



Designation: D7645 – 16

Standard Test Method for Determination of Aldicarb, Aldicarb Sulfone, Aldicarb Sulfoxide, Carbofuran, Methomyl, Oxamyl, and Thiofanox in Water by Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)¹

This standard is issued under the fixed designation D7645; 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 procedure covers the determination of aldicarb, aldicarb sulfone, aldicarb sulfoxide, carbofuran, methomyl, oxamyl, and thiofanox (referred to collectively as carbamates in this test method) in water by direct injection using liquid chromatography (LC) and detected with tandem mass spectrometry (MS/MS). These analytes are qualitatively and quantitatively determined by this test method. This test method adheres to multiple reaction monitoring (MRM) mass spectrometry.

1.2 The Detection Verification Level (DVL) and Reporting Range for the carbamates are listed in [Table 1](#).

1.2.1 The DVL is required to be at a concentration at least 3 times below the Reporting Limit (RL) and have a signal/noise ratio greater than 3:1. [Fig. 1](#) displays the signal/noise ratios of the primary single reaction monitoring (SRM) transitions, and [Fig. 2](#) displays the confirmatory SRM transitions at the DVLs for the carbamates.

1.2.2 The reporting limit is the concentration of the Level 1 calibration standard as shown in [Table 2](#) for the carbamates.

1.3 *Units*—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 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.*

¹ This test method is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.06 on Methods for Analysis for Organic Substances in Water.

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2. Referenced Documents

2.1 ASTM Standards:²

- D1129 Terminology Relating to Water
- D1193 Specification for Reagent Water
- D2777 Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D19 on Water
- D3694 Practices for Preparation of Sample Containers and for Preservation of Organic Constituents
- D3856 Guide for Management Systems in Laboratories Engaged in Analysis of Water
- D4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents
- D5847 Practice for Writing Quality Control Specifications for Standard Test Methods for Water Analysis
- E2554 Practice for Estimating and Monitoring the Uncertainty of Test Results of a Test Method Using Control Chart Techniques

2.2 Other Documents:³

- EPA Publication SW-846 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods
- EPA Method 531 Measurement of *N*-Methyl Carbamoyloximes and *N*-Methyl Carbamates in Drinking Water by Direct Aqueous Injection HPLC with Post Column Derivatization
- EPA Method 531.2 Measurement of *N*-Methylcarbamoyloximes and *N*-Methylcarbamates in Water by Direct Aqueous Injection HPLC with Postcolumn Derivatization

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), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA, 22161 or at <http://www.epa.gov/epawaste/hazard/testmethods/index.htm>.

TABLE 1 Detection Verification Level and Reporting Range

Analyte	DVL (ng/L)	Reporting Range (µg/L)
Aldicarb	250	1-100
Aldicarb Sulfone	250	1-100
Aldicarb Sulfoxide	250	1-100
Carbofuran	250	1-100
Methomyl	250	1-100
Oxamyl	250	1-100
Thiofanox	250	1-100

EPA Method 538 Determination of Selected Organic Contaminants in Drinking Water by Direct Aqueous Injection-Liquid Chromatography/Tandem Mass Spectrometry (DAI-LC/MS/MS)

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this standard, refer to Terminology **D1129**.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *carbamates, n*—in this test method, aldicarb, aldicarb sulfone, aldicarb sulfoxide, carbofuran, methomyl, oxamyl, and thiofanox collectively.

3.2.2 *detection verification level, DVL, n*—a concentration that has a signal/noise ratio greater than 3:1 and is at least 3 times below the Reporting Limit (RL).

3.2.3 *independent reference material, IRM, n*—a material of known purity and concentration obtained either from the National Institute of Standards and Technology (NIST) or other reputable supplier. The IRM shall be obtained from a different lot of material than is used for calibration.

