

# Atomic Mass Nouns: Unity, Plurality and Semantic Flexibility\*

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Atomic mass nouns share morphosyntactic properties with prototypical mass nouns. At the same time, the former semantically deviate from the latter. Based on re-examined empirical data, I propose that the semantics of atomic mass nouns is *flexible*. Particularly, a semantic shift occurs when the default interpretation of an atomic mass noun results in implausible interpretation or ungrammaticality.

## 1. Introduction

Many languages, such as English and German, draw a distinction between *mass* nouns and *count* nouns, which is typically characterized by a variety of grammatical properties such as restriction of plural morphology (e.g., (1)) and determiner selection (e.g., (2)).

- (1) a. Chairs were purchased by the new neighbors.  
b. \*Furnitures were purchased by the new neighbors.
- (2) a. many cars / \*much team(s) / several computers  
b. \*many sand / much water / \*several equipment(s)

Prototypical count nouns denote discrete and bounded objects such as bananas and books (Lasersohn 2011: 1131), whereas mass nouns prototypically denote entities without salient atomic structures, for example, wine and powder. Nonetheless, a number of exceptions to the latter have long been noticed, among which there are **furniture**, **equipment** and **footwear**. Particularly, a mass noun could be almost (though imperfectly) synonymous to a count

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noun, as is illustrated by **footwear** and **shoes**. These mass nouns denote objects with salient atomicity. Hence, they are named *atomic mass nouns*.

Thereby, Chierchia (1998) claims that the mass/count distinction is independent from the structure of denotations. Based on the same observation, Rothstein (2010) draws the conclusion that the mass/count distinction is a grammatical rather than ontological distinction, and therefore must be accounted for in terms of how expressions refer instead of the objects they refer to. Under the framework of model-theoretic semantics, it needs to be specified how the denotations of nouns are formally represented in the derivation of meaning.

Crucially, atomic mass nouns display several properties that do not align with prototypical mass nouns (i.e., whose denotations do not have salient atomic structures). These properties indicate that atomic mass nouns call for a semantic analysis deviating from that for prototypical mass nouns.

- (i) Although both atomic mass nouns and prototypical mass nouns can be associated with classifiers such as **piece**, the objects falling under the denotation of the resultant nominal phrases of the latter are subject to constraints of size or shape (e.g., (3)). For instance, **a piece of cheese** normally cannot denote a huge cheese wheel. In contrast, classifiers extract atomic objects denoted by atomic mass nouns without constraining the shape or size of the extracted atoms. Instead, **piece** retrieves all FURNITURE-atoms and EQUIPMENT-atoms regardless of their shape or size.

(3) a piece of cheese, a piece of wood

(4) a piece of furniture, a piece of equipment

- (ii) Barner & Snedeker (2005) discover that quantity judgment with respect to prototypical mass nouns is determined by mass or volume (e.g., (5a)); whereas comparison of quantity with respect to atomic mass nouns is based on the number of individuals (e.g., (5b)), which is in line with that regarding prototypical count nouns (e.g., (5c)).

(5) a. Jack bought more cheese than Jane did.

b. Jack bought more furniture than Jane did.

c. Jack bought more chairs than Jane did.

At the same time, atomic mass nouns share most of the grammatical properties with prototypical mass nouns, such as singular verb agreement (6) and determiner selection (7).

- (6) a. The furniture is/\*are made in USA.  
 b. The gold is/\*are made in USA.
- (7) a. Jack purchased much/\*many furniture.  
 b. Jack purchased much/\*many gold.

Because of this duality of atomic mass nouns' semantic and grammatical properties, the formal representation of their meaning is rather controversial. There have been lots of attempts to address this issue, two of which are reviewed in Section 3, namely, Chierchia 1998 and Rothstein 2010. Despite plenty of evidence provided to justify the two analyses, I show that their main proposals contradict examples that are readily available.

