

S1. Allan variation for averaging interval determination

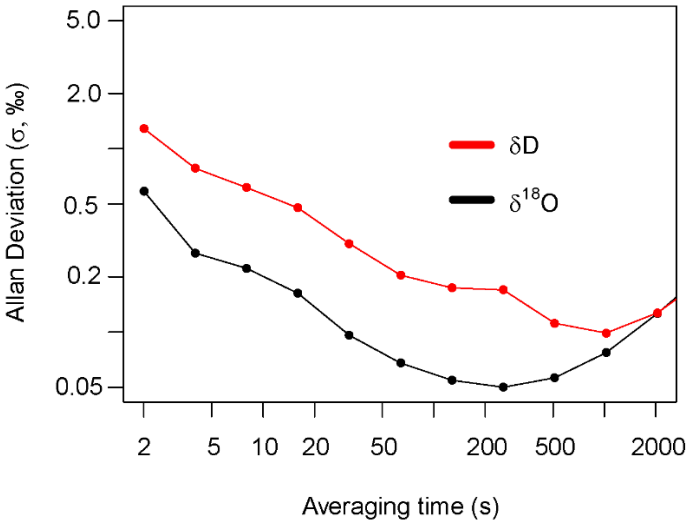


Figure S1. Example Allan deviation (σ) plot for slow analyzer air flow indicates 1000 s for δD and 250 s for $\delta^{18}O$ as the optimal averaging times over 18 hours of unchanging WVISS-produced vapor ($\sim 9,300$ ppm_v) for δD (red) and $\delta^{18}O$ (black). While a longer averaging time is optimal to reduce noise, we chose not to average for δD and $\delta^{18}O$ but used a 10 s running average for D-excess as a way to reduce noise without excessively smoothing signal changes. Allan variance was calculated using R’s “avar” package (Guerrier et al., 2020).

S2. Bev-A-Line XX

We also tested Bev-A-Line XX, with a Hytrel® inner liner, as a service to the research community as it was easily available. Bev-A-Line XX is another example of a bad tubing, as seen below.

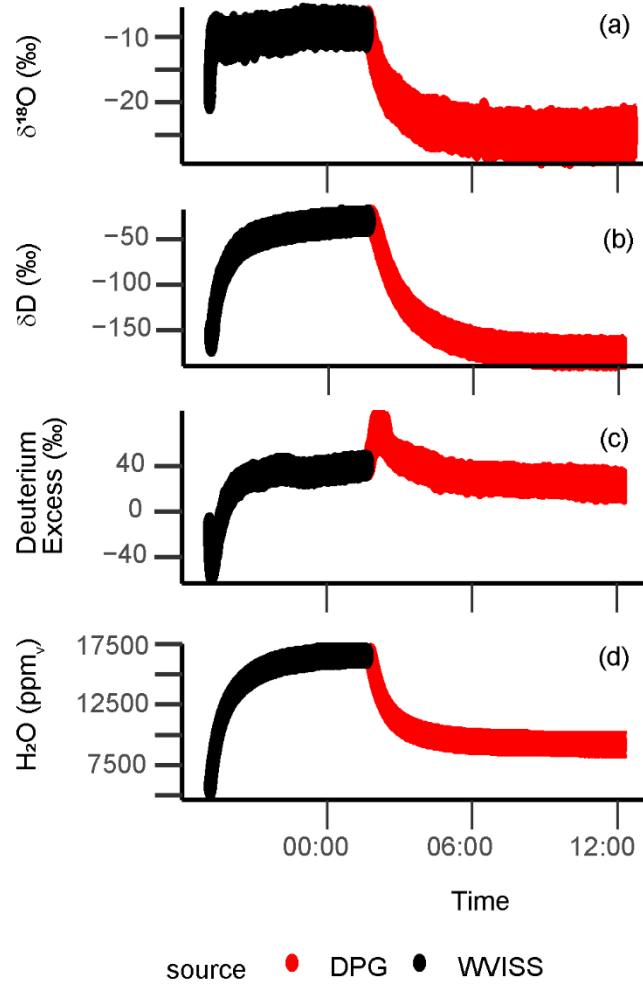


Figure S2. Full sweepout curve of 100 ft (~ 30.5 m) Bev-A-Line XX for $\delta^{18}\text{O}$ (a), δD (b), D-excess (c), and H_2O (d) in both depleted-to-enriched (black points) and enriched-to-depleted (red points) directions. Bev-A-Line XX takes approximately 6 h to fully equilibrate in either direction of the switch. The time to equilibration is longer in the enriched-to-depleted direction.

