Supplementary Information

Stability of the local electronic properties of $La_3Ni_2O_7$ under pressure

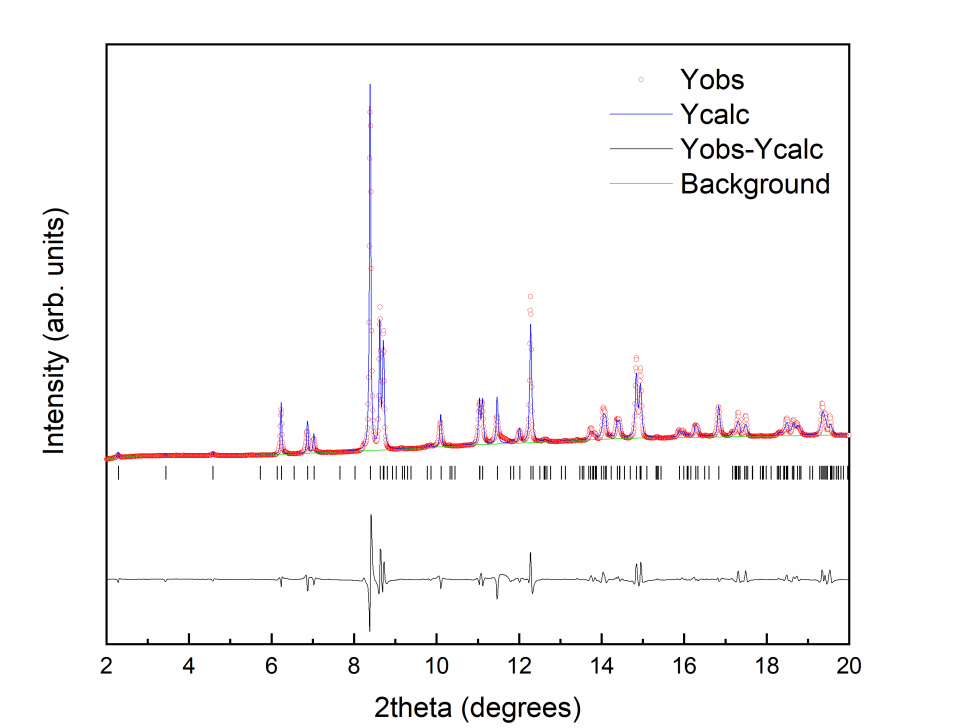

Figure S1: Powder X-ray diffraction measurements at ambient conditions confirm that the sample is phase-pure $La_3Ni_2O_7$. The diffraction pattern was fitted using the ambient pressure orthorhombic structure with the Cmmm space group. The refined lattice parameters (a = 5.38902 Å, b = 5.44791 Å, c = 20.50644 Å) are in good agreement with previously reported literature values. Diffraction pattern was collected at ID15b beamline of ESRF with x-ray photon energy at 30 keV ($\lambda \sim 0.41$ Å).

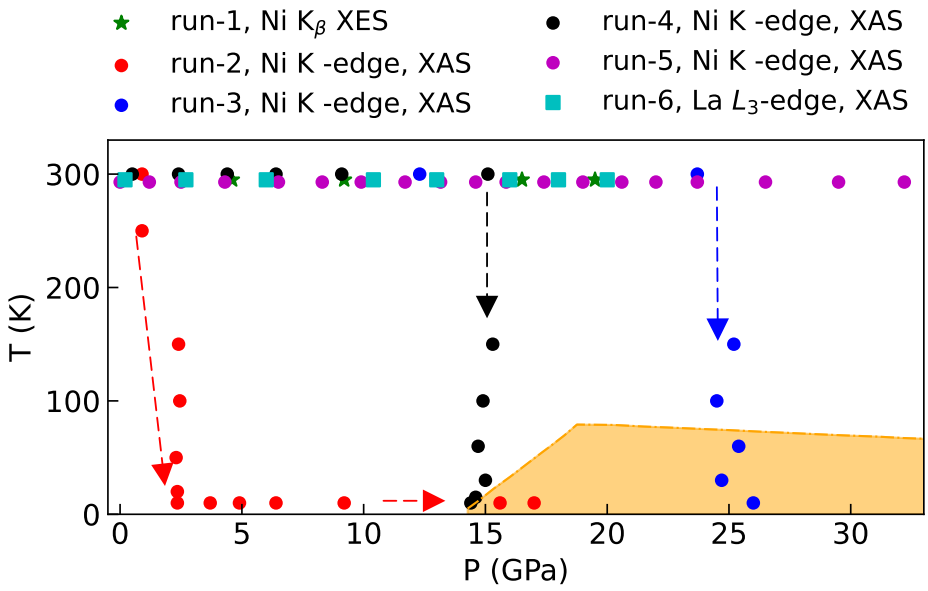

Figure S2: Experimental conditions and routes mapped onto the phase diagram of $La_3Ni_2O_7$ reported by H. Sun et al (Nature 621, 493, 2023).

