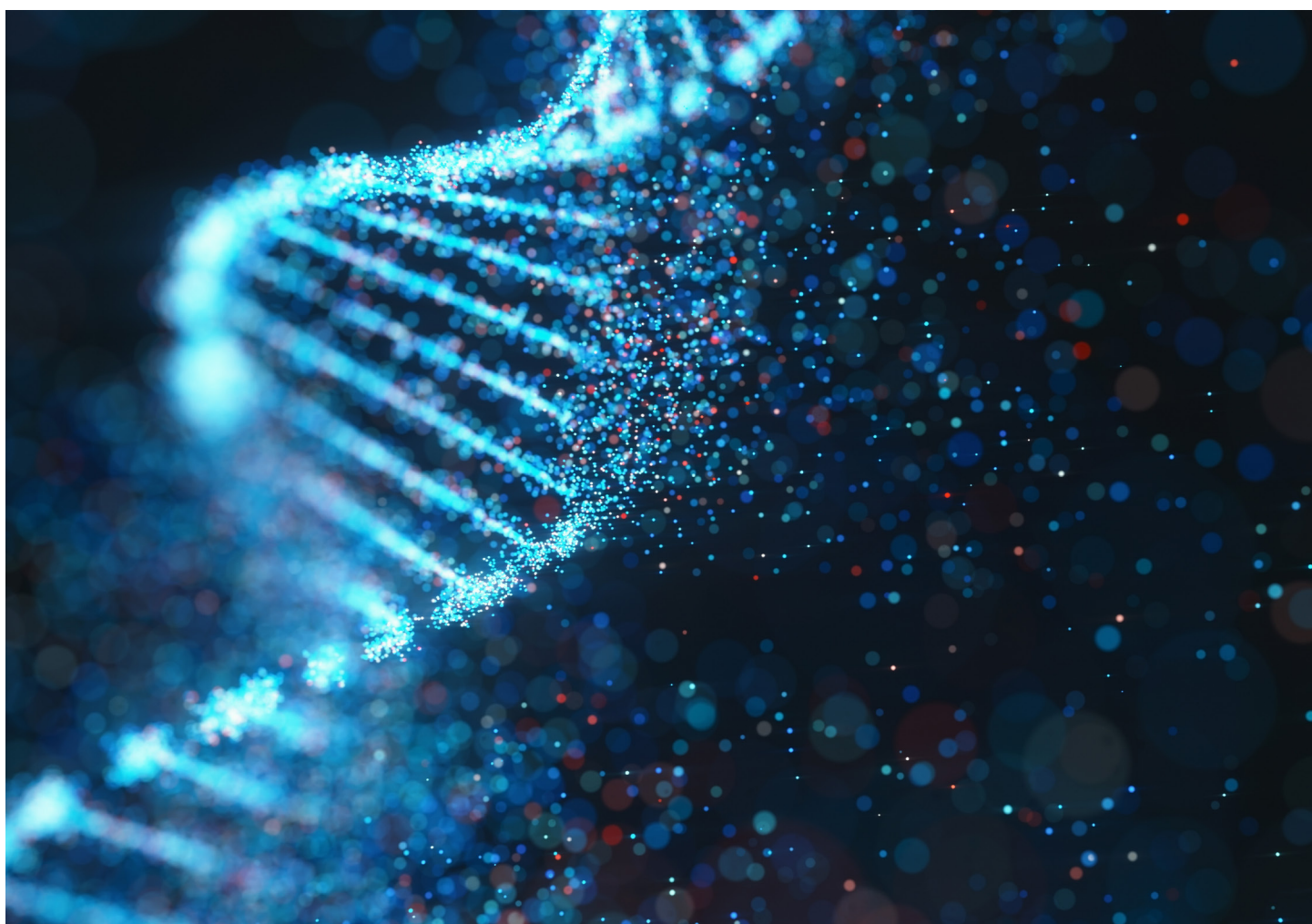




Cambridge Isotope Laboratories, Inc.
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Stable Isotope-Labeled Nucleic Acids and Related Compounds



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Introduction

Nucleic acids (includes DNA and RNA) are necessary building blocks of living organisms, which are fundamentally important to a multitude of cellular processes. Compositionally, nucleic acids are comprised of nucleobases (e.g., adenine, cytosine), nucleosides (e.g., adenosine, guanosine), and nucleotides (e.g., ATP, CDP). These compounds may be used as starting materials in the enzymatic or chemical synthesis of RNA and DNA. Applications of stable isotope labeled nucleic acids are broad, ranging from the evaluation of protein structure and dynamics to the evaluation of nucleic acids as potential biotherapies, such as RNA therapeutics.

To assist with RNA/DNA-related NMR- and/or MS-based research, CIL offers a large selection of various stable isotope-labeled compounds. We also offer sets of deoxyribonucleoside monophosphates (dNMPs), deoxyribonucleoside triphosphates (dNTPs), and ribonucleoside triphosphate (rNTPs) in different unit configurations for ease of use. Please visit isotope.com for product details, pricing, availability, and to inquire about compounds of interest that may not be featured in this catalog.

Nuclear Magnetic Resonance (NMR) Spectroscopy

NMR spectroscopy is an extremely powerful and versatile tool for studying the dynamics and structure of RNA and DNA molecules in solution and in the solid state. Most often, nucleic acids containing roughly less than ~40 nucleotides will require simple ^{15}N or $^{13}\text{C}/^{15}\text{N}$ enrichment to provide the constraints necessary to determine full three-dimensional structures. For studying larger proteins, the use of selectively and uniformly deuterated nucleotides and segmental isotope labeling using deuterium has been critical. The types of information gained from NMR studies of RNA and DNA include:

- Base-pairing pattern
- Site-specific information regarding ligand binding
- Delineation of secondary structure motifs, such as hairpins and bulges
- Conformational equilibria
- Local structure and dynamics
- Global structure derived from RDCs

Example Reference

Furtig, B; Richter, C; Wohnert, J; Schwalbe, H. **2003**. NMR spectroscopy of RNA. *Chembiochem*, 4(10), 936-962.

“We are grateful for the continued support from CIL and Eurisotop. Since March 2020, we have been focusing our efforts on characterizing the proteome and the genome of SARS-CoV-2. Our research is conducted in a coordinated manner within the COVID19-NMR network. The work conducted by groups worldwide has led to the NMR characterization of all conserved viral RNA elements as well as the majority of all viral proteins. With NMR chemical shift assignments at hand, we are able to screen viral drug targets for their interactions with low molecular weight binders to contribute to the development of antiviral drugs. These massive efforts require reliable, high-quality isotope precursor compounds – a resource that CIL and Eurisotop are continuously providing to us.”

Harald Schwalbe, PhD
BMRZ, Goethe University Frankfurt (Germany)

Ribonucleic Acids (RNA)

Ribonucleoside Triphosphates (rNTPs)

The most popular approaches to produce labeled RNA molecules for NMR studies use enzymatic *in vitro* transcription methods that employ labeled rNTPs, T7-RNA polymerase, and either linearized plasmids or double-stranded DNA as templates. These techniques are used to construct labeled RNA molecules of which all of one type of nucleotide is labeled.

