxyethanol	890	*n*-Methyl-2-pyrrolidone	1009

Table 3 (*continued*)

	BP-1		**BP-10**
n-Nonane	900	Cyclohexanol	1010
Isopropylbenzene	919	*n*-Propylbenzene	1014
Bromobenzene	921	Butoxyethanol	1015
Ethanediol monoacetate	925	Furfuryl alcohol	1019
2-Methylcyclohexanone	930	*m*-Ethyltoluene	1022
3-Methylcyclohexanone	931	Furfuryl alcohol	1023
4-Methylcyclohexanone	937	*p*-Ethyltoluene	1023
Benzaldehyde	940	1,3,5-Trimethylbenzene	1029
α-Pinene	941	Cyclohexanone	1030
n-Propylbenzene	949	1,1,2,2-Tetrachloroethane	1045
Phenol	951	Ethanediol monoacetate	1046
m-Ethyltoluene	956	*o*-Ethyltoluene	1047
p-Ethyltoluene	958	α-Methylstyrene	1050
1,3,5-Trimethylbenzene	963	2-Methylcyclohexanone	1060
3-Methylnonane	972	1,2,4-Trimethylbenzene	1060
α-Methylstyrene	972	3-Methylcyclohexanone	1088
o-Ethyltoluene	975	4-Methylcyclohexanone	1095
1,2,4-Trimethylbenzene	990	1,2,3-Trimethylbenzene	1097
Benzyl chloride	996	*p*-Dichlorobenzene	1099
Benzyl chloride	997	*n*-Undecane	1100
n-Decane	1000	1-Methyl-2-isopropylbenzene	1104
p-Dichlorobenzene	1004	Benzaldehyde	1105
p-Dichlorobenzene	1004	1,3-Diethylbenzene	1111
n-Methyl-2-pyrrolidone	1009	Indane	1117
1,2,3-Trimethylbenzene	1019	Propenylbenzene	1117
o-Dichlorobenzene	1027	1,4-Diethylbenzene	1118
o-Cresol	1027	*n*-Butylbenzene	1120
Indane	1033	Benzyl chloride	1128
1-Methyl-2-isopropylbenzene	1034	Ethanediol diacetate	1130
Indene	1039	*o*-Dichlorobenzene	1135
Propenylbenzene	1041	1,3-Dimethyl-4-ethylbenzene	1146
p-Cresol	1047	Indene	1147
m-Cresol	1047	Benzyl chloride	1162
1,4-Diethylbenzene	1051	Butoxyethyl acetate	1185
n-Butylbenzene	1052	*n*-Dodecane	1200