

High-resolution Rovibrational and Rovibronic Spectra of $^{12}\text{C}^{16}\text{O}$

Salman Mahmoud¹, Nayla El-Kork¹, Nariman Abu Elkher¹, Chenyi Tao², Mubarak Almehairbi¹, Malathe Samir Khalil¹, Rania Al Abdallah¹, Tibor Furtenbacher³, Attila G. Császár³, Aleksandra Stasik⁴, Rafal Hakalla⁴, Wim Ubachs⁵, Robert W. Field⁶, Nelson de Oliveira⁷, Wojciech Szajna⁴, Stanislaw Ryzner⁴, Marzena I. Malicka⁸, Olga P. Yurchenko², Sergey N. Yurchenko² and Jonathan Tennyson²

¹ College of Engineering and Physical Sciences, Khalifa University, Abu Dhabi, UAE

² University College London, Department of Physics and Astronomy, London, WC1E 6BT UK

³ Institute of Chemistry, ELTE Eötvö Loránd University, Budapest, Hungary

⁴ Materials Spectroscopy Laboratory, Institute of Physics, University of Rzeszów, Poland

⁵ Department of Physics & Astronomy, and LaserLaB, Vrije Universiteit, Amsterdam, NL

⁶ Department of Chemistry, Massachusetts Institute of Technology, Cambridge, USA

⁷ Synchrotron SOLEIL, Orme de Merisiers, St. Aubin, France

⁸ Faculty of Mathematics & Applied Physics, Rzeszów University of Technology, Rzeszów, PL

Carbon monoxide (CO) plays a crucial role in understanding the atmospheric composition and chemical processes of exoplanets, as it is a key indicator of planetary atmospheric chemistry, thermal structure, and potential habitability. The availability of reliable CO spectroscopic data enhances the robustness of retrievals in exoplanet characterization and directly supports the scientific goals of present and future missions such as Ariel, JWST, and Twinkle. Available tools, such as MARVEL (Measured Active Rotational-Vibrational Energy Levels), and ab-initio calculations are necessary to achieve such goal. In MARVEL, the input consists of experimentally observed transition frequencies, each with an associated uncertainty and quantum state label. These transitions are validated and processed to create a spectroscopic network (SN) where nodes represent energy levels and edges represent transitions. By solving the network using weighted least-squares fitting, MARVEL yields a set of term energies that best reproduce the measured data within their uncertainties. In this work, accurate, MARVEL experimental rovibrational and rovibronic energy levels, with associated labels and uncertainties, are reported for the ground and lowest low-lying singlet and triplet electronic states of the diatomic $^{12}\text{C}^{16}\text{O}$ molecule. The energy levels are obtained through careful analysis of high-resolution experimental spectra of CO from more than seventy-five literature sources. The obtained data is used to fit energy levels that were obtained in previous work through ab-initio methods. Comparisons of our results with published work show remarkable agreement.