General Comments:

In recent years, air pollution is seriously threatening the health of millions of people in China. Sulfate is one of the major chemical species in PM$_{2.5}$, and play a critical role in human health, and environmental chemistry. However, its formation in the atmosphere remains controversial. In this study, both observational data ($\delta^{34}$S and $\delta^{18}$O values) and laboratory simulation are used to constrain SO$_2$ oxidation pathways. The authors found that the sulfate in PM$_{2.5}$ was mainly formed from the oxidation of SO$_2$ by OH, H$_2$O$_2$ and TMI. This work provides a valuable dataset of $\delta^{34}$S and $\delta^{18}$O that add critical constraints for sulfate formation pathways.

Specific Comments:

1. Page 4, Lines 83-84 The authors mention that the sulfur isotopic fractionation factor of SO$_2$ oxidation by OH determined with laboratory experiments by Harris et al. (2012) was 1.0087. However, they discussed that “It is reported that sulfur isotope fractionation about SO$_2$ was -9‰ for homogeneous oxidation process (Tanaka et al., 1994)”. The sulfur isotopic fractionation factor for homogeneous pathway (SO$_2$+OH) obtained by Tanaka et al. (1994) is different from the laboratory results by Harris et al. (2012). The authors need to compare these two values and explain which to be used for their discussion.

2. Page 17, lines 345-348 Their calculations displayed that the H$_2$O$_2$ pathway is predominated during heterogeneous oxidation of SO$_2$. Could the authors discuss the sources of H$_2$O$_2$ in atmosphere if it plays an important role in heterogeneous oxidation of SO$_2$?

3. The conclusion seems to be a bit dry. I suggest that the important implications for this work should be added, besides summarize the main points.

Technical corrections:

Page 8, Line 163 Please change “The concentrations of PM$_{2.5}$, SO$_4^{2-}$ and SO$_2$” to “Variations in concentrations of PM$_{2.5}$, SO$_4^{2-}$ and SO$_2$”.

Page 9, Line 197 Please change “Sulfur isotope compositions in sulfate and SO$_2$” to “Variations in sulfur isotope compositions in sulfate and SO$_2$”. In addition, the black solid circles represent the $\delta^{34}$S values of sulfate instead of PM$_{2.5}$. 