Adsorption of Y^{3+} ions from aqueous solutions by neodymium supported titanium dioxide

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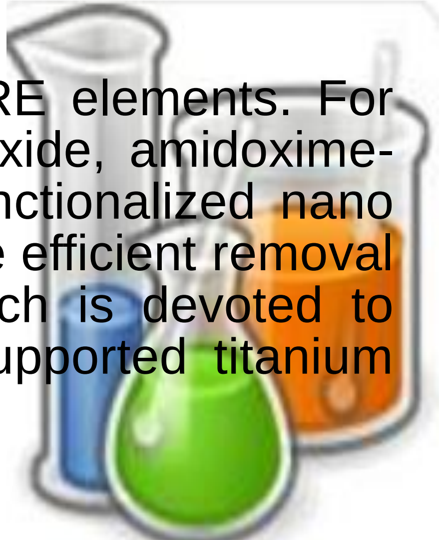
The relevance of research of adsorption of Y^{3+}

- The relevance of research of adsorption of Y^{3+} ions is due to many factors: (a) yttrium isotopes together with other fission radionuclides can be in Nuclear Power Plant waste and spend nuclear fuel; (b) yttrium is daughter radionuclide of strontium in beta-decay chaine; (c) radioactive nuclides in secular equilibrium are often used in radiation oncology. β-particles from ^{90}Y in secular equilibrium with ^{90}Sr are used to treat intraocular lesions. The activity of the ^{90}Sr–^{90}Y ophthalmic irradiator decays with the physical half-life of ^{90}Sr (28 years), whereas a source of ^{90}Y alone decays with the 64-hour half-life of ^{90}Y

- Together with Rare Earth elements yttrium forms a group of YRE elements. For adsorption of YRE elements offer calcite, amorphous ferric hydroxide, amidoxime-hydroxamic acid polymer, cellulose – HO_7Sb_3 nanocomposite, functionalized nano silica, TiO_2/La, etcetera. But the search for a new adsorbents for the efficient removal of Y^{3+} ions from aqeous solutions is still ongoing. This research is devoted to adsorption of Y^{3+} ions from aqueous solutions by neodymium supported titanium dioxide (TiO_2/Nd).



Experimental technique. Results and discussion

The adsorption of yttrium was investigated in the butch mode, neutral medium in the range of 185 mg/L- 4202 mg/L equilibrium concentrations. The dependence of adsorption value of Y^{3+} ions by TiO_2/Nd from time interaction, solution acidity and equilibrium concentration of yttrium ions was investigated. With the aid of a fluorescent X-ray analyzer and energy dispersive spectroscopy (EDS) by using REMMA-102-02 Scanning Electron Microscope Analyzer (JCS SELMI, Ukraine), the composition of the sorbent formed was determined as well as yttrium presence on the surface of the sorbent after the sorption process.

