Chromatography

MACHEREY-NAGEL

Derivatization reagents for GC

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A guide to derivatization reagents for Gas Chromatography

Regarding derivatization

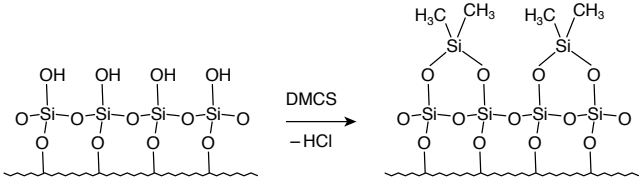
Derivatization is one of the most common ways to prepare compounds for GC that are otherwise difficult to separate. Through derivatization, it is possible to improve the separation by replacing active hydrogens from the analyte with various groups that are easier to handle. Derivatization generally improves the following GC parameters:

- chromatographic behavior
- tailing
- thermal and chemical stability
- detectability
- volatility.

To achieve a satisfying rate of derivatization, it is essential to keep the following requirements in mind:

- the derivatization reaction needs to be complete ≈ 100 %
- no loss of sample during derivatization
- the overall structure of the analyte will not be altered
- produced derivative will be stable over time
- no interaction between the reagent and the chromatographic system.

It is also important that all the instruments, e.g., laboratory glassware, will not interfere with the sample. To make sure that no compounds containing -OH, -SH or -NH groups will be adsorbed by present Si-OH on the surface of the glass, a deactivation process may be necessary. This is commonly achieved by rinsing the glass with a silylating agent, e.g., DMCS or HMDS, hence masking all silanols with non adsorptive methyl groups.



Glass **Silanized glass**

Silanization Procedure for Glass inserts

Procedure:
The inserts are silanized under reflow with a solution of 40 % HMDS (Bis(trimethylsilyl)amine, REF 701240.510) in toluene for two hours. When the inserts have cooled down, they are at first rinsed with methanol then with dichloromethane, before they are dried in a cabinet desiccator at 100 °C for another 60 minutes. Silanized inserts may only be touched with suitable gloves.

As a matter of course, all other components of the sample preparation and handling process need to be contaminant-free and in top condition. Since water is, in most cases, a problem, it has to be removed from the derivatization process, e.g. by adding Na_2SO_4 to the reaction mixture. Like all reactions, derivatization takes time and a certain amount of heat to go to completion. As duration may vary greatly, dependent on the reactivity of the analyte, it is often necessary to screen several reagents for the best result. It is also important to realize that there is no such thing as the best derivatization method. There will always be several working solutions to a chromatographic problem with its own advantages and drawbacks, dependent on the equipment or on the approach of the chemist.

Derivatization reagents

There many reagents in use today for derivatization. There are three categories they can be allocated to: *Acylation*, *Alkylation* (Methylation) and *Silylation*.

Acylation / Benzoylation

Generally, Acylation involves the introduction of an acyl group into a molecule with a replaceable hydrogen, or across a double bond. Acylation is used to convert compounds like alcohols, amines and thiols into their respective esters, amides and thioesters. Additionally, they enhance the detectability of the compounds by adding halogenated carbon to the compounds. This is achieved through the reaction with fluorinated acyl halides, anhydrides or bisacylamides. While the corresponding acidic by-products of the reactions with acyl halides and anhydrides need to be removed from the system by a suited base, e.g., pyridine, to prevent column damage. By-products of bisacylamides are not acidic and normally do not interfere with the subsequent analysis. Hence, they are favorable reagents for Acylations.

Acylation reagents from MACHEREY-NAGEL:

Acyl halides:

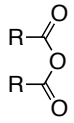
Pentafluorobenzoyl chloride (PFBC):
R= C_6F_5, X=Cl

M: 230.52 g/mol, Bp: 158–159 °C (760 mm Hg), density d20 °/4 ° = 1.601

Will react with hydroxyls, primary and secondary amines, amides and thiols

REF 701270.201

Anhydrides:



Trifluoroacetic acid anhydride (TFAA):
R=CF_3

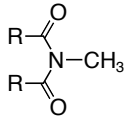
M: 210.04 g/mol, Bp: 39.5–40.5 °C (760 mm Hg), density d20 °/4 ° = 1.490

Heptafluorobutyric acid anhydride (HFBA):
R=C_3F_7

M: 410.06 g/mol, Bp: 106–107 °C (760 mm Hg), density d20 °/4 ° = 1.665

Acylation with fluorinated acid anhydrides can be used for alcohols, phenols, carboxylic acids, amines, amino acids and steroids forming volatile, stable derivatives suited for FID as well as for ECD detection.

