MEAN ATOMIC WEIGHT AND THERMOPHYSICAL PROPERTIES OF ÇANAKKALE METEORITE.
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Introduction: Physical properties are important to characterize minerals, rocks, planets, moons and asteroids, and are important to classify meteorites. Recently interrelationships between mean atomic weight (Amean), grain density (dgrain), and iron to silicon ratio for planetary materials were revealed and applied for predicting and verifying mean atomic weight, Fe/Si atomic ratio, and grain density of ordinary chondrites, enstatite chondrites, Earth, Venus, Mars, Mercury, Moon, and Vesta [1-7]. The aim of the paper was to determine mean atomic weight and to predict specific heat, thermal conductivity, thermal diffusivity, and thermal inertia of Çanakkale meteorite. The meteorite fell in late July, 1964, near Çanakkale, Turkey, and has been classified as L6 chondrite [8].

Results and discussion: Predictions presented in this report were made using various empirical relationships recently established.

To determine mean atomic weight of Çanakkale meteorite relationships between mean atomic weight and selected physical properties such as: grain density Amean(dgrain), magnetic susceptibility Amean(χ), and Fe/Si ratio Amean(Fe/Si) have been used. They are expressed by the equations [4]:

Amean(dgrain) = 7.51 ∙ dgrain - 2.74,  
Amean(χ) = 1.49 ∙ log χ + 16.6,  
Amean(Fe/Si) = 6.25 ∙ Fe/Si + 20.19.  

Experimental data on grain density and magnetic susceptibility for Çanakkale meteorite measured by Macke [9]: dgrain = 3.51±0.02 g/cm³, and log χ = 4.71±0.09 substituted into eqs. (1) and (2) predict Amean(dgrain) = 7.51 ± 0.02, and Amean(Fe/Si) = 6.25 for Çanakkale chondrite. Value of Fe/Si atomic ratio (0.542) for Çanakkale was calculated by Fe/Si(dgrain) dependence [4]:

Fe/Si(dgrain) = (dgrain - 3.06)/0.83  

These Çanakkale Amean values lead to the arithmetic mean: 23.61±0.02. Mean atomic weight of Çanakkale is within the L6 falls range: 23.6-24.4 [10], and is the same as Bursa L6 chondrite Amean (23.6±0.17) [7]. The results indicate that Çanakkale Fe/Si atomic ratio is relatively low: 0.542, but is also within the L6 falls range: 0.53-0.65 [10].

Grain density of Çanakkale meteorite was verified by dgrain(Amean) relationship [1,4]:

dgrain(g/cm³) = 0.133 ∙ Amean + 0.37,  

for which RMSE = 0.07 g/cm³. Substituting Amean = 23.61 into eq. (5) gives dgrain = 3.51 g/cm³ for Çanakkale chondrite. This is the same value as that measured by Macke [9].

Mean atomic weight enables one to predict room temperature (RT) values of specific heat capacity of ordinary chondrites, and common mean atomic heat of ordinary chondrites is equal to: 17.5±0.6 J/(mol∙K) at 300 K [11]. Cp(Amean) dependence is expressed by the equation [11]:

Cp(Amean, J/(kg∙K)) = (17.5±0.6)/Amean.  

Substituting Amean = 23.61 into eq. (6) gives Cp = 741±25 J/(kg∙K) for Çanakkale chondrite at 300 K. This is a reliable value for this L6 chondrite, since many experimental data on CP’s for various individual ordinary chondrites are close to this value [7, 11-16].

Knowledge of bulk density (dbulk) enables one to predict thermal properties of meteorites such as: specific heat, thermal diffusivity, and thermal conductivity [11-13, 17, 18].

To predict room temperature (300 K) value of specific heat (Cp) of Çanakkale chondrite relationship between specific heat and bulk density Cp(dbulk) was also applied. It is expressed by the equation [11-13]:

Cp(dbulk) = a ∙ b/dbulk,  

where constant a = 306 J/(kg∙K), and constant b = 1310 kJ/(m³ K). Macke’s measurements have shown that bulk density of the Çanakkale chondrite equals to: dbulk = 3.29±0.04 g/cm³ [9].

Cp(dbulk) dependence leads to the value of specific heat capacity of Çanakkale: Cp = 704±15 J/(kg∙K) at 300 K, which is somewhat smaller but still reasonable value.

Our both predictions indicate that Çanakkale chondrite Cp(300 K) is within the range: 704-741 J/(kg∙K), and their mean:

Cpmean(300 K) = (Cp(Amean) + Cp(dbulk))/2,  

is equal to: 722±26 J/(kg∙K). This Çanakkale Cp(300 K) is close to the experimental values of Cp for other L6 chondrites: 728±35 J/(kg∙K) for Sołtmany [13], 727±32 J/(kg∙K) for Braunschweig [19], and 740±33 J/(kg∙K) for Bursa [7].
Since specific heat of ordinary chondrites at 200 K is 1.33 times lower than at 300 K we expect that for Çanakkale chondrite $C_p(200 \text{ K}) = 543 \pm 20 \text{ J/(kg-K)}$.

