MODAL COMPOSITION OF BRAUNSCHWEIG CHONDRITE. M. A. Szurgot, Lodz University of Technology, Center of Mathematics and Physics, Al. Politechniki 11, 90 924 Lodz, Poland (mszurgot@p.lodz.pl).

Introduction: Quantitative data on elemental and mineral composition of meteorites, relative abundance of constituent minerals, their density and porosity enable ones to estimate physical properties of meteorites and their parent bodies. Mineralogy, petrology and selected physical properties of Braunschweig chondrite (L6, S4, W0, fall in 2013 in Germany) have been studied [1-3]. The aim of the study was to determine modal composition of the Braunschweig meteorite, verify its bulk composition, mean atomic weight, and grain density.

Methods: Literature data on elemental composition of the Braunschweig meteorite, and composition of minerals [1], and trial and error method have been used to determine relative abundance of minerals in the chondrite, and contribution of minerals to the bulk composition. To calculate mean atomic weight *Amean,* and grain density *dgrain* of the meteorite the following formulas have been used

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

$$dgrain = \sum wi/\sum (wi/di), \qquad (2)$$

where *wi(wt %)* is the mass fraction of *ith* mineral, *Ai* is the atomic weight, and *di* is the grain density of *ith* constituent mineral. Experimental data on composition of Braunschweig's ten minerals: olivine (Fo74.6Fa24.9Te0.5), hyperstene (Opx) (En77.4Fs21.0Wo1.6), diopside (Cpx) (En47.0Fs8.3Wo44.7), plagioclase (Ab83.6An10.3Or6.1), troilite (FeS), kamacite (Fe94.3Ni5.8Co1.0), taenite (Fe76.6Ni22.4Co0.6), chromite ($FeCr_2O_4$), ilmenite ($FeTiO_3$), and merrillite ($Ca_{18}Na_2Mg_2(PO_4)_{14}$) have been used [1].

Results: Our data indicate that Braunschweig chondrite consists of the following minerals (wt%): olivine 46%, orthopyroxene 22%, clinopyroxene 7%, plagioclase 9.3%, troilite 4.8%, kamacite 4.7%, taenite 4.7%, chromite 0.8%, ilmenite 0.2%, and merrillite 0.6%. Modal composition of Braunschweig expressed in volume %: olivine 46.4%, orthopyroxene 24.4%, clinopyroxene 7.8%, plagioclase 12.3%, troilite 3.6%, kamacite 2.1%, taenite 2.1%, chromite 0.6%, ilmenite 0.1%, and merrillite 0.7%. The comparison of the Braunschweig's abundance of minerals with the literature data for L chondrites [4,5] shows a satisfactory agreement. For example, the modal composition of New Concord L6 chondrite established by Dunn and coworkers [4] is as follows (wt %): olivine 44.7%, orthopyroxene 21.6%, clinopyroxene 8.8%, plagioclase 10%, troilite 5%, metal (Fe, Ni, Co) 9.4%, other minerals (chromite, ilmenite and merrillite) 1.4%.

Quantitative data on abundance of constituent minerals in Braunschweig chondrite together with the composition of minerals [1] gave the possibility to verify mean atomic weight and grain density of the chondrite. The calculations show that mean atomic weight *Amean(modal)* = 23.90 (eq.(1)), and grain density (eq.(2)) of the Braunschweig *dgrain(modal)* = 3.552 g/cm^3. These theoretically predicted values are close to those recently determined: *Amean(Bulk composition)* = 23.68 [3], and *dgrain* = 3.553 g/cm^3 [1].

Comparison of the predicted bulk composition of Braunschweig chondrite by its modal composition, represented by *Wipredicted(wt%)* values, with the experimental data on abundance of elements *Wiexper(wt%)* reveals a relatively good agreement (Fig. 1). *Wipredicted(Wiexper)* relationship is expressed by the linear fit:

$$Wipredicted = 1.002\ Wiexper + 0.03, \qquad (3)$$

for which $R^2 = 0.9999$, and RMSE = 0.16.

The following values of *Wipredicted(wt%)* have been obtained for the Braunschweig chondrite: Si = 18.44 (18.55), Ti = 0.118 (0.0644)), Al = 1.095 (1.16), Cr = 0.3707 (0.3804), Fe = 22.13 (21.6)), Mn = 0.262 (0.267), Mg = 15.16 (15.00), Ca = 1.56 (1.41), Na = 0.691 (0.712), K = 0.083 (0.102), P = 0.121 (0.131), Ni = 1.324 (1.23), Co = 0.078 (0.0601), S = 1.75 (1.75), O = 36.43 (36.55). The experimental values of abundance

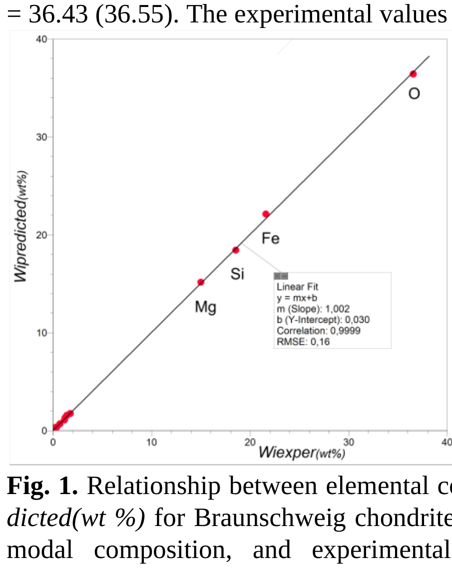

Fig. 1. Relationship between elemental content *Wipredicted(wt %)* for Braunschweig chondrite predicted by modal composition, and experimental data *Wiexper(wt%)* [1] concerning the bulk composition of the meteorite.

of elements *Wiexper(wt%)* presented above and determined by ICP technique [1] are in parentheses. Silicon abundance in Braunschweig chondrite was not measured so it was added assuming that is equal to the average for L6 chondrites [6], similarly as oxygen abundance which for Braunschweig chondrite was calculated by adding up to 100%.

