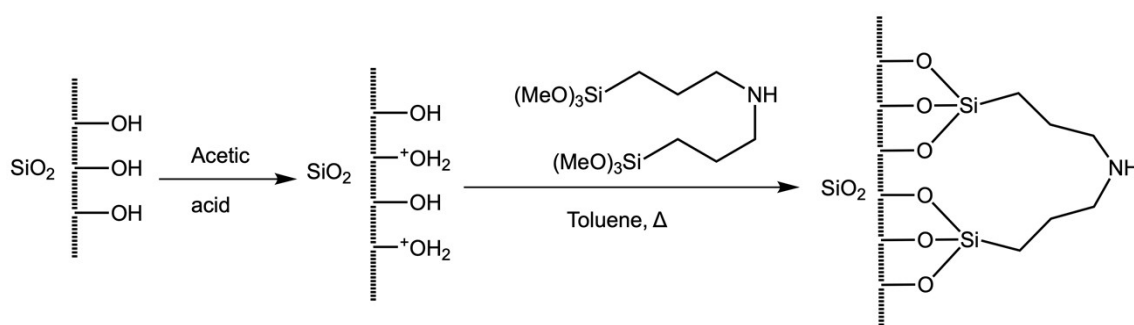


Supporting Information

Supporting Information contains the synthesis of BTMSPA-SG, 1-D and 2-D NMR, FTIR and mass spectra of the ligand, Experimental procedure outlining the adsorption method, SEM images, PXRD graphs, BET isotherms, TGA-DTA graphs and effect of volume graphs. Tables reporting the BET, XRF, CHNS, adsorption isotherms and kinetic models as well as the adsorption capacity results are also included.



Scheme S1 Immobilization of bis(3-(trimethoxysilyl)-propyl)amine onto silica gel.

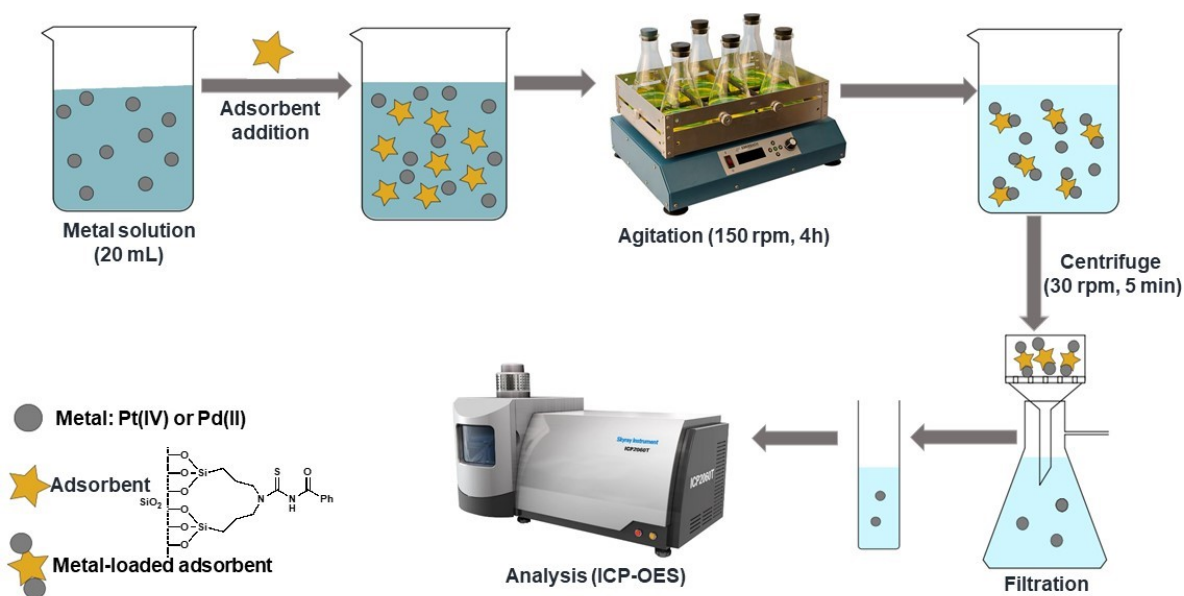


Figure S1 Experimental procedure outlining the batch adsorption of Pt and Pd.