Uniformly Deuterated rNTPs

Perdeuterated NTPs can be used in combination with protonated NTPs to create RNA molecules in which specific types of nucleotides are protonated, thus allowing spectral editing without the significant signal broadening associated with ^{13}C incorporation.

| Catalog No. | Description |
|-------------|---|
| DLM-7514-CA | Adenosine 5'-triphosphate, ammonium salt (D_8 , 98%) (in solution) CP 95% |
| DLM-7515-CA | Cytidine 5'-triphosphate, ammonium salt (D_8 , 98%) (in solution) CP 95% |
| DLM-7516-CA | Guanosine 5'-triphosphate, ammonium salt (D_7 , 98%) (in solution) CP 95% |
| DLM-7517-CA | Uridine 5'-triphosphate, ammonium salt (D_8 , 98%) (in solution) CP 95% |

Example References

Song, Z.; Gremminger, T.; Singh, G.; et al. **2021**. The three-way junction structure of the HIV-1 PBS-segment binds host enzyme important for viral infectivity. *Nucleic Acids Res*, 49(10), 5925-5942.

Lu, K.; Miyazaki, Y.; Summers, M. **2010**. Isotope labeling strategies for NMR studies of RNA. *J Biomol NMR*, 46(1), 113-125.

Selectively Deuterated rNTPs

Because severe signal degeneracy has hampered NMR studies of larger RNAs, key researchers in this area have utilized selectively deuterated rNTPs, in conjunction with *in vitro* synthesis methods, to reduce spectral complexity, spectral line-widths, and for observing NOEs over larger distances.

| | Catalog No. | Description |
|------|--------------|--|
| | DLM-8815-CA | Adenosine 5'-triphosphate, ammonium salt (2-D, 98%) (in solution) CP 95% |
| NEW! | DLM-11405-CA | Adenosine 5'-triphosphate, ammonium salt (4'-D, 97%) (in solution) CP 95% |
| NEW! | DLM-9268-CA | Adenosine 5'-triphosphate, ammonium salt (2,8- D_2 , 98%) (in solution) CP 95% |
| NEW! | DLM-11406-CA | Adenosine 5'-triphosphate, ammonium salt (5',5''- D_2 , 97%) (in solution) CP 95% |
| | DLM-9619-CA | Adenosine 5'-triphosphate, ammonium salt (ribose-1',2',3',4',5',5''- D_6 , 98%) (in solution) CP 95% |
| | DLM-9366-CA | Cytidine 5'-triphosphate, ammonium salt (cytosine-5-D, 98%) (in solution) CP 95% |
| | DLM-9267-CA | Cytidine 5'-triphosphate, ammonium salt (5,6- D_2 , 98%) (in solution) CP 95% |
| | DLM-8594-CA | Cytidine 5'-triphosphate, ammonium salt (cytosine-5-D, 6-H; ribose-1,2,3,4,5,5- D_6 , 98%) (in solution) CP 95% |
| NEW! | DLM-11407-CA | Guanosine 5'-triphosphate, ammonium salt (3'-D, 97%) (in solution) CP 95% |
| | DLM-9365-CA | Uridine 5'-triphosphate, ammonium salt (uracil-5-D, 97%) (in solution) CP 95% |
| | DLM-9100-CA | Uridine 5'-triphosphate, ammonium salt (5,6- D_2 , 98%) (in solution) CP 95% |
| | DLM-8637-CA | Uridine 5'-triphosphate, ammonium salt (uracil-5-D, 6-H; ribose-1,2,3,4,5,5- D_6 , 98%) (in solution) CP 95% |

Example Reference

Pang, H.; Lilla, E.A.; Zhang, P.; et al. **2020**. Mechanism of rate acceleration of radical C-C bond formation reaction by a radical SAM GTP 3',8-cyclase. *J Am Chem Soc*, 142(20), 9314-9326.

“We’ve been using CIL’s perdeuterated rNTPs for many years to facilitate NMR studies of larger RNAs. Their newer products, which include partially deuterated rNTPs, have been extraordinarily helpful, and have enabled high resolution NMR structural studies of RNAs that were previously intractable.”

Michael Summers, PhD, Howard Hughes Medical Institute, University of Maryland, Baltimore County (USA)

“Without these labeled rNTPs from CIL we would not have been able to prepare such high-quality samples which made the assignment and structure determination possible.”

Michael Durney, PhD, Department of Molecular and Cellular Biology, Harvard University (USA)

Alternatively Labeled rNTPs

| | Catalog No. | Description |
|-------------|---------------|--|
| NEW! | CLM-8932-CA | Adenosine 5'-triphosphate, ammonium salt (2- ¹³ C, 99%) (in solution) CP 95% |
| NEW! | CLM-11402-CA | Adenosine 5'-triphosphate, ammonium salt (4'- ¹³ C, 99%) (in solution) CP 95% |
| NEW! | CLM-11403-CA | Adenosine 5'-triphosphate, ammonium salt (5'- ¹³ C, 99%) (in solution) CP 95% |
| NEW! | CLM-11404-CA | Adenosine 5'-triphosphate, ammonium salt (1',2',3',4',5'- ¹³ C ₅ , 99%) (in solution) CP 95% |
| | CLM-8426-CA | Adenosine 5'-triphosphate, ammonium salt (¹³ C ₁₀ , 99%) (in solution) CP 95% |
| | NLM-3987-CA | Adenosine 5'-triphosphate, ammonium salt (¹⁵ N ₅ , 98%) (in solution) CP 95% |
| | CNLM-4265-CA | Adenosine 5'-triphosphate, ammonium salt (¹³ C ₁₀ , 99%; ¹⁵ N ₅ , 98%) (in solution) CP 95% |
| NEW! | DNLM-10985-CA | Adenosine 5'-triphosphate, ammonium salt (ribose-D ₆ , 98%; ¹⁵ N ₅ , 98%) (in solution) CP 95% |
| | CLM-10987-CA | Cytidine 5'-triphosphate, ammonium salt (¹³ C ₉ , 99%) (in solution) CP 95% |
| | NLM-4266-CA | Cytidine 5'-triphosphate, ammonium salt (¹⁵ N ₃ , 98%) (in solution) CP 95% |
| | CNLM-4267-CA | Cytidine 5'-triphosphate, ammonium salt (¹³ C ₉ , 99%; ¹⁵ N ₃ , 98%) (in solution) CP 95% |
| | CLM-10988-CA | Guanosine 5'-triphosphate, ammonium salt (¹³ C ₁₀ , 99%) (in solution) CP 95% |
| | NLM-4268-CA | Guanosine 5'-triphosphate, ammonium salt (¹⁵ N ₅ , 98%) (in solution) CP 90% |
| | CNLM-4269-CA | Guanosine 5'-triphosphate, ammonium salt (¹³ C ₁₀ , 99%; ¹⁵ N ₅ , 98%) (in solution) CP 95% |
| NEW! | DNLM-10913-CA | Guanosine 5'-triphosphate, ammonium salt (ribose-1',2',3',4',5',5''-D ₆ , 98%; ¹⁵ N ₅ , 98%) (in solution) CP 90% |
| | CLM-10914-CA | Uridine 5'-triphosphate, ammonium salt (¹³ C ₉ , 99%) (in solution) CP 95% |
| | NLM-4270-CA | Uridine 5'-triphosphate, ammonium salt (¹⁵ N ₂ , 98%) (in solution) CP 95% |
| | CNLM-4271-CA | Uridine 5'-triphosphate, ammonium salt (¹³ C ₉ , 99%; ¹⁵ N ₂ , 98%) (in solution) CP 95% |
| NEW! | DNLM-10986-CA | Uridine 5'-triphosphate, ammonium salt (ribose-D ₆ , 98%; uracil- ¹⁵ N ₂ , 98%) (in solution) CP 95% |

Please inquire for lithium salts.