Bisacylamides:



N-methyl-bis(trifluoroacetamide) (MBTFA):
R=CF_3

M: 223.08 g/mol, Bp: 123–124 °C (760 mm Hg), density d20 °/4 ° = 1.55

N-methyl-bis(heptafluorobutyramide) (MBHFBA):
R=C_3F_7

M: 423.1 g/mol, Bp: 165–166 °C (760 mm Hg), density d20 °/4 ° = 1.673

Acylation with fluorinated acid amides is recommended for alcohols, primary and secondary amines as well as for thiols under mild, neutral conditions. MBTFA also forms very volatile derivatives with carbohydrates.

Acylation Procedures:

Acylation with fluorinated acid anhydrides

Procedure:
Dissolve 0.1 to 1 mg sample in 0.1 mL solvent, add 0.1 mL of the anhydride and heat to 60–70 °C for 1–2 h. If the sample need not be concentrated prior to the analysis and if there is no danger of catalytically induced side reactions, pyridine is used as solvent. The reaction solution can be injected directly into the gas chromatograph. Otherwise, use a volatile solvent and evaporate solvent, excess reagent and free acid in a stream of nitrogen. Dissolve residue in 50 µL hexane, chloroform etc. and inject aliquot portions.

TFAA MN Appl. No. 213041 · HFBA MN Appl. No. 213042

Acylation with fluorinated acid amides

Procedure:
Add 0.5 mL MBTFA or MBHFBA to about 2 mg sample. If there is no reaction at ambient temperature, heat the reaction mixture to 120 °C. Compounds difficult to dissolve, can be trifluoroacetylated in suitable solvent mixtures. It is recommended to use a ratio of solvent to MBTFA or MBHFBA of 4:1. The reaction mixture is chromatographed directly.

MBTFA MN Appl. No. 213051 · MBHFBA MN Appl. No. 213052

Summary Acylation:

- Addition of halogenated carbons enhances detectability by ECD
- Derivatives are hydrolytically stable
- Increased sensitivity by adding molecular weight

but

- Acylation reagents are moisture sensitive
- Reaction products (acidic by-products) often have to be removed before analysis

Alkylation (Methylation) / Esterification

Alkylation is a derivatization method used to replace an acidic hydrogen with an alkyl or methyl group. It is generally restricted to amines or hydroxy groups like in amino or carboxylic acids. The resulting derivatives are ethers, esters, methylamines or –amides and less polar than the original compounds. Therefore, less hydrogen bonding occurs. The acidity of the hydrogen to be replaced significantly determines the conditions needed to perform the Alkylation. The less acidic, the more vigorous the conditions.

Methylation reagents from MACHEREY-NAGEL:

Dialkylacetals

N,N-dimethylformamide dimethylacetal (DMF-DMA)

M: 119.17 g/mol, Bp: 106–107 °C (760 mm Hg),
density d20 °/4 ° = 0.897

DMF-DMA is recommended for sterically hindered carboxylic acids, aldehydes, phenols and amines.

Trimethylsulfonium compounds

Trimethylsulfonium hydroxide (TMSH, 0.2 M in methanol)

M: 94.06 g/mol

Methylation with TMSH is recommended for free acids, chlorophenoxycarboxylic acids, their salts and derivatives as well as for phenols and chlorophenols. Lipids or triglycerides can be converted to the corresponding fatty acid methyl esters (FAMEs) by a simple transesterification.

This reaction is very elegant and convenient, because it is just necessary to add the reagent (0.2 M in methanol) to the sample solution. Removal of excess reagent is not required, since in the injector of the gas chromatograph, at 250 °C, pyrolysis to volatile methanol and dimethylsulfide will occur. Due to the high reactivity, complete derivatization is often obtained at ambient temperature. However, heating (e.g., 10 min at 100 °C) in a closed sample vial may be necessary to complete the reaction.