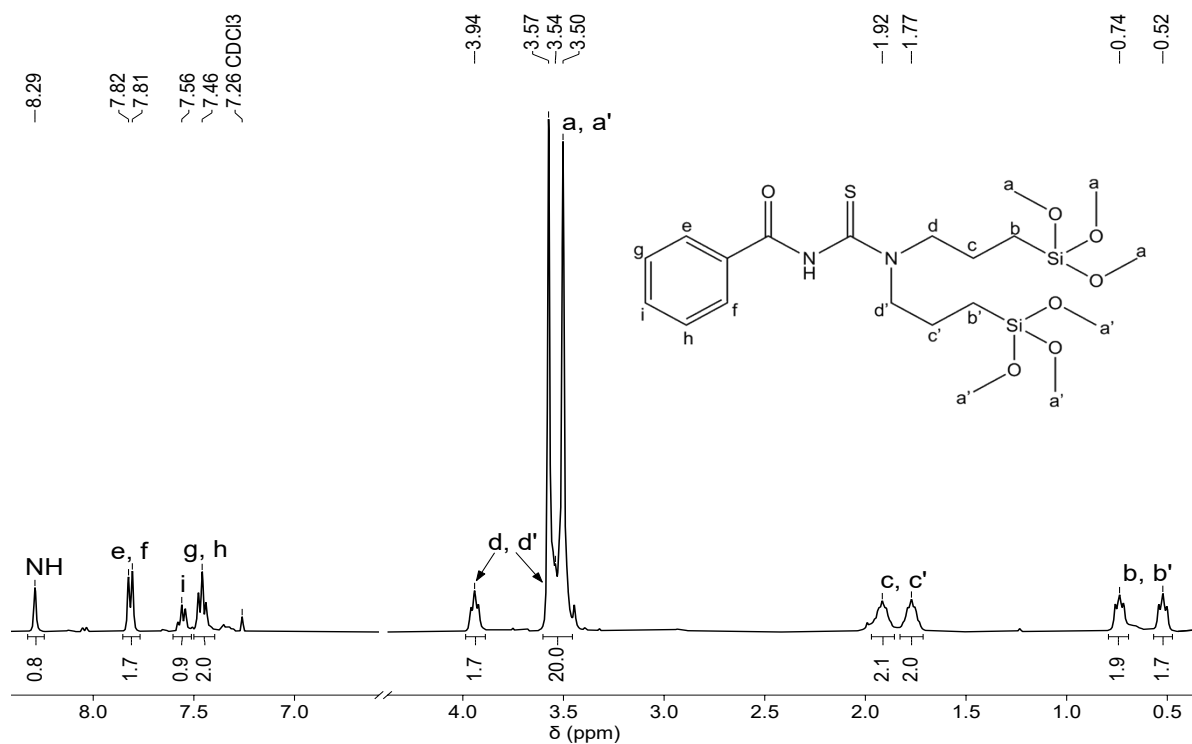


Figure S2 ^1H NMR spectrum of DTMSP-BT in CDCl_3 at 25°C (Note the break in scale between 4.0–7.0 ppm).

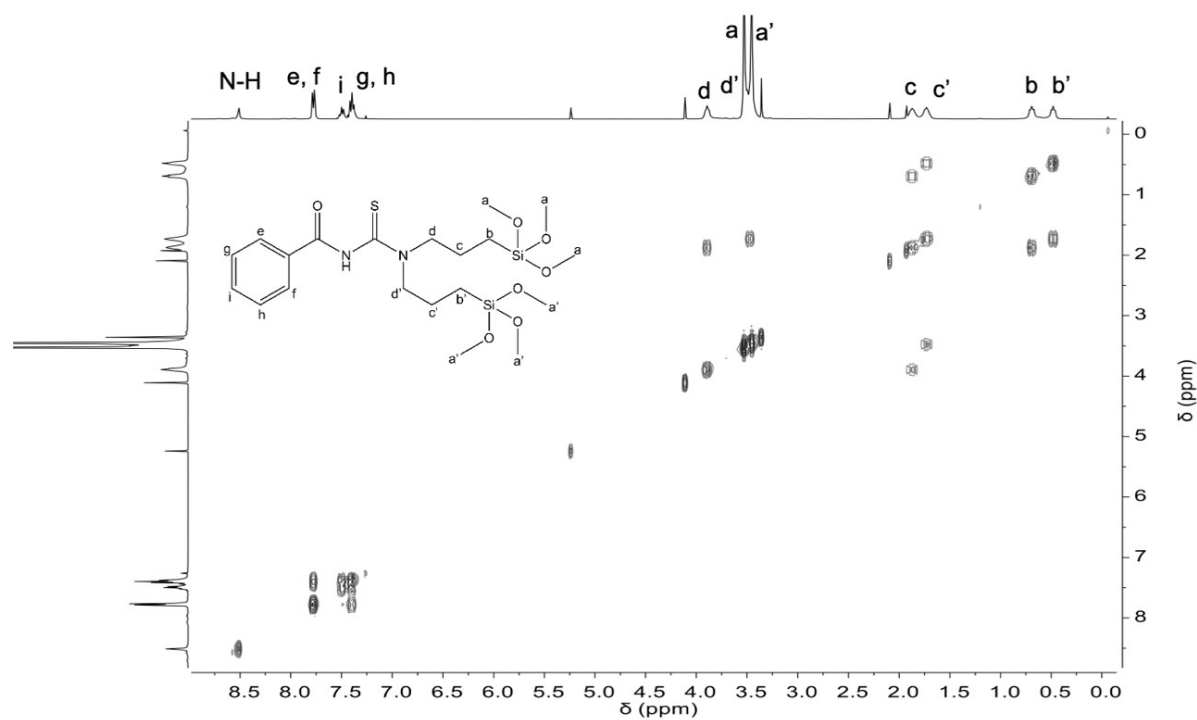


Figure S3 The 2D COSY spectrum of DTMSP-BT in CDCl_3 at 25°C .

