

## **Vanadium-doped Sodium phosphomolybdate salts as catalysts in the terpene alcohols oxidation with hydrogen peroxide**

CASTELO BANDANE VILANCULO<sup>1\*</sup>, MÁRCIO JOSÉ DA SILVA<sup>2</sup>, ALANA ALVES RODRIGUES,  
SUKARNO OLAVO FERREIRA<sup>2</sup> AND RENE CHAGAS DA SILVA<sup>2</sup>

<sup>1</sup>*Chemistry Department, Pedagogic University of Mozambique, FCNM, Campus de Lhanguene, Av. de Moçambique, km 1, Maputo, C.P.: 4040, Fax: (+258)21401082.*

<sup>2</sup>*Chemistry Department, Federal University of Viçosa, Viçosa, Minas Gerais, Brasil. zip-code: 36590-000*

### **Supplemental material**

List of Figures

**Figure 1SM.** FT-IR spectra of Sodium phosphomolybdate and vanadophosphomolybdate Sodium salts.

**Figure 2SM.** UV-Vis spectra of Vanadium trisubstituted phosphomolybdate catalyst in aqueous solution.

**Figure 3SM.** Secondary structure of Na<sub>4</sub>PMo<sub>11</sub>VO<sub>40</sub>

**Figure 4SM.** Isotherms of adsorption and desorption of N<sub>2</sub> and volume and diameters porous (inset) of pure Sodium phosphomolybdate catalyst and after the Vanadium doping.

**Fig. 5SM** Scanning electronic microscopy images of undoped and Vanadium-doped Sodium phosphomolybdate salts.

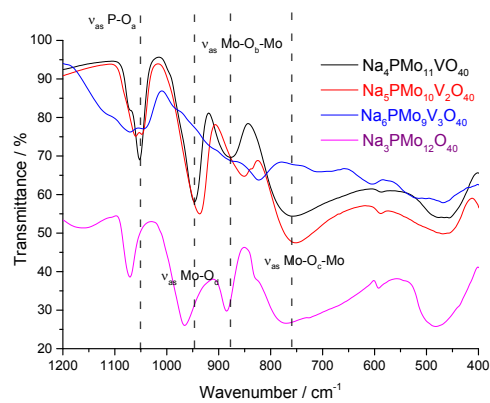
**Fig. 6SM** EDS spectra of undoped and Vanadium-doped Sodium phosphomolybdate salts.

List of Tables

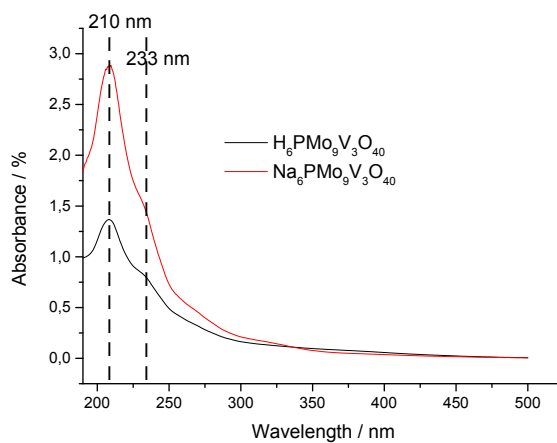
**Table 1SM.** Porosimetry characteristics of pure and Vanadium doped-Sodium phosphomolybdate salts<sup>a</sup>

**Table 2SM.** Hydration water number per mol of catalyst determined through thermal analysis.

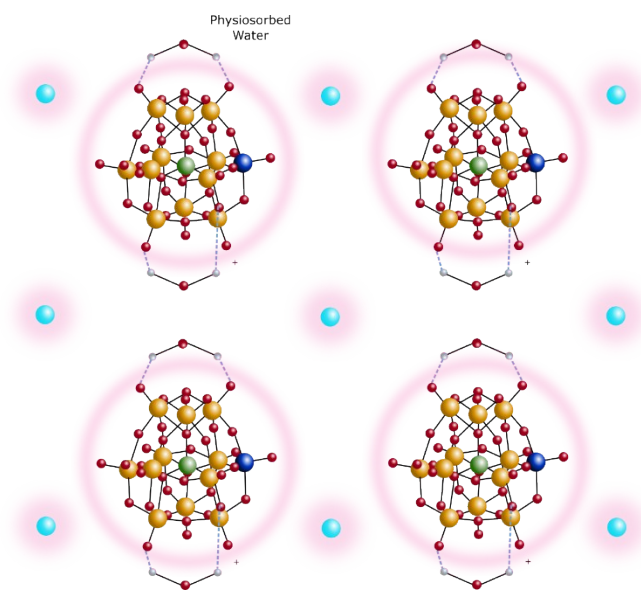
**Table 3SM.** Elemental analysis data theoretical and experimental obtained from undoped and Vanadium-doped phosphomolybdate salts.