Esterification reagents

Methylation with methanol/TMCS

A 1M solution of TMCS in methanol is suited for the esterification of free carboxylic acids and transesterification of glycerides. Formation of HCl catalyzes the reaction. TMCS and silyl ether remove water and thus drive the reaction to completion. The mixture should be freshly prepared.

Alkylation procedures:

Methylation with TMSH

Procedure:
Dissolve 100 mg sample (e.g., butter) in 5 mL of a solvent (e.g., tert.-butyl methyl ether). Add 50 µL reagent to 100 µL of this solution. The mixture is injected directly. The temperature of the injector must be at least 250 °C.

MN Appl. No. 213060

Methylation with DMF-DMA

Procedure:
Add 1 mL of a mixture of DMF-DMA and pyridine (1:1) to 1–50 mg fatty acids. The sample can be injected as soon as a clear solution has formed. It is recommended, however, to heat the solution to 60–100 °C for 10–15 min.

MN Appl. No. 213070

Methylation with methanol – TMCS

Procedure:
Add 1 mL methanol – TMCS to about 50 mg carboxylic acid or glyceride and heat. Then evaporate in a stream of nitrogen and dissolve again for injection in, e.g., n-heptane.

MN Appl. No. 213080

Summary Alkylation (Methylation):

- Methylation derivatives are generally stable
- Wide range of reaction conditions (from strongly acidic to strongly basic)
- Some reactions can be achieved with water present

but

- Reactions are limited to acidic hydrogens or amines
- Reaction conditions may be extreme

Silylation

Silylation is the most versatile method of derivatization in GC, i.e. more than 80 % of all derivatization reactions are actually silylations. Usually the term silylation in GC stands for replacement of active hydrogen atoms by a trimethylsilyl group (TMS derivative). Sometimes, however, trialkylsilyl groups or dimethylalkylsilyl groups with longer alkyl chains are used for derivatization. The trialkylsilyl group increases volatility and enhances thermal stability of the sample.

As with Methylation, the replacement of an active hydrogen with a silyl group, reduces the polarity of the compound, as well as hydrogen bonding. Additionally, Silylation improves volatility, so that many compounds that are normally considered nonvolatile or thermally instable, can be chromatographed easily. Introducing a silyl group may also enhance the GC-MS properties of the derivative, either through characteristic ions or more favorable diagnostic patterns for structure investigations. However, the reaction is very susceptible to water and/or alcohol, so the reagents should always be dry and pure. It is also important to mention that silylated compounds should not be used with WAX or FFAP phases, as the OH groups of the stationary phase will definitely become derivatized by the silylating reagent.

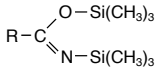
Silylation can be catalyzed either acidically by addition of TMCS or basically by addition of pyridine or TSIM (e.g., for sterically hindered molecules, such as tertiary alcohols).

Reactivity of silylation reagents (acc. to M. Donike): TMS amides (e.g., BSA, MSTFA) > TMS amine = TSIM > Enol-O-TMS ether > S-TMS ether > O-TMS ether > TMS-O-TMS

Stability of the TMS derivatives: O-TMS ether > S-TMS ether > Enol-O-TMS ether > TMS amine > TMS amide

Silylation reagents from MACHEREY-NAGEL:

Amides:



N,O-bis-trimethylsilyl-acetamide (BSA):
$R=CH_3$

M: 203.4 g/mol, Bp: 71–73 °C (35 mm Hg), density d20 °/4 ° = 0.832

BSA is a strong silylation reagent that forms very stable TMS derivatives with a large variety of compounds, e.g., non-sterically hindered alcohols, amines, carboxylic acids, phenols, enols, steroids, biogenic amines and alkaloids. Presence of 1% water can increase the reaction rate substantially.

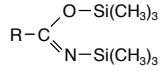
Not recommended for use with carbohydrates or very low molecular weight compounds

Good solvent for polar compounds, but frequently used in combination with a solvent (pyridine, DMF etc.), with other silylation reagents or catalysts such as TFA, HCl or TMBS.