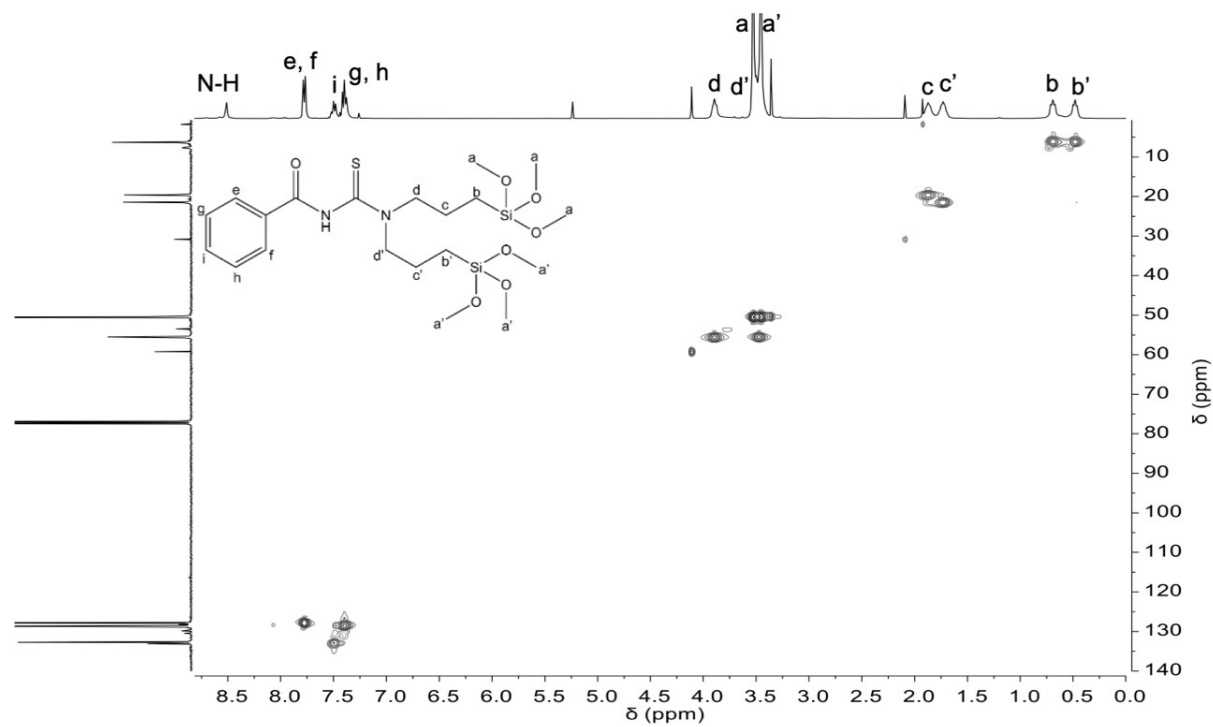


Figure S4 The 2D HSQC spectrum of DTMSP-BT in $CDCl_3$ at 25°C.

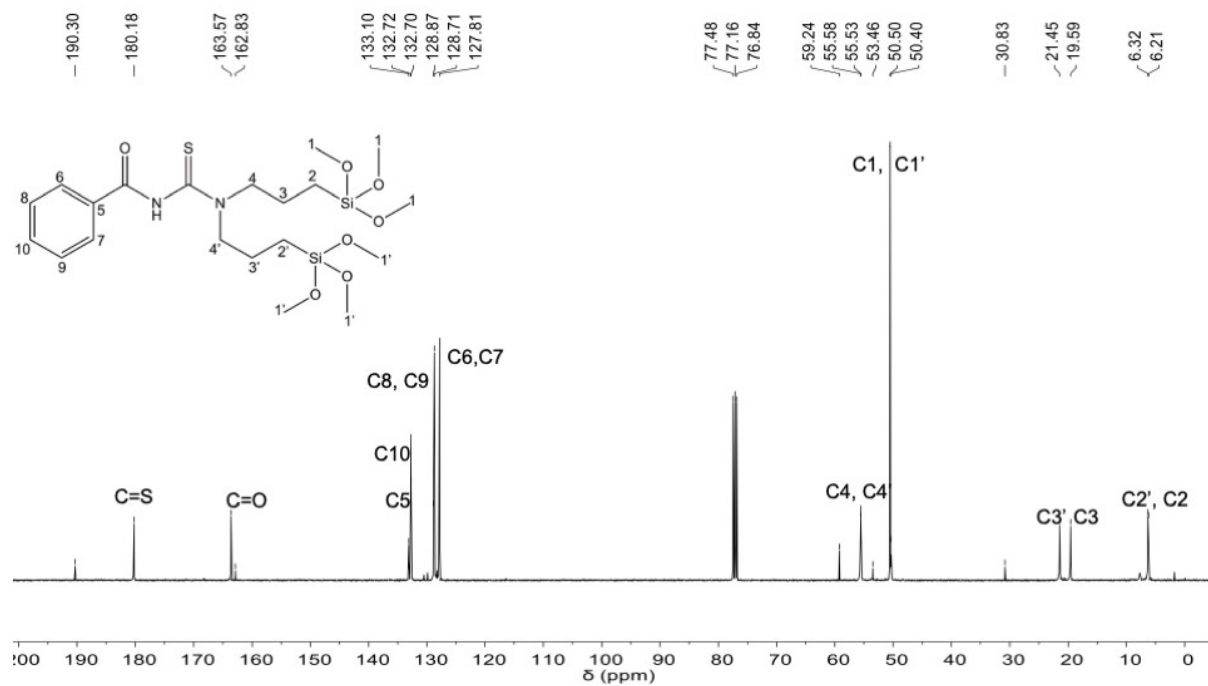


Figure S5 The ^{13}C spectrum of DTMSP-BT in $CDCl_3$ at 25°C.