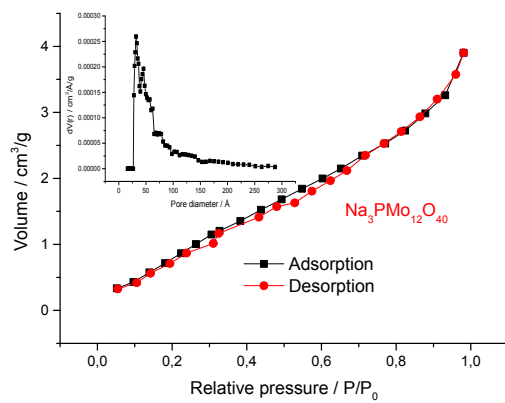
**Fig. 1SM** FT-IR spectra of Sodium phosphomolybdate salts unsubstituted and Vanadium substituted.



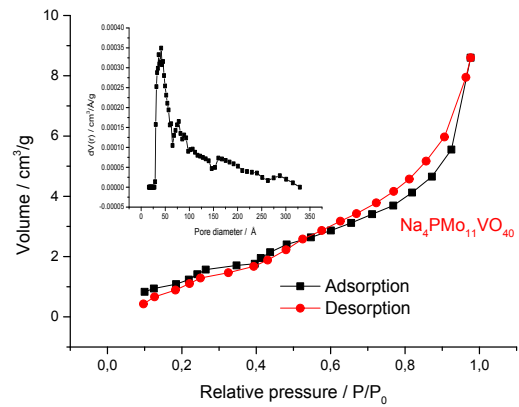
**Figure 2SM.** UV-Vis spectra of Vanadium trisubstituted phosphomolybdate catalyst in aqueous solution



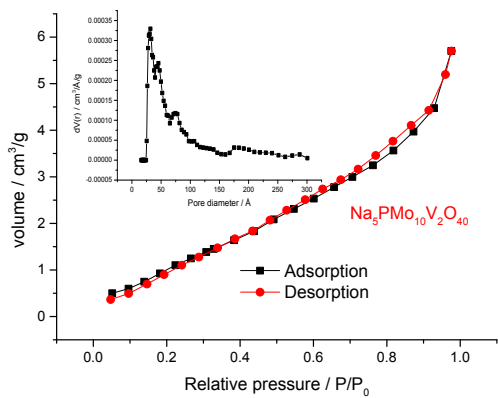
**Fig. 3SM.** Secondary structure of Na<sub>4</sub>PMo<sub>11</sub>VO<sub>40</sub>



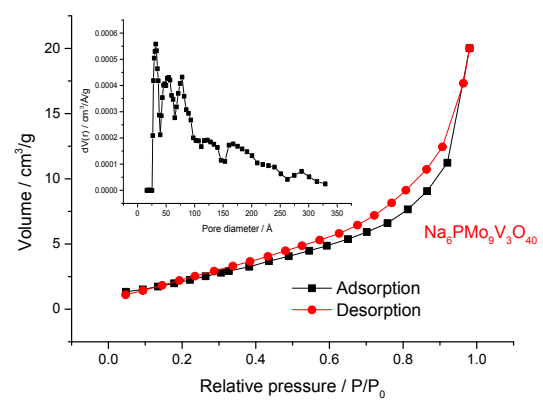
(a)



(b)

