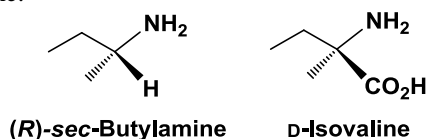


ENANTIOMERIC COMPOSITION OF METEORITIC *SEC*-BUTYLAMINE AND ISOVALINE. J. C. Aponte^{1,2}, J. P. Dworkin¹ and J. E. Elsila¹, ¹Solar System Exploration Division, Code 691, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA, ²Department of Chemistry, Catholic University of America, Washington, DC 20064, USA. Email: Jose.C.Aponte@nasa.gov

Amino acids constitute the basic building blocks of all protein-based living organisms on Earth, and thus, they are among the most studied organic compounds in carbonaceous chondrites. Most amino acids are chiral molecules (can exist as non-superimposable mirror images), and with rare exceptions only left-handed amino acids (L) are used by biological systems. A few meteoritic amino acids, most notably isovaline, have been found to contain an L-enantiomeric excess (L-*ee*), suggesting the origin of biological homochirality on Earth may not have occurred as a random process [1,2].

Aliphatic amines are a group of meteoritic organic compounds that are structurally related to amino acids and can also be chiral (Scheme 1). *Sec*-butylamine and isovaline share similar aliphatic branches, raising the possibility that they share common chemical origins [3,4]. Furthermore, these compounds showed similar ¹³C-isotopic compositions within experimental error in the Murchison meteorite, constraining their synthetic origins to the same primordial carbon pool [5].

Scheme 1. Structures of (*R*)-*sec*-butylamine and D-isovaline.



Isovaline is not abundant in Earth's biosphere, but it is frequently the most abundant five-carbon amino acid in carbonaceous chondrites [6,7]. Additionally, isovaline is not prone to geologically rapid racemization under aqueous or radiogenic conditions [8]. Therefore, isovaline is likely to preserve its primordial enantiomeric composition, including any measurable *ee* when present. Similarly, *sec*-butylamine is often the most abundant four-carbon amine isomer in chondrites, and is also highly resistant to racemization through parent body processes [5,9]. Thus, evaluating the enantiomeric composition of meteoritic *sec*-butylamine may provide valuable insights about the origins of the *ee* in isovaline.

We measured the enantiomeric composition of *sec*-butylamine (*R/S*) in five carbonaceous chondrites, and compared those values to previously reported enantiomeric compositions of isovaline (D/L; Table 1). In contrast to the L-*ee* found for the amino acid, *sec*-

butylamine was found as a racemic mixture within experimental error.

Table 1. Enantiomeric ratios of isovaline (D/L) and *sec*-butylamine (*R/S*).

Compound	Isovaline (D/L) ^a	<i>Sec</i> -butylamine (<i>R/S</i>)
Orgueil (CI1)	0.73 ± 0.07 ^a	0.95 ± 0.06
ALH 83100 (CM1/2)	0.84 ± 0.07	0.99 ± 0.02
Murchison (CM2)	0.83 ± 0.01 ^b	1.00 ± 0.01 ^b
LON 94101 (CM2)	0.95 ± 0.08 ^a	0.99 ± 0.02
LEW 90500 (CM2)	0.94 ± 0.03 ^a	0.98 ± 0.03

^aGlavin D. P. et al. (2011) *Meteorit. Planet. Sci.*, 45, 1948-1972.

^bAponte et al. (2014) *Geochim. Cosmochim. Acta*, 141, 331-345.

Since *sec*-butylamine and isovaline may have formed in the same cosmochemical environment, our results suggest that the processes that caused isovaline's asymmetry did not affect the enantiomeric composition of *sec*-butylamine in the same manner. Additionally, the racemic nature of *sec*-butylamine may not be consistent with processes that could lead to large enantiomeric excesses in aliphatic amines before the accretion of the meteorite parent body (e.g., circularly polarized light, radiation-induced processes). Nonetheless, the L-*ee* in isovaline may be the result of various amplification processes that occurred inside the parent body out of an originally small enantiomeric imbalance, which was not amplified or measurable for *sec*-butylamine.

Future studies investigating the selective synthesis or destruction of chiral aliphatic amines through energetic sources and radiation and those evaluating potential amplification mechanisms inside the parent body will complement the meteoritic molecular distributions and may provide further clues on the primordial synthesis and development of these prebiotic compounds.

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