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Viable anionic exchange membrane electrolysis reactors for H_2 production require highly active hydrogen evolution reaction (HER) catalysts that are both robust and cost-effective. While transition metal catalysts are cost-effective compared to platinum group metal ones, they are not as active for HER due to their vigorous passivation in high pH media. However, their oxide forms are essential for the adsorption of water during the water splitting step (Volmer steps). Here, a Ni-based catalyst is prepared via pyrolysis of a chelated metal salt in the presence of carbon support. The functionalized Ni surface contains an efficient amount of Ni^0 and NiO_x active sites for H-adsorption and OH-adsorption, respectively, during prolonged HER performance in 0.1M KOH. The original ratio of Ni^0:NiO_x is maintained due to the protection of Ni^0 sites by several layers of graphene introduced during synthesis. The presence of the graphene layers was confirmed by high-resolution transmission electron microscopy (HR-TEM) while the material's resistance to passivation was demonstrated by *in-situ* X-ray absorption spectroscopy studies. The stability and activity of the functionalized Ni catalyst were demonstrated in half-cell RDE, practical AEM–H_2 pump cell and AEM–electrolyzer cell. In the case of AEM–electrolyzer cell, the exceptionally stable performance of the non-PGM catalysts enabled a low-cost H_2 production from the low potential for 1,000 hours, and was documented for the first time.