

AQUEOUS CHEMISTRY OF VANADIUM CONSIDERATIONS FOR RfD DERIVATION

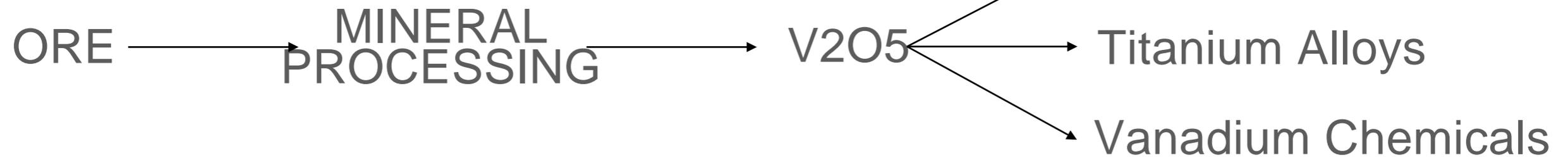


Dr David J White

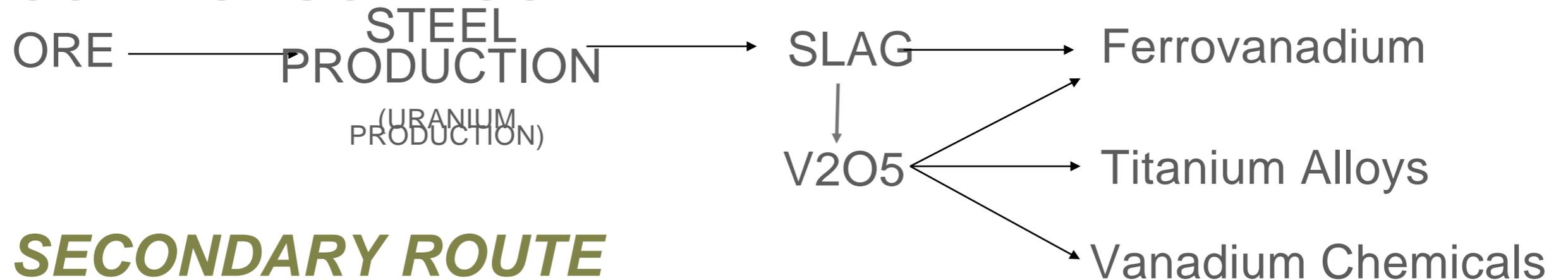
THE INDUSTRIAL PRODUCTION OF VANADIUM

Most Vanadium, and all US Vanadium is produced from by-products and waste

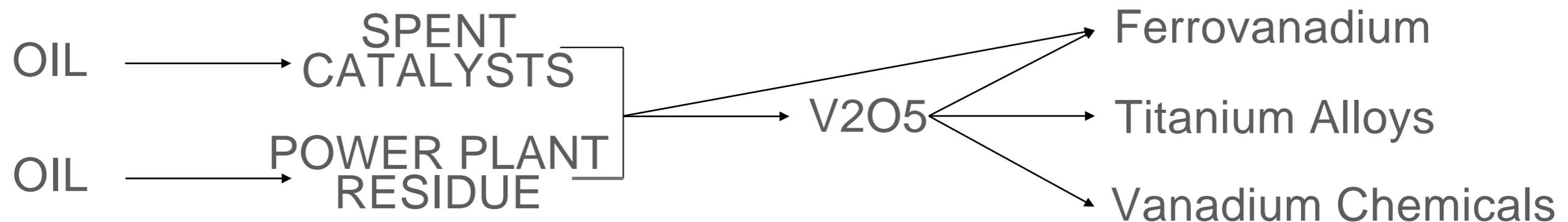
PRIMARY ROUTE



CO-PRODUCT ROUTE

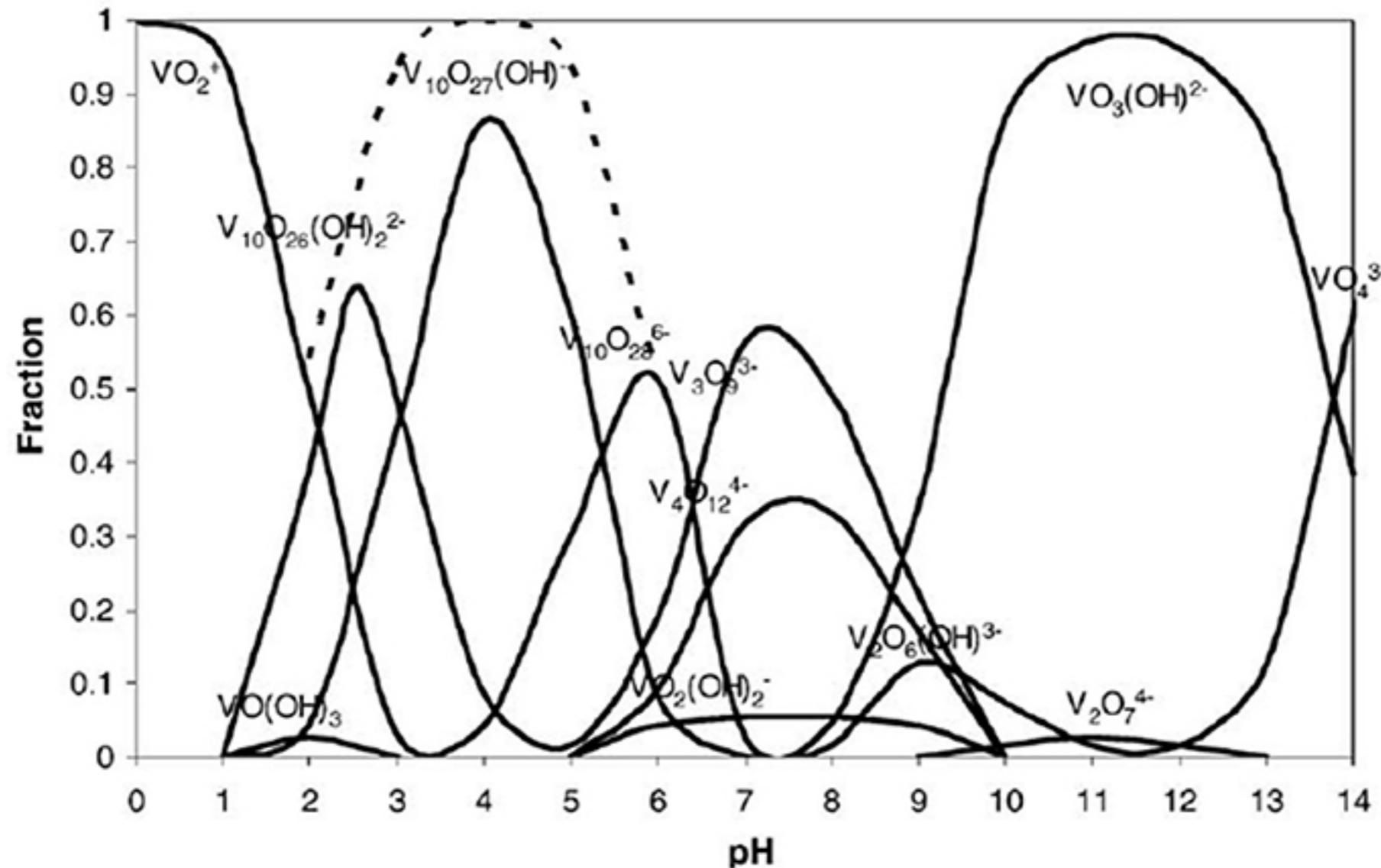


SECONDARY ROUTE



THE COMPLEXITY OF AQUEOUS VANADIUM CHEMISTRY

Compared to some other metals such as copper or nickel, vanadium, and especially vanadium +5 has complex aqueous chemistry



Reproduced from Baes, C. F. Jr., and Mesmer, R. E. (eds.). (1976). "The first transition series vanadium," in *The Hydrolysis of Cations*, (New York, NY: John Wiley and Sons), 193–210.