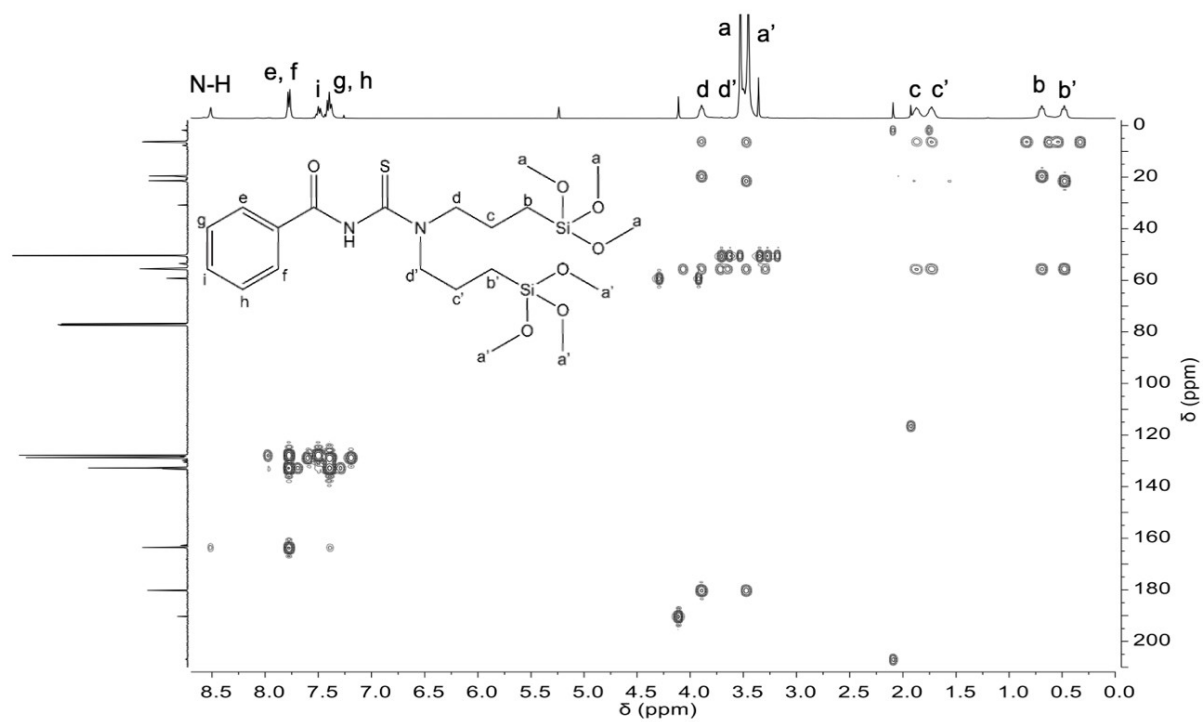


Figure S6 The 2D HMBC spectrum of DTMSP-BT in $CDCl_3$ at 25°C.

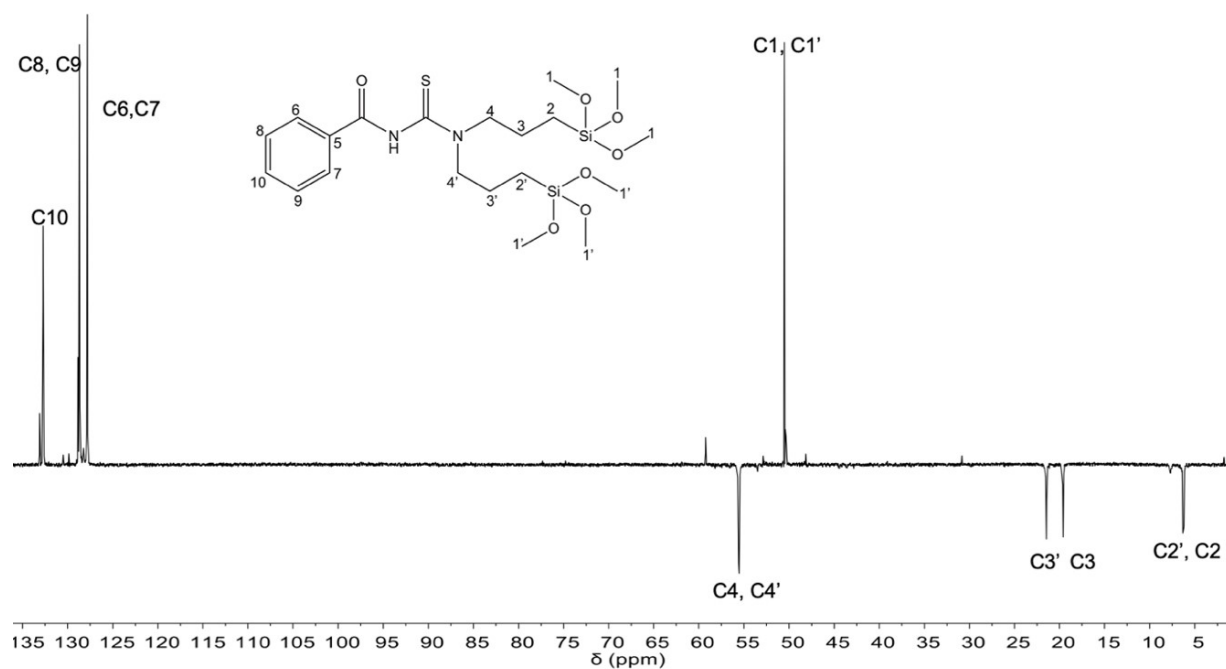


Figure S7 ^{13}C DEPT spectrum of DTMSP-BT at 25°C.