Moreover, these two semantic analyses of atomic mass nouns, like many others, may have based their arguments on illusionary grammaticality judgment of sentences in which reciprocals take atomic mass NPs as antecedents. In order to verify the (un)grammaticality of certain sentences underlying the theoretic debate, an online survey concerning the interaction of atomic mass nouns and reciprocals is presented in Section 4 to reinforce the empirical basis of the analysis developed in this article. Basically, the results provide preliminary evidence that mass noun phrases serving as antecedents of reciprocals do *not* necessarily lead to absolute ungrammaticality that is on a par with typical ill-formed sentences such as (1b). Instead, the grammaticality judgment involving atomic mass nouns displays non-trivial cross-speaker variation and an overall neutral evaluation. Particularly, these results deviate from the grammaticality judgment reported by Chierchia (1998) and Rothstein (2010) and hence cast doubt on the soundness of the their analyses.

Given the re-examined empirical data, my main proposal is put forward in Section 5 to account for the duality of atomic mass nouns' semantic and grammatical properties. Rather than trying to derive all of the properties from a single semantic representation, I propose that the interpretation of atomic mass nouns is *flexible*. Specifically, the default interpretation is formally atomless (i.e., in which the atomic objects denoted by atomic mass nouns are 'invisible') and thus explains the properties shared with prototypical mass nouns. Further, an alternative interpretation with accessible atomic objects is activated as a 'last resort' in order to avoid implausibility or

ungrammaticality. For example, without a particular preceding context, the speaker of (5b) would not compare the quantities of furniture in terms of mass or volume. Instead, the quantity judgment is based on number of FURNITURE-atoms, which is in support of incorporating atomicity into the interpretation of atomic mass nouns.

Before diving into the discussion on the semantics of atomic mass nouns, two distinct formal representations of aggregations, *plurality* and *mereological sum*, are introduced in Section 2 which underlie the distinction between formal atomicity and formal atomlessness.

## 2. Two Types of Formal Aggregations

As has been widely noticed (e.g., Moltmann 1998, Nicolas 2008), there are several formal representations of aggregations employed in semantic analyses of nominals. One of them is *plurality*, which typically represents entities falling under the denotations of plural noun phrases. Formally,  $a \sqcup a'$  is the plurality consisting of exactly  $a$  and  $a'$ , and is also the denotation of the noun phrase **A and A'** where  $\llbracket \mathbf{A} \rrbracket = a$  and  $\llbracket \mathbf{A}' \rrbracket = a'$ . The components contained in a plurality are grammatically accessible. For instance, sentence (8) can mean that John had a glass of wine and Mary had another.

(8) John and Mary had a glass of wine.

Let  $\trianglelefteq$  denote the relation *among* between pluralities and their components. Formally,

$$a \trianglelefteq b \text{ iff } \exists A[a \in A \wedge b = \bigsqcup A]$$

In contrast, another formal representation of aggregation, *mereological sum* or *'fusion'* essentially comes with unity.<sup>1</sup> For example, the fusion of  $a$  and  $a'$  (notation:  $a \oplus a'$ ) is used to represent the aggregation of  $a$  and  $a'$  as a single entity, though possibly physically discrete (e.g.,  $a$  does not overlap with  $a'$ ). The unity of  $a \oplus a'$  can be formulated as (9).

(9)  $\forall d[d \trianglelefteq a \oplus a' \rightarrow d = a \oplus a']$

Two different pluralities  $g_1$  and  $g_2$  can have the same mereological sum. For instance, the upper half of a glass of water and the lower half form a plurality

<sup>1</sup> See Champollion & Krifka 2014 for an axiomatic characterization of *sum*.

that is not identical to the plurality formed by the left half and the right half, despite the mereological sums of the two pluralities being the same.

Let  $\leq$  denote the relation (*mereological*) *part-of*, which characterizes the relation between a mereological fusion and its parts and which can be defined in terms of sum/fusion as follows.

$$a \leq b \text{ iff } a \oplus b = b$$

Moreover,  $a$  is a *proper part of*  $b$  (notation:  $a < b$ ) iff  $a \leq b$  and  $a \neq b$ . A simple example illustrating the difference between *among* and *part-of* is as follows. Let  $a$  and  $b$  be two chairs and  $a'$  a leg of  $a$ . Then,  $a'$  stands in the mereological part-of relation  $\leq$  to  $a$  as well as to  $a \oplus b$ . Formally,  $a' \leq a$  and  $a' \leq a \oplus b$ . In contrast, the relation *among*  $\trianglelefteq$  holds between  $a$  and  $a \sqcup b$  but not between  $a'$  and  $a$  or between  $a'$  and  $a \sqcup b$ . In other words, neither  $a$  nor  $a \sqcup b$  is a plurality that contains  $a'$  as a component. More generally,  $\leq$  is transitive while  $\trianglelefteq$  is not.