VANADATE PREDOMINANCE DIAGRAM EXAMPLES TAKAHASHI AND GUSTAFSSON

Diagrams vary dependent on the exact system under investigation but have fundamental similarities

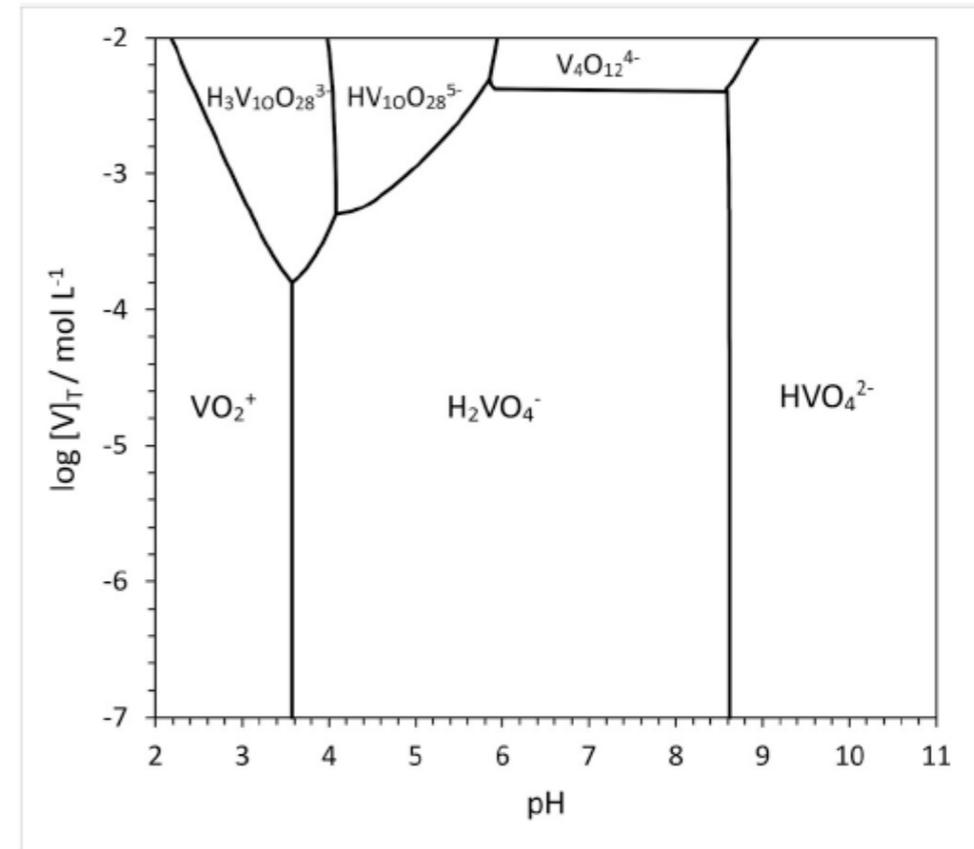