Example References

Gato, A.; Catala, M.; Tisne, C.; et al. **2021**. A method to monitor the introduction of post-transcriptional modifications in tRNAs with NMR spectroscopy. *Methods Mol Biol*, 2298, 307-323.

Nam, H.; Becette, O.; LeBlanc, R.M.; et al. **2020**. Deleterious effects of carbon-carbon dipolar coupling on RNA NMR dynamics. *J Biomol NMR*, 74(6-7), 321-331.

Pang, H.; Lilla, E.A.; Zhang, P.; et al. **2020**. Mechanism of rate acceleration of radical C-C bond formation reaction by a radical SAM GTP 3',8-cyclase. *J Am Chem Soc*, 142(20), 9314-9326.

Barraud, P.; Gato, A.; Heiss, M.; et al. **2019**. Time-resolved NMR monitoring of tRNA maturation. *Nat Commun*, 10, 3373-3387.

Warden, M.S.; Cai, K.; Cornilescu, G.; et al. **2018**. Conformational flexibility in the enterovirus RNA replication platform. *RNA*, 25(3), 376-387.

Song, Y.; Marmion, R.A.; Park, J.O.; et al. **2017**. Dynamic control of dNTP synthesis in early embryos. *Dev Cell*, 42(3), 301-308.

Le, M.T.; Brown, R.E.; Simon, A.E.; et al. **2015**. *In vivo*, large-scale preparation of uniformly ¹⁵N- and site-specifically ¹³C-labeled homogeneous, recombinant RNA for NMR studies. *Methods Enzymol*, 565, 495-535.

Alverado, L.J.; Longhini, A.P.; LeBlanc, R.M.; et al. **2014**. Chemo-enzymatic synthesis of selectively ¹³C/¹⁵N labeled RNA for NMR structural and dynamics studies. *Methods Enzymol*, 549, 133-162.

Ribonucleoside Monophosphates (rNMPs)

| | Catalog No. | Description |
|-------------|-------------|--|
| | NLM-3792 | Adenosine 5'-monophosphate, lithium salt (¹⁵ N ₅ , 98%) (in solution) CP 95% |
| | CNLM-3802 | Adenosine 5'-monophosphate, lithium salt (¹³ C ₁₀ , 98%; ¹⁵ N ₅ , 98%) (in solution) CP 95% |
| NEW! | CLM-11433 | Cyclic adenosine-3',5'-monophosphate (ribose- ¹³ C ₅ , 95%) CP 96% |
| | NLM-3793 | Cytidine 5'-monophosphate (CMP), lithium salt (¹⁵ N ₃ , 98%) (in solution) CP 95% |
| | CNLM-3803 | Cytidine 5'-monophosphate (CMP), lithium salt (¹³ C ₉ , 98%; ¹⁵ N ₃ , 98%) (in solution) CP 95% |
| | NLM-3794 | Guanosine 5'-monophosphate, lithium salt (¹⁵ N ₅ , 98%) (in solution) CP 95% |
| | CNLM-3804 | Guanosine 5'-monophosphate, lithium salt (¹³ C ₁₀ , 98%; ¹⁵ N ₅ , 98%) (in solution) CP 95% |
| | NLM-3795 | Uridine 5'-monophosphate, lithium salt (¹⁵ N ₂ , 98%) (in solution) CP 95% |
| | CNLM-3805 | Uridine 5'-monophosphate, lithium salt (¹³ C ₉ , 98%; ¹⁵ N ₂ , 98%) (in solution) CP 95% |

“When we prepare labeled RNAs, we want the yield of transcription to be as high as possible. In our hands, transcription efficiencies using CIL rNTPs ammonium salt solutions are indistinguishable from those performed with top-quality unlabeled rNTPs solutions. Our transcriptions are always perfectly reproducible using CIL rNTPs. We are very happy with the quality of the labeled RNA samples we get.”

Pierre Barraud, PhD
Institute of Physico-Chemical Biology, CNRS, Paris City University (France)

Chemical purity (CP) is 98% or greater, unless otherwise specified. For research use only. Not for use in diagnostic procedures.

Deoxyribonucleic Acids (DNA)

Labeled DNA oligonucleotides are routinely synthesized using enzymatic *in vitro* methods that require labeled dNTPs, a DNA polymerase, and a cDNA template. One particular advantage of using enzymatic methods over synthetic chemistry methods is that large oligonucleotides (e.g., >50 nucleotides in length) can be easily prepared in milligram quantities.

Deoxyribonucleoside Triphosphates (dNTPs)

| Catalog No. | Description |
|---------------|--|
| DLM-7507 | 2-Deoxyadenosine 5'-triphosphate, lithium salt (D, 98%) (in solution) CP 95% |
| NLM-6215 | 2'-Deoxyadenosine 5'-triphosphate, lithium salt (¹⁵ N ₅ , 98%) (in solution) CP 95% |
| CNLM-6219-CA* | 2'-Deoxyadenosine 5'-triphosphate, ammonium salt (¹³ C ₁₀ , 99%; ¹⁵ N ₅ , 98%) (in solution) CP 90% |
| DLM-7508 | 2-Deoxycytidine 5'-triphosphate, lithium salt (D, 98%) (in solution) CP 95% |
| NLM-6216 | 2'-Deoxycytidine 5'-triphosphate, lithium salt (¹⁵ N ₃ , 98%) (in solution) CP 95% |
| CNLM-6220 | 2'-Deoxycytidine 5'-triphosphate, lithium salt (¹³ C ₉ , 98%; ¹⁵ N ₃ , 98%) (in solution) CP 95% |
| DLM-7509 | 2-Deoxyguanosine 5'-triphosphate, lithium salt (D, 98%) (in solution) CP 95% |
| NLM-6217-CA* | 2'-Deoxyguanosine 5'-triphosphate, ammonium salt (¹⁵ N ₅ , 98%) (in solution) CP 95% |
| CNLM-6221-CA* | 2'-Deoxyguanosine 5'-triphosphate, ammonium salt (¹³ C ₁₀ , 99%; ¹⁵ N ₅ , 98%) (in solution) CP 95% |
| DLM-7510 | Thymidine 5'-triphosphate, lithium salt (D, 98%) (in solution) CP 95% |
| NLM-6218 | Thymidine 5'-triphosphate, lithium salt (¹⁵ N ₂ , 98%) (in solution) CP 95% |
| CNLM-6222 | Thymidine 5'-triphosphate, lithium salt (¹³ C ₁₀ , 98%; ¹⁵ N ₂ , 98%) (in solution) CP 95% |

*Please inquire for lithium salts.