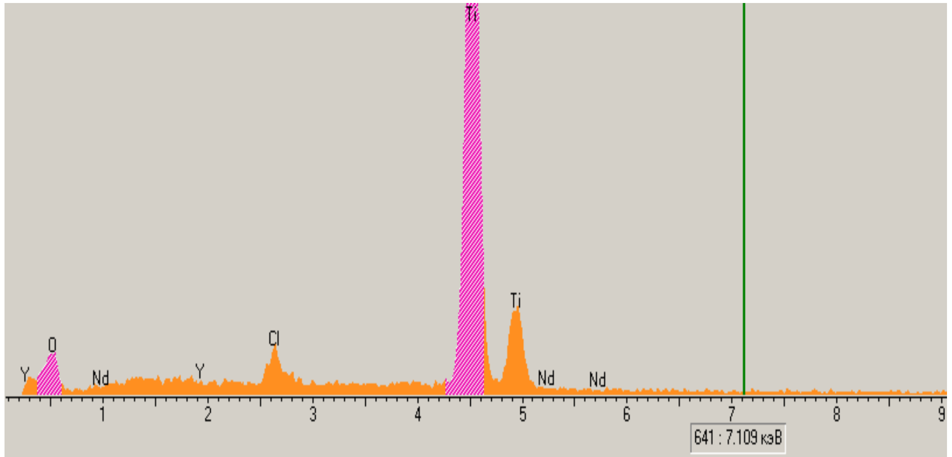


Fig. 1. EDS spectroscopy of TiO_2/Nd samples with Y^{3+} on the surface

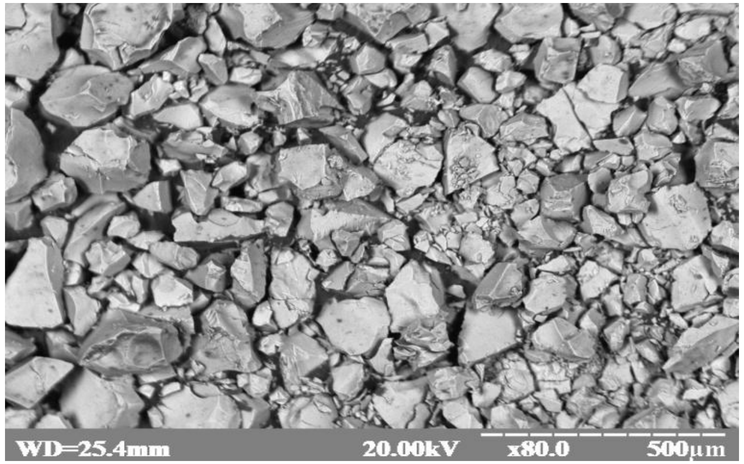


Fig. 2. Morphology of TiO_2/Nd.

Kinetic of Y^{3+} adsorption by TiO_2/Nd

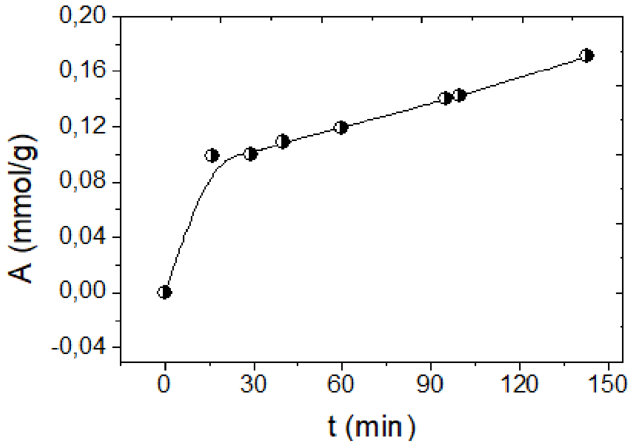


Fig. 3. Kinetic of Y^{3+} adsorption by TiO_2/Nd. Initial concentration of YCl_3 0,01M; pH=7; T:P=100 (V=5ml; m =0,05g)

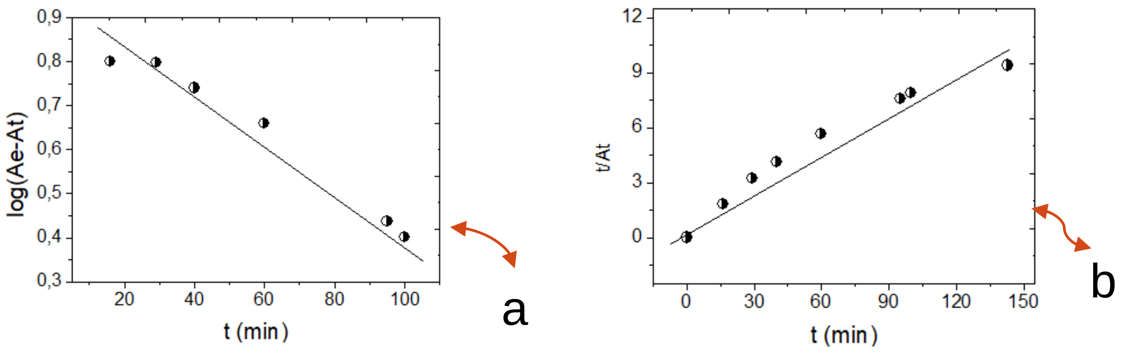


Fig. 4. Applying of pseudo-first (a) and pseudo-second (b) kinetic models to experimental data

Table 2. Applying kinetic models to experimental data of adsorption of Y^{3+} by TiO_2/Nd.

Kinetic model	Adsorption equation	Coefficient	R^2
diffusion	A_t= 0,81 $t^{1/2}$ + 4,8	D_{ipd} =0,81±0,127	0,9540
Elovich	A_t =0,036 lnt – 0,024	-	0,9879
Pseudo-first order	log(A_e- A_t)=-0,005t+0,93	k1=0,00506±0,0 0065	0,9718
Pseudo-second order	t/ A_t =0,065t+1	k2= 0,06525±0,002	0,9577