Prototypical mass nouns cannot contain pluralities in their denotations by default. This claim is evidenced by the ungrammaticality of taking a naturally atomless mass definite as the antecedent of a reciprocal. Suppose that the denotation of each atomless mass noun stem **P** contains pluralities, it will be unexpected that a single mass noun phrase cannot be the antecedent of a reciprocal while a conjunction of two mass noun phrases can, because the components of the ‘plurality’ denoted by **the water** should be accessible as are John and Mary in the denotation of **John and Mary**. This is illustrated by (10a) and (10b).

- (10) a. \*The water repels each other.  
b. The water and the oil repel each other.

### 3. Existing Theories

#### 3.1. Chierchia 1998

In order to formally spell out his observation that the mass/count distinction is independent from the structures of denotations, Chierchia (1998) employs two formal entities to represent aggregations of objects: *plurality* and *groups*. Under his formal framework, a plurality is modeled as a *set*, which is not of primary interest for the discussion here; whereas groups are assumed to be

*atomic* (and thus singular) entities that essentially represent the denotations of group nouns such as **committee** and **family**. Crucially, each group consists of atomic constituents that could be retrieved from the containing group, so that (11) could describe such a situation that each family member is picking some apples him/herself, in contrast with a situation in which the whole family is collaborating in picking a common set of apples.

- (11) The family is picking apples.

Chierchia's (1998) treatment of atomic mass nouns can be summarized as follows: mass definites built from atomic mass nouns denote groups, which is enforced by the fact that they are morphologically singular. Given the intuitive proposal that plural definites denote pluralities, Chierchia's account appears to be able to explain the contrast between (12a) and (12b). Specifically, (12a) is perfectly grammatical while (12b) is claimed to be ungrammatical, despite the fact that **those pieces of furniture** and **that furniture** could denote the same external objects. Chierchia's analysis is straightforward: the former is formally represented as a plurality of FURNITURE-atoms while the latter denotes the group constituted of the FURNITURE-atoms.

- (12) a. The pieces of furniture are piled on top of each other.  
b. %The furniture is piled on top of each other.

Ultimately, this analysis of the interaction between reciprocals and atomic mass nouns, like many others, relies on the assumption that reciprocals require a (at least) semantically plural antecedent. In other words, the denotation of the antecedent of a reciprocal must contain multiple grammatically accessible constituents, which should be a plurality under Chierchia's (1998) framework.

Nonetheless, this analysis turns out to be ignorant of the semantic difference between group nouns and atomic mass nouns. Since both **the furniture** and **the family** denote a group, it could be expected that (13) is as ill-formed as (12b). This expectation of equal grammaticality is among Chierchia's (implicit) assumptions.

- (13) The family is supporting each other.

However, various sources of empirical data point toward the contrary. For instance, almost all of my informants think that (13) is to a large extent a fine

sentence, which is significantly better than (12b).<sup>2</sup> This difference is also noted by Rothstein (2010: 380). Therefore, a semantic analysis which treats the two types of nouns in the same way cannot account for the perceivable contrast between (12b) and (13).

### 3.2. Rothstein 2010

Basically, Rothstein (2010) attempts to account for various phenomena regarding the mass/count distinction in terms of type match/mismatch. In her formal framework, there is one primitive representation of aggregations, namely, (mereological) sum  $\oplus$  over a unique *mass domain*  $M$ .<sup>3</sup> Uniformly, each noun  $\mathbf{P}$  is associated with a root noun meaning  $P_{\text{root}} \subseteq M$ , i.e., the set of entities that have the property of being  $\mathbf{P}$ . In addition, the interpretation of an utterance is always relative to a specific context  $c$ , which formally consists of the atomic objects in the context. What semantically distinguishes count nouns from mass nouns is the types of their denotations. The denotation of a mass noun is identical to its root meaning (formally, (14a)); whereas each element falling under the denotation of a count noun is formally indexed by the context, which is formulated as (14b).

$$(14) \quad \begin{array}{ll} \text{a.} & \llbracket \mathbf{P}_{\text{mass}} \rrbracket_c = P_{\text{root}} \\ \text{b.} & \llbracket \mathbf{P}_{\text{count}} \rrbracket_c = \{ \langle d, c \rangle : d \in P_{\text{root}} \cap c \} \end{array}$$

The abstract entities employed in the formal representation that are of the form  $\langle d, c \rangle$  are named *count atoms* (Rothstein 2010: 363). Literally, count atoms are what serve as the units of grammatical counting. Despite the fact that the denotation of **furniture** also consists of salient atomic objects, they are not represented as count atoms, as is enforced by its status as a mass noun which cannot be directly associated with numerals.