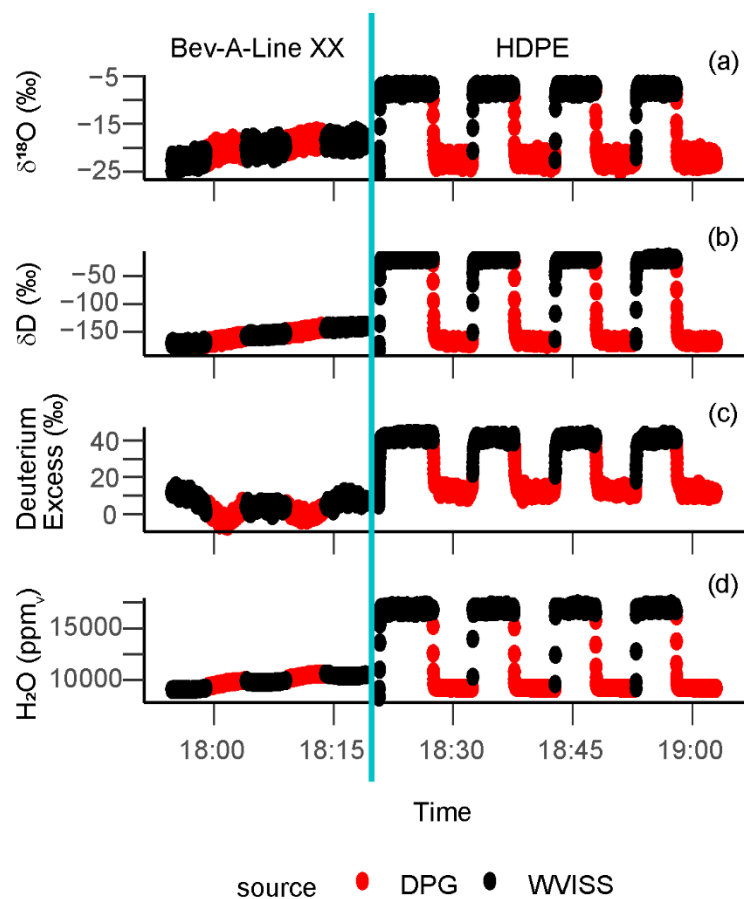


Figure S3. Switching experiments comparing the transitions of ~ 79 in. (2 m) Bev-A-Line XX and HDPE for $\delta^{18}\text{O}$ (a), δD (b), D-excess (c), and H_2O (d). While HDPE has fast transitions in all variables, Bev-A-Line XX does not fully equilibrate in either direction over the course of the ~ 5 min switches. The teal vertical line indicates when the tubings were switched.