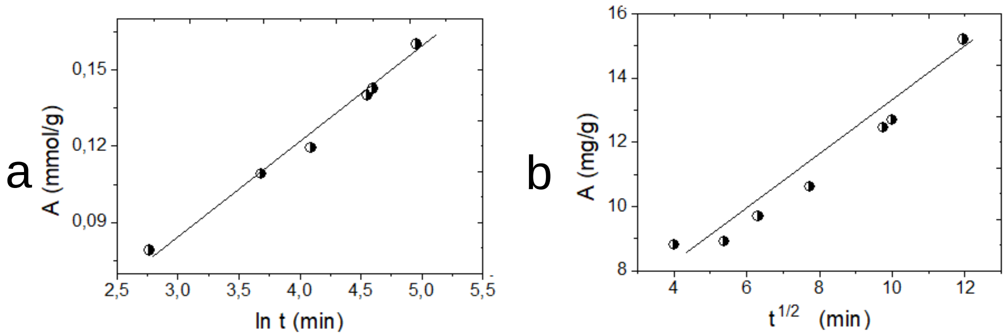


Fig. 5. Applying Elovich (a) and diffusion (b) kinetic models to experimental data of adsorption of Y^{3+} by TiO_2/Nd.

Equilibrium adsorption. Langmuir adsorption theory

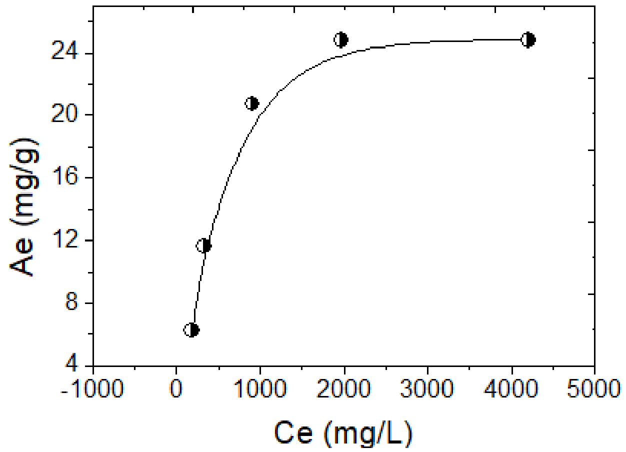
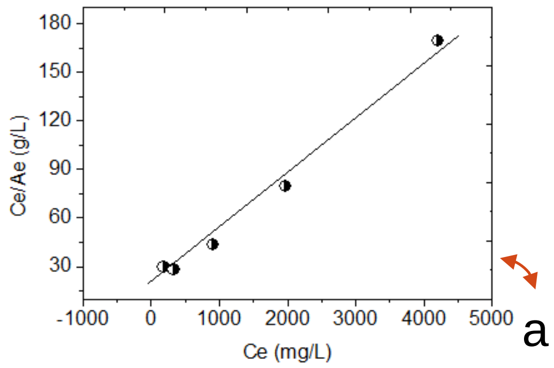


Fig.6. Adsorption isotherm of Y^{3+} by TiO_2/Nd. pH=7; T:P=100 (V=5ml; m =0,05g)

Langmuir adsorption theory is use to describe the equilibrium between adsorbate and adsorbent system, where the adsorbate (Y^{3+} - in our case) adsorption is limited to one molecular layer, and locate on adsorption centers. This theory is applicate in nanotechnology in the removal of heavy metal from water.



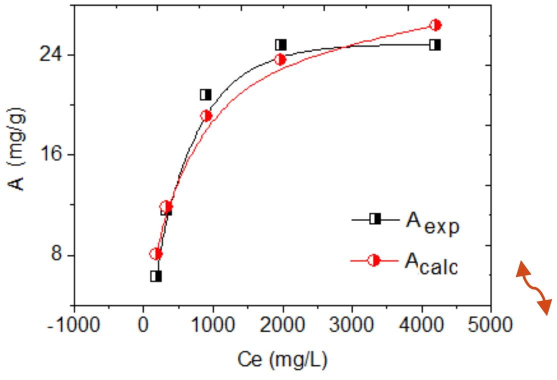


Fig. 7. Adsorption isotherm of Y^{3+} by TiO_2/Nd. Linear (a) and nonlinear (b) fitting by Langmuir theory.

Table 3. Parameters of Langmuir equation for adsorption of Y^{3+} by TiO_2/Nd

fitting	A_{max}, mg/g	K_L	R^2
linear	16,059	0,0356	0,9907
nonlinear	29,48487	0,002934	0,9992
A_{max} experimental	A_{max}, (mg/g) 24,8		

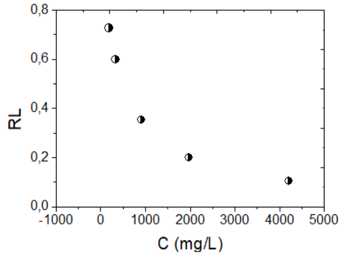


Fig. 8. Dependence of factor R_L from initial yttrium concentration.