As for the semantics of reciprocals, Rothstein imposes the following constraint (15) in order to account for the ‘ungrammaticality’ of sentences such as (12b).

<sup>2</sup> The informants reported in this article, whom I directly talk to, are native English-speaking non-semanticists at the Department of Linguistics of the University of Pennsylvania.

<sup>3</sup> Although Rothstein (2010) does not explicitly state that the sum operation employed in her analysis is *mereological* sum, several pieces of evidence support this conjecture. For instance, the *part-of* relation defined by  $\oplus$  is claimed to hold between her left thumb and her left hand.

- (15) The antecedent of a reciprocal must denote a plural entity in  $M \times \{c\}$ .<sup>4</sup>

In Rothstein’s (2010) analysis, **the furniture** is not a legitimate antecedent of the reciprocal since (i) the root meaning of any noun contains no count atoms and (ii) there is no reason to assume that the definite article **the** could shift the type of the head noun **furniture**. In other words, **the furniture** cannot serve as the antecedent of the reciprocal because the denotation of the mass definite NP is not a plural entity of the form  $\langle d, c \rangle$ .

Although the ‘ungrammaticality’ of (12b) appears to be well explained by (15), this approach runs into difficulties when conjunctive mass NPs are taken into account. As an illustration, sentence (16) is perfectly grammatical in which the antecedent is a conjunction of two mass definite NPs, which do denote sets of elements of the mass domain  $M$  rather than count atoms of the form  $\langle d, c \rangle$ . Rothstein explains the grammaticality of (16) by employing the operation of *group formation*, which converts  $\llbracket \text{the curtaining} \rrbracket$  and  $\llbracket \text{the carpeting} \rrbracket$  into two groups. Rothstein also assumes that groups are count atoms. Hence, **the curtaining and the carpeting** denotes a plural entity in  $M \times \{c\}$ , satisfying constraint (15).

- (16) The curtaining and the carpeting resemble each other.

Nonetheless, such an explanation is incompatible with the imperfectness of (12b). According to Rothstein 2010,  $\llbracket \text{the furniture} \rrbracket$  and  $\llbracket \text{the pieces of furniture} \rrbracket$  are both plural entities. The former is of the form  $\oplus P$  whereas the latter  $\langle \oplus P, c \rangle$ . The perfect grammaticality of (16) shows that group formation should also be applicable to  $\llbracket \text{the furniture} \rrbracket$ , as this operation is separately applied to  $\llbracket \text{the curtaining} \rrbracket$  and  $\llbracket \text{the carpeting} \rrbracket$  in (16). As a consequence,  $\llbracket \text{the furniture} \rrbracket$  can also be converted into a group. Since  $\llbracket \text{the family} \rrbracket$  is also a group, the contrast between (12b) and (13) remains unexpected.

Therefore, neither Chierchia (1998) nor Rothstein (2010) is able to capture the fine-grained data regarding reciprocals, atomic mass nouns and group

<sup>4</sup> According to Rothstein 2010, plural entities are obtained via the mereological sum  $\oplus$ . A plural entity of the form  $\langle d, c \rangle$  is such that  $d$  is a plural element in the mass domain  $M$ . Specifically,  $d$  is an aggregation of its atomic constituents obtained via  $\oplus$ . However, it has been noticed by Nicolas (2008) that it is problematic to represent plurality in terms of mereological sum. In this article, I will put aside this debate and focus on the logical consequence of this constraint on the grammaticality of reciprocals.



nouns.

#### 4. Reciprocals: From the Empirical Perspective

In the two existing theories reviewed in Section 3, sentences such as (12b) are marked with an asterisk \* which is by default used on ungrammatical sentences. Nonetheless, many of my informants report that they find (12b) significantly better than typical ungrammatical sentences like (17).