Deoxyribonucleoside Monophosphates (dNMPs)

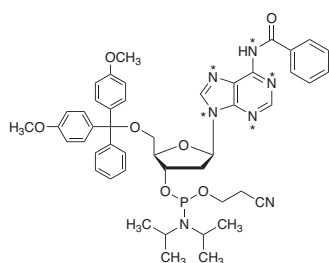
| Catalog No. | Description |
|-------------|--|
| NLM-3919 | 2'-Deoxyadenosine 5'-monophosphate, lithium salt (¹⁵ N ₅ , 98%) (in solution) CP 95% |
| CNLM-3918 | 2'-Deoxyadenosine 5'-monophosphate, lithium salt (¹³ C ₁₀ , 98%; ¹⁵ N ₅ , 98%) (in solution) CP 95% |
| NLM-3921 | 2'-Deoxycytidine 5'-monophosphate, lithium salt (¹⁵ N ₃ , 96%) (in solution) |
| CNLM-6834 | 2'-Deoxycytidine 5'-monophosphate, lithium salt (¹³ C, 98%; ¹⁵ N, 98%) (in solution) CP 95% |
| NLM-6835 | 2'-Deoxyguanosine 5'-monophosphate, lithium salt (¹⁵ N, 98%) (in solution) CP 95% |
| CNLM-6836 | 2'-Deoxyguanosine 5'-monophosphate, lithium salt (¹³ C, 98%; ¹⁵ N, 98%) (in solution) CP 95% |
| NLM-3925 | Thymidine 5'-monophosphate, lithium salt (¹⁵ N ₂ , 98%) (in solution) |
| CNLM-3924 | Thymidine 5'-monophosphate, lithium salt (¹³ C ₁₀ , 98%; ¹⁵ N ₂ , 98%) (in solution) CP 95% |

DNA Phosphoramidites

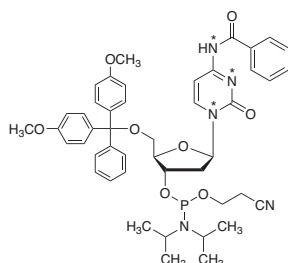
Position-specific labeled DNA molecules can be synthesized using standard phosphoramidite chemistry to overcome the limited chemical-shift dispersion of DNA, as well as to obtain residue-specific functional, structural, and dynamic information.

¹⁵N-Labeled

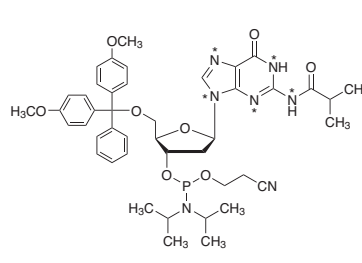
| | |
|----------|--|
| NLM-6829 | 2'-Deoxyadenosine phosphoramidite (¹⁵ N ₅ , 98%) CP 95% |
| NLM-6827 | 2'-Deoxycytidine phosphoramidite (¹⁵ N ₃ , 98%) CP 95% |
| NLM-6826 | 2'-Deoxyguanosine phosphoramidite (¹⁵ N ₅ , 98%) CP 95% |
| NLM-6823 | Thymidine phosphoramidite (¹⁵ N ₂ , 98%) CP 95% |



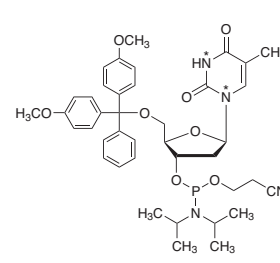
NLM-6829



NLM-6827



NLM-6826

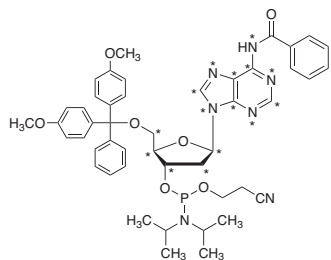


NLM-6823

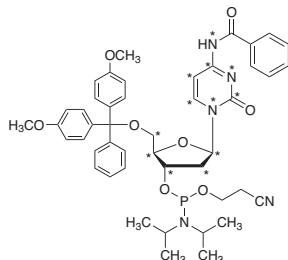
Chemical purity (CP) is 98% or greater, unless otherwise specified. For research use only. Not for use in diagnostic procedures.

¹³C/¹⁵N-Labeled

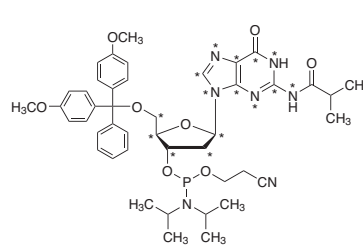
| Catalog No. | Description |
|-------------|---|
| CNLM-6828 | 2'-Deoxyadenosine phosphoramidite (¹³ C ₁₀ , 98%; ¹⁵ N ₅ , 98%) CP 95% |
| CNLM-6830 | 2'-Deoxycytidine phosphoramidite (¹³ C ₉ , 98%; ¹⁵ N ₃ , 98%) CP 95% |
| CNLM-6825 | 2'-Deoxyguanosine phosphoramidite (¹³ C ₁₀ , 98%; ¹⁵ N ₅ , 98%) CP 95% |
| CNLM-6824 | Thymidine phosphoramidite (¹³ C ₁₀ , 98%; ¹⁵ N ₂ , 98%) CP 95% |



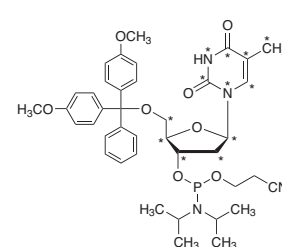
CNLM-6828



CNLM-6830



CNLM-6825



CNLM-6824

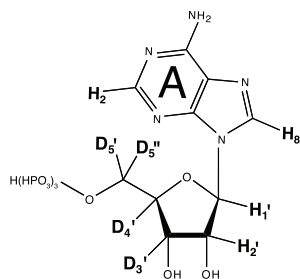
RNA and DNA Ribonucleoside Sets and Mixes

To simplify the purchasing process for those looking to label all residues in an oligomer, CIL offers the following sets for your convenience.