S3. Depleted-to-enriched or DPG-to-WVISS attenuation curves

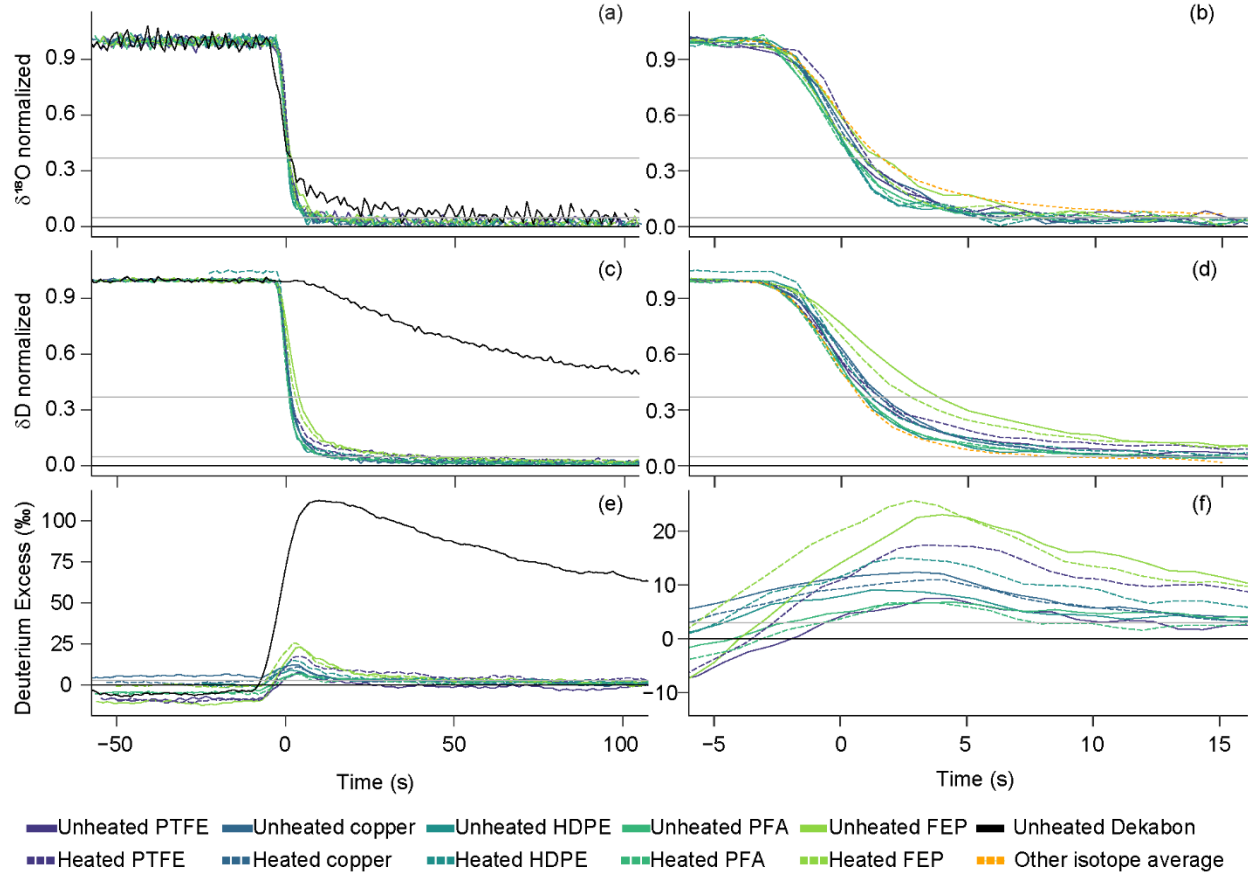


Figure S4. Mean attenuation curves for enriched-to-depleted (WVISS-to-DPG) H_2O -matched transitions of each tubing type for $\delta^{18}\text{O}$ (a, b), δD (c, d), and D-excess (e, f) plotted as seconds since the $\delta^{18}\text{O}$ impulse function peak (i.e., $\delta^{18}\text{O}$ -location-adjusted time). Panels (a), (c), and (e) depict time from -50 to 100 s, while panels (b), (d), and (f) zoom in on -5 to 15 s and exclude the Dekabon results. Solid lines indicate unheated experiments, while dashed lines indicate heated experiments. For δD , $\delta^{18}\text{O}$, and D-excess, only Dekabon and FEP show clear differences in material type, and only FEP shows clear differences in heated and unheated experiments. The full Dekabon attenuation curve can be found in Fig. S9. The orange curve in panel (b) shows the mean δD of all experiments for comparison with $\delta^{18}\text{O}$, and the orange curve in panel (d) shows the mean $\delta^{18}\text{O}$ for comparison with δD ; these means exclude Dekabon. Here, FEP is long and thin-walled as a comparison to the rest of the thin-walled tubing. HDPE is thick-walled and has a smaller i.d. than the other tubing shown here. Horizontal gray lines indicate thresholds of 95 % and 63 % transition completion for δD and $\delta^{18}\text{O}$, or 3 % for D-excess, while a black line at zero indicates full equilibrium completion. Enriched-to-depleted results are presented in the main manuscript. D-excess plots were flipped for easier graphical comparison with the enriched-to-depleted transition.