3.3 Acronyms:

- 3.3.1 *CCC, n*—Continuing Calibration Check
- 3.3.2 *IC, n*—Initial Calibration
- 3.3.3 *LC, n*—Liquid Chromatography
- 3.3.4 *LCS/LCSD, n*—Laboratory Control Sample/
Laboratory Control Sample Duplicate
- 3.3.5 *MeOH, n*—Methanol
- 3.3.6 *mM, n*—millimolar, 1×10^{-3} moles/L
- 3.3.7 *MRM, n*—Multiple Reaction Monitoring
- 3.3.8 *MS/MSD, n*—Matrix Spike/Matrix Spike Duplicate
- 3.3.9 *NA, adj*—Not Available
- 3.3.10 *ND, n*—non-detect
- 3.3.11 *P&A, n*—Precision and Accuracy
- 3.3.12 *PPB, n*—parts per billion
- 3.3.13 *PPT, n*—parts per trillion
- 3.3.14 *QA, adj*—Quality Assurance
- 3.3.15 *QC, adj*—Quality Control
- 3.3.16 *RL, n*—Reporting Limit
- 3.3.17 *RSD, n*—Relative Standard Deviation
- 3.3.18 *RT, n*—Retention Time
- 3.3.19 *SDS, n*—Safety Data Sheets

3.3.20 *SRM, n*—Single Reaction Monitoring

3.3.21 *SS, n*—Surrogate Standard

3.3.22 *TC, n*—Target Compound

3.3.23 *µM, n*—micromolar, 1×10^{-6} moles/L

3.3.24 *VOA, n*—Volatile Organic Analysis

4. Summary of Test Method

4.1 This is a performance-based method, and modifications are allowed to improve performance.

4.2 For carbamate analysis, samples are shipped to the lab acidified between 0°C and 6°C and analyzed within 14 days of collection. In the lab, the samples are spiked with surrogates, filtered using a syringe driven filter unit, and analyzed directly by LC/MS/MS.

4.3 The carbamates, methomyl- $^{13}\text{C}_2$, ^{15}N (surrogate) and carbofuran- $^{13}\text{C}_6$ (surrogate) are identified by retention time and two SRM transitions. The target analytes and surrogate are quantitated using the primary SRM transitions utilizing an external calibration. The final report issued for each sample lists the concentration of carbamates and the surrogate recoveries.

5. Significance and Use

5.1 This test method has been developed by U.S. EPA Region 5 Chicago Regional Laboratory (CRL).

5.2 The *N*-methyl carbamate (NMC) pesticides: aldicarb, carbofuran, methomyl, oxamyl, and thiofanox have been identified by EPA as working through a common mechanism. These affect the nervous system by reducing the ability of enzymes. Enzyme inhibition was the primary toxicological effect of regulatory concern to EPA in assessing the NMC's food, drinking water, and residential risks. In most of the country, NMC residues in drinking water sources are at levels that are not likely to contribute substantially to the multi-pathway cumulative exposure. Shallow private wells extending through highly permeable soils into shallow, acidic ground water represent what the EPA believes to be the most vulnerable drinking water. Aldicarb sulfone and aldicarb sulfoxide are breakdown products of aldicarb and should also be monitored due to their toxicological effects.⁴

5.3 This test method has been investigated for use with reagent, surface, and drinking water for the selected carbamates: aldicarb, aldicarb sulfone, aldicarb sulfoxide, carbofuran, methomyl, oxamyl, and thiofanox.

6. Interferences

6.1 Method interferences may be caused by contaminants in solvents, reagents, glassware, and other apparatus producing discrete artifacts or elevated baselines. All of these materials are demonstrated to be free from interferences by analyzing laboratory reagent blanks under the same conditions as samples.

⁴ Additional information about Carbamate pesticides area available from United States Environmental Protection Agency (EPA), <http://www.epa.gov>.