Used in combination with DMF, BSA is the reagent of choice for derivatizing phenols

N,O-bis-trimethylsilyl-trifluoroacetamide (BSTFA): R=CF_3

M 257.4 g/mol, Bp 40 °C (12 mm Hg),
density d20 °/4 ° = 0.961



BSTFA is a powerful trimethylsilyl donor with approximately the same donor strength as the nonfluorinated analog BSA. Advantage of BSTFA over BSA: greater volatility of its derivatives (particularly useful for GC of some lower boiling TMS amino acids). BSTFA will generally react with all organic material present, but may not derivatize some amides, secondary amines and hindered hydroxyl groups. However, adding 1% TMCS (SILYL-991) will solve that problem.

N-methyl-N-trimethylsilyl-trifluoroacetamide (MSTFA):
R' = CF_3, R" = CH_3

M: 199.1 g/mol, Bp: 70 °C (75 mm Hg),
density d20 °/4 ° = 1.11

MSTFA is the most volatile trimethylsilyl amide available.

MSTFA is a very strong TMS donor that does not cause any noticeable FID fouling even after long-time measuring series. It is one of the most important silylating reagents. It can be used, to silylate the hydrochloride salts of amines or amino acids directly.

The already good solution characteristics can be improved by adding submolar quantities of protic solvents (e.g., TFA for extremely polar compounds such as hydrochlorides) or pyridine (e.g., for carbohydrates).

Recommended applications:

Carboxylic acids, hydroxyl- and ketocarboxylic acids, amino acids, amines, alcohols, polyalcohols, sugars, mercaptans and similar compounds with active hydrogen atoms.

Advantages:

- Complete reaction with high reaction rates, even without a catalyst (1–2 % TMCS or TSIM)
- By-product of the reaction (N-methyltrifluoroacetamide) features high volatility and short retention time.

N-methyl-N-trimethylsilyl-heptafluorobutyramide (MSHFBA):
R' = C_3F_7, R" = CH_3

M: 299.1 g/mol, Bp: 148 °C (760 mm Hg)

Similar to MSTFA in reactivity and chromatography.

Recommended applications:

Carboxylic acids, alcohols, phenols, primary and secondary amines and amino acids.

Used either alone or in combination with a catalyst (TMCS, TSIM) or another silylation reagent with or without solvent.

By-product N-methylheptafluorobutyric amide has a lower retention time than the silylating reagent.

Especially useful for FID, because, due to the large 7:1 ratio of fluorine to silicon, the degradation of excess MSHFBA does not produce SiO_2 but volatile, non-corrosive silicon compounds.

N-methyl-N-tert-butyldimethylsilyl-trifluoroacetamide (MBDSTFA):
R' = CF_3, R" = C_4H_9

M: 241.3 g/mol, Bp: 168–170 °C (760 mm Hg),
density d20 °/4 ° = 1.121

MBDSTFA is a silylation reagent that donates a tert-butyldimethylsilyl group (TBDMS) for derivatizing active hydrogens in hydroxyl, carboxyl and thiol groups, primary and secondary amines, as well as in amino acids.

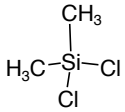
Fast reactions (typically 5–20 min) with high yields (> 96 %). By-products are neutral and volatile.

TBDMS ethers are 104 times more stable than the corresponding TMS ethers. Chromatographic retention times are longer due to the large protecting group, which may improve some separations.

Very useful for GC-MS applications, because of a high molecular ion concentration at M+-57 applications.

Silanes / Silazanes:

Dimethyldichlorosilane (DMCS):

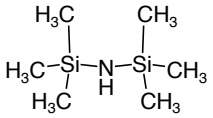


M: 129.06 g/mol, Bp: 70 °C (760 mm Hg),
density d20 °/4 ° = 1.07

DMCS is used to form dimethylsilyl (DMS) derivatives.

DMS derivatives are much more susceptible to hydrolysis than TMS derivatives. Therefore, strictly anhydrous conditions during the reaction are very important.

Hexamethyldisilazane (HMDS):

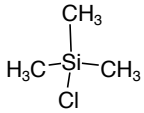


M: 161.4 g/mol,
Bp: 126 °C (760 mm Hg),
density d20 °/4 ° = 0.7742

HMDS is a weak TMS donor. If used as sole reagent, it is slow and not very effective. After addition of catalytic quantities (e.g., 1 %) of TMCS or as a mixture with TMCS (2:1, v/v; SILYL-21 and SILYL-2110), it is a fast and quantitative reagent for trimethylsilylation of organic compounds.