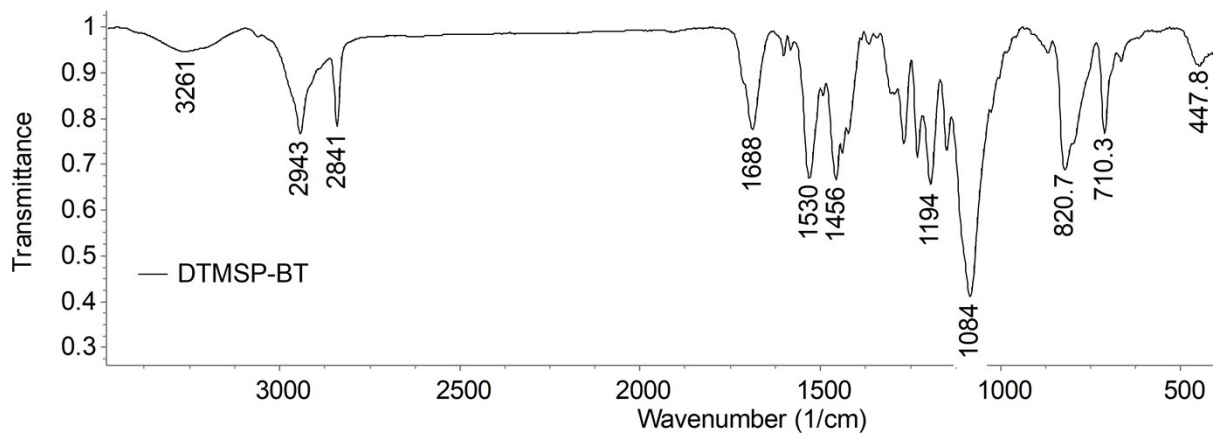


Figure S8 FT-IR Spectroscopy spectrum of DTMSP-BT

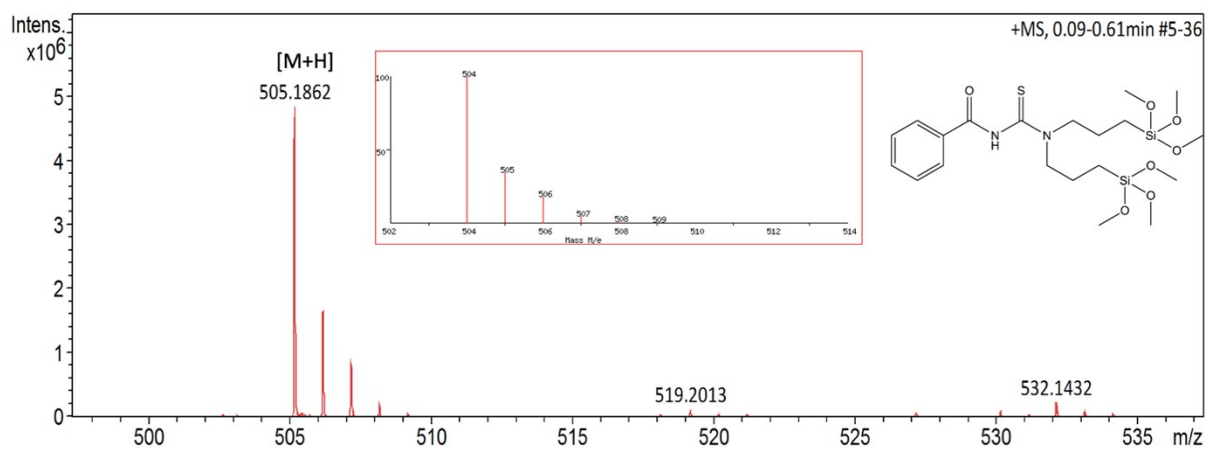


Figure S9 Mass Spectrometry spectrum of DTMSP-BT.

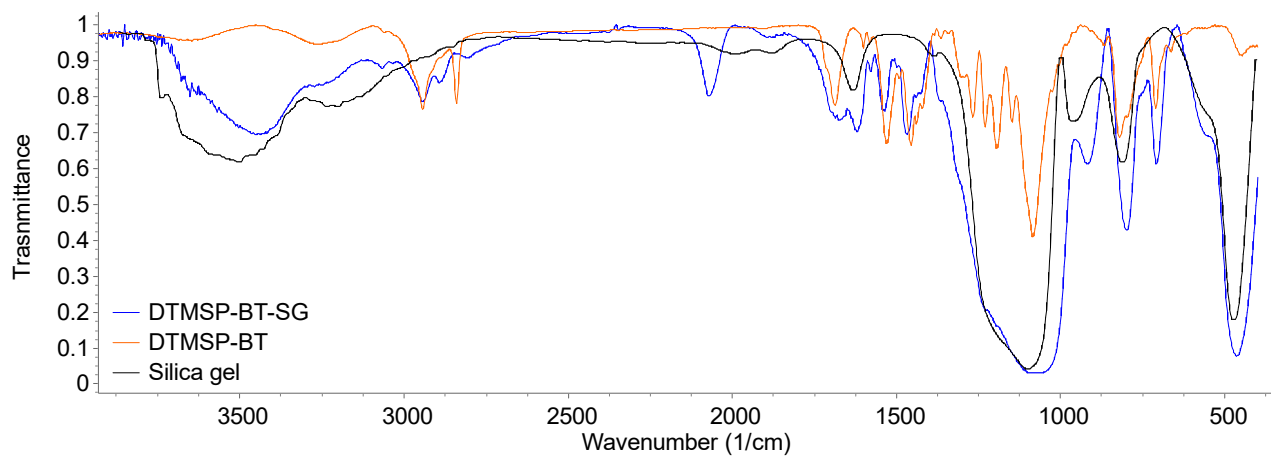


Figure S10 FT-IR spectra of the unmodified silica gel, DTMSP-BT and DTMSP-BT-SG.