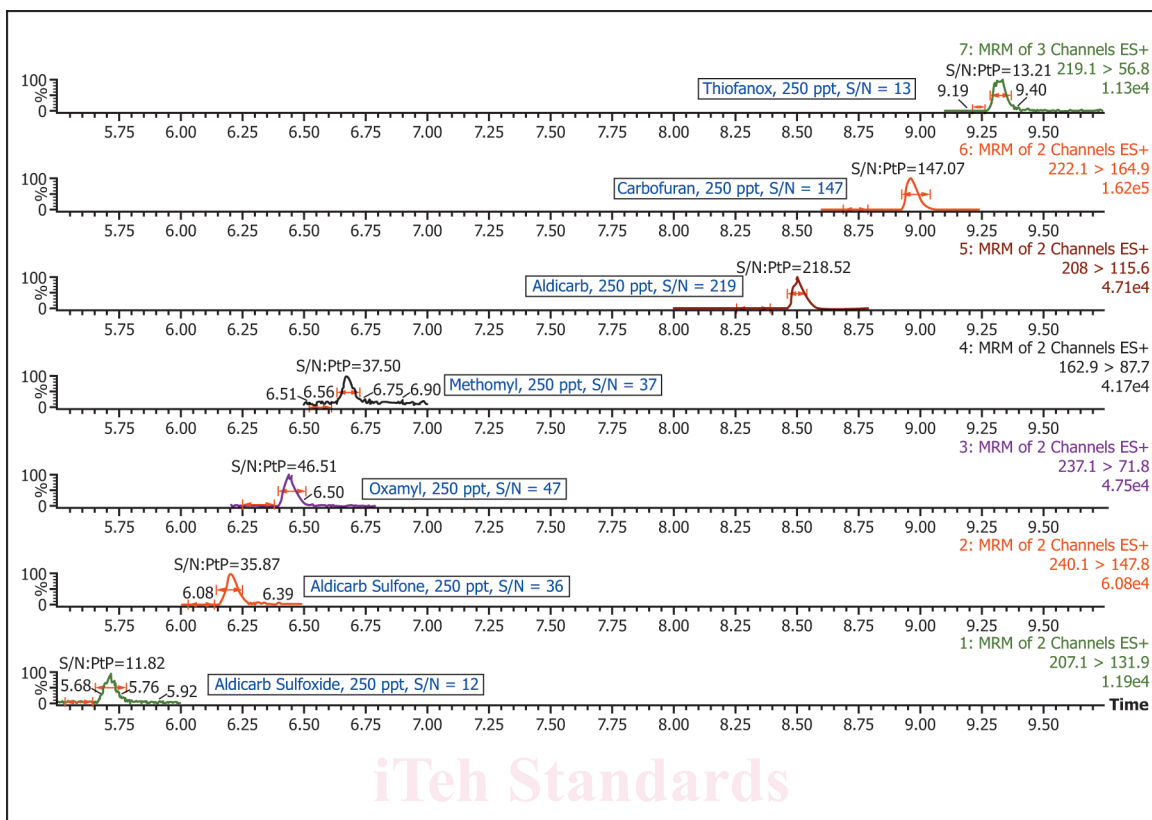


FIG. 1 Example Primary SRM Chromatograms Signal/Noise Ratios

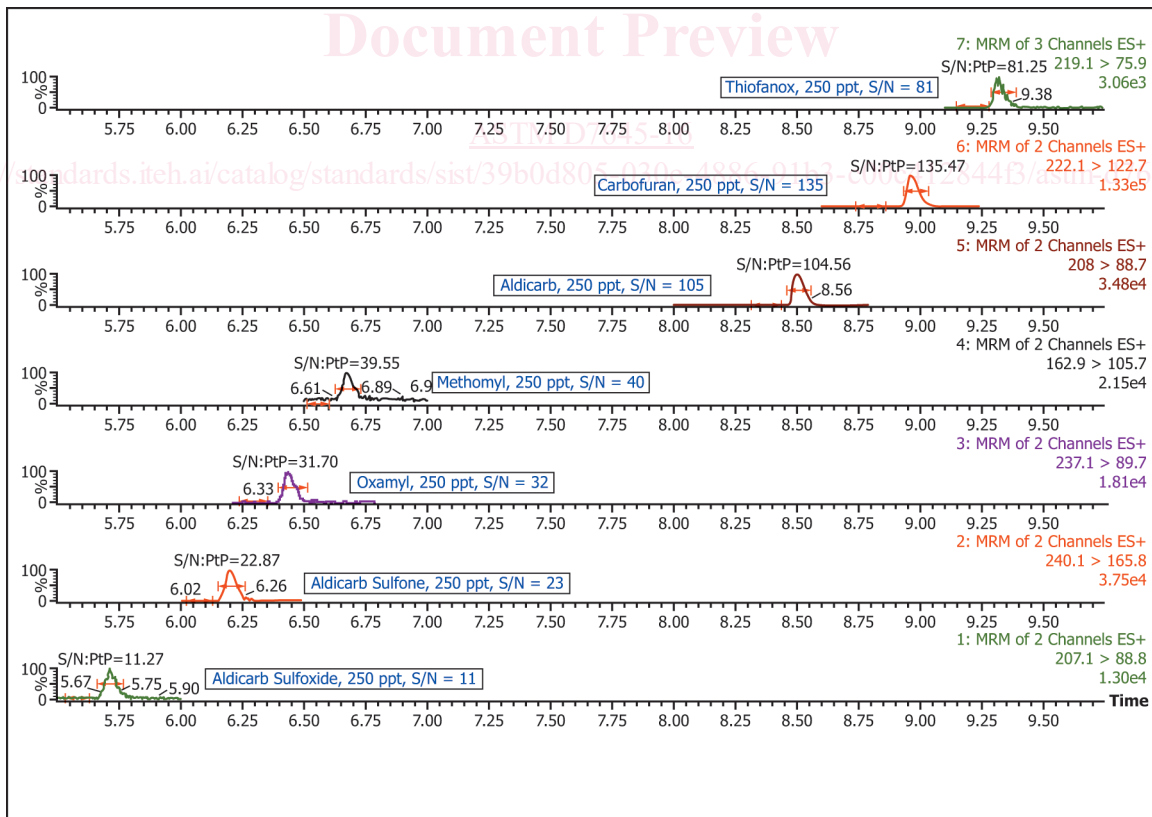


FIG. 2 Example Confirmatory SRM Chromatograms Signal/Noise Ratios

TABLE 2 Concentrations of Calibration Standards (PPB)

Analyte/Surrogate	LV 1	LV 2	LV 3	LV 4	LV 5	LV 6	LV 7	LV 8
Aldicarb	1	5	10	25	35	50	75	100
Aldicarb Sulfone	1	5	10	25	35	50	75	100
Aldicarb Sulfoxide	1	5	10	25	35	50	75	100
Carbofuran	1	5	10	25	35	50	75	100
Methomyl	1	5	10	25	35	50	75	100
Oxamyl	1	5	10	25	35	50	75	100
Thiofanox	1	5	10	25	35	50	75	100
Carbofuran- ¹³ C ₆ (Surrogate)	1	5	10	25	35	50	75	100
Methomyl- ¹³ C ₂ , ¹⁵ N (Surrogate)	1	5	10	25	35	50	75	100

6.2 All glassware is washed in hot water with detergent and rinsed in hot water followed by distilled water. The glassware is then dried and heated in an oven at 250°C for 15 to 30 minutes. All glassware is subsequently cleaned with acetone followed by methanol.

6.3 All reagents and solvents should be pesticide residue purity or higher to minimize interference problems.

6.4 Matrix interferences may be caused by contaminants in the sample. The extent of matrix interferences can vary considerably from sample source depending on variations of the sample matrix.

7. Apparatus

7.1 LC/MS/MS System:

7.1.1 *Liquid Chromatography (LC) System*—A complete LC system is needed to analyze samples.⁵ This should include a sample injection system, a solvent pumping system capable of mixing solvents, a sample compartment capable of maintaining required temperature and a temperature controlled column compartment. A system that is capable of performing at the flows, pressures, controlled temperatures, sample volumes, and requirements of the standard may be used.