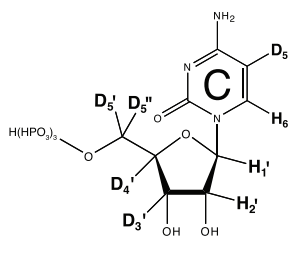
| Catalog No. | Description |
|--------------|--|
| DLM-7518-CA | Set of 4 ribonucleoside 5'-triphosphates, ammonium salt (D, 98%) (in solution) CP 95% |
| NLM-7519-CA | Set of 4 ribonucleoside 5'-triphosphates, ammonium salt (¹⁵ N, 98%) (in solution) CP 90% |
| CNLM-7503-CA | Set of 4 ribonucleoside 5'-triphosphates, ammonium salt (¹³ C, 98%; ¹⁵ N, 98%) (in solution) CP 95% |
| CNLM-7871 | Set of 4 2'-deoxyribonucleoside 5'-monophosphates, lithium salt (¹³ C, 98%; ¹⁵ N, 98%) (in solution) CP 95% |
| DLM-7511 | Set of 4 2'-deoxyribonucleoside 5'-triphosphates, lithium salt (D, 98%) (in solution) CP 95% |
| NLM-7512 | Set of 4 2'-deoxyribonucleoside 5'-triphosphates, lithium salt (¹⁵ N, 98%) (in solution) CP 95% |
| CNLM-7513 | Set of 4 2'-deoxyribonucleoside 5'-triphosphates, lithium salt (¹³ C, 98%; ¹⁵ N, 98%) (in solution) CP 95% |

Equimolar Mix

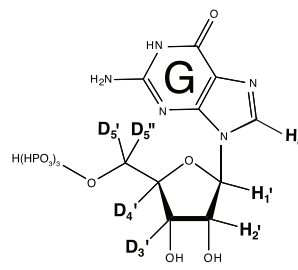
| | |
|----------|--|
| DLM-7862 | Equimolar Mix: ATP, CTP, GTP, UTP, ammonium salt (ribose-3',4',5',5''-D ₄ , 98%) (in solution) CP 95% |
|----------|--|



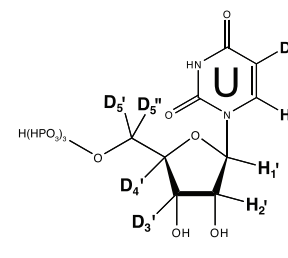
DLM-8922 (ATP)



DLM-8924 (CTP)

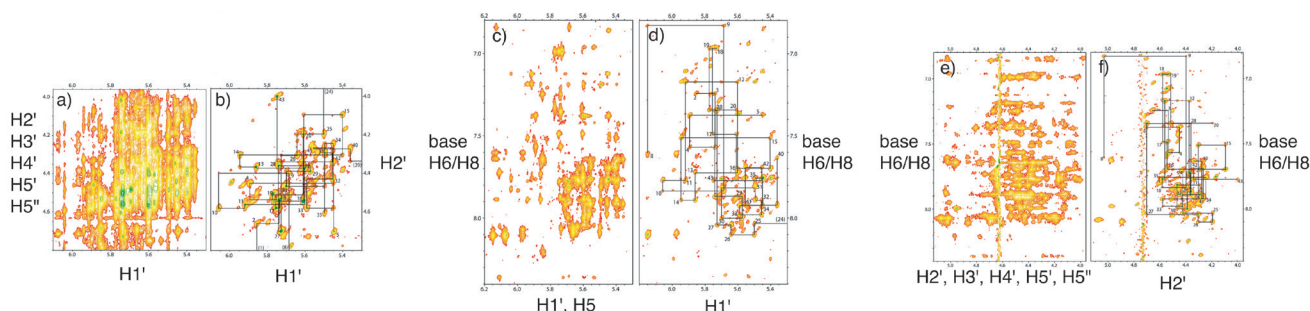


DLM-8923 (GTP)



DLM-8925 (UTP)

| | |
|-------------|--|
| DLM-8922-CA | Adenosine-5'-triphosphate, ammonium salt (ribose-3',4',5',5''-D ₄ , 98%) (in solution) CP 95% |
| DLM-8924-CA | Cytidine-5'-triphosphate, ammonium salt (5-D, ribose-3',4',5',5''-D ₄ , 98%) (in solution) CP 95% |
| DLM-8923-CA | Guanosine-5'-triphosphate, ammonium salt (ribose-3',4',5',5''-D ₄ , 98%) (in solution) CP 95% |
| DLM-8925-CA | Uridine-5'-triphosphate, ammonium salt (5-D, ribose-3',4',5',5''-D ₄ , 98%) (in solution) CP 95% |



¹H-¹H-NOESY Spectra of the Tetraloop-Receptor RNA (45 nt dimer; 30 kDa). Spectra above are from unlabeled RNA (a, c, e) and selectively deuterated RNA (b, d, f). The selectively deuterated RNA was prepared using the equimolar mix (CIL catalog no. DLM-7862). The left two panels (a, b) contain NOEs between the H1' proton and all other ribose protons. The middle two panels (c, d) contain NOEs between the base protons and H1' protons. The right two panels (e, f) contain NOEs between the base and other ribose protons. Spectra taken from Davis, J.H., et al. (see reference below) were provided courtesy of professor Sam Butcher at the University of Wisconsin. The sequential assignment pattern of inter- and intranucleotide NOEs is shown for the D₅-RNA. The advantages of the selectively deuterated pattern are evident in these key regions of the spectra.

Example Reference

Davis, J.H.; Tonelli, M.; Scott, L.G.; et al. **2005**. Helical packing in solution: NMR structure of a 30 kDa GAAA tetraloop-receptor complex. *J Mol Biol*, 351(2), 371-382.

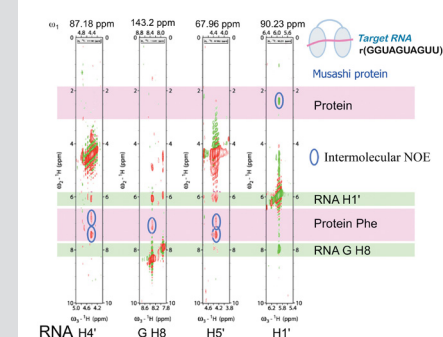
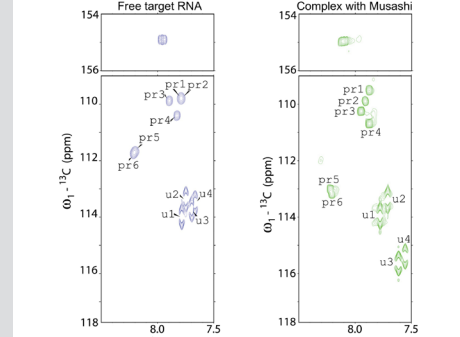
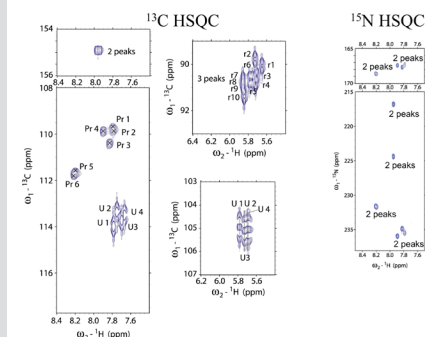
“The detailed analyses by means of stable isotope-labeled RNA are provided on the interaction between Musashi protein, which regulates the neural differentiation and its target RNA. It has been difficult to detect chemical shift changes for RNA bases upon complex formation, because base signals overlap each other and also with protein signals. This time, however, the introduction of stable isotope-labeled RNAs enables us to sensitively detect the RNA residues involved in the interaction with protein by utilizing either carbon or nitrogen frequency in addition to proton frequency.”