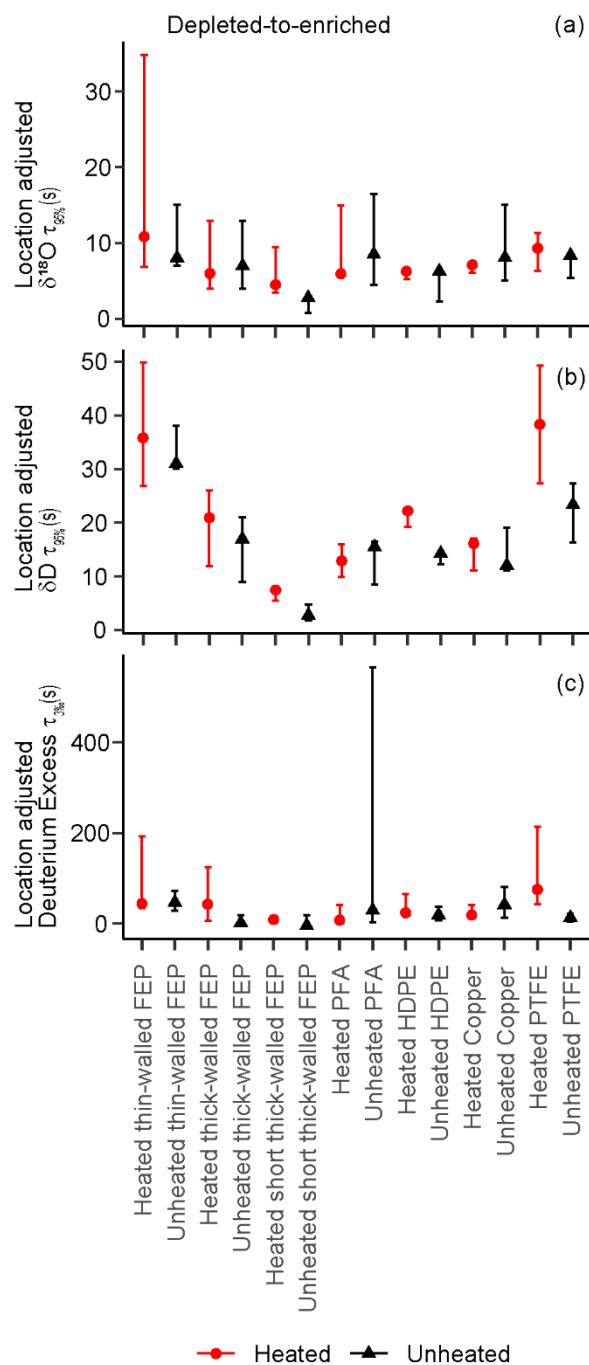


Figure S5. $\delta^{18}\text{O}$ -location-adjusted $t_{95\%}$ for $\delta^{18}\text{O}$ and δD (a, b) and $t_{3\%}$ (c) times comparing heated (red) and unheated (black) experiments for all tubing types. The depleted-to-enriched switch direction is depicted here, while the enriched-to-depleted transition data are located in Fig. 5. We did not see clear differences in tubing temperature influence, and only very small differences were noted between tubing material types. Thick-walled FEP is presented here as a direct comparison to thick-walled HDPE, while the rest of the materials were thin-walled with larger i.d. values. Thin-walled, thick-walled, short, and long FEP experiments are shown in Figure S6 and discussed in Sect. 3.4.