Aprotic solvents, e.g., acetonitrile, pyridine, dimethylformamide, carbon disulfide and dimethylacetamide are recommended for use with HMDS.

Trimethylchlorosilane (TMCS):



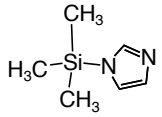
M: 108.7 g/mol, Bp: 57 °C (760 mm Hg),
density d20 °/4 ° = 0.8580

TMCS is often used as a catalyst with other trimethylsilyl reagents. Without additives it can be used for preparing TMS derivatives of organic acids.

Together with methanol, TMCS can be used for Methylation.

Imidazoles:

N-Trimethylsilyl-imidazole (TSIM):



M: 140.3 g/mol,
Bp: 94–96 °C (760 mm Hg),
density d20 °/4 ° = 0.961

TSIM is the strongest hydroxyl silylator, the reagent of choice for carbohydrates and most steroids (even highly hindered steroids).

The reagent is unique in that it reacts quickly and smooth with hydroxyl (even tert. OH) and carboxyl groups, but not with amines. This characteristic makes TSIM particularly useful in multi-derivatization schemes for compounds with different functional groups that are to be derivatized differently, e.g., -O-TMS / -N-HFB derivatives of catecholamines.

Reaction mixes:

SILYL-271 BSA – HMDS – TSIM (2:7:1)

SILYL-271 will derivatize all hydroxyl groups in any position. Useful in multiderivatization schemes involving hydroxyl or amine groups.

SILYL-1139 TSIM – pyridine (11:39)

The presence of water does not interfere with the use of SILYL-1139.

Recommended application: alcohols, phenols, organic acids, steroids, hormones, glycols, nucleotides and narcotics.

SILYL-21 HMDS – TMCS (2:1)

SILYL-21 will derivatize amides and many secondary amines and hindered hydroxyls that would not be completely derivatized by HMDS alone. It can be used without solvent.

SILYL-2110 HMDS – TMCS – pyridine (2:1:10)

SILYL-2110 will derivatize alcohols, bile acids, phenols, most steroids, sterols, and sugars that would not be completely derivatized by HMDS alone. SILYL-2110 is fast and easy to use, and can be used without solvent.

SILYL-991 BSTFA – TMCS (99:1)

BSTFA is a powerful trimethylsilyl donor. For silylating of fatty acid amides, hindered hydroxyls and other compounds that are difficult to silylate, e.g., secondary alcohols and amines, we recommend BSTFA + 1 % TMCS, available under the designation SILYL-991.

Silylation procedures:

Silylation with BSA, BSTFA or SILYL-991 (BSTFA + 1 % TMCS)

Procedure:
BSA alone silylates all sterically unhindered hydroxyl groups of the steroid skeleton; addition of TMCS will enable reaction of moderately hindered OH groups (reaction time 3–6 h at 60 °C). After addition of TSIM even strongly hindered hydroxyl groups will react (reaction time 6–24 h at 60 °C).

MN Appl. No. 213100

Silylation with BSA in combination with other silylation reagents

Procedure:
Add 0.5 mL of the silylation reagent to 1–10 mg sample; if necessary, add some solvent (normally pyridine or DMF [dimethylformamide]). Heat to 60–80 °C for 20 min to increase the reaction rate. 1–2 drops of TMCS (trimethylchlorosilane) or TSIM will also speed up the reaction.

BSA MN Appl. No. 213091 · BSTFA MN Appl. No. 213092
SILYL-991 MN Appl. No. 213093

Silylation with MSTFA, MSHFBA or MBDSTFA

Procedure:
Dissolve 10–15 mg sample in 0.8 mL solvent, then add 0.2 mL of the silylation reagent. The reaction mixture can be heated to 60–70 °C for up to 1 h and can be analyzed directly. If TFA is used as a solvent, proceed as follows [M. Donike, J. Chromatogr. 85 (1973) 1–7]: dissolve 1–2 mg sample in 100 µL TFA. Dropwise add 0.9 mL of the silylating reagent. After cooling the sample can be chromatographed directly.