Masato Katahira, PhD
Institute of Advanced Energy, Kyoto University (Japan)

NMR Spectra of ¹³C-, ¹⁵N-labeled target RNA: r(GGUAGUAGUU)

Identification of RNA residues interacting with Musashi protein

Observation of intermolecular NOEs between RNA and Musashi protein



Overlapping of signals is basically resolved owing to the introduction of either ¹³C- or ¹⁵N-frequencies in addition to ¹H-frequency.

NMR spectra of free ¹³C-, ¹⁵N-labeled target RNA (left) and the complex with Musashi protein (right). The chemical shift changes for RNA residues interacting with Musashi protein are sensitively detected because of the resolution of overlapping of signals owing to the introduction of either ¹³C- or ¹⁵N-frequencies in addition of ¹H-frequency.

Intermolecular NOEs are successfully observed from the ¹³C-edited NOESY spectrum of the complex between ¹³C-, ¹⁵N-labeled target RNA and nonlabeled Musashi protein.

These data were provided by Dr. Takako Ohyama, Graduate School of Nanobioscience, Yokohama City University, Japan.

Fluorine-Labeled Compounds

The fluorine nucleus is extremely sensitive to the local chemical environment, which leads to a wide chemical shift range. This makes it an excellent probe for secondary structure, especially where the chemical shift dispersion is limited, such as in RNA. Although researchers have used ^{19}F -NMR to study nucleic acids for decades, only recently has a larger RNA been uniformly labeled with fluorine and investigated using ^{19}F -NMR. CIL offers fluorinated nucleoside triphosphates and other related compounds for use in studying structure and dynamics of RNA using ^{19}F -NMR.

| | Catalog No. | Description |
|------|--------------|--|
| NEW! | CLM-11562 | 2-Fluoroadenosine 5'-triphosphate, lithium salt ($2\text{-}^{13}\text{C}$, 98%) (in solution) CP 95% |
| NEW! | ULM-11411-CA | 2-Fluoro-2'-deoxyadenosine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 95% |
| | ULM-11243-CA | 2'-Fluoro-2'-deoxyadenosine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 90% |
| | ULM-11244-CA | 2'-Fluoro-2'-deoxycytidine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 90% |
| | ULM-11245-CA | 2'-Fluoro-2'-deoxyguanosine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 90% |
| | ULM-11246-CA | 2'-Fluoro-2'-deoxythymidine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 90% |
| | ULM-11247-CA | 2'-Fluoro-2'-deoxyuridine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 90% |
| | CNLM-10422 | 2'-Fluoro-2'-deoxyuridine (uracil- $^{13}\text{C}_4$, 99%; $^{15}\text{N}_2$, 98%) |
| NEW! | ULM-11412-CA | 5-Fluoro-2'-deoxycytidine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 95% |
| NEW! | ULM-11413-CA | 5-Fluoro-2'-deoxyuridine 5'-triphosphate, ammonium salt (unlabeled) (in solution) CP 95% |
| | ULM-10698-CA | 2-Fluoroadenosine 5'-triphosphate (2F-ATP), ammonium salt (unlabeled) (in solution) CP 90% |
| | ULM-10697-CA | 5-Fluorocytidine 5'-triphosphate (5F-CTP), ammonium salt (unlabeled) (in solution) CP 90% |
| | ULM-10696-CA | 5-Fluorouridine 5'-triphosphate (5F-UTP), ammonium salt (unlabeled) (in solution) CP 90% |
| | NLM-798 | 5-Fluorouracil ($1,3\text{-}^{15}\text{N}_2$, 99%) |
| | CNLM-3916 | 5-Fluorouracil ($^{13}\text{C}_4$, 99%; $^{15}\text{N}_2$, 98%) |

Example Reference

Sochor, F.; Silvers, R.; Muller, D.; et al. **2016**. ^{19}F -labeling of the adenine H2-site to study large RNAs by NMR spectroscopy. *J Biomol NMR*, 64(1), 63-74.

“CIL has been a strong supporter of NMR methods of development over the years, providing critical isotope-enriched reagents for research and development, without which many of the recent advances in biomolecular NMR would simply not have been possible. In particular, the broad biological impact and tremendous success of the multi-dimensional triple-resonance biomolecular NMR would not have been achieved without the high quality and broadly accessible reagents that CIL has provided to the scientific community over the last 40 years.”

Gaetano Montelione, PhD
Nexomics Biosciences (USA)

“We have enjoyed a close working relationship with CIL for over 15 years, both as a customer and a collaborator. We've had great interactions with sales, management, and the chemists from top to bottom. CIL is a great company that you can really work with in this specialized area. We've been able to do science that we couldn't have done without working with CIL.”

James R. Williamson, PhD
The Skaggs Institute for Chemical Biology – The Scripps Research Institute (USA)

Miscellaneous Compounds and Starting Materials

RNA Nucleosides

| Catalog No. | Description |
|----------------------------|---|
| CLM-3698 | Adenosine (ribose-2- ¹³ C, 99%) |
| CLM-3678 | Adenosine (ribose- ¹³ C ₅ , 98%) CP 97% |
| DLM-7676 | Adenosine (ribose-1-D, 98%) |
| DLM-7677 | Adenosine (ribose-2-D, 97%) |
| DLM-7678 | Adenosine (ribose-5,5-D ₂ , 98%) |
| NLM-9750 | Adenosine (U- ¹⁵ N ₅ , 98%) |
| CNLM-3806-CA | Adenosine (¹³ C ₁₀ , 99%; ¹⁵ N ₅ , 98%) CP 95% |
| NEW! CLM-8518-CA | Adenosine, hydrate (¹³ C ₁₀ , 99%) |
| CLM-3605 | Adenosine·H ₂ O (ribose-1- ¹³ C, 99%) CP 95% |
| CLM-7674 | Adenosine·H ₂ O (3'- ¹³ C, 98%) |
| CLM-3611 | Cytidine (ribose-1- ¹³ C, 99%) |
| CLM-3699 | Cytidine (ribose-2- ¹³ C, 99%) |
| CLM-3679 | Cytidine (ribose- ¹³ C ₅ , 98%) |
| DLM-7681 | Cytidine (ribose-5,5-D ₂ , 98%) |
| NLM-3797 | Cytidine (¹⁵ N ₃ , 98%) |
| CNLM-3807 | Cytidine (¹³ C ₉ , 99%; ¹⁵ N ₃ , 99%) |
| DLM-9101-CA | Cytidine·H ₂ O (5,6-D ₂ , 98%) CP 95% |
| DLM-1846 | Guanidine·DCI (D ₆ , 98%) |
| CLM-7688 | Guanosine·H ₂ O (ribose-1- ¹³ C, 98%) |
| DLM-7689 | Guanosine·H ₂ O (ribose-5,5-D ₂ , 98%) |
| CNLM-3808-CA | Guanosine·H ₂ O (¹³ C ₁₀ , 99%; ¹⁵ N ₅ , 98%) |
| NLM-3798 | Guanosine·2H ₂ O (¹⁵ N ₅ , 99%) |
| NEW! CNLM-11120 | 2'-O-Methyladenosine (¹³ C ₁₀ , 98%; ¹⁵ N ₅ , 96%) |
| NEW! CLM-11345-CA | Pseudouridine (¹³ C ₉ , 99%; ¹⁵ N ₂ , 98%) (in solution) |
| NEW! ULM-11347-CA | Pseudouridine (unlabeled) (in solution) |
| NEW! CLM-11344-CA | Pseudouridine 5'-monophosphate, ammonium salt (¹³ C ₉ , 99%; ¹⁵ N ₂ , 98%) (in solution) |
| NEW! ULM-11346-CA | Pseudouridine 5'-monophosphate, ammonium salt (unlabeled) (in solution) |
| CLM-3629 | Ribothymidine (ribose-1- ¹³ C, 99%) |
| CLM-3630 | Uridine (ribose-1- ¹³ C, 99%) |
| CLM-3680 | Uridine (ribose- ¹³ C ₅ , 98%) |
| NEW! DLM-11408-CA | Uridine (5-D, 97%) (in solution) CP 95% |
| DLM-7693 | Uridine (ribose-5,5-D ₂ , 98%) |
| NLM-812 | Uridine (¹⁵ N ₂ , 98%) |
| NEW! CDLM-11409-CA | Uridine (5-D, 97%; 1',2',3',4',5'- ¹³ C ₅ , 99%) (in solution) CP 95% |
| NEW! CDNLM-11410-CA | Uridine (2,4,5,6- ¹³ C ₄ , 99%; 5-D, 97%; 1,3- ¹⁵ N ₂ , 98%) (in solution) CP 95% |
| CNLM-3809-CA | Uridine·H ₂ O (¹³ C ₉ , 99%; ¹⁵ N ₂ , 98%) CP 95% |

