X04a Mass-Metallicity Relation of Galaxies at $z = 5 - 9$ with Improved Reduction and Calibration of First Batch of JWST/NIRSpec Data

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The metallicity of the inter-stellar medium in galaxies is a key property for understanding the physical processes that regulate the galaxy growth, such as star formation/explosion, outflow of metal-enriched gas, and infall of metal-poor gas. Interestingly, there is a clear relationship between galaxy mass, metallicity, and star formation rate (SFR) that is claimed to be redshift-independent from $z = 0$ to 3, suggesting that galaxies have metallicity equilibrium conditions for the balance between star formation, gas outflow and infall, possibly in the same form over the past 12 billion years. The next important question is whether the same relation holds for galaxies at higher redshifts. Here we summarize mass-metallicity (MZ) relation studies on galaxies at $z = 5$–9 with the JWST/NIRSpec data, presenting new results of our carefully improved reduction and calibration. Using our fluxes and errors, we obtain the MZ relation notably for four Early Release Observations' galaxies at $z = 6.3$–8.5 with an electron temperature measurement, and find no significant evolution from $z = 2$–3. The same conclusion is reached by adding >10 objects from the other data releases of the first batch of the NIRSpec observations whose metallicities are empirically derived. Importantly, the MZ-SFR relation does not evolve from $z = 0$ to $z = 5$–9 within $\Delta \log(\mathrm{O/H}) = 0.3$ dex, suggesting that chemical properties of the gas-phase inter-stellar medium of galaxies at $z = 5$–9 are very similar to those of lower-redshift counterparts.