7.1.2 *Analytical Column*⁶—A C18 column was used to develop this test method.

7.2 *Tandem Mass Spectrometer (MS/MS) System*—A MS/MS system capable of MRM analysis.⁷ Any system that is capable of performing at the requirements in this standard may be used.

7.3 Filtration Device:

7.3.1 *Hypodermic syringe*—A lock tip glass syringe capable of holding a syringe-driven filter unit or similar may be used.

7.3.1.1 A 25-mL lock tip glass syringe size is recommended since a 25-mL sample size is used in this test method.

⁵ An ACQUITY UltraPerformance Liquid Chromatography (UPLC) (a trademark of Waters Technologies Corporation in Wilmington, DE) System was used to develop this test method. All parameters in this test method are based on this system and may vary depending on your instrument.

⁶ Waters ACQUITY UPLC (a trademark of Waters Technologies Corporation in Wilmington, DE) BEH C18, 2.1 × 100 mm, 1.7 μm particle size was used to develop this test method. Any column that achieves adequate resolution may be used. The retention times and order of elution may change depending on the column used and need to be monitored.

⁷ A Quattro Premier XE (a trademark of Waters Technologies Corporation in Wilmington, DE) tandem quadrupole mass spectrometer was used to develop this test method. All parameters in this test method are based on this system and may vary depending on your instrument.

7.3.2 *Filter unit*⁸—PVDF filter units were used to filter the samples.