MSTFA MN Appl. No. 213111 · MSHFBA MN Appl. No. 213112 · MBDSTFA MN Appl. No. 213113

Silylation with TSIM or SILYL-1139 (TSIM – pyridine 11:39)

Procedure:
Dissolve 10–15 mg sample in 0.8 mL solvent, then add 0.2 mL of the silylation reagent. The reaction mixture can be heated to 60–70 °C for up to 1 hour and can be analyzed directly.

Recommended solvent pyridine

When using SILYL-1139, the presence of water does not interfere.

TSIM MN Appl. No. 213121 · SILYL-1139 MN Appl. No. 213122

Silylation with SILYL-21 or SILYL-2110

Procedure:
Carefully add SILYL-21 or SILYL-2110 to 1–10 mg of the sample. Precipitated ammonium chloride does not interfere. If the sample should not dissolve within 5 min, heat to 75–85 °C. If no mutarotation is to be expected, you may dissolve the sugar in warm pyridine first and then add the silylation reagent. In some cases it may be advantageous to use a different solvent instead of pyridine. For derivatization of 3-ketosteroids we recommend to use DMF (dimethylformamide).

SILYL-21 MN Appl. No. 213131 · SILYL-2110 MN Appl. No. 213132

O-Trimethylsilylation with MSTFA followed by N-trifluoroacetylation with MBTFA

Procedure:
Completely silylate 2 mg of the sample with 0.3 mL MSTFA. After addition of 0.3 mL MBTFA the N-trimethylsilyl group is replaced by the N-trifluoroacetyl group. The mixture can be analyzed directly.

MN Appl. No. 213140

Summary Silylation:

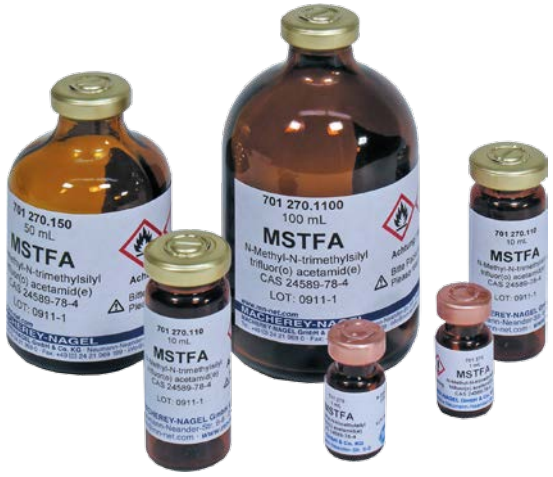
- Silylation can be applied on many compounds
- Silylating reagents are easily prepared
- Large variety of reagents available

but

- most derivatives are susceptible to water and hydrolysis
- Reactions only in aprotic solvents possible

References:

1. MN Chromatography catalog Edition 8
2. Blau, K., Halket, J., Handbook of Derivatives for Chromatography, Second Edition; John Wiley & Sons; Chichester, 1993
3. Knapp, D.R. Handbook of Analytical Derivatizations Reactions; John Wiley & Sons; New York, 1979



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Derivatization reactions (Overview)

Oxygen Type

Functional Group	Silylation*	Acylation/Benzoylation	Alkylation	Special
Primary alcohols	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	TFAA, HFBA, MBTFA, MBHFBA, PFBC	TMSH	
Secondary alcohols	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	TFAA, HFBA, MBTFA, MBHFBA, PFBC	TMSH	
Tertiary (and sterically hindered) alcohols	TSIM, BSTFA, SILYL-991	TFAA, HFBA, PFBC		
Thiols	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	MBTFA, MBHFBA, HFBA, TFAA	TMSH	
Phenols	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	TFAA, HFBA, MBTFA, MBHFBA, PFBC	DMF-DMA, TMSH	
Glycols	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	TFAA, HFBA, MBTFA, MBHFBA, PFBC	TMSH	
Aldehydes	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	TFAA, HFBA, MBTFA, MBHFBA, PFBC	DMF-DMA, TMSH, MeOH/TMCS	After oxidation to -COOH
Ketones	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	TFAA, HFBA, MBTFA, MBHFBA, PFBC	DMF-DMA, TMSH, MeOH/TMCS	After oxidation to -COOH
Carboxylic acids	BSA, MSTFA, MSHFBA, TSIM, SILYL-2110, SILYL-21, SILYL-1139	TFAA, HFBA, MBTFA, MBHFBA, PFBC	DMF-DMA, TMSH, MeOH/TMCS	
Carbohydrates/Sugars	MSTFA, TSIM, SILYL-2110, SILYL-991	TFAA, MBTFA, PFBC		
Acid anhydrides			MeOH/TMCS	Esterification
α-hydroxy acids	MSTFA	MBTFA		simultaneous