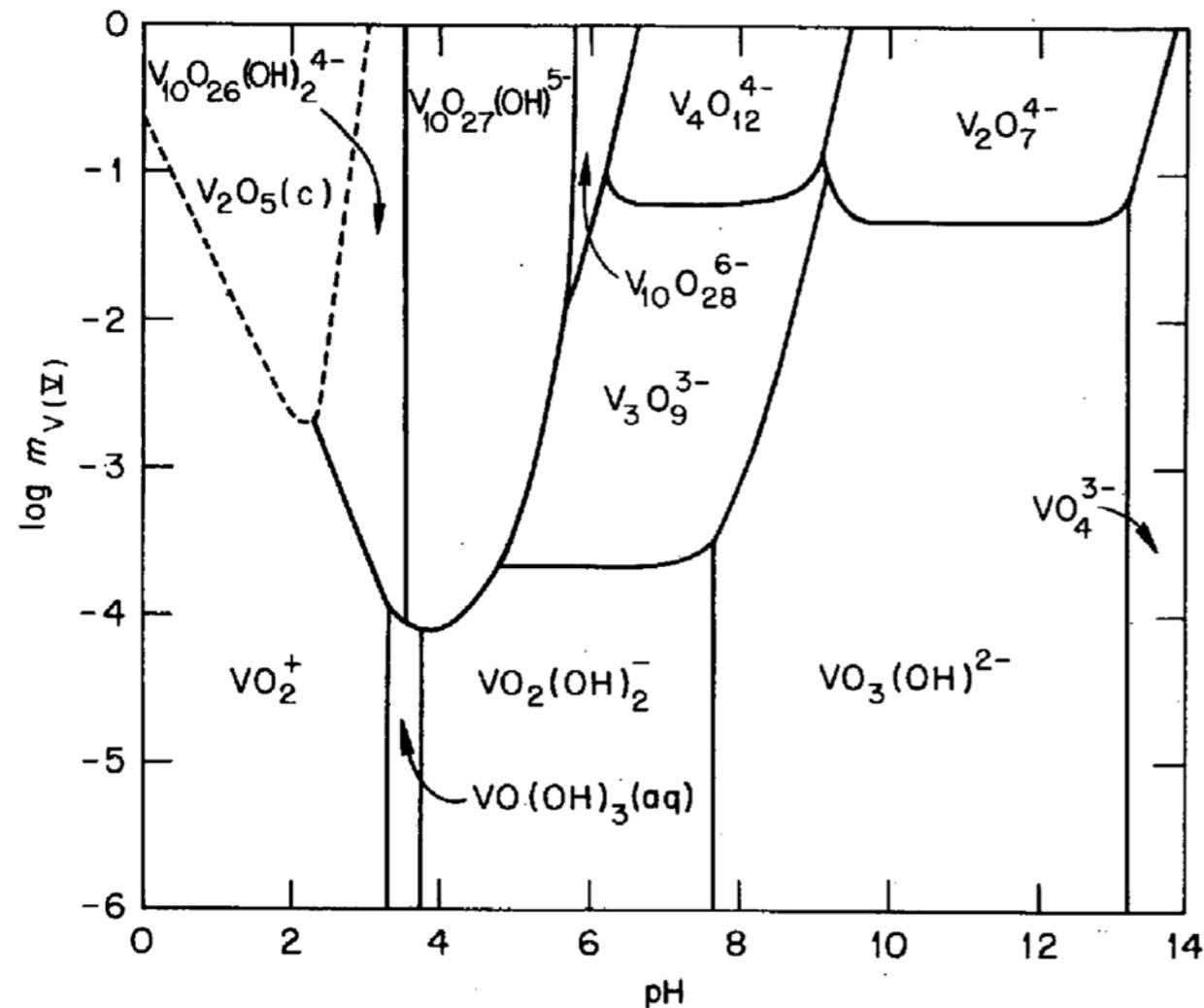
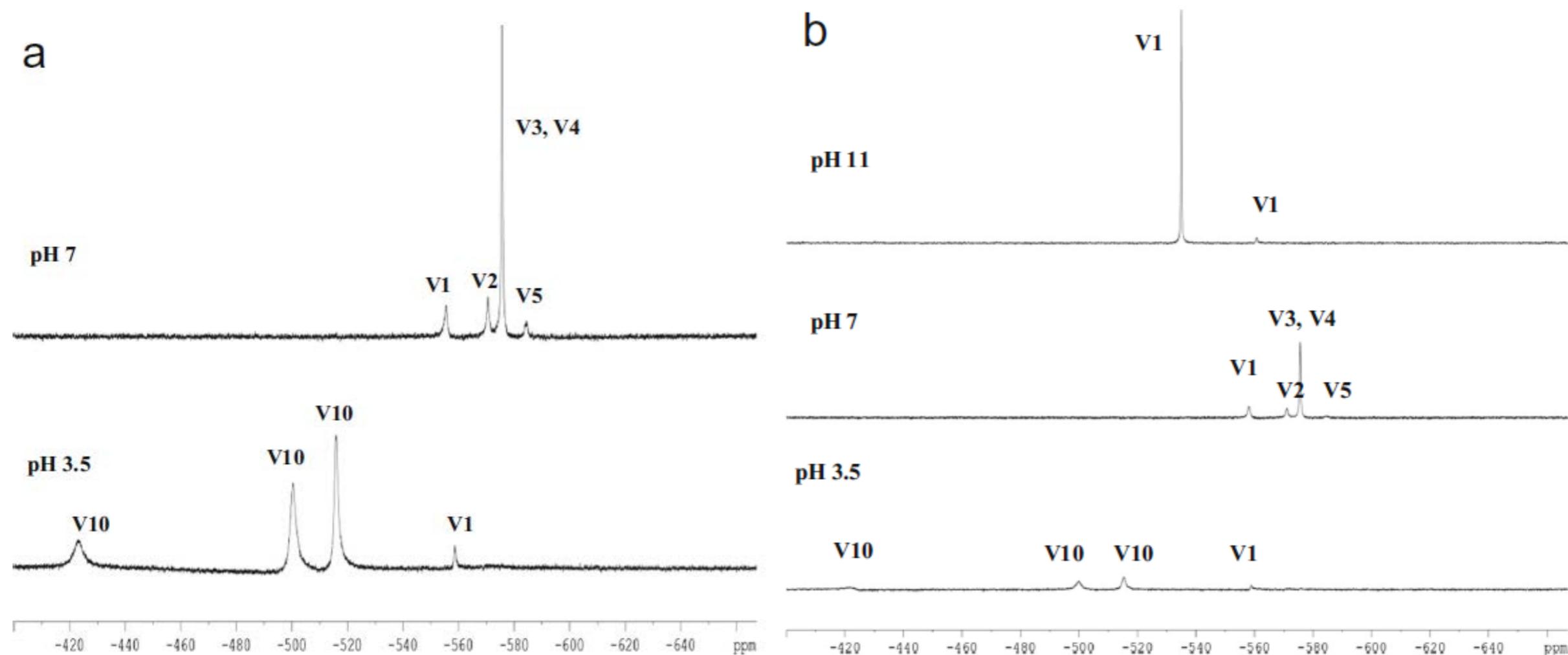