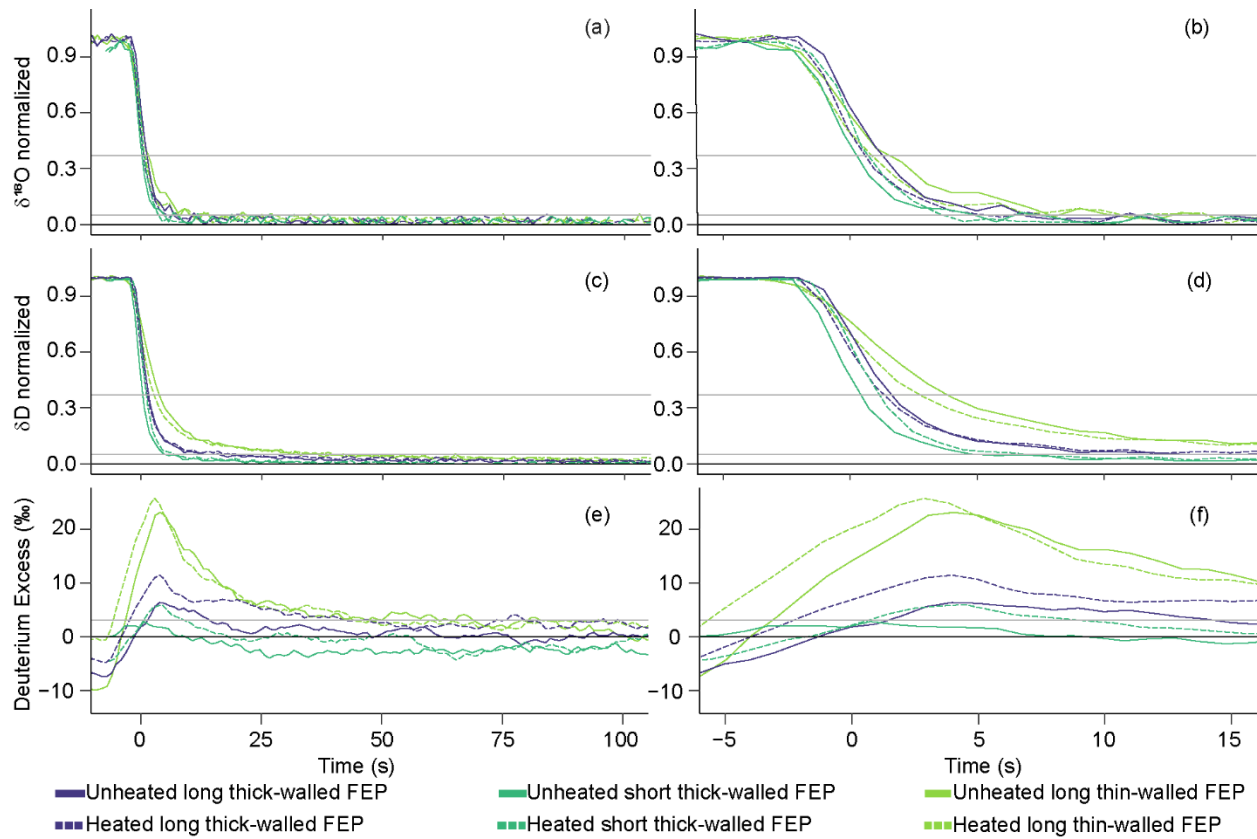
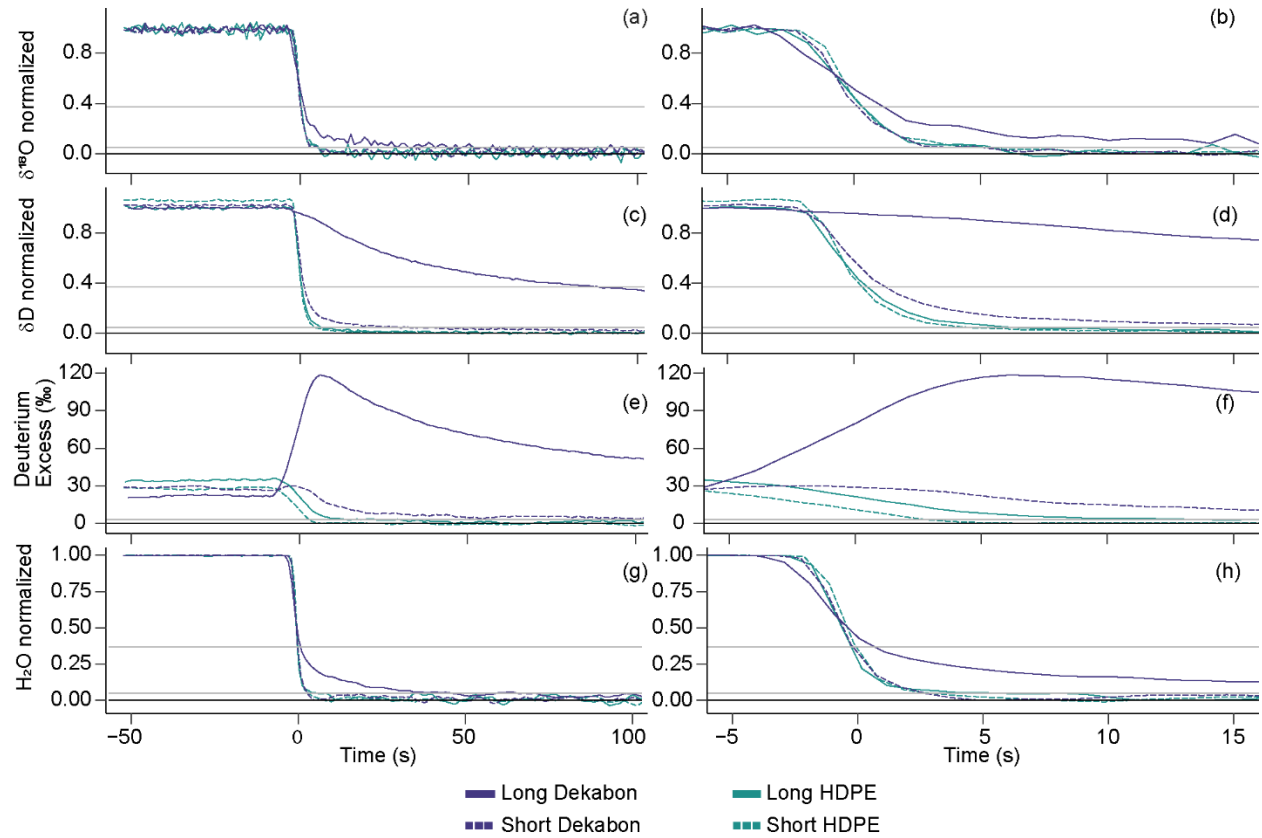


