MEAN ATOMIC WEIGHT OF ORDINARY CHONDRITES FROM SPANISH FALLS. M. Szurgot, Lodz University of Technology, Center of Mathematics and Physics, Al. Politechniki 11, 90 924 Lodz, Poland, (mszurgot@p.lodz.pl).

Introduction: Mean atomic weight, *Fe/Si* ratio, bulk and grain densities, and magnetic susceptibility are important properties to characterize minerals, rocks, planets, moons and asteroids, and are important to classify meteorites, and to characterize meteorite parent bodies [1-11]. The aim of the paper was to determine and analyze mean atomic weight (*Amean*) and *Fe/Si* ratio of fourteen ordinary chondrites from Spanish falls. The bulk composition, mineral composition, grain density, and magnetic susceptibility of the chondrites, determined by various researchers [1,12-21] were applied in calculations.

Results and discussion: Two groups of chondrites were analysed. First group included seven chondrites for which data on bulk composition are known: one LL (Olivenza), four L (Villalbeto de la Peña, Ojuelos Altos, Reliegos, and Ardón), and two H chondrites (Guareña, and Olmedilla de Alarcón). Second group included seven old Spanish chondrites: one L/LL (Cabezo de Mayo), one L (Madrid), and five H chondrites (Nulles, Molina, Cangas de Onis, Sena, and Cañellas). In this group of chondrites data on bulk composition are inaccessible, but grain density, magnetic susceptibility, and total *Fe* and *Si* content known.

First, bulk composition data were used to calculate mean atomic weight *Amean* by the equation:

$$Amean = \sum wi / \sum (wi/Ai), \quad (1)$$

where *wi*(wt%) is the mass fraction of i*th* element, and of *ith* oxide, and *Ai* is atomic weight of i*th* element.

Next, *Fe/Si* ratio, grain density (*dgrain*), and magnetic susceptibility (χ) were used to predict *Amean* values by *Amean(Fe/Si)*, *Amean(dgrain)*, and *Amean(log*χ*)* relationships, recently established by Szurgot (e.g. [3-11]):

$$Amean(Fe/Si) = (5.72 \pm 0.52) \cdot Fe/Si + (20.25 \pm 0.34), \quad (2)$$

$$Amean(dgrain) = 7.51 \cdot dgrain - 2.74, \quad (3)$$

$$Amean(\log\chi) = 1.49 \cdot \log\chi + 16.6. \quad (4)$$

$$Amean(d,\chi) = [Amean(dgrain) + Amean(\log\chi)]/2. \quad (5)$$

$$Amean(Fe/Si,d,\chi) = [Amean(Fe/Si) + Amean(dgrain) + Amean(\log\chi)]/3. \quad (6)$$

Table 1 compiles values of *Amean* and *Fe/Si* ratio calculated for Olivenza, Villalbeto de la Peña, Ojuelos Altos, Reliegos, Ardón, Olmedilla de la Alarcón, and Guareña chondrites. Literature data on bulk composition (without H_2O) of these meteorites have been used to determine both *Fe/Si* atomic ratio, and *Amean* values using eqs. (1) and (7). Figure 1 presents a linear relationship between *Amean* and *Fe/Si* ratio. For Spanish ordinary chondrites it is expressed by the equation:

$$Amean(Fe/Si) = (6.25 \pm 0.16) \cdot Fe/Si + (20.19 \pm 0.11). \quad (7)$$

For this fit: $R^2 = 0.998$, and RSME = 0.05.

Both equations: (2) and (7) represent the same relationship and lead to comparable, reliable values of *Amean*, but *Amean(Fe/Si)* values for Spanish OCs are better predicted by eq. (7) than by eq. (2).

Table 1 Mean atomic weight *Amean*, and *Fe/Si* atomic ratio of Olivenza, Villalbeto de la Peña, Ojuelos Altos, Reliegos, Ardón, Olmedilla de la Alarcón, and Guareña chondrites.

