**Introduction:** In our continuing effort to resolve and interpret the sulfur isotopic heterogeneity of meteorites [1-5], we analyzed a number of achondritic meteorites. Like oxygen, sulfur has more than two stable isotopes and therefore it is feasible to deconvolute the isotopic anomaly from the mass dependent isotopic fractionation that occurred during parent body processes. Any non-mass dependent fractionation process produced due to mass independent photochemical or physical-chemical processes in the presolar nebula may be characterized by a nonzero (or variable) \(^{34}\text{S} / ^{36}\text{S}\). It has been shown that the gas phase photochemical reactions, involving \(\text{CS}_2\), \(\text{SO}_2\) and \(\text{H}_2\text{S}\), either in the Earth’s Archaean as well as present day atmosphere, Mars, or in laboratory experiments, fractionate \(\text{S}\) isotopes mass independently [6-12]. Lab studies of photochemical reactions have shown that the sign of mass independent fractionation (MIF) depends upon the wavelength of UV light [7], presumably due to the energetics of intersystem, electronic state crossings. In light of these observations, it is important to investigate \(\text{S}\) in various meteorites as other than oxygen, sulfur is the only multi-isotopic element that could potentially record early mass independent processes, both self shielding, as first hypothesized by [13], photochemical, or mass independent chemical reactions.

Sulfur exists in a variety of valence states in meteorites its composition is remarkably constant [1,2] with exceptions for isolated phases in Allende and Murchison [14,5]. Unlike primitive chondrites where the anomalous isotopic composition of various elements has been observed, in achondrites, these primitive signatures were lost during parent body differentiation. For sulfur, this scenario differs as \(^{33}\text{S}\) enriched components have been observed in ureilites and oldhamite from the Norton County aubrite [16,4]. In order to resolve the origin of the \(^{33}\text{S}\) anomaly and to investigate whether it is present in other achondrites, we have analyzed sulfur form six HEDs, five aubrites, two acapulcoite-lodranite and anomalous Weatherford, Bencubbin meteorites for bulk \(\text{S}\) isotopic composition. For HEDs, sulfur data has been reported for the first time whereas we have analyzed two more samples from the unique acapulcoite-lodranite group. Bencubbin and Weatherford are interesting as they have been shown to possess very heavy nitrogen [17]. Despite several detailed studies, the origin of heavy nitrogen is still unexplained. The study of \(\text{S}\) in these meteorites may be helpful in understanding the origin of anomalous nitrogen.

**Results and Discussions:** In Fig. 1, \(\delta^{34}\text{S}\) is plotted against \(\delta^{33}\text{S}\) for achondrites analyzed here.

**HEDs.** In this study we analyzed one howardite (EET7503.95), three eucrites (EET90020, PCA82502 and Moor County) and two diogenites (LAP91900, ALH77256). They generally have low \(\text{S}\) content, between 0.1-0.2 % (by wt.). The average \(\delta^{34}\text{S}_{\text{CDT}}\) of the six analyses are \(0.37\pm0.17\%\_e\) with a range from 0.24 to 0.69\%e. The average value of \(^{33}\text{S}\) is \(0.036\pm0.039\%\_e\) with a standard error of 0.016\%e. The average value of \(^{36}\text{S}\) is \(-0.259\pm0.622\%\_e\) with a standard error of 0.254\%e.

**Aubrite.** Aubrites are a group of achondrites formed from enstatite chondrite-like parental material. Oldhamite separates from Norton County were shown to have significantly enriched in \(^{33}\text{S}\) though bulk sample analysis did not show any enrichment of \(^{33}\text{S}\) [4]. Here the five bulk samples (ALH8409.14; ALH84023.9; Cumberland Falls, ALH78113; ALH84010) have been analyzed in which two of them are paired. Aubrites contain \(\text{S}\) between 0.3–0.6\%. They exhibit a relatively large range in \(\delta^{34}\text{S}\); from \(-0.58\%e\) to 1.7\%e (Fig.1) with average \(\delta^{34}\text{S}\) value of six analyses including Norton County [4] is 0.32
need to be done. The observed mass independent
though there remain a number of experiments that
produce changes in photochemical reactions of S compounds enrich
thesis, there is not an accompanied
sufficient exposure age and iron target, for nucleosynthesis
enrichment is not cosmic ray spallation or stellar nucleosynthesis
Oldhamite (NC)

Acapulcoite-Lodranites. After inclusion of data of
two new samples to the previous analysis of [5], the
grafted S is changed to 0.015±0.147‰ with standard error of
seven measurements of 0.056‰. The average value of \( \Delta^{34}\)S is 0.026±0.020‰ with standard error of 0.008‰.

Based on S content, HEDs are similar to ureilites, they both have low S concentration. In Fig.1, it can be seen clearly that ureilites, HEDs and acapulcoite-lodranites lie above MFL, the deviation though small, is resolvable at the high precision of the measurements. The average \( \Delta^{33}\)S value of HEDs is higher than that of acapulcoite-lodranites and close to, but lower than that of ureilites (Fig. 2). It is clear that all the three achondrite groups have resolvable excesses of \( ^{33}\)S, beyond the experimental uncertainty. Aubrites, on the other hand contain relatively higher concentration of S compared to ureilites and HEDs. Despite the observation of \( ^{33}\)S enriched oldhamite and a relatively larger range of \( ^{34}\)S than that of other achondrites, most of the bulk aubrites fall very close to the MFL (Fig. 1) indicating that the larger proportion of normal S along with anomalous oldhamite dilutes the anomaly. Origin of this anomalous \( ^{33}\)S enrichment is not cosmic ray spallation or stellar nucleosynthesis [5,15]. In the case of cosmic rays, there is insufficient exposure age and iron target, for nucleosynthesis, there is not an accompanied \( ^{36}\)S anomaly.

In laboratory experiments, it has been shown that photochemical reactions of S compounds enrich \( ^{33}\)S mass independently but also produce changes in \( ^{36}\)S [7,8] though there remain a number of experiments that need to be done. The observed mass independent S anomaly most closely matches that observed in SO$_2$ photolysis experiment with high pressure Xe arc lamp in the spectral region (>220nm) [7] (Fig 2). SO$_2$ photolysis might be the more appropriate for observed mass independent S in Archean sediments but not for the \( ^{33}\)S anomaly in meteorites as SO$_2$ is unlikely to be present in the early solar nebula. Photopolymerization of CS$_2$ or CS and photochemical reactions of H$_2$S are more appropriate for nebular settings but the sign of fractionation is opposite to that is observed in the latter case while the former also shows a relatively large depletion in \( ^{36}\)S along with enrichment \( ^{33}\)S [8,6] (Fig 2). It has been shown that mass independent fractionation is strongly wavelength dependent [7] and most of the laboratory experiments have been performed at higher UV wavelengths. It is now critically important to study these reactions at shorter wavelengths that are appropriate for presolar nebular conditions.