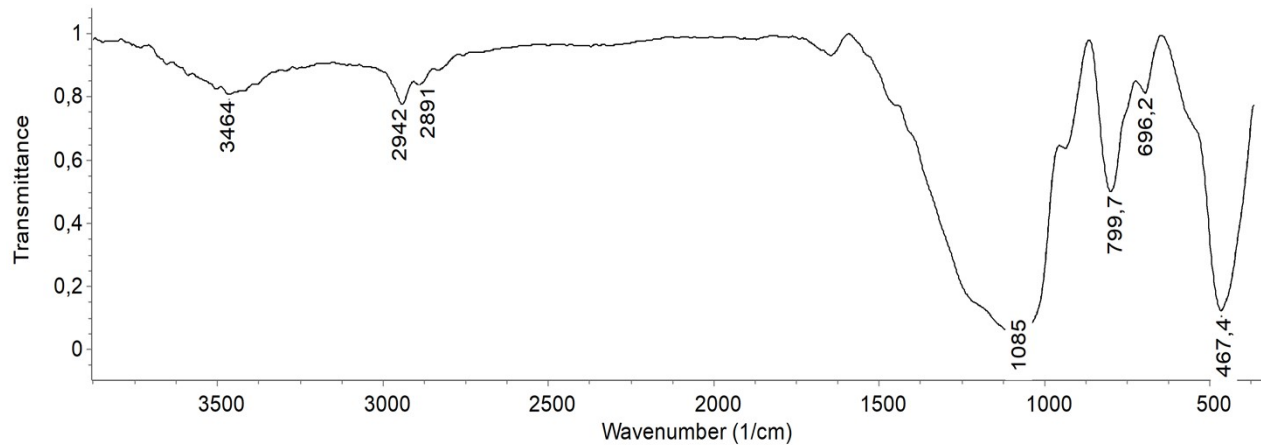


Figure S11 FT-IR Spectroscopy spectrum BTMSPA-SG.

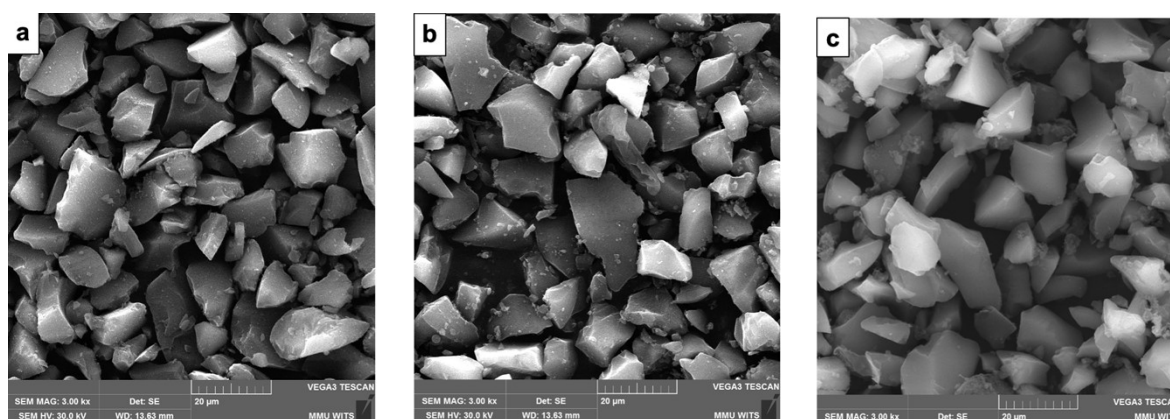


Figure S12 SEM images of: a) Silica gel, b) DTMSP-BT-SG and c) BTMSPA-SG.

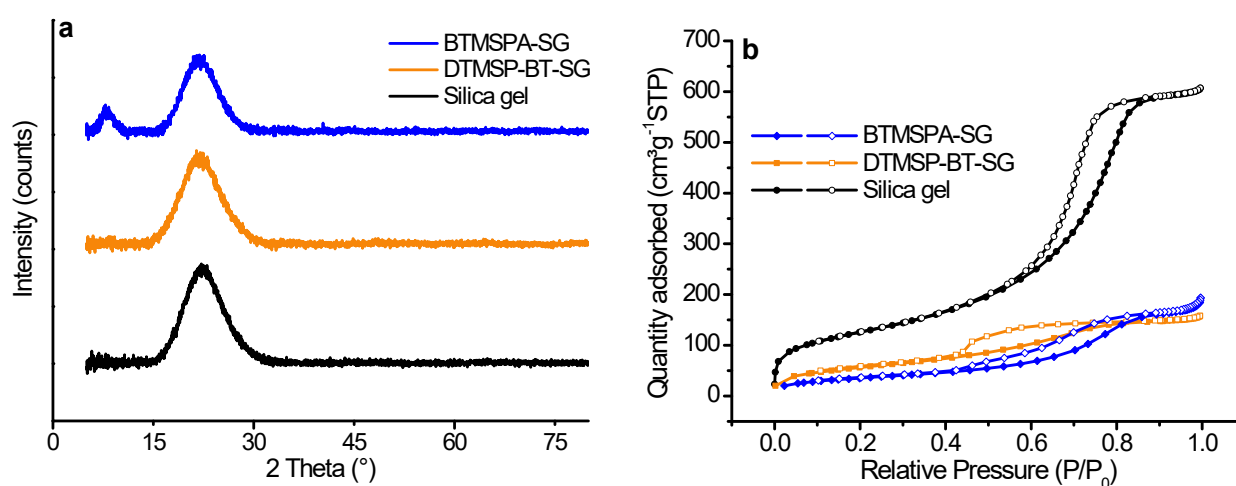


Figure S13 a) PXRD patterns and b) BET N_2 adsorption (●) desorption (○) isotherms.