(17) \*The furnitures were purchased by the new neighbors.

Doubtlessly, it is crucial for an analysis regarding atomic mass nouns, and more generally, the mass/count distinction, to clarify people's judgment of the ill/well-formedness of this construction. Hence, a quick survey is conducted online to reinforce the reliability of the empirical data underlying my analysis presented in the next Section.

Overall, 102 native English-speaking participants (based on self-identification) were recruited via Mechanical Turk who were directed to the experiment hosted on Ibex Farm. Participants were instructed to evaluate the well-formedness of six sentences in terms of acceptability on a 5-point scale, with 1 standing for *definitely unacceptable*, 2 for *probably unacceptable*, 3 for *unsure*, 4 for *probably acceptable* and 5 for *definitely acceptable*. The six sentences presented to each participant consist of (i) four fillers, which are common to everyone and which are in the same order; and then (ii) a random sentence out of (18a) – (18d) and a random one out of (19a) – (19d) in a random order.

(18) a. The furniture is piled on top of each other.  
 b. The sawdust is piled on top of each other.  
 c. The chair is piled on top of each other.  
 d. The chairs are piled on top of each other.

(19) a. The equipment is connected to each other.  
 b. The water is connected to each other.  
 c. The computer is connected to each other.  
 d. The computers are connected to each other.

Each sentence was displayed and rated on a separate page, which constantly contains the question *How acceptable do you think this sentences is* and

five options of rating (e.g., *probably acceptable*), but the numerical value corresponding to each option was hidden. The survey proceeded immediately after each subject clicked on a rating option. The subjects could not return to an earlier sentence once it had been rated.

The results of the survey show the acceptability of different types of definite NPs serving as the antecedents of reciprocals. The primary results are summarized as follows, to which the Wilcoxon rank sum test was applied.

Sentence	Mean	SD	Sentence	Mean	SD
(18a)	3.71	1.24	(19a)	3.22	1.48
(18b)	2.75	1.48	(19b)	1.55	1.06
(18c)	1.69	1.06	(19c)	1.54	1.10
(18d)	4.81	0.60	(19d)	4.80	0.52

Take (18) as an example. Obviously, the atomic mass definite **the furniture** ( $N = 28$ ,  $M = 3.71$ ) serving as the antecedent of the reciprocal is significantly more acceptable ( $Z = 4.78$ ,  $p < .001$ ) than the singular count definite **the chair** ( $N = 23$ ,  $M = 1.69$ ), though it is still far from being perfectly well-formed ( $Z = 4.29$ ,  $p < .001$ ) comparing with the plural definite **the chairs** ( $N = 31$ ,  $M = 4.81$ ). In addition, (18a) displays noticeable cross-speaker variation ( $SD = 1.24$ ). Similarly, an overall neutral evaluation and a cross-speaker variation are also observed in the result regarding (19a) ( $N = 23$ ,  $M = 3.22$ ,  $SD = 1.48$ ).

Interestingly, sentence (18b) ( $N = 20$ ,  $M = 2.75$ ) is also better ( $Z = 2.73$ ,  $p = .003$ ) than (18c) and its acceptability is only slightly lower ( $Z = 2.21$ ,  $p = .014$ ) than (18a), though **sawdust** does not denote objects with perfectly salient atomic structure. Nonetheless, it could be imagined that the sawdust is constituted of perceivable chips, despite the fact that it is not always the case. Thus, sentence (18b) may be interpreted as a description of a scenario in which numerous chips of wood are piled on top of each other. In contrast, atomicity is by default much less salient in the denotation of **the water**, which explains the ill-formedness of (19b) ( $N = 31$ ,  $M = 1.55$ ). Furthermore, the large standard deviation of (18b) ( $SD = 1.48$ ) indicates that people differ from each other with respect to the acceptability of (18b) more than with respect to the other sentences in (18). This phenomenon may well be a consequence of sawdust's intermediate level of salience of atomic structure.

