Homework #5

Mass Spectrometry, Stardust

Assigned: March 22, 2021 Due: March 29, 2021

Percentages for each problem of the total grade (100%) as given. Sub-problems, if present, split the problem's percentage equally. Please show your work!

Problem 1 Time-of-Flight Mass Analyzer (20%)

In a time-of-flight (TOF) mass analyzer, ions are separated by mass over charge based on the flight time they each take to travel a given distance d. After passing an electrical potential (U), all ions are given the same energy $E_{\mathrm{el}} = qU$. Depending on their mass, they will fly through the mass analyzer at different velocities. Show that the flight time is proportional to $\sqrt{m/q}$ and determine the proporitonality constant. What quantities go into the proportianlity constant?

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Problem 2 Delta-Values (20%)

The solar abundances of ^{46}Ti and ^{48}Ti are 204 and 1820 (normalized such that silicon is equal to 10^6).

a. Calculate the $\delta^{46}\mathrm{Ti}_{48}$ for a sample that shows a titanium isotope ratio of $^{46}\mathrm{Ti}/^{48}\mathrm{Ti} = 0.2$.

b. What would it mean if a study reports $\delta^{46}\mathrm{Ti}_{48} = -1000‰$?

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Problem 3 Solar System Contamination (20%)

The *s*-process model by Lugaro et al. (2018), see Figure 7.10 in the lecture notes, predicts for a $M = 2.5\,M_\odot$, $Z = 2Z_\odot$ star the following δ-values for the zirconium isotopic composition in the last thermal pulse in which most of the mass-loss happens:

- $\delta^{92}\mathrm{Zr}_{94} = -207‰$
- $\delta^{96}\mathrm{Zr}_{94} = -937‰$

Assume that the measured presolar grian composition is a mixture of this *s*-process component and some solar contamination. This contamination would have solar composition. In the Solar System, the relative abundances of ^{92}Zr, ^{94}Zr, and ^{96}Zr are 17.146%, 17.38%, and 2.799%, respectively. Create a δ-plot analogous to Figure 7.10 where you show (1) the *s*-process composition, (2) the solar composition, and (3) a mixing line in between the two. *Hint:* Mixing is not linear in δ-units, thus you must calculate mixing with isotope ratios.

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Problem 4 Number of Atoms per Presolar Grain (20%)

Assume that you have a spherical SiC grain with $1\,\mu$m radius. The density of SiC is $3.21\,\mathrm{g\,cm^{-3}}$ and the molar mass about $40\,\mathrm{g\,mol^{-1}}$.

a. With Avogadro's constant $N_A = 6.022 \times 10^{23}\,\mathrm{mol^{-1}}$, calculate the number of SiC molecules in the grain.

b. Assume that iron (molar mass: $56\,\mathrm{g\,mol^{-1}}$) has a concentration in the grain of 10 ppm by weight. Calculate the number of iron atoms in the grain. *Hint:* Be careful to not mix up weight fractions and number fractions!

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Problem 5 Solar System SiC? (20%)

The constituents of the Solar System condensed from a hot molecular cloud. Explain why all SiC grains found in meteorites are bona fide stardust samples. Why did no SiC condense in the solar nebula?

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