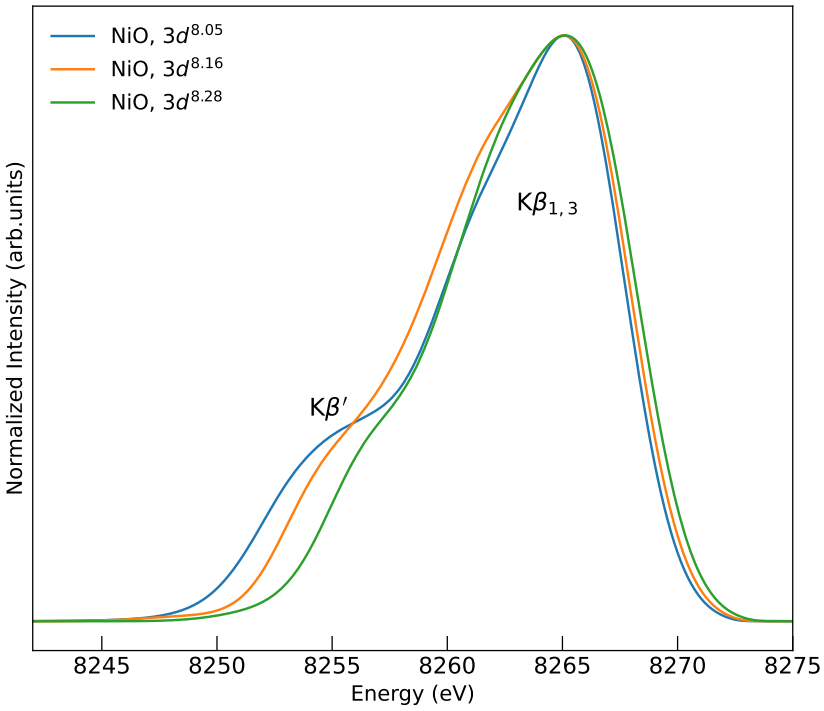

Figure S3: Simulation of Ni $K\beta$ XES for different 3d filling.