Table S1 Textural properties of the unmodified silica gel and modified silica gel.

	Pore size (nm)	Pore volume (cm ³ g ⁻¹)	Surface area (m ² g ⁻¹)
Silica gel	6.47	0.94	451.25
DTMSP-BT-SG	4.09	0.25	207.62
BTMSPA-SG	6.28	0.29	130.06

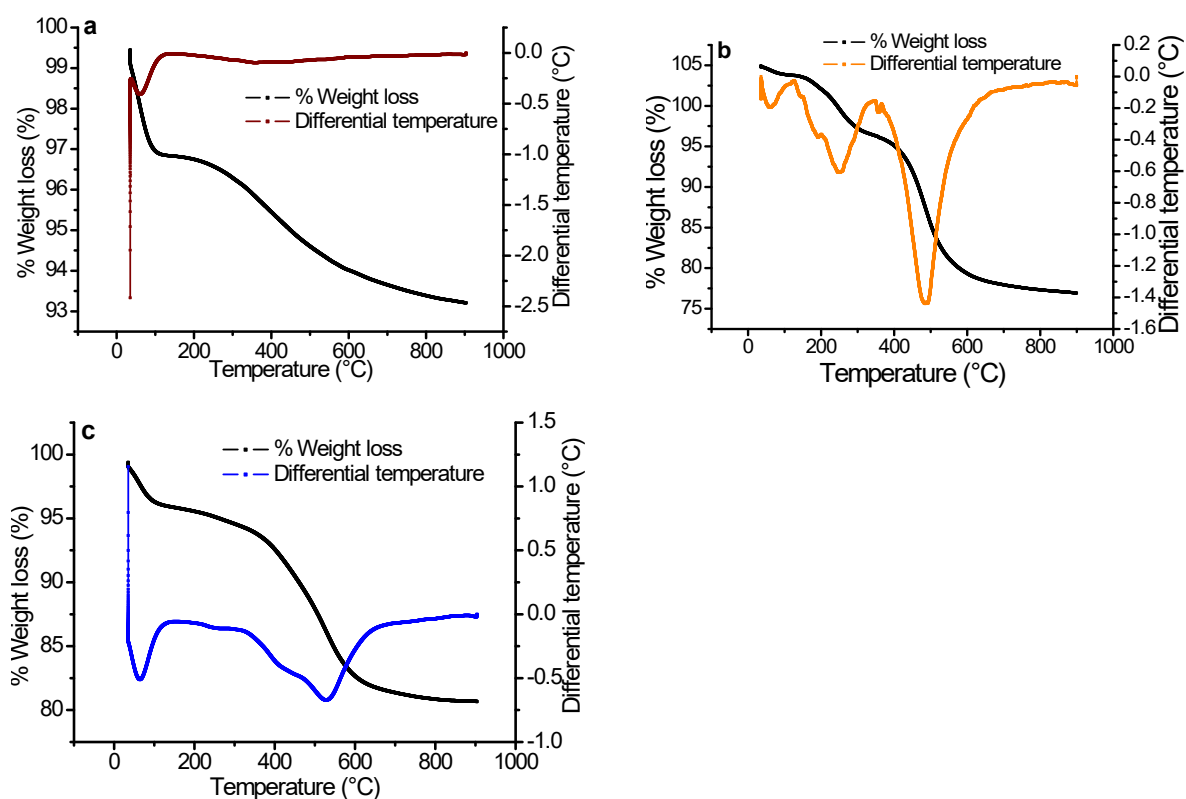


Figure S14 TGA and DTA graphs of: a) Silica gel, b) DTMSP-BT-SG and c) BTMSPA-SG.

Table S2 The XRF chemical compositions of the unmodified silica gel and modified silica gel.

	Silica gel	DTMSP-BT-SG	BTMSPA-SG
Compounds	Percentage composition (wt.%)		
SiO ₂	89.20	68.59	74.63
Al ₂ O ₃	0.09	0.08	0.07
Fe ₂ O ₃	-0.03	-0.03	-0.02
MnO	0	0	0.01
MgO	0.02	0	0.02
CaO	0.07	0.09	0.10
Na ₂ O	0.07	0.01	0.04
K ₂ O	-0.03	-0.03	0
TiO ₂	0.03	0.02	0.01
P ₂ O ₅	0.04	0.01	0.01
Cr ₂ O ₃	-0.01	0	0
NiO	0	0	0
Loss of Ignition (LOI)	9.67	30.90	23.74
TOTAL	99.12	99.61	98.57

Table S3 Elemental analysis of the unmodified and modified silica gel and the ligand concentrations.

	C		H		N		S	
Adsorbents	%	mmol/g	%	mmol/g	%	mmol/g	%	mmol/g
Silica gel	0.00		0.86		0.00		0.00	
DTMSP-BT-SG	18.02	1.07	2.24		2.89	1.03	2.17	
BTMSPA-SG	12.97	1.80	2.89		2.35	1.68	0.00	

Table S4 The theoretical and experimental loading capacities of Pt and Pd and volumes of expected maximum adsorption.

