

Supplementary Information

Optimization and Characterization of Castor Oil (*Ricinus communis* L.) and 1,10-Phenantroline-Based Polyurethane Membrane for Al³⁺ Ion Selective Application

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Table S1. The chemical composition of PU membranes.

No.	Castor Oil (g)	TDI (g)	1,10-Phenantroline (mg)
1.	3.5	1.75	0
2.	3.5	1.75	3
3.	3.5	1.75	5
4.	3.5	1.75	7
5.	3.5	1.75	10
6.	3.5	1.75	13

Table S2. Variations of the internal solution composition.

No.	Al(NO ₃) ₃ (M)	KCl (M)
1.	0	0.1
2.	0.1	0.1
3.	0.3	0.1
4.	0.5	0.1
5.	0.7	0.1

Table S3. Comparison of membrane composition on electrode sensitivity, linear range, and linearity.

No.	Membrane composition (%)				Sensitivity	Dynamic	R^2
	Castor oil	TDI	1,10-phenantroline	Ace-ton		Range M	
1.	37.83	18.91	0	43.24	1.27 ± 0.05	10^{-9} - 10^{-5}	0.953
2.	37.83	18.91	0.03	43.23	2.16 ± 0.11	10^{-9} - 10^{-4}	0.999
3.	37.82	18.91	0.05	43.22	4.68 ± 0.42	10^{-9} - 10^{-4}	0.999
4.	37.83	18.91	0.07	43.21	7.58 ± 0.33	10^{-9} - 10^{-4}	0.999
5.	37.83	18.90	0.10	43.20	19.86 ± 0.34	10^{-9}-10^{-4}	0.999
6.	37.83	18.89	0,13	43.18	22.64 ± 0.05	10^{-9} - 10^{-5}	0.999

Table S4. Comparison of internal solution variations on electrode sensitivity.

Internal solution composition		Sensitivity (mV/decade)	Dynamic Range (M)	Determination coefficient (R^2)
Al(NO ₃) ₃ (M)	KCl (M)			
0		10.03 ± 0.55	10 ⁻⁹ -10 ⁻⁶	0.999
0.1		19.66 ± 0,34	10⁻⁹-10⁻⁴	0.999
0.3	0.1	22.11 ± 0.06	10 ⁻⁹ -10 ⁻⁵	0.999
0.5		23.78 ± 0.06	10 ⁻⁹ -10 ⁻⁵	0.999
0.7		24.68 ± 0.57	10 ⁻⁹ -10 ⁻⁵	0.999

Table S5. Al³⁺ ISE response on using and using TISAB solutions.

No.	-log [Al ³⁺] (M)	Without TISAB (mV)	TISAB (mV)
1.	1	-246.3	-147.3
2.	2	-258.1	-155.3
3.	3	-265.1	-162.2
4.	4	-271.1	-163.0
5.	5	-291.3	-182.5
6.	6	-309.5	-202.3
7.	7	-329.5	-223.1
8.	8	-350.1	-243.1
9.	9	-373.1	-264.1
10.	10	-379.2	-280.1
Sensitivity (mV/decade)		20.18 ± 0.29	19.83 ± 0.15
Dynamic range (M)		10 ⁻⁹ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴
(R^2)		0.999	0.999

Table S6. Determination of the selectivity coefficient (K_{ij}) of the Al³⁺ ISE.

No.	Foreign Ions	a_i	a_j	K_{ij}
1.	K ⁺	7.96 x 10 ⁻⁵	9.7 x 10 ⁻⁵	0.0017
2.	Li ⁺	7.96 x 10 ⁻⁵	9.7 x 10 ⁻⁵	0.0017
3.	Zn ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0382

4.	Pb ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0382
5.	Ca ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0382
6.	Cu ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0382
7.	Ni ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0382
8.	Hg ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0382
9.	Bi ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0383
10.	Co ²⁺	7.96 x 10 ⁻⁵	8.6 x 10 ⁻⁵	0.0382
11.	Na ⁺	7.96 x 10 ⁻⁵	9.7 x 10 ⁻⁵	0.0017
12.	Cr ³⁺	7.96 x 10 ⁻⁵	7.96 x 10 ⁻⁵	0.994
13.	Fe ³⁺	7.96 x 10 ⁻⁵	7.96 x 10 ⁻⁵	0.992

Table S7. Determination of sensitivity of Al³⁺ ISE to different measurement days.

Days	Nerst Factor (mV/decade)	(R ²)	Decrease in Sensitivity (%)
1	1968 ± 0.28	0.999	0
2	19.67 ± 0.29	0.996	0.04
3	19.47 ± 0.38	0.998	1.08
4	19.43 ± 0.31	0.997	1.29
5	19.23 ± 0.16	0.999	2.31
11	19.22 ± 0.14	0.995	2.36
12	19.22 ± 0.17	0.999	2.32
13	19.13 ± 0.41	0.999	2.79
14	18.90 ± 0.53	0.994	3.96
15	18.86 ± 0.44	0.997	4.18
21	18.41 ± 0.30	0.997	6.50
22	18.26 ± 0.63	0.997	7.19
23	18.25 ± 0.66	0.997	7.27
24	17.45 ± 0.59	0.996	11.36
25	16.12 ± 0.44	0.994	18.12
31	15.73 ± 0.50	0.999	20.12
32	15.63 ± 0.32	0.994	20.63
33	15.10 ± 0.73	0.999	23.32

34	14.41 $\pm$ 2.18	0.996	26.80
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Table S8. Electrode reproducibility.

Electrode	I	II	III	IV	V
Sensitivity (mV/decade)	19.43	20.01	20.00	19.57	20.69
Linear Range (M)	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴
(<i>R</i> ²)	0.998	0.999	0.997	0.999	0.995

Measurement	I	II	III	IV	V
Sensitivity (mV/decade)	20.03 $\pm$ 0.12	20.03 $\pm$ 0.12	20.26 $\pm$ 0.12	20.20 $\pm$ 0.12	20.27 $\pm$ 0.12
Linear Range (M)	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴	10 ⁻¹⁰ -10 ⁻⁴
<i>R</i> ²	0.998	0.999	0.999	0.995	0.998

Table S9. The repeatability of the Al³⁺ ISE.