8. Reagents and Materials

8.1 *Purity of Reagents*—High Performance Liquid Chromatography (HPLC) pesticide residue analysis and spectrophotometry grade chemicals shall be used in all tests. Unless indicated otherwise, it is intended that all reagents shall conform to the Committee on Analytical Reagents of the American Chemical Society.⁹ Other reagent grades may be used provided they are first determined to be of sufficiently high purity to permit their use without affecting the accuracy of the measurements.

8.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type 1 of Specification D1193. It must be demonstrated that this water does not contain contaminants at concentrations sufficient to interfere with the analysis.

8.3 *Gases*—Ultrapure nitrogen and argon.

8.4 Acetonitrile (CAS # 75-05-8).

8.5 Methanol (CAS # 67-56-1).

8.6 Acetone (CAS # 67-64-1).

8.7 Ammonium Formate (CAS # 540-69-2).

8.8 Acetic Acid (Glacial, CAS # 64-19-7).

8.9 Aldicarb (CAS # 116-06-3).

8.10 Aldicarb Sulfone (CAS # 1646-88-4).

8.11 Aldicarb Sulfoxide (CAS # 1646-87-3).

8.12 Carbofuran (CAS # 1563-66-2).

8.13 Oxamyl (CAS # 23135-22-0).

8.14 Methomyl (CAS # 16752-77-5).

8.15 Thiofanox (CAS # 39196-18-4).

⁸ A Millex HV Syringe Driven Filter Unit PVDF 0.22 μm (Millipore Corporation, Catalog #SLGV033NS; Millex is a trademark of Merck KGAA, Darmstadt, Germany) has been found suitable for use for this test method, any filter unit may be used that meets the performance of this test method may be used.

⁹ Reagent Chemicals, American Chemical Society Specifications, American Chemical Society, Washington, D.C. For Suggestions on the testing of reagents not listed by the American Chemical Society, see Annual Standards for Laboratory Chemicals, BDH Ltd., Poole, Dorset, U.K., and the United States Pharmacopeia and National Formulators, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

8.16 Methomyl-¹³C₂, ¹⁵N (acetohydroxamate-¹³C₂, ¹⁵N, CAS # (unlabeled) 16752-77-5).

8.17 Carbofuran-¹³C₆ (Ring-¹³C₆, CAS # (unlabeled) 1563-66-2).

9. Hazards

9.1 Normal laboratory safety applies to this test method. Analysts should wear safety glasses, gloves, and lab coats when working in the lab. Analysts should review the Safety Data Sheets (SDS) for all reagents used in this test method.

10. Sampling

10.1 *Sampling and Preservation*—Grab samples should be collected in ≥25 mL pre-cleaned amber glass bottles with Teflon¹⁰-lined caps demonstrated to be free of interferences. All samples are acidified with glacial acetic acid to pH ≤3.8 upon collection. A few drops or less of glacial acetic acid is required per 40 mL water sample collected. Chlorinated drinking water samples are also dechlorinated with ascorbic acid; 10 mg of ascorbic acid is added to each 40 mL volume of water prior to collection. Drinking water samples must be dechlorinated upon collection. Aldicarb oxidizes when residual chlorine is present in the sample. This test method is based on a 25 mL sample size per analysis. If different sample sizes are used, spiking solution amounts and preservatives will need to be modified. Conventional sampling practices should be followed. Refer to Guide [D3856](#) and Practices [D3694](#). Store samples between 0°C and 6°C from the time of collection until analysis. Analyze the sample within 14 days of collection.

NOTE 1—Less sample volume is acceptable, but the spike amounts and sample preservatives must be adjusted accordingly.

10.1.1 EPA Method 531.2 demonstrated that carbamates are more stable under acidic conditions. Potassium dihydrogen citrate buffer is used in Method 531.2 to bring the pH to ~3.8, but this buffer is incompatible with LC/MS/MS. Therefore, the pH adjustment is accomplished with acetic acid in this test method. EPA Method 531.2 demonstrated that carbamates under acidic conditions are stable for at least 28 days. EPA Method 531 demonstrated that oxamyl and methomyl are stable for at least 70 days at pH 3 ± 0.2. Holding time is dependent upon your individual matrix and will vary. Practice [D4841](#) may be used to conduct a holding time study on your individual matrix.