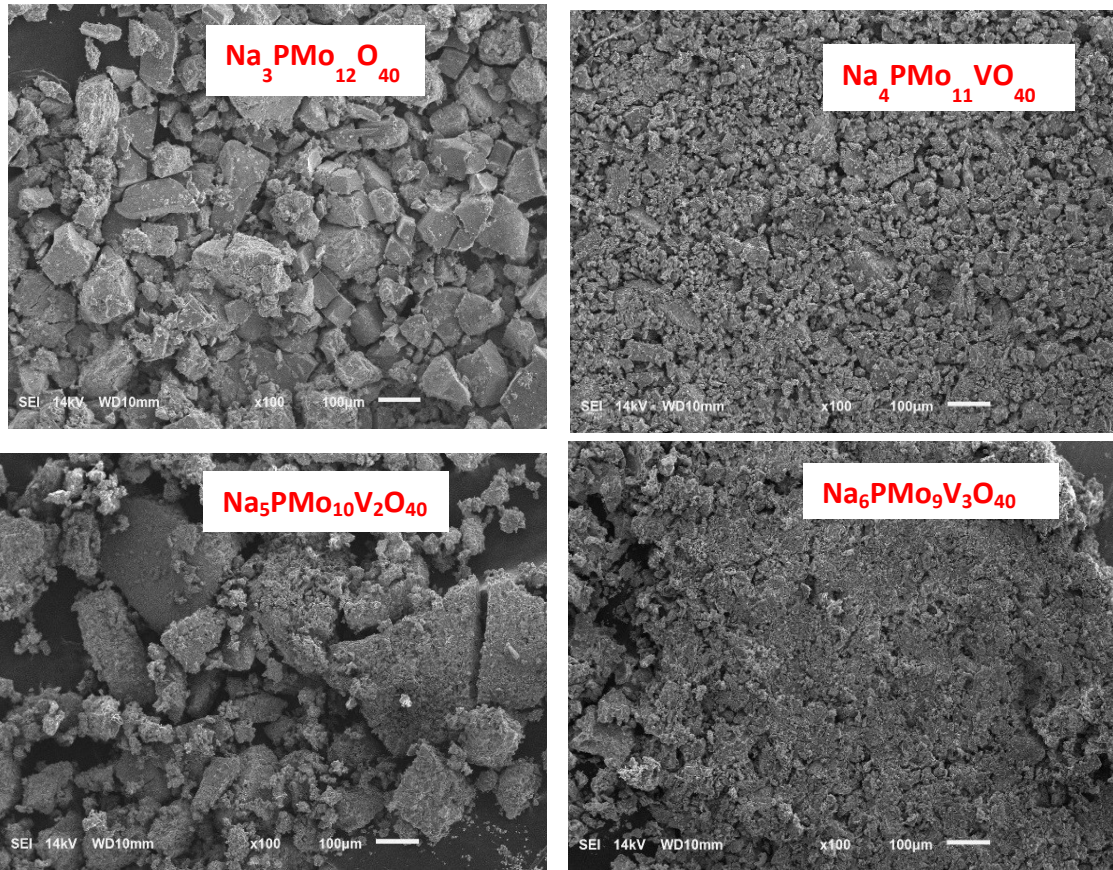


(c)

