Polycyclic aromatic hydrocarbons in Jbilet Winselwan carbonaceous CM chondrite: Novel molecular proxies for thermal metamorphism of asteroids

Hiroki Kato[1], *Hikaru Yabuta[1]

1. Hiroshima University, Department of Earth and Planetary Systems Science

Introduction: On June 27, 2018, Hayabusa2 spacecraft arrived at the C-type asteroid Ryugu (Watanabe et al. 2019). The surface of Ryugu is thought to have experienced thermal metamorphism, according to the remote sensing observations (Kitazato et al. 2019). Therefore, it is important to investigate the chemical compositions of thermally metamorphosed CM chondrites for understanding the surface process of asteroid Ryugu. Although the extents of thermal metamorphism of CM chondrites have been evaluated by elemental and molecular compositions of insoluble organic matter (IOM) (Naraoka et al. 2004; Yabuta et al. 2005), molecular-level evolution of IOM is still unknown. Soluble organic molecules from the thermally metamorphosed CM chondrites have not been quantified (Shimoyama et al. 1989). Therefore, in this study, we analyzed polycyclic aromatic hydrocarbons (PAHs) in Jbilet Winselwan CM chondrite, which is a thermally metamorphosed CM chondrite and show similar reflectance spectrum to that of asteroid Ryugu (Sugita et al. 2019), for precise evaluation of parent body thermal metamorphism. The relative abundances of the hydrocarbons were compared with those of Murray CM chondrite and Allende CV3 chondrite.

Samples and Methods: Powdered samples of Jbilet Winselwan (CM2), Murray (CM2), and Allende (CV3) meteorites (0.2-0.4g) were extracted with dichloromethane/methanol (9:1) by sonication. The extracts were applied to a silica gel column. From the column, aliphatic hydrocarbons were eluated with hexane and then PAHs were eluated with dichloromethane. The hexane and dichloromethane eluates were concentrated to 100 μl individually under a nitrogen flow for analysis by a GC-MS. Identification and quantification of compounds were made by comparison of peak retention times on mass chromatograms and mass spectra, and peak areas, respectively, with those of standard compounds. For compounds without standard compounds, identification was made by comparison of mass spectra with library data.

Results and discussion: Total concentration of PAHs from Jbilet Winselwan meteorite (0.22 μg/g meteorite) was 350 times lower than those from Murray meteorite (74.0 μg/g meteorite). Di- and trimethylnaphthalenes, fluorene, phenanthrene, pyrene, fluoranthene, methylbiphenyl (0.002-0.036 μg/g meteorite) were identified from Jbilet Winselwan, while low molecular weight PAHs, such as naphthalene, methylnaphthalene, and acenaphthene, and cata-condensed PAHs, such as anthracene, benz[a]anthracene, chrysene, were not detected. Thus, highly volatile and/or structurally unstable PAHs in Jbilet Winselwan meteorite were preferentially lost during thermal metamorphism. On the other hand, biphenyl-type PAHs, such as biphenyl (BIP), methylbiphenyls (MBP), diphenylamine, benzophenone, fluorenone, dinenzofuran, oxibisbenzene, are relatively abundant in Jbilet Winselwan compared to those in Murray and Allende. In order to evaluate the thermal metamorphism on the parent body of Jbilet Winselwan meteorite, we have applied several organic geochemical molecular thermal indicators: (i) a

ratio of fluorene to 2-methylbiphenyl (FLU/2-MBP) and (ii) methylphenanthrene (MP) isomer ratio ([2-MP+3-MP]/[1-MP+4-MP+9-MP]). The ratio of FLU/2-MBP for Jbilet Winselwan was one order of magnitude higher than Murray, indicating that cyclisation reaction of 2-MBP to give FLU prpbably occured during thermal metamorphism of the Jbilet Winselwan parent body. Also the MP isomer ratio for Jbilet Winselwan was three times higher than Murray, indicating that methyl rearrangement of methylphenanthrene isomers probabaly occured during thermal metamorphism of the Jbilet Winselwan parent body. Applying the ratios to the kinetic parameters of these two reactions obtained by organic geochemical studies (Alexander et al. 1988; Sanpei et al. 2004), it was estimated that Jbilet Winselwan meteorite experienced 410 –428 degrees Celcius for one week, or 387-397 degrees Celcius for one month.

Keywords: Carbonaceous chondrites, PAHs, Thermal metamorphism