Figure S6. Mean attenuation curves for only FEP tubing for depleted-to-enriched (WVISS-to-DPG) transitions comparing tubing length and inner diameter for $\delta^{18}\text{O}$ (a, b), δD (c, d), and D-excess (e, f) plotted as seconds since the $\delta^{18}\text{O}$ impulse function peak (i.e., $\delta^{18}\text{O}$ -location-adjusted time). Panels (a), (c), and (e) depict time from -50 to 100 s, while panels (b), (d), and (f) zoom in on -5 to 15 s. Solid lines indicate unheated experiments, while dashed lines indicate heated experiments. Horizontal gray lines indicate thresholds of 95 % and 63 % transition completion for δD and $\delta^{18}\text{O}$, or 3 % for D-excess, while a black line at zero indicates full equilibration. D-excess plots were flipped for easier graphical comparison with the enriched-to-depleted transition. The $\delta^{18}\text{O}$ location adjustment for the short tubing is much shorter than that of the long tubing, leading to a line that appears to start abruptly at approximately -8 s.



65 **Figure S7.** Mean attenuation curves comparing length for ~ 79 in. (2 m) and 100 ft (~ 30.5 m) HDPE and Dekabon
 tubing for enriched-to-depleted (WVISS-to-DPG) transitions for $\delta^{18}\text{O}$ (**a**, **b**), δD (**c**, **d**), D-excess (**e**, **f**), and H_2O (**g**,
h), plotted as seconds since the $\delta^{18}\text{O}$ impulse function peak (i.e., $\delta^{18}\text{O}$ -location-adjusted time). Panels (**a**), (**c**), (**e**), and
 70 (**g**) depict time from -50 to 100 s, while panels (**b**), (**d**), (**f**), and (**h**) zoom in on -5 to 15 s. Solid lines indicate 100 ft
 (~ 30.5 m) lengths, whereas dashed lines indicate ~ 79 in. (2 m) lengths. D-excess plots were flipped for easier
 graphical comparison with the enriched-to-depleted transition. Horizontal gray lines indicate thresholds of 95 % and
 63 % transition completion for δD and $\delta^{18}\text{O}$, or 3 ‰ for D-excess, while the black line at zero indicates full
 equilibration.