The volumetric heat capacity of Çanakkale chondrite

$$ C_{volumetric} = C_p \cdot dbulk, \quad (9) $$

is equal to $2.4\pm0.1 \text{ MJ/(m}^3\text{-K)}$ at RT, and is close to the RT value characteristic of stony meteorites: $2.5 \text{ MJ/(m}^3\text{-K)}$ [12]. Our results show that low temperature value of volumetric heat capacity $C_{volumetric}(200 \text{ K}) = 1.8\pm0.1 \text{ MJ/(m}^3\text{-K)}$.

Thermal diffusivity ($D$) of Çanakkale chondrite was predicted by $D(dbulk)$ dependence. Thermal diffusivity

$$ D(10^6 \text{ m}^2/\text{s}) \text{ is a linear function of bulk density } dbulk(\text{kg/m}^3) \text{ and is expressed by the empirical equation:} $D(dbulk) = E \cdot dbulk + F, \quad (10) $$

and coefficients $E$ and $F$ are constants for a given temperature: $E = 2.49\cdot10^{-6} \text{ m}^2/\text{s}$, $F = -7.11\cdot10^{-6} \text{ m}^2/\text{s}$ at 298 K [18,13]. According to eq. (10) Çanakkale chondrite room temperature value of thermal diffusivity $D(298 \text{ K}) = 1.1\pm0.1\cdot10^{-6} \text{ m}^2/\text{s}$. This value is within the range of experimental $D$ values established by Yomogida and Matsui for L chondrites: $(0.1\text{-}1.1)\cdot10^{-6} \text{ m}^2/\text{s}$ [20], and within the range of experimental data established by Szurgot and Wojtatowicz for chondrites: $(0.5\text{-}2)\cdot10^{-6} \text{ m}^2/\text{s}$ [18].

Thermal conductivity $K(\text{W/(m-K)})$ of Çanakkale chondrite was predicted by well-known relationship between $K$, $C_p$, $dbulk$, and $D$:

$$ K = C_p \cdot D(dbulk), \quad (11) $$

and by $K(dbulk)$ dependence expressed by the equation:

$$ K(dbulk) = A \cdot dbulk + B, \quad (12) $$

and coefficients $A$ and $B$ are constants for a given temperature: $A = 8.81\cdot10^{-3} \text{ Wm}^2/\text{kg}$, $B = -26.7\cdot10^{-6} \text{ W/(m-K)}$ at 298 K [17,13].

According to eq. (11) Çanakkale chondrite room temperature value of thermal conductivity is equal to $2.6\pm0.4 \text{ W/(m-K)}$, and according to eq. (12) is equal to $2.3\pm0.4 \text{ W/(m-K)}$. This reveals the range of $K(298 \text{ K})$: $2.3\text{-}2.6 \text{ W/(m-K)}$, and the average $K_{mean}(298 \text{ K}) = 2.45\pm0.21 \text{ W/(m-K)}$ for RT thermal conductivity of Çanakkale chondrite, This value is comparable with that measured for Dar al Gani 610 H4 chondrite: $2.5 \text{ W/(m-K)}$ [17], and is relatively close to the average value of $K(300 \text{ K}) = 1.6\pm1.2 \text{ W/(m-K)}$ reported by Ostrowski and Bryson for L chondrites [15]. Çanakkale chondrite room temperature value of thermal conductivity is within the range of experimental $K(RT)$’s established by Opeil and coworkers for L chondrites: $0.5\text{-}5.2 \text{ W/(m-K)}$ [21].

Thermal inertia $Γ$ quantifies the ability of material to store and retain daytime heat. Thermal inertia $Γ(300 \text{ K})$ of Çanakkale chondrite was calculated for RT by the well-known relationship:

$$ Γ = (K \cdot C_p \cdot dbulk)^{1/2}. \quad (13) $$

Substituting predicted values: $K_{mean}(298 \text{ K}) = 2.45\pm0.21 \text{ W/(m-K)}$, and $C_pmean(300 \text{ K}) = 722\pm26 \text{ J/(kg-K)}$, and measured by Macke [9]: $dbulk = 3.29\pm0.04 \text{ g/cm}^3$ into eq. (13) gives thermal inertia $Γ(300 \text{ K}) = (2.4\pm0.2)\cdot10^3 \text{ J s}^{-1/2} \text{ K}^{-1} \text{ m}^2$ for Çanakkale chondrite. This is a reliable value, expected for ordinary chondrites.

**Conclusions:** Mean atomic weight indicates that Çanakkale belongs to L6 chondrites, and is similar to Bursa meteorite. Specific heat, thermal diffusivity, thermal conductivity, and thermal inertia of Çanakkale meteorite are within the range of experimental values established for ordinary chondrites.