DNA Nucleosides

| | |
|--------------------------|---|
| CLM-3700 | 2'-Deoxyadenosine·H ₂ O (deoxyribose-1- ¹³ C, 99%) |
| CLM-3701 | 2'-Deoxyadenosine·H ₂ O (deoxyribose-2- ¹³ C, 99%) |
| CLM-7682 | 2'-Deoxyadenosine·H ₂ O (ribose-5- ¹³ C, 98%) |
| CLM-4579 | 2'-Deoxyadenosine·H ₂ O (ribose- ¹³ C ₅ , 99%) |
| DLM-7683 | 2'-Deoxyadenosine·H ₂ O (ribose-5,5-D ₂ , 98%) |
| NLM-3895 | 2'-Deoxyadenosine·H ₂ O (¹⁵ N ₅ , 99%) |
| CNLM-3896-CA | 2'-Deoxyadenosine·H ₂ O (¹³ C ₁₀ , 99%; ¹⁵ N ₅ , 98%) |
| NLM-3897 | 2'-Deoxycytidine (¹⁵ N ₃ , 99%) |
| CNLM-3898 | 2'-Deoxycytidine (¹³ C ₉ , 98%; ¹⁵ N ₃ , 98%) |
| CLM-7684 | 2'-Deoxycytidine·H ₂ O (ribose-1- ¹³ C, 98%) |
| CLM-3702 | 2'-Deoxycytidine·H ₂ O (deoxyribose-2- ¹³ C, 99%) |
| DLM-7685 | 2'-Deoxycytidine·H ₂ O (ribose-5,5-D ₂ , 98%) |
| CLM-7686 | 2'-Deoxyguanosine·H ₂ O (ribose-1- ¹³ C, 98%) |
| NEW! CLM-11401-CA | 2'-Deoxyguanosine·H ₂ O (¹³ C ₁₀ , 99%) CP 95% |

Continued ➤

Chemical purity (CP) is 98% or greater, unless otherwise specified. For research use only. Not for use in diagnostic procedures.

Miscellaneous Compounds and Starting Materials (continued)

| Catalog No. | Description |
|--------------|--|
| DLM-7687 | 2'-Deoxyguanosine-H ₂ O (ribose-5,5-D ₂ , 98%) |
| NLM-3899-CA | 2'-Deoxyguanosine-H ₂ O (¹⁵ N ₅ , 98%) CP 95% |
| CNLM-3900-CA | 2'-Deoxyguanosine-H ₂ O (¹³ C ₁₀ , 98%; ¹⁵ N ₅ , 96-98%) |
| NLM-10691 | α-Thymidine (¹⁵ N ₂ , 98%) |
| CLM-3647 | Thymidine (methyl- ¹³ C, 98%) CP 97% |
| CLM-4289 | Thymidine (deoxyribose-1- ¹³ C, 99%) |
| CLM-3703 | Thymidine (deoxyribose-2- ¹³ C, 99%) |
| CLM-7692 | Thymidine (deoxyribose-3- ¹³ C, 99%) |
| DLM-7691 | Thymidine (deoxyribose-5,5-D ₂ , 98%) |
| DLM-3327 | Thymidine (methyl-D ₃ , ring-6-D, 97%) CP 95% |
| NLM-3901 | Thymidine (¹⁵ N ₂ , 98%) |
| CNLM-4263 | Thymidine (deoxyribose- ¹³ C ₅ , 98%; ¹⁵ N ₂ , 98%) CP 95% |
| CNLM-3902 | Thymidine (¹³ C ₁₀ , 98%; ¹⁵ N ₂ , 96-98%) |

Nitrogenous Bases

| | |
|-----------|---|
| CLM-1654 | Adenine (8- ¹³ C, 95%) (may contain up to 7% 2- ¹³ C) |
| NLM-6924 | Adenine-HCl (½ H ₂ O) (¹⁵ N ₅ , 98%) |
| CLM-1001 | Cytosine (2- ¹³ C, 99%) |
| CNLM-4424 | Cytosine (2- ¹³ C, 99%; 1,3- ¹⁵ N ₂ , 98%) |
| CLM-1019 | Guanine (8- ¹³ C, 99%) |
| NLM-6925 | Guanine (¹⁵ N ₅ , 98%) |
| CNLM-3990 | Guanine (8- ¹³ C, 99%; 7,9- ¹⁵ N ₂ , 98%) |
| CLM-3764 | Thymine (6- ¹³ C, 99%) |
| DLM-1089 | Thymine (α,α,α,6-D ₄ , 98%) |
| NLM-3995 | Thymine (1,3- ¹⁵ N ₂ , 98%) |
| CNLM-6945 | Thymine (¹³ C ₅ , 98%; ¹⁵ N ₂ , 98%) |
| CLM-3276 | Uracil (2- ¹³ C, 99%) |
| CLM-692 | Uracil (4,5- ¹³ C ₂ , 99%) |
| CLM-10507 | Uracil (¹³ C ₄ , 99%) |
| DLM-8633 | Uracil (5-D, 98%) |
| DLM-8502 | Uracil (5,6-D ₂ , 98%) |
| NLM-637 | Uracil (1,3- ¹⁵ N ₂ , 98%) |
| CNLM-3917 | Uracil (¹³ C ₄ , 99%; ¹⁵ N ₂ , 98%) |