Meteorite (class)/*Fall*	*A(Bulk compos.)*	*Fe/Si*	*A(Fe/Si)*
Olivenza (LL5)/ *1924*	**23.29**	0.493	23.27
Villalbeto de la Peña (L6 S4)/ *2004*	**23.80**	0.578	23.80
Ojuelos Altos (L6)/*1926*	**23.82**	0.572	23.77
Reliegos (L5)/*1947*	**23.91**	0.601	23.95
Ardón (L6 S3)/*1931*	**23.97**	0.614	24.03
Olmedilla de Alarcón (H5)/*1929*	**25.13**	0.796	25.16
Guareña (H6)/*1892*	**25.32**	0.813	2527

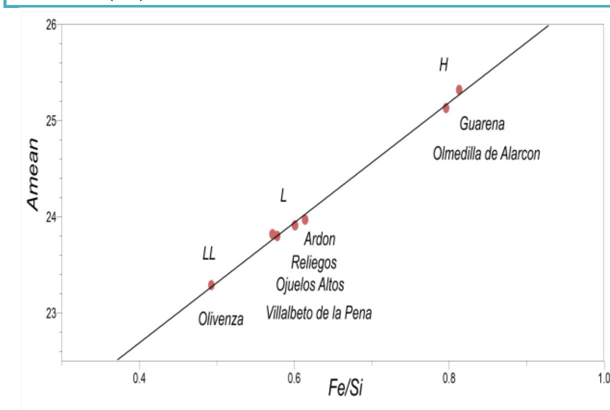

Fig. 1 Relationship between *Amean* and *Fe/Si* atomic ratio for Spanish ordinary chondrites.

Figure 2 and eq. (8) show that *Amean* values determined by bulk composition (eq. (1)) and *Amean* values determined by *Fe/Si* atomic ratio (eq. (7)) are nearly identical for Spanish ordinary chondrites, what is represented by the equation:

$$Amean(Bulk\ Compos.) = 1.001 \cdot A(Fe/Si) - 0.03, \quad (8)$$

for which $R^2 = 0.998$, and RSME = 0.05.

This proves that *Amean(Fe/Si),* and *Amean(Fe/Si,d,χ)* values represent verifiable and precise *Amean* data, on condition that *Fe/Si*, *dgrain*, and χ values are precise.

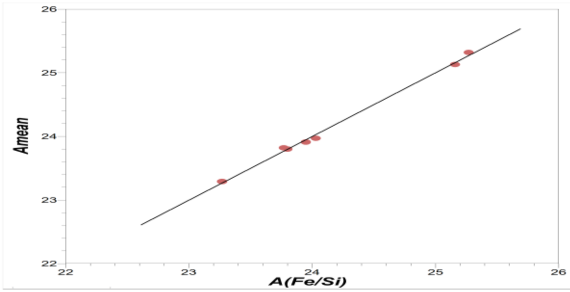

Fig. 2 Relationship between *Amean* determined by bulk composition (eq. (1)) and *Amean* determined by *Fe/Si* atomic ratio (*Amean*(*Fe/Si*)), eq. (7)) for Spanish ordinary chondrites. The fit is given by eq. (8).

Table 2 compiles values of *Amean* and *Fe/Si* ratio for Madrid, Cabezo de Mayo, Nulles, Molina, Cangas de Onis, Sena, and Cañellas chondrites calculated using eqs. (5), (6), and (9).

Table 2 Mean atomic weight *Amean*, and *Fe/Si* atomic ratio of Madrid, Cabezo de Mayo, Nulles, Molina, Cangas de Onis, Sena, and Cañellas chondrites.

Meteorite (class)/*Fall*	*Fe/Si*	*A(Fe/Si)*	*A(Fe/Si,d,χ)* *[A(d, χ)]*
Madrid (L6)/*1896*	**0.575***	23.78	**23.86#**
Cabezo de Mayo (L/LL6)/*1870*	**0.597**	23.92	**24.00**
Nulles (H6)/*1851*	**0.771***	25.01	**24.82**
Molina (H5)/*1858*	-	-	**[24.47]**
Cangas de Onis (H5)/*1866*	**0.863**	25.58	**25.17**
Sena (H4)/*1773*	**0.575***	23.78	**24.14**
Cañellas (H4)/*1861*	**0.745***	24.85	**24.75**

**Fe/Si* predicted by eq. (9). #Madrid's (L6) *Amean* and *Fe/Si* values are close to Ojuelos Altos, and Villalbeto de la Peña.