To sum up, the variations of acceptability within both (18) and (19) correlate with the salience of atomic structure of the denotations of reciprocals' antecedents. This is consistent with the judgments provided by other informants. Admittedly, the results are not as conclusive as people might expect, for several reasons. For instance, the category of atomic mass nouns is only instantiated by two nouns (i.e., **furniture** and **equipment**), which leaves the logical possibility that other atomic nouns would have different behavior in such a test. Still, these preliminary results tend to suggest that natural atomicity (or equivalently, salience of atomic structure) also plays a crucial role in determining the grammaticality of reciprocal constructions. This suggestion in turn implies that natural atomicity may trigger an interpretation of atomic mass nouns in which atomic entities are grammatically accessible, which is required by the grammaticality of reciprocal constructions. As a consequence, those theories which do not capture the intermediate grammaticality of sentences such as (18a) is likely to over-simplify the grammatical and semantic properties of atomic mass nouns.

## 5. Atomic Mass Nouns are Flexible

Suppose that the atomic elements of **[[furniture]]** are not grammatically accessible, it will be rather hard to understand why constraints of shape or size are not imposed on the denotation of **piece of furniture**. That is, the most plausible reason why those constraints apply to prototypical mass nouns but not to atomic mass nouns is: the atomic entities contained in the denotations of atomic mass nouns are grammatically accessible while no atomic objects are accessible in those of prototypical mass nouns.

This explanation is readily justified, provided that (a) a primary function of atomic entities is to facilitate counting and thus measuring the overall quantity of objects, and that (b) counting requires units. Objects denoted by prototypical mass nouns need to satisfy certain conditions such as shape and size in order to be countable, as many or most of them are inappropriate for counting, considering their diversity of shape, size and form of aggregation. In contrast, the atomicity of the objects denoted by atomic mass nouns provides the units of counting and thus are exempted from the constraints of shape or size on counting units.

Therefore, atomic objects must be contained in the denotations of atomic mass nouns in such a way that their grammatical accessibility is preserved,

so that the atomic objects can be readily retrieved. These observations point toward (20), where  $P_c^{\text{AT}}$  is the set of atomic objects denoted by  $\mathbf{P}$  in context  $c$ , e.g., **furniture** denotes pluralities of FURNITURE-atoms, since the atomic objects falling under the denotations of atomic mass nouns need to be retrieved in the interpretation of (4) and (5b) (repeated below as (21a) and (21b)). Pluralities, rather than mere atoms, should be contained, since (i) quantity judgment is determined by number of atoms, which often involves multiple atoms; and (ii) there is no overt morphosyntactic marking for pluralization of mass nouns. Therefore, plurality must be built into the interpretation (20).

$$(20) \quad \llbracket \mathbf{P}_{\text{atom, mass}} \rrbracket_c = \{ \sqcup S : S \subseteq P_c^{\text{AT}} \wedge S \neq \emptyset \}$$

- (21) a. a piece of furniture, a piece of equipment  
 b. Jack bought more furniture than Jane did.

The meaning of **piece** can be represented as follows where  $\psi$  is the constraint on shape/size that is encoded in **piece**. The type of count atom defined in Rothstein 2010 is adopted.

$$\llbracket \text{piece of } \mathbf{P} \rrbracket_c = \begin{cases} \{ \langle d, c \rangle : \exists d' \in \llbracket \mathbf{P} \rrbracket_c [d \leq d'] \} & \text{if (22) is satisfied;} \\ \{ \langle d, c \rangle : d \leq \oplus \llbracket \mathbf{P} \rrbracket_c \wedge \psi(d) \} & \text{otherwise.} \end{cases}$$

- (22)  $\llbracket \mathbf{P} \rrbracket_c$  contains (non-trivial) pluralities of elements of  $M$  (i.e., the mass domain).

Nonetheless, an atomic mass noun phrase serving as the antecedent of a reciprocal leads to partial ungrammaticality (e.g., (18a)), which is subject to cross-speaker variation and which is unexpected given (20). Those who think (18a) is ungrammatical mostly explain their intuition by appealing to the generalization that a reciprocal requires a plural antecedent, while **the furniture** is singular/non-plural.

Hence, the semantic representation of atomic mass nouns involves both plurality and atomlessness, and thus both visibility and invisibility of atoms. Furthermore, in the semantics of atomic mass nouns, these contrastive features are combined in such a way that is distinct from the way they are combined in the semantics of group/collective nouns, given the contrast in acceptability between (18a) and (13). That is, the atomic elements contained in  $\llbracket \mathbf{P}_{\text{atom, mass}} \rrbracket_c$  are not as readily accessible as are those contained in the denotations of group nouns.