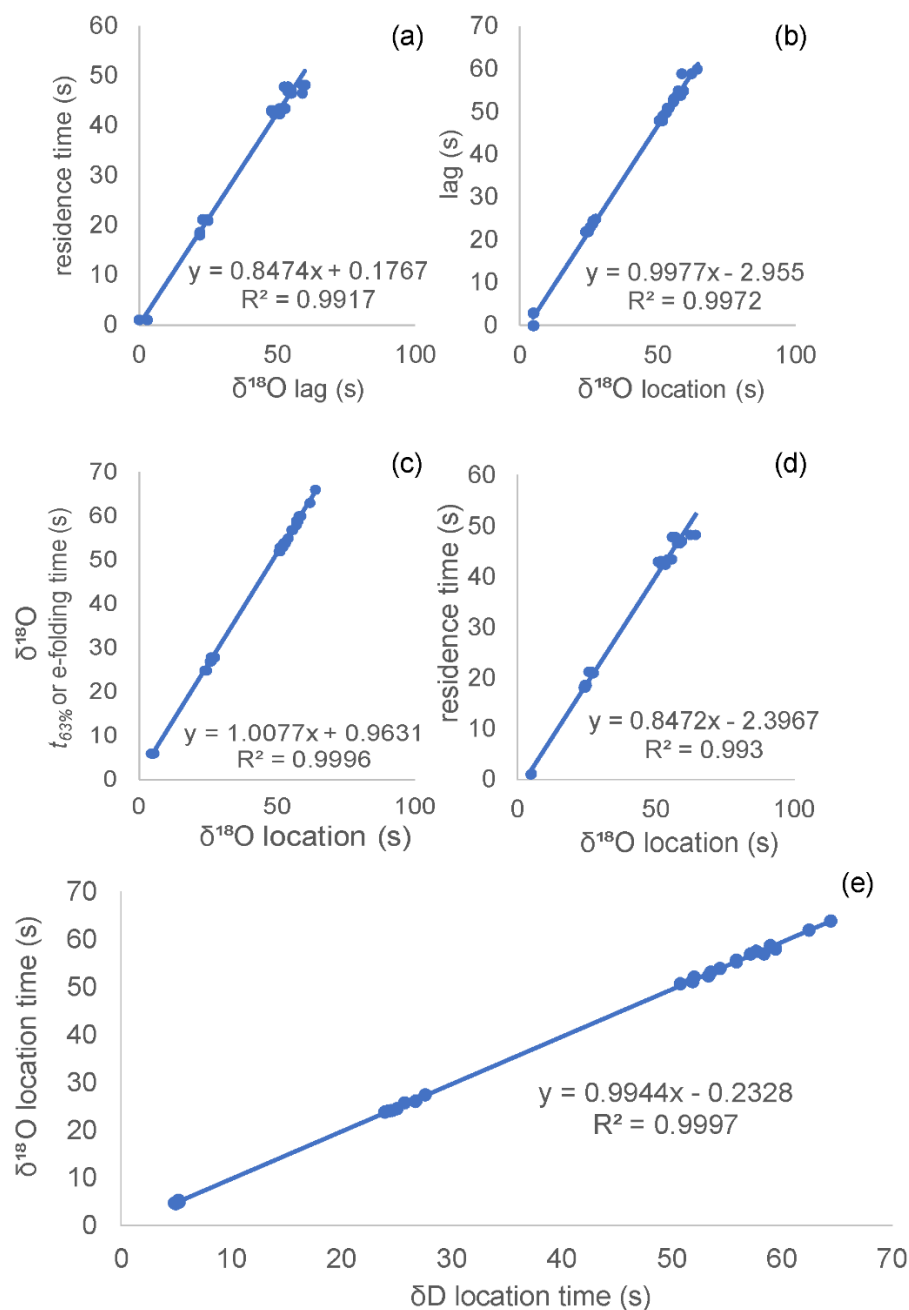


Figure S8. Comparison of residence time, lag, location, and threshold memory times for H_2O -varied experiments, excluding Dekabon (due to instrument malfunction). Panel (a) compares observed lag times with temperature-dependent residence times for $\delta^{18}\text{O}$. Panel (b) compares observed lag times with location times for $\delta^{18}\text{O}$. Panel (c) compares the temperature-adjusted theoretical residence times with location times for $\delta^{18}\text{O}$. Panel (d) compares the $t_{63\%}$ (e-folding times, not location time adjusted) with location times for $\delta^{18}\text{O}$. Panel (e) compares $\delta^{18}\text{O}$ and δD location times for all tubing types (excluding Dekabon).

