



Extended Data Figure 5 | Effect of water vapour and H₂ on the solid sources (MoX₂ and WX₂). **a**, Raman spectral evolution of the MoO₂ oxide phase from both MoSe₂ and MoS₂ solid sources upon reaction with a constant flow of N₂ + H₂O vapour for more than 20 min at 1,060 °C (Supplementary Table 2). **b**, Raman spectral evolution of different oxide phases of WX₂ upon reaction with different reactive gas environment for more than 20 min at 1,060 °C as follows. Only Ar + H₂ (5%) through H₂O (200 s.c.c.m.); the Raman spectra is composed of WSe₂, most likely a Se-deficient surface as well as a mixture of complex oxide phases as indicated by the broad peak around 800 cm⁻¹ (1); first partially oxidized by N₂ + H₂O (5 min) followed by Ar + H₂ (5%) through H₂O (200 s.c.c.m.) for 10 min. The dominant phase observed in the Raman spectra is WO₂^{36–39,42} (2); completely oxidized by N₂ + H₂O flow for 20 min—the dominant phase observed in the Raman spectra is W₂₀O₅₈ (3). **c**, **d**, Reduction of different metal oxide (MoO₃ and WO₃) and selenide (MoSe₂ and WSe₂) solid sources as a function of reaction time and carrier gases: in N₂ + H₂O (**c**) and Ar + H₂ (5%) (**d**) flow conditions at 1,060 °C. It can be observed that the weight loss of MoO₃ (38.5% in 2 min) is very rapid compared to that of WO₃ (1% in 2 min). In contrast, the reduction

rate of MoSe₂ and WSe₂ solid precursors are almost linear during H₂ exposure at high temperatures. During oxidation by H₂O, however, the weight loss of MoSe₂ is two and five times faster than that of WSe₂ and WO₃ respectively. **e–h**, A direct visualization of the reaction of MoSe₂ can be gained from the change in colour of the source precursor under different conditions: bulk powder of MoSe₂ (**e**); after reaction in Ar + H₂ (5%) through H₂O (200 s.c.c.m.) (**f**); after reaction in N₂ through H₂O (200 s.c.c.m.); the chocolate brown indicates the MoO₂ phase (**g**); the shiny surface indicates the presence of metallic molybdenum reduced from MoX₂ along with the MoO₂ phase (**h**). **i–l**, Different oxide phases of WX₂ upon reaction with different reactive gas environment for more than 20 min at 1,060 °C. Bulk powder of WSe₂ (**i**); only Ar + H₂ (5%) through H₂O (200 s.c.c.m.) (**j**), corresponding to spectrum 1 in **b**); first partially oxidized by N₂ + H₂O (5 min) followed by Ar + H₂ (5%) through H₂O (200 s.c.c.m.) for 10 min (chocolate brown, **k**, corresponding to spectrum 2 in **b**)^{36–39,42}; completely oxidized by N₂ + H₂O flow for 20 min—the dominating phase observed in the Raman spectra is W₂₀O₅₈ (blue-violet, **l**, corresponding to spectrum 3 in **b**). The insets of **l** show the high magnification image (left) and the materials in an alumina boat (right).