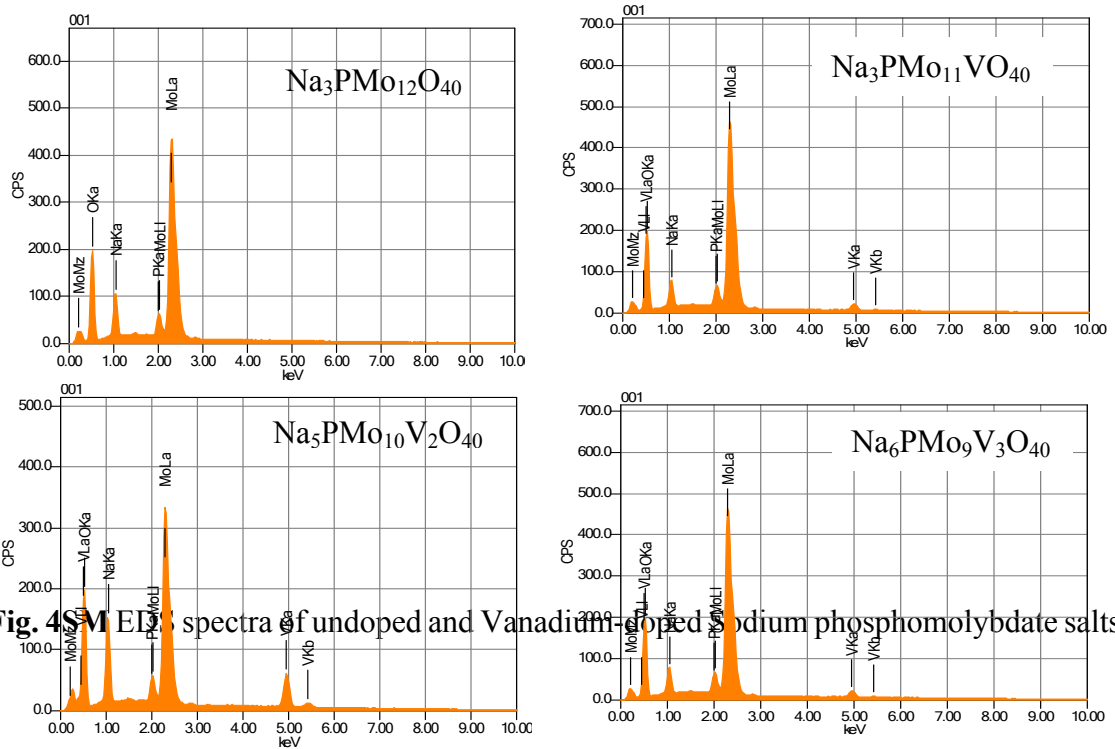


(d)

**Fig. 4SM** Isotherms of adsorption and desorption of  $N_2$ , volume, and distribution of porous diameters (inset) of pure Sodium phosphomolybdate catalyst before (a) and after the Vanadium doping (b-d).



**Fig. 5** SEM Scanning electronic microscopy images of undoped and Vanadium-doped Sodium phosphomolybdate salts.



**Fig. 4** SEM EDS spectra of undoped and Vanadium-doped Sodium phosphomolybdate salts

**Fig. 6** SEM EDS spectra of undoped and Vanadium-doped Sodium phosphomolybdate salts.

**Table 1SM.** Porosimetry characteristics of undoped and Vanadium doped-Sodium phosphomolybdate salts<sup>a</sup>

Catalyst	S <sub>BET</sub> (m <sup>2</sup> /g)	V <sub>DFT</sub> (cm <sup>3</sup> /g)	D (Å)
Na <sub>3</sub> PMo <sub>12</sub> O <sub>40</sub>	1.8	5.2 x 10 <sup>-3</sup>	31.7
Na <sub>4</sub> PMo <sub>11</sub> VO <sub>40</sub>	3.1	1.5 x10 <sup>-3</sup>	41.5
Na <sub>5</sub> PMo <sub>10</sub> V <sub>2</sub> O <sub>40</sub>	3.7	7.6 x 10 <sup>-3</sup>	31.7
Na <sub>6</sub> PMo <sub>9</sub> V <sub>3</sub> O <sub>40</sub>	6.4	25.3 x 10 <sup>-3</sup>	31.7

<sup>a</sup>S<sub>BET</sub> = surface area; V<sub>DFT</sub> = cumulative pore volume; D = pore diameter

**Table 2SM.** Hydration water number per mol of catalyst determined through thermal analysis (TG/DTG).

Catalyst	Total hydration water (573 K)
Na <sub>3</sub> PMo <sub>12</sub> O <sub>40</sub>	10
Na <sub>4</sub> PMo <sub>11</sub> VO <sub>40</sub>	7
Na <sub>5</sub> PMo <sub>10</sub> V <sub>2</sub> O <sub>40</sub>	10
Na <sub>6</sub> PMo <sub>9</sub> V <sub>3</sub> O <sub>40</sub>	13



**Table 3SM.** Elemental analysis data theoretical and experimental obtained from undoped and Vanadium-doped phosphomolybdate salts.

Catalyst	Elemental composition									
	(wt. %)									
	Na		P		Mo		V		O	
	Calc.	Exp.	Calc.	Exp.	Calc.	Exp.	Calc.	Exp.	Calc.	Exp.
$\text{Na}_3\text{PMo}_{12}\text{O}_{40}$	4	5	2	2	61	62	0	0	33	31
$\text{Na}_4\text{PMo}_{11}\text{VO}_{40}$	5	5	2	2	56	58	3	3	34	33
$\text{Na}_5\text{PMo}_{10}\text{V}_2\text{O}_{40}$	6	8	2	2	52	50	5	9	35	31
$\text{Na}_6\text{PMo}_9\text{V}_3\text{O}_{40}$	8	10	2	2	47	45	8	12	35	31