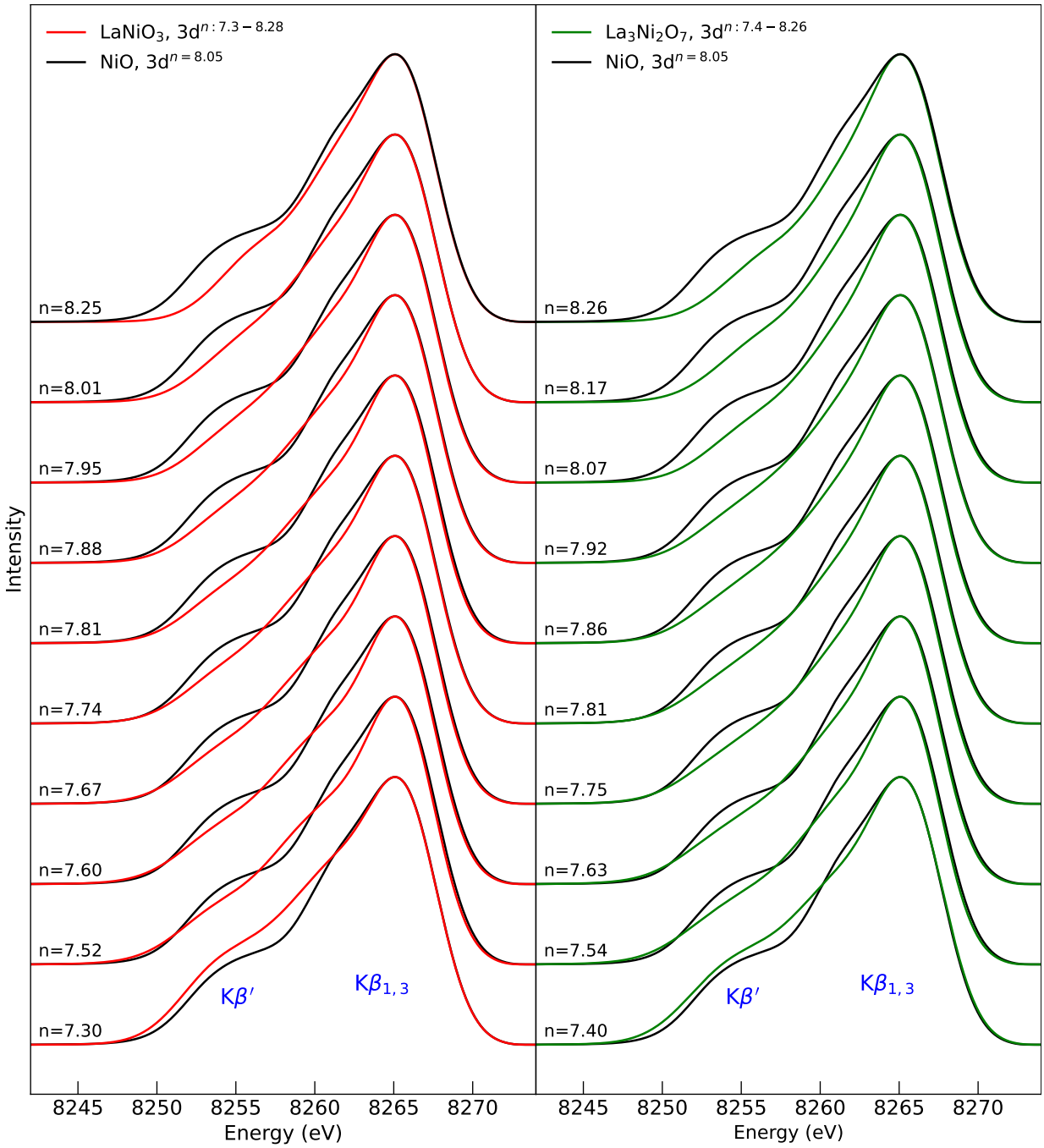

Figure S4: Simulated Ni $K\beta$ XES spectra of $LaNiO_3$ (a) and $La_3Ni_2O_7$ (b) with various 3d occupancies, compared with the spectrum of NiO calculated for a $3d^{8.05}$ configuration.