Fig. 3. Predominance diagram showing the speciation of vanadate (V) as a function of pH and total concentration of vanadium, $[V]_T$. $T = 25\text{ }^\circ\text{C}$, $I = 0.01\text{ mol L}^{-1}$ (as NaCl). To produce the diagram, equilibrium constants selected for Visual MINTEQ were used (Table S3).

From 1) Takahashi et al, Extraction of Vanadium from Ammonia Slag under Near-Atmospheric Condition, *Metals* 2018, 8(6), 414; <https://doi.org/10.3390/met8060414> and 2) Gustafsson JP, Vanadium geochemistry in the biogeosphere –speciation, solid-solution interactions, and ecotoxicity, *Applied Geochemistry*, 102, 2019, 1-25, <https://doi.org/10.1016/j.apgeochem.2018.12.027>.

MUTLU *ET AL* MASS SPECTROMETRY



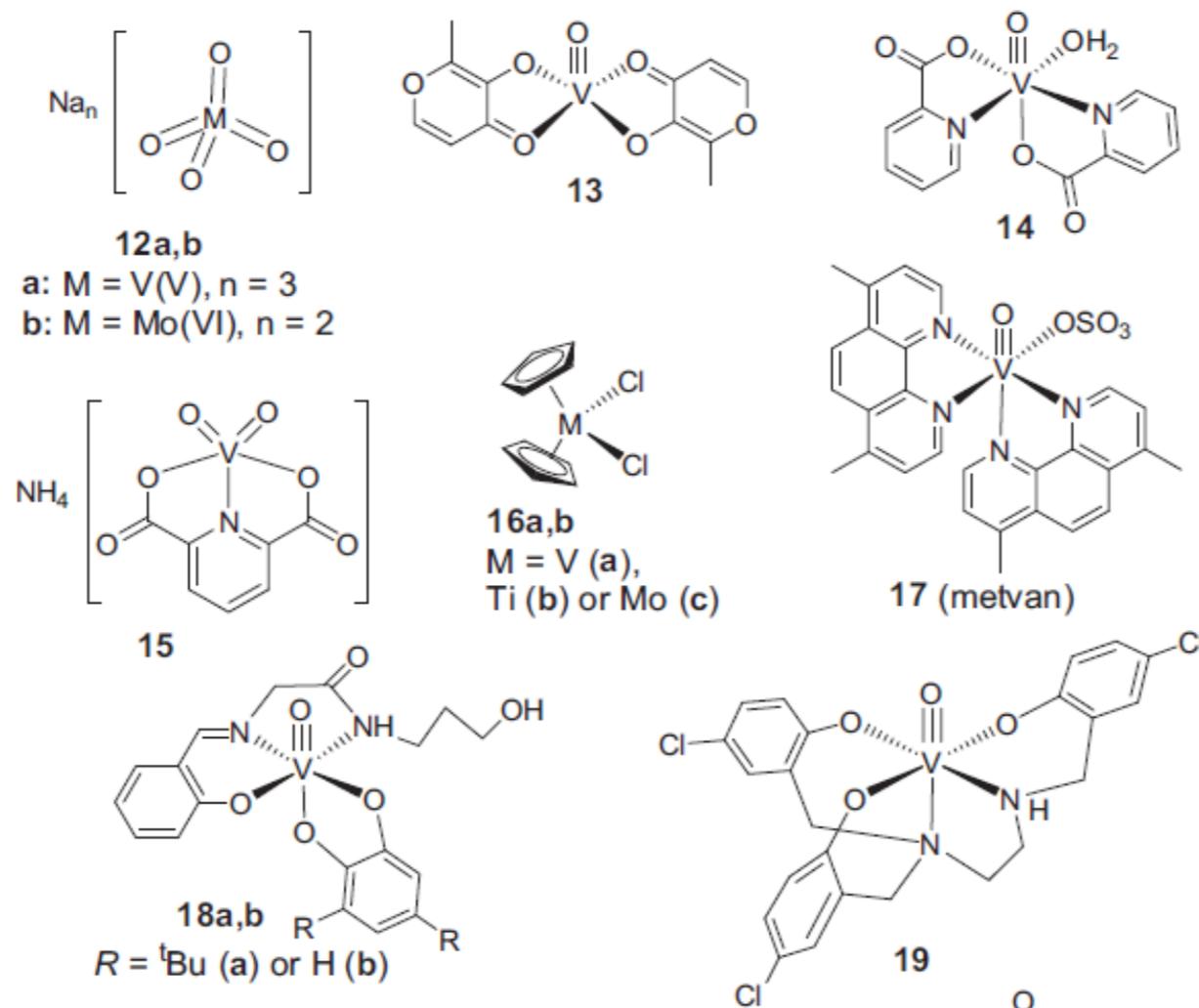
Anionic mass spectrometry of (a) sodium metavanadate and (b) sodium orthovanadate at 2000 ppm and various pH values showed polyoxometalates were prevalent

From Mutlu, E., Cristy, T., Graves, S.W. et al. Characterization of aqueous formulations of tetra- and pentavalent forms of vanadium in support of test article selection in toxicology studies. *Environ Sci Pollut Res* 24, 405–416 (2017).

<https://doi.org/10.1007/s11356-016-7803-x>

ORGANIC VANADIUM COMPOUNDS

Vanadium forms a wide array of compounds with organic ligands and proteins in organisms



Example well characterized vanadium coordination complexes

From Levina, Crans, & Lay, Speciation of metal drugs, supplements and toxins in media and bodily fluids controls in vitro activities, Coordination Chemistry Reviews, 352,2017, 473-498, <https://doi.org/10.1016/j.ccr.2017.01.002>.

VANADIUM ESSENTIALITY

- **Vanadium has been shown to be essential for nitrogen fixing microorganisms in soils**
- **Nutritional studies also show that it is essential in animals including chicks, rats and goats**
- **Despite no elucidation of a clear biochemical role for the element, based on other evidence the World Health Organization have stated that “vanadium may play a significant role in human nutrition”**