Equilibrium adsorption. Dubinin-Radushkevych adsorption equation

The Dubinin-Radushkevych equation was proposed as the empirical adaptation of the Polanyi adsorption potential theory. The equation based the postulate that the mechanism of adsorption in micropores is that pore filling rather than layer-by-layer surface coverage. The Dubinin-Radushkevych equation generally applies well to adsorption system involving only Van der Waals forces in micropores of adsorbents [Theoretical basis for the Dubinin-Radushkevych adsorption isotherm equation. Nick D.Hutson, Ralph T. Yang, 1997 http://DOI.org.:10.1007/BFO1650130]

$$A_e = A_{max} \times exp(-\beta\varepsilon^2) = A_{max} \times \left[-\beta \times \left(RT \ \ln\left(1 + \frac{1}{C_e}\right)^2\right)\right]$$

A_e – adsorption value, mmol·g^{-1} C_e –equilibrium concentration mol·L^{-1}; A_{max}- maximal adsorption value, mg·g^{-1}; β- constant (mol^2·J^{-2}); ε – Polyani potential (J·mol^{-1}); R – universal gas constant J·mol^{-1}·K^{-1}, T – temperature (К).

Constant β is relate with adsorption Energy (kJ/mol) by equation below:

$$E = \frac{1}{(2\beta)^{\frac{1}{2}}}$$

Equilibrium adsorption. Applying of Dubinin-Radushkevych equation

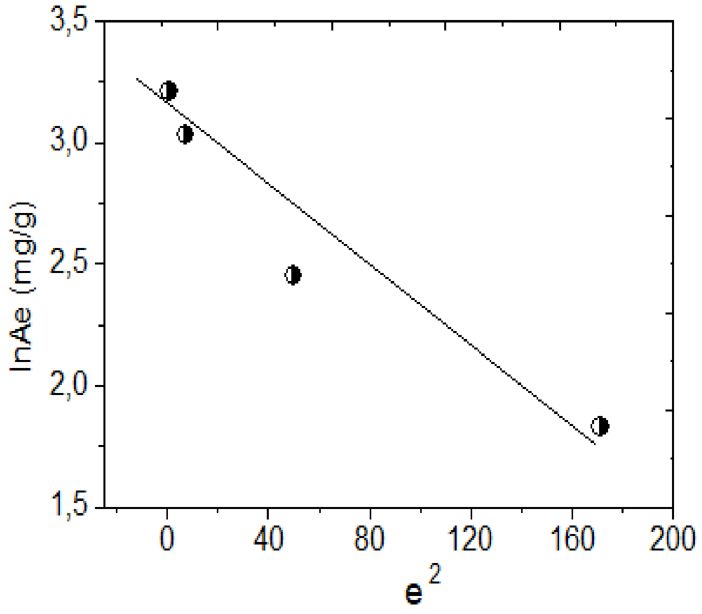


Fig. 9. Adsorption isotherm of Y^{3+} by TiO_2/Nd. Linear fitting by Dubinin-Radushkevych theory.

Table 5. Parameters of Dubinin-Radushkevych equation for adsorption of Y^{3+} by TiO_2/Nd.

Ce, mg/L	$ε^2$	β	E, kJ/mol	β	E 1/√ - 2slope kJ/mol	R^2
185	171,3481	0,00805	7,866	0,0079	7,9428	0,9308
329,8	49,85772	0,0152	5,737			
905	7,043716	0,0252	4,454			

Conclusion

- The adsorption of yttrium was investigated in the butch mode, neutral medium in the range of 185 mg/L-4202 mg/L yttrium equilibrium concentrations.

- It was shown that adsorption of Y^{3+} strongly depend from time interaction and fitting well by Elovich kinetic model. The process of adsorption of yttrium in equilibrium conditions is fitting well and can be describe by Langmuir theory - adsorption is limited to one molecular layer, and locate on adsorption centers.

- The Dubinin –Radushkevych equation was applied to experimental data and energy of adsorption of yttrium by TiO_2/Nd was calculated. The value of adsorption energy was found near 7kJ/mol, which correspond to adsorption on physical mechanism.

- The presence of neodymium in the TiO_2 structure and it influence on adsorption processes is not clear yet. We suppose that precepitation of $Y(OH)_3$ or $Y(OH)_2^+$ compounds on the surface of TiO_2/Nd is the dominant mechanism of adsorption.