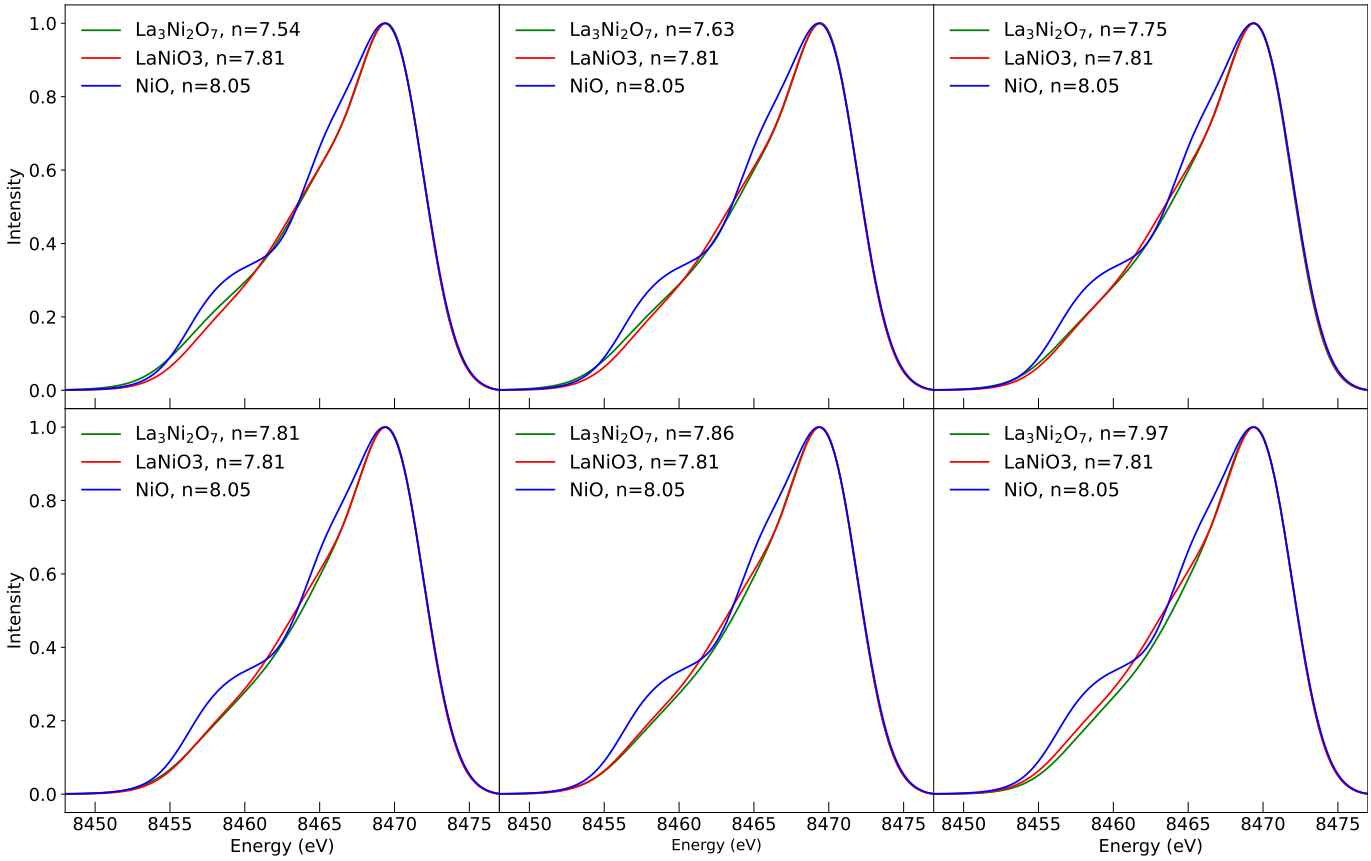

Figure S5: Simulated Ni $K\beta$ XES spectra of $La_3Ni_2O_7$ with various 3d occupancies, compared with those of NiO and $LaNiO_3$, calculated for $3d^{8.05}$ and $3d^{7.81}$ configurations, respectively.