Nitrogen type

Functional Group	Silylation*	Acylation/Benzoylation	Alkylation	Special
Primary amines	BSA, MSTFA, MSHFBA, SILYL-991	TFAA, HFBA, MBTFA, MBHFBA, PFBC	DMF-DMA	
Secondary amines	BSA, MSTFA, MSHFBA, SILYL-991	TFAA, HFBA, MBTFA, MBHFBA, PFBC	DMF-DMA	
Amides	Silylamides are not stable	TFAA, HFBA, MBTFA, MBHFBA, PFBC		
Amino acids	BSA, BSTFA, MSTFA, MSHFBA	TFAA, HFBA, MBTFA, MBHFBA, PFBC	MeOH/TMCS, TMSH	
Amino sugars	BSA, MSTFA, MSHFBA, SILYL-991	TFAA, HFBA, MBTFA, MBHFBA, PFBC		
Imino acids	BSA, MSTFA, MSHFBA, SILYL-991	TFAA, HFBA, MBTFA, MBHFBA, PFBC		
Carbamides	Silylamides are not stable	TFAA, HFBA, MBTFA, MBHFBA		
Alkylamides	Silylamides are not stable	PFBC		
Amino alcohols	MSTFA	MBTFA		simultaneous

* (Avoid polar stationary phases containing active protons, e.g., FFAP or Wax)

Ordering information

Substance	10 x 1 mL	20 x 1 mL	1 x 10 mL	5 x 10 mL
HFBA*		701110.201	701110.110	701110.510
MBTFA*		701410.201	701410.110	701410.510
MBHFBA*	701420.101	701420.201		
PFBC*	701120.101			
TFAA*			701130.110	701130.510
DMF-DMA*		701430.201	701430.110	
TMSH*	701520.101	701520.201	701520.110	701520.510

Substance	20 x 1 mL	1 x 10 mL	5 x 10 mL	1 x 50 mL
BSA*		701210.110	701210.510	701210.150
BSTFA*	701220.201	701220.110	701220.510	

Substance	10 x 1 mL	20 x 1 mL	1 x 10 mL	5 x 10 mL	1 x 100 mL	6 x 50 mL	6 x 100 mL	12 x 100 mL
MSHFBA*		701260.201	701260.110	701260.510	701260.1100		701260.6100	
MSTFA*		701270.201	701270.110	701270.510	701270.1100	701270.650	701270.6100	701270.12100
MBDSTFA*	701440.101	701440.201						

Substance	20 x 1 mL	1 x 10 mL	5 x 10 mL	6 x 50 mL
DMCS*				701230.650 **
HMDS*			701240.510	701240.650 **
TMCS*	701280.201 **			701280.650 **
TSIM	701310.201	701310.110	701310.510	

Mixture	Composition	20 x 1 mL	1 x 10 mL	5 x 10 mL	1 x 50 mL	1 x 100 mL
SILYL-271	BSA - HMDS - TSIM (2:7:1)	701450.201	701450.110	701450.510		
SILYL-1139	TSIM - pyridine (11:39)	701460.201				
SILYL-21	HMDS - TMCS (2:1)	701470.201				
SILYL-2110	HMDS - TMCS - pyridine (2:1:10)	701480.201				
SILYL-991	BSTFA - TMCS (99:1)	701490.201			701490.150	701490.1100

* These products contain harmful chemicals which must be specially labeled as hazardous. For detailed information please see MSDS.

Due to their purpose, derivatization reagents are very reactive chemicals. For this reason, they should be stored cool and protected from moisture. For easy access with a syringe, our derivatization reagents are supplied in vials with crimp caps (** in vials with screw caps). Vials with pierced sealing disks have limited stability and should be used up soon.

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