Other

| | | |
|-------------|--------------|--|
| NEW! | CLM-11441-CA | Adenylosuccinate (AdS), ammonium salt (ribose- ¹³ C ₅ , 99%) (in solution) CP 95% |
| NEW! | NLM-12312 | DL-Allantoin (¹⁵ N ₄ , 98%) CP 97% |
| NEW! | DLM-11273-CA | 2',3'-cGAMP, ammonium salt (adenosine-1',2',3',4',5',5''-D ₆ , 98%) (in solution) CP 90% |
| | CNLM-8771-CA | 2'-Deoxyuridine, ammonium salt (¹³ C ₉ , 99%; ¹⁵ N ₂ , 98%) (in solution) CP 90% |
| | DLM-4391 | 5,6-Dihydrothymine (5,6,6-D ₃ , methyl-D ₃ , 99%) |
| | CNLM-4510 | 5,6-Dihydrouracil (¹³ C ₄ , 99%; ¹⁵ N ₂ , 98%) |
| | NLM-6715 | 8-Hydroxy-2'-deoxyguanosine (¹⁵ N ₅ , 98%) CP 95% |
| | CNLM-3832 | 8-Hydroxyadenine (8- ¹³ C, 98%; 6,9-diamino- ¹⁵ N ₂ , 98%) |
| | CNLM-4392 | 5-Hydroxycytosine (2- ¹³ C, 99%; 1,3- ¹⁵ N ₂ , 98%) |
| NEW! | NLM-8712-CA | Inosine 5'-monophosphate, ammonium salt (¹⁵ N ₄ , 98%) (in solution) CP 95% |
| | DLM-6142 | 5-Methyl-2'-deoxycytidine-HCl (methyl-D ₃ , ring-6-D, 96%) CP 95% |
| | DLM-7471 | 3-Methyladenine (methyl-D ₃ , 98%) |
| | DLM-7473 | 6-O-Methylguanine (methyl-D ₃ , 98%) |
| | DLM-7472 | 7-Methylguanine (methyl-D ₃ , 98%) |
| NEW! | CLM-9427-CA | 1-(5'-Phosphoribosyl)-5-amino-4-imidazole-carboxamide salt (² NH ₄ ⁺) (ribose- ¹³ C ₅ , 99%) CP 90% |
| NEW! | CLM-11442-CA | 1-(5'-Phosphoribosyl)-4-(N-succinocarboxamide)-5-aminoimidazole, ammonium salt (ribose- ¹³ C ₅ , 99%) (in solution) CP 95% |
| | CNLM-10505 | 2-Pyrimidinone (2- ¹³ C, 99%; ¹⁵ N ₂ , 98%) |
| NEW! | CLM-11443-CA | 1-Ribosyl-4-(N-succinocarboxamide)-5-aminoimidazole, ammonium salt (ribose- ¹³ C ₅ , 99%) (in solution) CP 95% |
| NEW! | CLM-11348-CA | 1-Ribosyl-5-aminoimidazole-4-carboxamide (acadesine) (ribose- ¹³ C ₅ , 99%) |
| | CLM-3629 | Ribothymidine (ribose-1- ¹³ C, 99%) |
| NEW! | CLM-8700-CA | Xanthosine-5'-monophosphate, ammonium salt (¹³ C ₁₀ , 99%) (in solution) CP 95% |

Tips and Tricks

Unit Size Conversions

mg to μmol Conversion

Shorthand Formula:

$$\text{amt in } \mu\text{mol} = \frac{\text{amt in mg}}{\text{MW of compound}} \times 1000$$

I would like to order 50 mg of CNLM-4269-CA. How many μmol is that?

Shorthand example:

$$50 / (606.2) \times 1000 = 82.48 \mu\text{mol}$$

Longhand example:

$$50 \text{ mg} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol}}{606.2 \text{ g}} \times \frac{1000 \text{ mmol}}{1 \text{ mol}} \times \frac{1000 \mu\text{mol}}{1 \text{ mmol}} = 82.48 \mu\text{mol}$$

μmol to mg Conversion

Shorthand Formula:

$$\text{amt in mg} = \frac{(\text{amt in } \mu\text{mol} \times \text{MW of compound})}{1000}$$

How many mg of material are in the 20 μmol size of CNLM-4269-CA?

Shorthand example:

$$(20 \times 606.2) / 1000 = 12.12 \text{ mg}$$

Longhand example:

$$20 \mu\text{mol} \times \frac{1 \text{ mmol}}{1000 \mu\text{mol}} \times \frac{1 \text{ mol}}{1000 \text{ mmol}} \times \frac{606.2 \text{ g}}{1 \text{ mol}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 12.12 \text{ mg}$$

Top 10 Reasons to Use Ammonium Salts

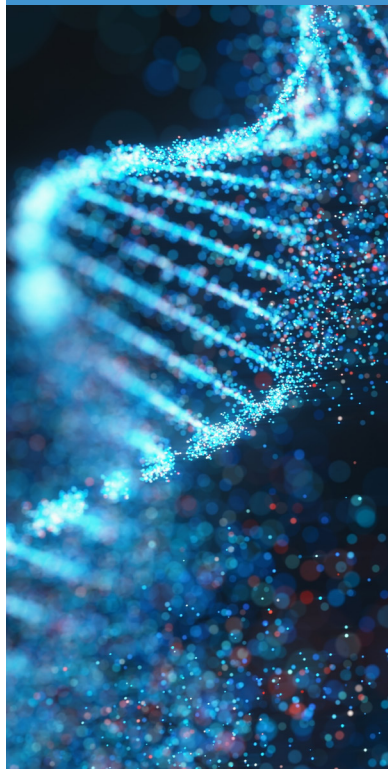
1. Self-buffering (pH ~7.6).
2. "Soft cation."
3. Nucleotides of ammonium salts are active with polymerases, synthetases, and phosphatases.
4. Volatile counter-ion.
5. The ammonium cation can be easily exchanged using DOWEX cation exchange resin.
6. The pH does not change during drying of the nucleotide (i.e. "speed-vac," lyophilize).
7. Stoichiometry between the counter-ion and the nucleotide is preserved.
8. Routinely compatible in down-stream syntheses.
9. Compatible in a variety of down-stream chromatography applications.
10. Tested to be comparable in side-by-side, *in vitro* transcription reactions!

A Special Thanks to Our Partner

Cassia LLC was founded in 2005 by noted NMR spectroscopists Drs. Jamie Williamson and Lincoln Scott. CIL gives special thanks to Cassia for the special relationship that combines CIL's isotopic material production and marketing with Cassia's unique expertise in RNA and DNA biosynthesis. Since 2005, CIL and Cassia have developed the most extensive product line of stable isotope-labeled RNA and DNA triphosphates, DNA phosphoramidites and other related compounds. All of these products are routinely available from CIL.



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