11. Preparation of LC/MS/MS

11.1 *LC Chromatograph Operating Conditions*:⁵

11.1.1 Injection volumes of all calibration standards and samples are made at 50 µL volume using a full loop injection. If a 50 µL volume loop is installed in the LC, a “full loop” mode is the preferred technique when performing fast, qualitative analyses. This mode should be used whenever accuracy and precision are the primary concerns. The first sample analyzed after the calibration curve is a blank to ensure there is no carry-over. The gradient conditions for the liquid chromatograph are shown in [Table 3](#).

TABLE 3 Gradient Conditions for Liquid Chromatography

Time (min)	Flow (µL/min)	Percent	
		95 % Water/ 5 % Methanol, 5 mM NH ₄ CO ₂ H	95 % Methanol/ 5 % Water, 5 mM NH ₄ CO ₂ H
0.0	300	100	0
2.0	300	100	0
3.0	300	95	5
5.0	300	85	15
10.0	300	0	100
11.5	300	0	100
12.0	300	100	0
14.0	300	100	0

11.2 *LC Sample Manager Conditions*:

11.2.1 *Wash Solvents*—Weak wash is 2.4 mL of 95 % water/5 % methanol. Strong wash is 1.2 mL of methanol. The strong wash solvent is needed to eliminate carry-over between injections of carbamate samples. The weak wash is used to remove the strong wash solvent. Instrument manufacturer specifications should be followed in order to eliminate sample carry-over.

11.2.2 *Temperatures*—Column, 30°C; Sample compartment, 15°C.

11.2.3 *Seal Wash*—Solvent: 50 Acetonitrile/50 Water; Time: 5 minutes.

11.3 *Mass Spectrometer Parameters*:⁷

11.3.1 To acquire the maximum number of data points per SRM channel while maintaining adequate sensitivity, the tune parameters may be optimized according to your instrument. Each peak requires at least 10 scans per peak for adequate quantitation. This test method contains two surrogates, which are isotopically labeled methomyl and carbofuran, and seven carbamates, which are split up into seven MRM acquisition functions to optimize sensitivity. Variable parameters regarding retention times, SRM transitions, and cone and collision energies are shown in [Table 4](#). Mass spectrometer parameters used in the development of this test method are listed below:

The instrument is set in the Electrospray positive source setting.
 Capillary Voltage: 3.5 kV
 Cone: Variable depending on analyte ([Table 4](#))
 Extractor: 2 Volts
 RF Lens: 0.1 Volts
 Source Temperature: 120°C
 Desolvation Temperature: 375°C
 Desolvation Gas Flow: 800 L/hr
 Cone Gas Flow: 25 L/hr
 Low Mass Resolution 1: 14.5
 High Mass Resolution 1: 14.5
 Ion Energy 1: 0.5
 Entrance Energy: -1
 Collision Energy: Variable depending on analyte ([Table 4](#))
 Exit Energy: 0
 Low Mass Resolution 2: 14.5
 High Mass resolution 2: 14.5
 Ion Energy 2: 0.7
 Multiplier: 650
 Gas Cell Pirani Gauge: 7.0 × 10⁻³ Torr
 Inter-Channel Delay: 0.005 seconds
 Inter-Scan Delay: 0.005 seconds
 Dwell: 0.075 seconds

12. Calibration and Standardization

12.1 The mass spectrometer must be calibrated in accordance with manufacturer specifications before analysis. In

¹⁰ Teflon is a trademark of The Chemours Company, LLC, in Wilmington, DE.

TABLE 4 Retention Times, SRM Ions, and Analyte-Specific Mass Spectrometer Parameters

Analyte	Primary/ Confirmatory	Retention Time (min)	Cone Voltage (Volts)	Collision Energy (eV)	SRM Mass Transition (Parent > Product)	Primary/ Confirmatory SRM Area Ratio
Aldicarb	Primary	8.50	10	7	208.0 > 115.6	1.4
	Confirmatory		10	16	208.0 > 88.7	
Aldicarb Sulfone	Primary	6.20	13	13	240.1 > 147.8	1.6
	Confirmatory		13	11	240.1 > 165.8	
Aldicarb Sulfoxide	Primary	5.72	16	6	207.1 > 131.9	1.1
	Confirmatory		16	14	207.1 > 88.8	
Carbofuran	Primary	8.96	22	12	222.1 > 164.9	1.2
	Confirmatory		22	20	222.1 > 122.7	
Methomyl	Primary	6.68	15	10	162.9 > 87.7	1.8
	Confirmatory		15	10	162.9 > 105.7	
Oxamyl	Primary	6.44	11	11	237.1 > 71.8	2.6
	Confirmatory		11	7	237.1 > 89.7	
Thiofanox	Primary	9.32	12	8	219.1 > 56.8	4.8
	Confirmatory		12	5	219.1 > 75.9	
Carbofuran- ¹³ C ₆ (Surrogate)	Primary	8.96	22	11	228.1 > 170.9	1.3
	Confirmatory		22	21	228.1 > 128.8	
Methomyl- ¹³ C ₂ , ¹⁵ N (Surrogate)	Primary	6.68	18	8	165.8 > 90.7	1.7
	Confirmatory		18	9	165.8 > 108.7	