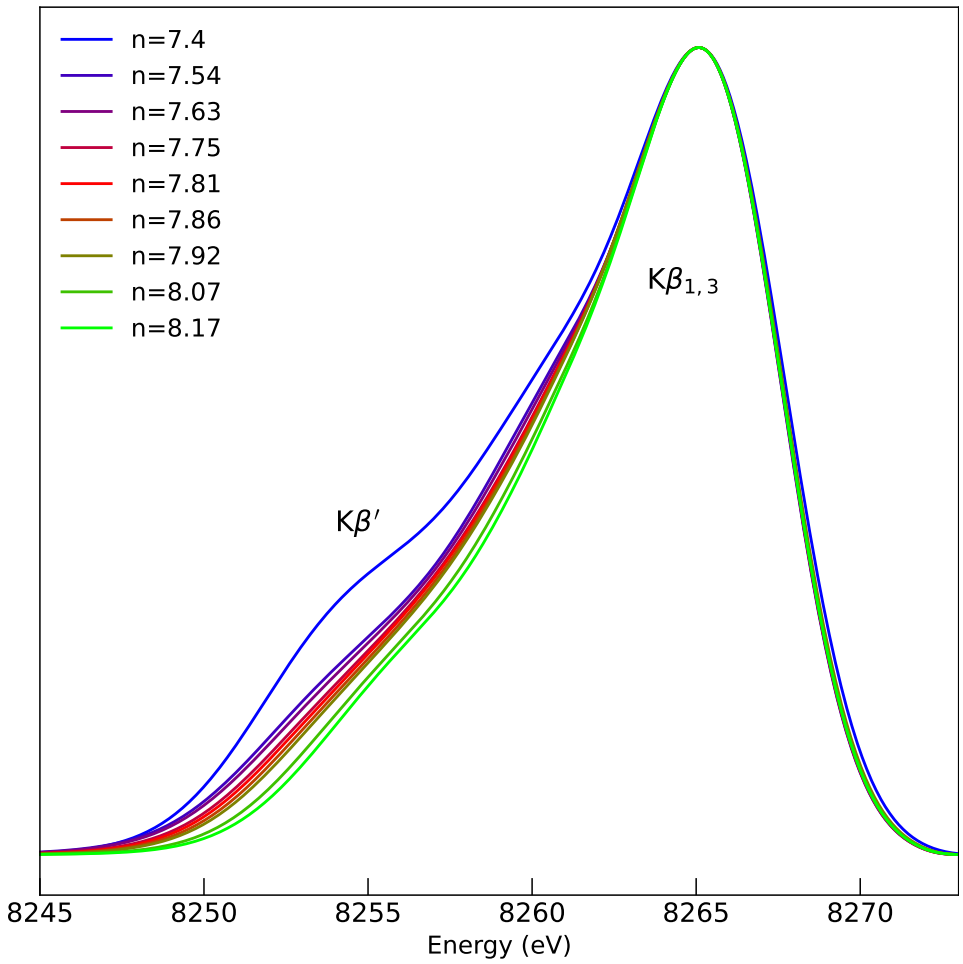

Figure S6: Simulated Ni $K\beta$ XES spectra of $La_3Ni_2O_7$ with various 3d occupancies, plotted on the same scale (without y-offset) for better comparison.

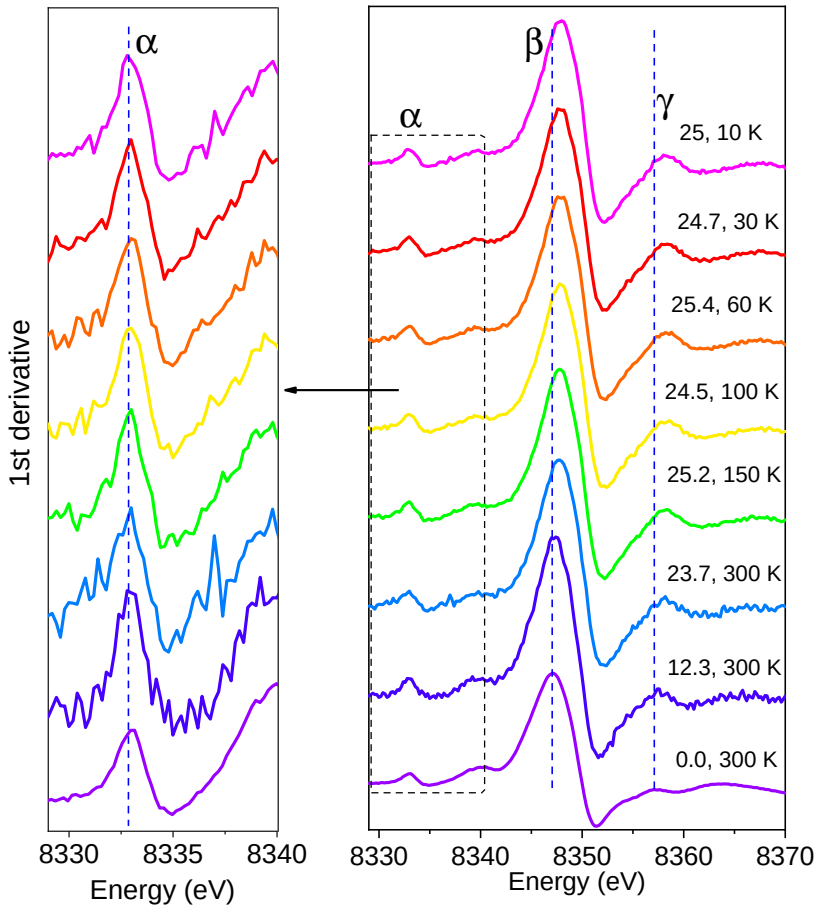

Figure S7: First derivative of the Ni K-edge XANES measured along the 2nd experimental run (run-2). Pre-edge range was shown with magnification at the left panel. Stable energy position and nearly similar line shapes of pre-edge peak **A** can be seen from the behavior of feature α in the first derivative spectra (left panel). Shift of the edge energy is evident from the movement of the main peak (feature β), while the enhancement of feature **C** is captured by the appearance of feature γ in the first derivative spectra (right panel). The absence of spectral modifications upon cooling at 23.7 $\sim$ 25 GPa (see Fig. 4d in the main text) is further confirmed by the identical line shapes of the first derivative spectra.