S5. H₂O-matched Dekabon mean attenuation curve

85 A complete isotopic transition of H₂O-matched Dekabon experiments used in Figs. 3 and S4 are presented below.

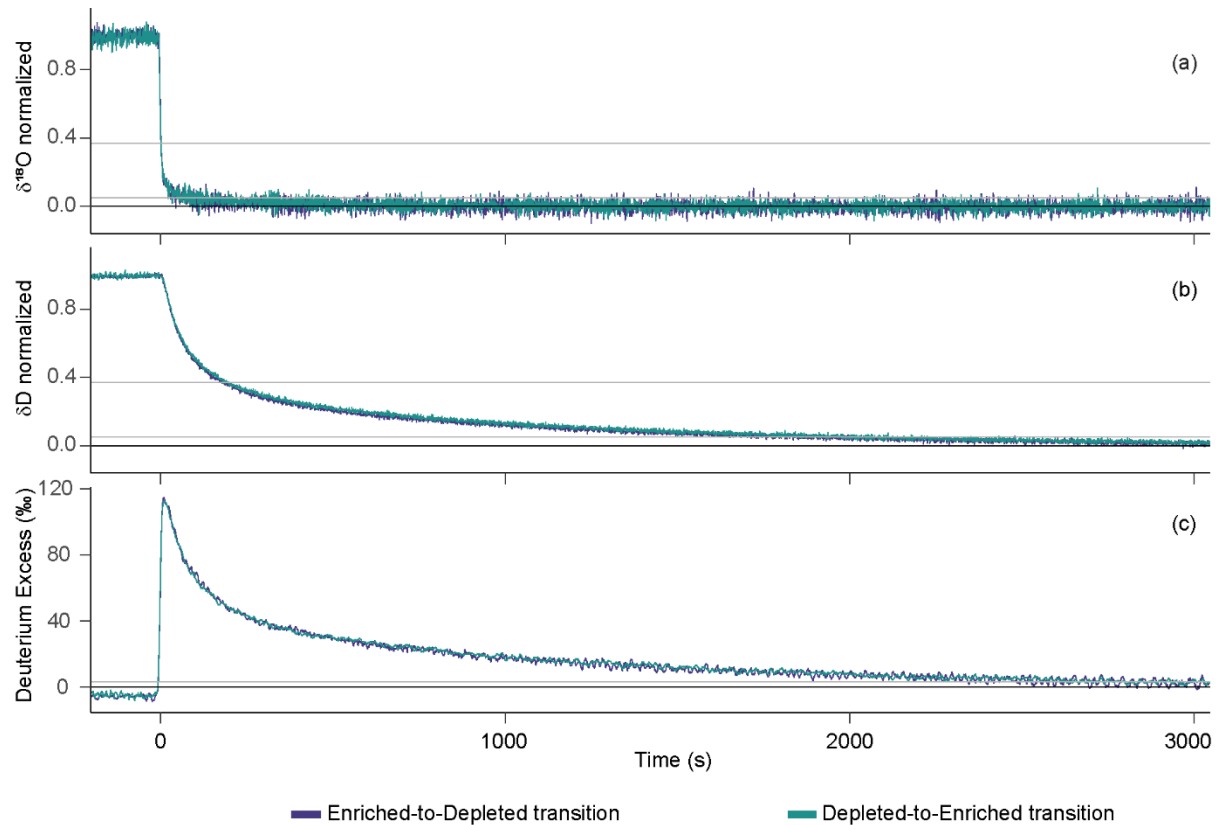


Figure S9. Mean attenuation curves of 100 ft (~ 30.5 m) Dekabon tubing for depleted-to-enriched (DPG-to-WVISS) and enriched-to-depleted (WVISS-to-DPG) H₂O-matched transitions for $\delta^{18}\text{O}$ (a), δD (b), and D-excess (c) plotted as seconds since the $\delta^{18}\text{O}$ impulse function peak (i.e., $\delta^{18}\text{O}$ -location-adjusted time). The plots depict time from 50 s before the peak of the $\delta^{18}\text{O}$ impulse function for each experiment to 3,000 s after, or the course of a full isotopic transition. Horizontal gray lines indicate thresholds of 95 % and 63 % transition completion for δD and $\delta^{18}\text{O}$, or 3 ‰ for D-excess, while a black line at zero indicates full equilibrium completion. The D-excess plot for the depleted-to-enriched transition was flipped for easier graphical comparison with the enriched-to-depleted transition. Both switch direction transitions are similar in length.