order to obtain accurate analytical values through using this test method within the confidence limits, the following procedures must be followed when performing the test method. Prepare all solutions in the lab using Class A volumetric glassware.

12.2 Calibration and Standardization—To calibrate the instrument, analyze eight calibration standards containing the eight concentration levels of the carbamates, methomyl-¹³C₂, ¹⁵N and carbofuran-¹³C₆ prior to analysis as shown in [Table 2](#). A calibration stock standard solution is prepared from standard materials or they are purchased as certified solutions. Stock Standard Solution A containing the carbamates and surrogates is prepared at Level 8 concentration and aliquots of that solution are diluted to prepare Levels 1 through 7. The following steps will produce standards with the concentration values shown in [Table 2](#). The analyst is responsible for recording initial component weights carefully when working with pure materials and correctly carrying the weights through the dilution calculations.

12.2.1 Prepare Stock Standard Solution A (Level 8) by adding to a 50 mL volumetric flask individual solutions of the following: 100 µL of aldicarb, aldicarb sulfone, aldicarb sulfoxide, carbofuran, methomyl, oxamyl, and thiofanox, each at 50 ppm in methanol and 50 µL of methomyl-¹³C₂, ¹⁵N in methanol and carbofuran-¹³C₆ in 1,4-dioxane each at 100 ppm, dilute to 50 mL with water. The preparation of the Level 8 standard can be accomplished using different volumes and concentrations of stock solutions as is accustomed in the individual laboratory. Depending on the prepared stock concentrations, the solubility at that concentration will have to be ensured.

12.2.2 Aliquots of Solution A are then diluted with water to prepare the desired calibration levels in 2-mL amber glass LC vials. The calibration vials must be used within 24 hours to ensure optimum results. Stock calibration standards are routinely replaced every 7 days if not previously discarded for quality control failure. Calibration standards are not filtered.

12.2.3 Inject each standard and obtain its chromatogram. An external calibration technique is used to monitor the primary

and confirmatory SRM transitions of each analyte. Calibration software is utilized to conduct the quantitation of the target analytes and surrogates using the primary SRM transition. The ratios of the primary/confirmatory SRM transition area counts are given in [Table 4](#) and will vary depending on the individual tuning conditions. The primary/confirmatory SRM transition area ratio must be within 35 % of the individual labs' accepted primary/confirmatory SRM transition area ratio. The primary SRM transition of each analyte is used for quantitation and the confirmatory SRM transition for confirmation. This gives added confirmation by isolating the parent ion, forming two product ions via fragmentation, and relating it to the retention time in the calibration standard.

12.2.4 The calibration software manual should be consulted to use the software correctly. The quantitation method is set as an external calibration using the peak areas in ppt or ppb units, as long as the analyst is consistent. Concentrations may be calculated using the data system software to generate linear regression or quadratic calibration curves. Forcing the calibration curve through the origin is not recommended.

12.2.5 Linear calibration may be used if the coefficient of determination, r^2 , is >0.98 for the analyte. The point of origin is excluded and a fit weighting of 1/X is used in order to give more emphasis to the lower concentrations. If one of the calibration standards other than the high or low point causes the r^2 of the curve to be <0.98, this point must be re-injected or a new calibration curve must be regenerated. If the low and/or high point is excluded, minimally a six point curve is acceptable but the reporting range must be modified to reflect this change.

12.2.6 Quadratic calibration may be used if the coefficient of determination, r^2 , is >0.99 for the analyte. The point of origin is excluded, and a fit weighting of 1/X is used in order to give more emphasis to the lower concentrations. If one of the calibration standards causes the curve to be <0.99, this point must be re-injected or a new calibration curve must be regenerated. Minimally a six point curve is acceptable using a