Planetary Geology 4460
Homework #3
Due Friday Sept. 22, 2017

#1 (20 points) Initial ^{26}Al abundances in CAI's

^{26}Al decays to ^{26}Mg with a half-life of 0.73 My. Because this is so short, essentially all the ^{26}Al which was originally present has now become ^{26}Mg. The isotopes ^{24}Mg and ^{27}Al are non-radiogenic and (assuming chemically closed systems) remain constant. We want to determine the amount of ^{26}Al which was originally present when our sample formed (actually, the ($^{26}Al/^{27}Al$) ratio), which we can then use to determine formation ages and formation conditions.

We determine this ($^{26}Al/^{27}Al$) ratio by measuring the abundance of current ^{26}Mg vs. current ^{27}Al in different minerals making up the sample. Ideally we use minerals rich in Al and poor in Mg, and also the reverse. As usual in isotope geochemistry we actually determine abundance ratios, in this case relative to ^{24}Mg, so we will plot ($^{26}Mg/^{24}Mg$) vs. ($^{27}Al/^{24}Mg$).

If we assume all the ^{26}Al had decayed to ^{26}Mg before the sample formed (and presumably homogenized the chemically "identical" isotopes of Mg) then all minerals in the sample will have the same $^{26}Mg/^{24}Mg$ ratio, regardless of how much Al they contain, because all the ^{26}Al was gone. In our plot all the minerals would lie on a horizontal line. However if live ^{26}Al was present when it formed, then the more Al rich a mineral is, the more excess ^{26}Mg it should now have. Again assuming isotopic homogenization, although the amount of Al in the different minerals vary, the initial $^{26}Al/^{27}Al$ ratio should be the same. The more ^{27}Al which was (and is) present, the more ^{26}Al was present, now become ^{26}Mg. Therefore the slope of the line in our plot will indicate the initial ($^{26}Al/^{27}Al$) abundance.

In the following a symbol like $^{26}Mg_0$ denotes the initial abundance while ^{26}Mg without a subscript $_0$ denotes the current value. For ^{24}Mg and ^{27}Al which do not change, $^{24}Mg_0 = ^{24}Mg$ and $^{27}Al_0 = ^{27}Al$ so the subscript can be added or dropped as is convenient.

$$
\begin{aligned}
^{26}Mg &= ^{26}Mg_0 + ^{26}Al_0 \\
&= ^{26}Mg_0 + ^{27}Al \times (^{26}Al_0/^{27}Al) \\
&= ^{26}Mg_0 + ^{27}Al \times (^{26}Al/^{27}Al)_0
\end{aligned}
$$

Or dividing both sides by the constant ^{24}Mg:

$$
\begin{array}{ccccccc}
(^{26}Mg/^{24}Mg) & = & (^{26}Mg/^{24}Mg)_0 & + & (^{27}Al/^{24}Mg) & \times & (^{26}Al/^{27}Al)_0 \\
Y & = & Y_0 & + & X & \times & \text{slope}
\end{array}
$$

Below is such a plot for 3 Calcium-Aluminum rich Inclusions (CAI's) from an E type chondrite, as published in Guan *et al.* (2000).

For the upper two panels (where you can readily determine the slope), find both the initial ($^{26}Al/^{27}Al)_0$ ratio and the initial ($^{26}Mg/^{24}Mg)_0$ ratios.

As a "sanity check", compare your ($^{26}Al/^{27}Al)_0$ result to the abundance ratio listed in the lowest panel. (I've erased the values in the upper two panels.) The value is so uncertain because the slope is uncertain – but the value should scale with the slope shown. As a further check you can use the ADS to find the Guan *et al.* paper and view the original version of the figure. However, even if you do this, show your work in calculating the slope and the abundance ratios.

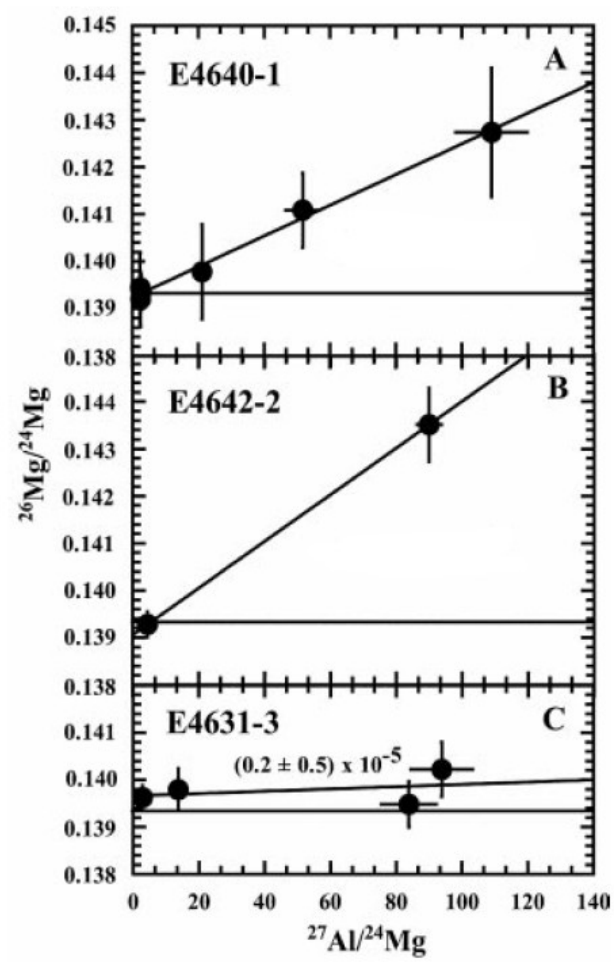

Fig. 2. Mg-Al isotopic systematics for three CAIs from E chondrites. (**A**) and (**B**) are hibonite-spinel inclusions. (**C**) is the hibonite-pyroxene microspherule that shows no resolvable $^{26}Mg^*$ excess. The ($^{26}Al/_{27}Al)_o$ ratios are listed on the plot for each inclusion.

#2. δ Notation for Isotope Abundances (10 points)

Because most isotopic ratios vary so little, the δ notation is often used for reporting results. In this notation rather that report the absolute ratio, you report the difference from some "standard" value. Also, you usually report the difference as a fraction (in parts per 1000) relative to that standard. For example

$$\delta^{26}Mg \equiv 1000 \times \{ \ (^{26}Mg/^{24}Mg)_{sample}/(^{26}Mg/^{24}Mg)_{standard} - 1 \ \}$$

$$= 1000 \times \{ \ [\ (^{26}Mg/^{24}Mg)_{sample} - (^{26}Mg/^{24}Mg)_{standard}) \ ] \ / \ (^{26}Mg/^{24}Mg)_{standard}) \ \}$$

Often, as a reminder that the excess ^{26}Mg is radiogenic, it is written $^{26}Mg^*$.

<u>Assuming</u> that $(^{26}Mg/^{24}Mg)_{standard} = 0.1394$, report the $(^{26}Mg/^{24}Mg)_0$ values you found above using the δ notation.