If *Fe*, and *Si* contents are unknown we can predict *Fe/Si* ratio by *Fe/Si(density)* relationship, recently discovered by Szurgot [7,11]:

$$Fe/Si = (d - 3.11)/0.765, \quad (9)$$

where *d* (g/cm^3) is uncompressed density of extraterrestrial object, or is grain density *dgrain* of the meteorie. Equation (9) predicts *Fe/Si* = 0.784 for Guareña (*dgrain* = 3.71 g/cm^3 [1]), and *Fe*, and *Si* content lead to about 4 % higher value: *Fe/Si* = 0.813 (Table 1). This means that eq. (9) predicts reliable value of *Fe/Si* ratio, comparable with the value resulting from the mean elemental composition of the meteorite.

Figure 1 and Tables 1 and 2 reveal three grups: LL, L, and H of Spanish ordinary chondrites. *Amean* and *Fe/Si* atomic ratio follow the inequalities:

AmeanLL(23.3)<AmeanL(23.8-24.0)<AmeanH(24.1-25.5), (10)

(Fe/Si)LL(0.49)<(Fe/Si)L(0.57-0.61)<(Fe/Si)H(0.74-0.86). (11)

Amean values of Spanish OCs are comparable to average *Amean* values determined by Szurgot for OC falls [5]:

AmeanLL(22.9)<AmeanL(23.7)<AmeanH(24.6)), (12)

and comparable to the mean values of *Fe/Si* ratios for OC falls [5]:

(Fe/Si)LL(0.52)<(Fe/Si)L(0.59)<(Fe/Si)H(0.81). (13)

This confirms the author's finding that the mean atomic weight can be used to resolve groups of ordinary chondrites [4-6,11]. However, Cabezo de Mayo (L/LL6) reveals too high, and Sena (H4) too low *Amean* and *Fe/Si* values, both typical of L group.

Conclusions: Mean atomic weight and *Fe/Si* ratio of Spanish ordinary chondrites confirmed classification of these meteorites. Mean atomic weight was proved to be a useful tool for verifying chondrite groups.

References: [1] Macke R. J. (2010) *PhD Thesis*, Univ. Central Florida, Orlando. [2] Flynn G. J. et al. (2017) *Chemie der Erde - Geochemistry*, *77*, in press. [3] Szurgot M. (2015) *LPSC XLVI*, Abstract #1536. [4] Szurgot M. (2015) *Metoritics & Planet. Sci. 50 Suppl. S1*, #5008.pdf. [5] Szurgot M. (2016) *LPSC XLVII*, Abstract #2180. [6] Szurgot M. (2016) *Metoritics & Planet. Sci.*, *51 Suppl. S1*, #6021.pdf. [7] Szurgot M. (2017) *Modern Analytical Methods II*, *LPI Contrib. No. 2021*, Abstract #6007. [8] Szurgot M. (2017) *LPI Contrib. No. 2021*, Abstract #6005. [9] Szurgot M. (2017) *LPS XLVIII*, Abstract #1130. [10] Szurgot M. et al. (2017) *Metoritics & Planet. Sci.*, *52 Suppl. S1*, #6002.pdf. [11] Szurgot M. (2017) *Metoritics & Planet. Sci.*, *52 Suppl. S1*, #6008.pdf. [12] Jarosewich E. (1990) *Meteoritics*, *35*, 323-337. [13] Urey H. C. and Craig H. (1953) *Geochim. Cosmochim. Acta*, *4*, 36-82. [14] McCoy T. J. et al. (1990) *Meteoritics*, *25*, 77-79. [15] Williams C. V. et al. (1985) *Meteoritics*, *20*, 331-345. [16] Casanova I. et. al. (1990) *Meteoritics*, *25*,127-135. [17] Escorza C. M. et al. (1999) *Tierra Tecnolog.*,*19*, 38-44. [18] Llorka J. et al. (2007) *Metoritics & Planet. Sci.*, *42, Nr 8 Suppl.*, A177-A182. [19] Lozano R. P. and Martin-Crespo T. (2004) *Metoritics & Planet. Sci.*, *39, Nr 8 Suppl.*, A157-A162. [20] Trigo-Rodriguez J. M. et al. (2014) *Metoritics & Planet. Sci.*, *49*, 1475-1484. [21] Garcia-Guinea J. et al. (2013) *Talanta*, *114*, 152-159.