Presented data indicate that the modal composition leads to the value of *Fe/Si* atomic ratio: *Fe/Si(modal)* = 0.604, which is close to the *Fe/Si* ratio determined by bulk composition: *Fe/Si(Bulk composition)* = 0.587 [3].

Knowledge of distribution of elements in minerals forming meteorites and in meteorite parent bodies, and their contribution to the total content is important for planning space missions for astro mining purposes.

The results of an analysis of the mineral contribution to the global bulk composition of Braunschweig chondrite presented below was based on Bartoschewitz and coworkers data [1] on the presence and content of elements in minerals of Braunschweig chondrite. The presence of elements indicated below in minerals of L6 Braunschweig chondrite is expected for L chondrites [7].

Oxygen, the major element in Braunschweig chondrite is present in olivine (OL), orthopyroxene (Opx), diopsode (Cpx), plagioclase (PL), chromite (Chr), ilmenite (Ilm), and in merrillite (Mer), according to the inequality:

O: OL(51.3%)>Opx(27.2%)>PL(12.3%)>Cpx(8.3%)> >Chr(0.9%)>Mer(0.005%)>Ilm(0.003%), where the percent represents the contribution of a given mineral to the global content of an element.

Iron, the major element in Braunschweig chondrite is present in olivine (OL), kamacite (Ka), taenite(Tae), troilite (Tr), orthopyroxene (Opx), diopsode (Cpx), plagioclase (PL), chromite (Chr), ilmenite (Ilm), chromite (Chr), and in ilmenite (Ilm):

Fe: OL(36.9%)>Ka(19.8%)>Tae(16.3%)>Tr(13.8)> >Opx(10.7%)>Cpx(1.3%)>Chr(0.9%)>Ilm(0.3%)> >PL(0.1%).

Magnesium, another major element is present in olivine (OL), orthopyroxene (Opx), diopsode (Cpx), and in chromite (Chr):

Mg: OL(70.3%)>Opx(25.0%)>Cpx(4.6%)>Chr(0.1%).

Nickel, and cobalt are present in kamacite (Ka), and in taenite (Tae):

Ni: Tae(79.5%)> Ka(20.5%),

Co: Ka(61.5%)>Tae(38.5%).

Calcium, the minor element in Braunschweig chondrite is present in diopside clinopyroxene (Cpx), in orthopyroxene (Opx), in plagioclase feldspar (PL), and in merrillite (Mer):

Ca: Cpx(69.2%)>Mer(12.9%)>Pl(9.2%)>Opx(8.3%).

Potassium is present only in plagioclase feldspar (100%), phosphorus only in merrillite (100%), and sulfur only in troilite (100%).

Aluminum, a minor constituent of Braunschweig chondrite is present almost entirely in plagioclase (PL), also in chromite (Chr), diopside (Cpx), and in orthopyroxene (Opx):

Al: PL(94.2%)>Chr(2.3%)>Cpx(1.7%)=Opx(1.7%).

Chromium, a minor constituent is present in chromite (Chr) and partly in diopside (Cpx), and in orthopyroxene (Opx):

Cr: Chr(83.8%)>Cpx(11.8%)>Opx(4.5%).

Titanium, a minor constituent in stony, and in stony iron meteorites is present in several phases [7]. In Braunschweig chondrite titanium is present in ilmenite (Ilm), orthopyroxene (Opx), in diopside (Cpx), and in chromite (Chr):

Ti: Ilm(53.5%)>Opx(20.2%)≥Cpx(19.9%)> >Chr(12.5%).

Manganese, a minor element in Braunschweig chondrite is present in olivine (OL), orthopyroxene (Opx), diopside (Cpx), and in merrillite (Mer):

Mn: OL(62.6%)>Opx(31.7%)>Cpx(5.7%)> >Mer(0.1%).

Sodium in Braunschweig chondrite is present in plagioclase (PL), in merrillite (Mer), orthopyroxene (Opx), and in diopside (Cpx):

Na: PL(97.4%)>Mer(1.7%)>Opx(0.5%)≥Cpx(0.4%).

Conclusions: Relative abundance of constituent minerals established for Braunschweig L6 chondrite is within the range of modal mineralogy of L chondrites. Grain density and mean atomic weight of the chondrite can be precisely predicted by modal mineralogy. Bulk chemical composition of Braunschweig chondrite and contribution of minerals to the bulk composition can be predicted using elemental composition of minerals, and modal composition of meteorite.

References: [1] Bartoschewitz R. et al. (2017) *Chemie der Erde Geochemistry 77*, 207-224. [2] Szurgot M. et al. (2014) LPI Contribution No. 1800, #5015.pdf. [3] Szurgot M. et al. (2017) LPI Contribution No. 1987, #6002.pdf. [4] Dunn T. L. et al. (2010) *Meteoritics & Planetary Science, 45*, 123-134. [5] McSween H. Y. Jr. et al. (1991) *Icarus, 90*, 107-116. [6] Jarosewich E. (1990) *Meteoritics 35*, 323-337. [7] Mason B. (1979) Cosmochemistry [in:] Data on Geochemistry, Fleischer M. (Ed.), Washington.