		Theoretical	Langmuir		Ligand	Adsorbent:	Vol for max			
		q_{\max}	experimental					conc.	metal ratio	adsorption
			q_{\max}							
		mg/g		mmol/g			mL			
DTMSP-	Pt	201.13	48.52	0.249	1.03	97.04	4.15			
BT-SG	Pd	109.72	29.68	0.279	1.03	59.36	3.69			
BTMSPA	Pt	329.55	6.63	0.034	1.68	13.26	49.36			
-SG	Pd	179.77	12.53	0.118	1.68	25.06	14.24			

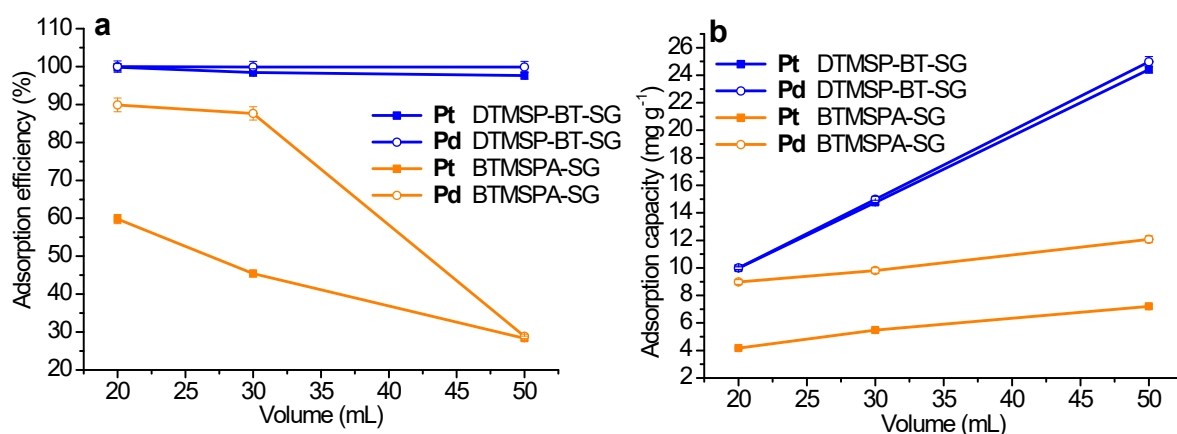


Figure S15 Effect of volume (20–50 mL) on the recovery of Pt and Pd (mass= 10 mg, pH= 2, concentration= 5 mg L⁻¹, temp= 25 °C, time= 4 h, n = 2, RSD < 3%).

Table S5 The Langmuir and Freundlich adsorption isotherm models of Pt and Pd.

Isotherms	Parameters	Metals			
		DTMSP-BT-SG		BTMSPA-SG	
		Pt	Pd	Pt	Pd
Langmuir	q_m (mg g ⁻¹)	48.52	29.68	6.63	12.53
	K_L (L mol ⁻¹)	1.85	26.74	0.36	6.82
	R^2	0.99	0.99	0.99	0.96
Freundlich	n	3.31	7.267	3.74	7.08

$K_F ((\text{mg g}^{-1})/(\text{mol L}^{-1})^{1/n})$	20.86	22.86	3.28	6.47
R^2	0.62	0.94	0.23	0.30

Table S6 Adsorption capacities of adsorbents used for the removal of Pt and Pd.⁴⁰

Adsorbents	q_m (mg/g)		Ref.
	Pt	Pd	
DTMSP-BT-SG	48.52	29.68	This work
BTMSPA-SG	6.63	12.53	47
Amberlite IRC 718	66.33	58.52	48
2-Mercaptobenzothiazole-bonded silica gel	6.50	18.00	40
Ethyl-3-(2-aminoethylamino)-2-chlorobut-2-enoate modified activated carbon	126.0	92.0	49
Fe_3O_4 nanoparticles	13.27	10.96	40
Bayberry tannin immobilized collagen fibre membrane	45.80	33.40	50
(E,E,E)-1-[(4-methylphenyl)sulfonyl]-6-[(2-trimethylsilyl-ethyl)-sulfonyl]-11-[(4-vinylphenyl)sulfonyl]]-1,6,11-triazacyclo-pentadeca-3,8,13-trienefunctionalized polystyrene	54.62	38.31	51
Glycine-modified chitosan	122.47	120.39	41
Thiourea-modified chitosan	129.87	112.36	

Table S7 Kinetic model parameters for the adsorption of Pt and Pd.

Kinetic model	Parameters	DTMSP-BT-SG		BTMSPA-SG	
		Pt	Pd	Pt	Pd
Pseudo-first-order	$q_{e(\text{exp})}$ (mg g ⁻¹)	9.88	9.99	5.75	9.78
	k_1 (min ⁻¹)	-3.01×10^{-5}	-2.63×10^{-6}	-3.26×10^{-7}	-1.75×10^{-5}
	$q_{e(\text{cal})}$ (mg g ⁻¹)	0.67	0.16	2.82	4.24
	R^2	0.53	0.52	0.70	0.85
Pseudo-second-order	$q_{e(\text{cal})}$ (mg g ⁻¹)	9.97	9.99	6.40	9.81
	k_2 (mg g ⁻¹ min ⁻¹)	0.103	0.460	0.014	0.010
	R^2	0.99	1.00	0.99	0.99