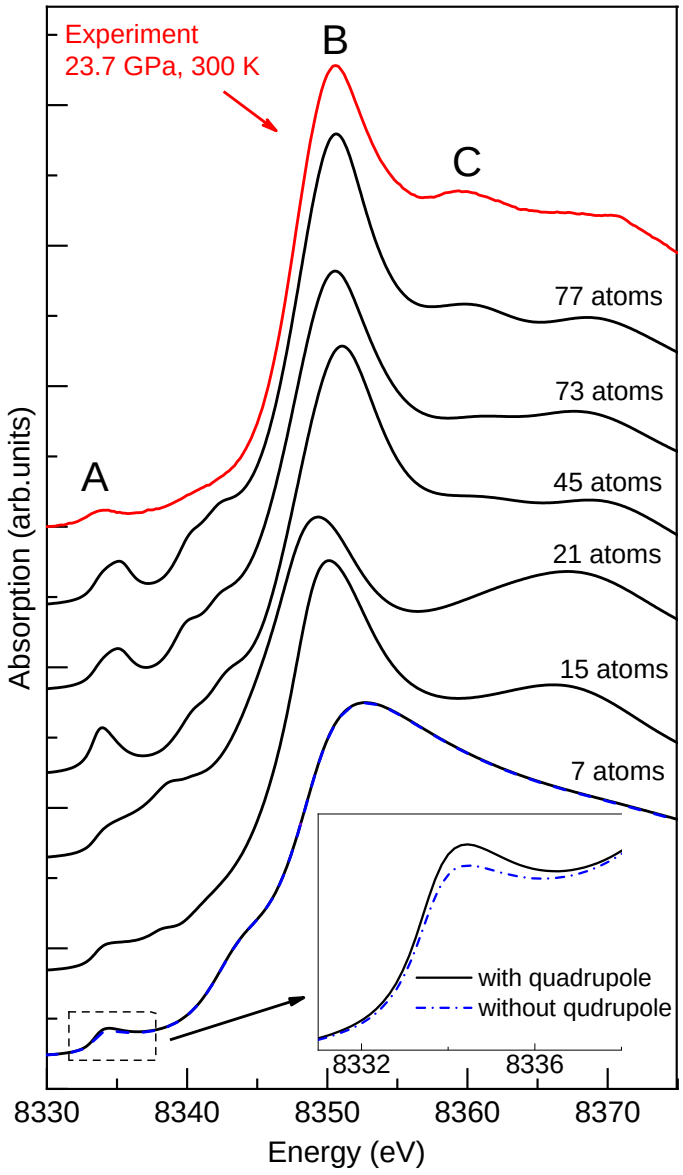

Figure S8: XANES simulations performed for various atomic cluster sizes. Experimental spectra (red curve) was measured at P=23.7 GPa under room temperature.

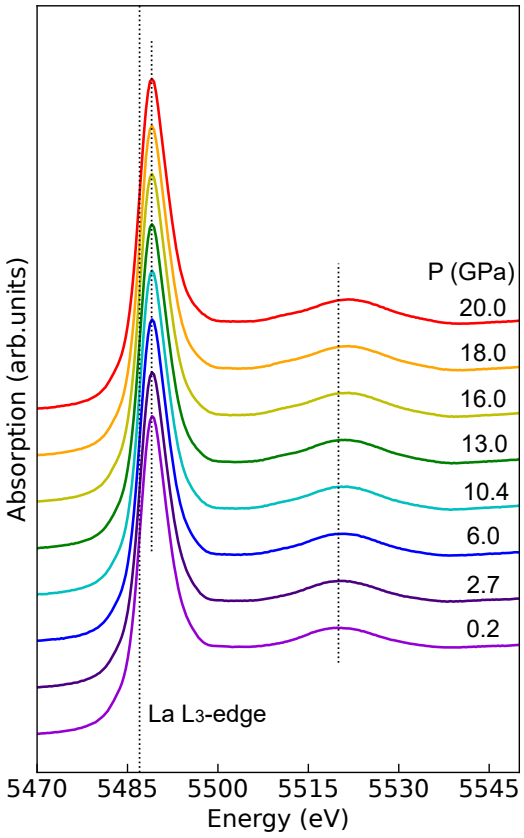

Figure S9: La L_3-edge XANES of $La_3Ni_2O_7$ measured along run-5 up to 20 GPa under room temperature.