The cross-speaker variation concerning (18a) and its overall neutral evaluation indicate that the semantic representation of atomic mass nouns is *flexible*. As a mass noun, **furniture** is interpreted according to (23) by default, since those characteristic properties of mass nouns (e.g., verb agreement) force the atomless and plurality-free interpretation of all mass nouns, which accounts for the ungrammaticality of (18a). Recall that the elements in (23) are fusions of atoms, thus the atoms are ‘invisible’, since the *part-of* relation  $\leq$  holds between a fusion and its atomic constituents as well as between the fusion and fragments of the atomic constituents. Therefore, *P*-atoms contained in elements of the default  $\llbracket \mathbf{P}_{\text{atom, mass}} \rrbracket_c$  cannot be retrieved without using additional items such as classifiers.

$$(23) \quad \llbracket \mathbf{P}_{\text{atom, mass}} \rrbracket_c = \{ \oplus S : S \subseteq P_c^{\text{AT}} \wedge S \neq \emptyset \}$$

Nonetheless, the plurality alternative (20) is pragmatically activated as a ‘last resort’, e.g., because of the lack of a grammatical antecedent of the reciprocal in (18a) (though only grammaticized by some speakers). Analogously, it is usually senseless to compare the quantity of furniture by volume; but the quantity judgment based on atomic entities requires the retrievability of FURNITURE-atoms and therefore invokes (20).

Furthermore, a contrast that needs to be accounted for is: the plural interpretation of atomic mass nouns is naturally activated in the interpretation of comparative constructions such as (5b), while the shift of interpretation is often resisted with respect to reciprocals. This can be understood if the motivation for shifting in the two situations are compared. If the plural interpretation is not triggered, the quantity judgment will have to be determined by volume of furniture, which is rather implausible. In this case, there is nothing that could inhibit the shift to the non-default interpretation (20). In contrast, if the default atomless interpretation (23) is preserved, sentences such as (18a) are ungrammatical; however, if the semantic shift occurs, sentence (18a) will become perfectly grammatical. That is, the shift from (23) to (20) results in a *categorical* change from ungrammatical to grammatical in reciprocal construction (18a), which makes people less certain about the legitimacy of such a move.

This section can be concluded with another desirable consequence of the proposal of semantic flexibility. Mainly, it can explain another fact concerning atomic mass nouns that Bale & Barner (2009) point out: atomic mass nouns are most resistant to count features such as pluralization. For example, **two waters** can be grammatical in particular contexts, but there

are no such contexts available for **furniture** or **equipment**. Given that the semantic representation of atomic mass nouns is flexible between (20) and (23), a hypothetical (singular) count interpretation of  $\mathbf{P}_{\text{atom, mass}}$ , where each element is a count atom of the form  $\langle d, c \rangle$  and whose plural form will denote pluralities of count atoms, is blocked by the plural interpretation (20). This is because, it would be rather confusing to have two different plural interpretations of the same noun, in both of which atomic objects are visible but are formally represented as being of different types. Moreover, following Rothstein (2010), only sets consisting of singular entities of the form  $\langle d, c \rangle$  can be pluralized.<sup>5</sup> Thus, there is no way to grammatically pluralize atomic mass nouns, even if the interpretation shifts to (20); instead, classifiers have to be employed as a type shifter.

## 6. Conclusion

The duality of semantic and grammatical properties of atomic mass nouns calls for a flexible semantics. The semantic flexibility is supported by preliminary evidence such as the overall neutral evaluation and the cross-speaker variation of the grammaticality of sentences containing atomic mass definites as the antecedents of reciprocals. The semantic shift is mostly driven by the pressure of plausibility or grammaticality. That is, the shift occurs when the default atomless interpretation leads to implausible interpretation or ungrammaticality.

Also, it has been argued that an approach which treats atomic mass nouns in the same way as group nouns or which appeals to mere type match/mismatch can only explain a limited part of the data. As for a semantic definition of group nouns, readers are referred to Cai 2015.

Still, it is not clear why certain nouns denoting entities with salient atomic structures are mass nouns. The answer might be obtained via historical investigation.

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<sup>5</sup> Similar constraints apply to other mass/count properties such as determiner selection.

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