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Developing potentiometric PVC-plasticized sensors for Sc^{3+}

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Problem Statement

Scandium applications

- ❑ Electronics
- ❑ Metallurgical industry
- ❑ Catalysis
- ❑ Aerospace
- ❑ Nuclear medicine
- ❑ Optic and Laser
- ❑ Energy saving and fuel cells

by-products of mining & extraction of other metals

Sources of environmental release:

Mining activities ***industrial wastes***

Conventional analytical methods

- ❑ ICP-MS (Inductively Coupled Plasma Mass Spectrometry)
- ❑ ICP-AES (Inductively Coupled Plasma Atomic Emission Spectroscopy)
- ❑ NAA (Neutron Activation Analysis)
- ❑ XRF (X-ray Fluorescence)

Disadvantages

- ❑ Time-consuming
- ❑ High capital and operating costs
- ❑ Need for trained staff
- ❑ Sample preparation steps

Problem Statement

Potentiometric sensors

- ❑ Cost effective
- ❑ Portable
- ❑ Real-time measurements
- ❑ High sensitivity
- ❑ Low detection limit
- ❑ Miniaturization capability
- ❑ Reasonable precision
- ❑ Fast response

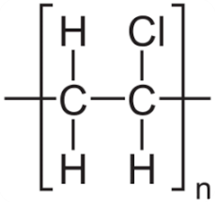
Purpose of study

- ❑ The first potentiometric sensors for Sc^{3+}
- ❑ Potentiometric sensitivity towards Sc^{3+}
- ❑ Study on selectivity coefficients
- ❑ Study on limit of detection
- ❑ Study the response time

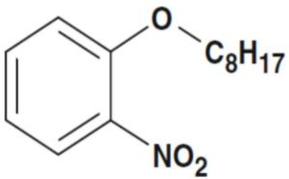
Experimental

Membranes

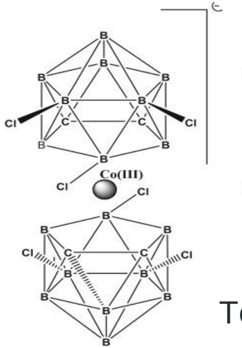
- **Polymeric matrix** → **PVC**
- **Plasticizer** → **NPOE**
- **Cation exchanger** → **CCD**, **NaTFPB**
- **Neutral ligand** → **Diamides and phosphine oxides**



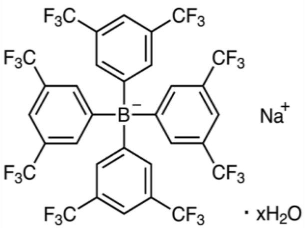
Polyvinyl chloride
(33 wt.%)



o-Nitrophenyl octyl ether
(59.5–64.3 wt.%)



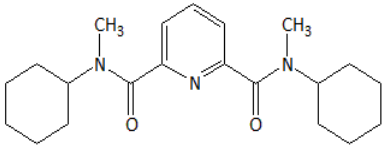
Chlorinated Cobalt Dicarbollide
(10 mmol/kg)

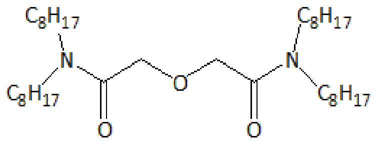


Tetrakis[3,5-bis(trifluoromethyl)phenyl]borate
(10 mmol/kg)

50 mmol/kg

Experimental


M1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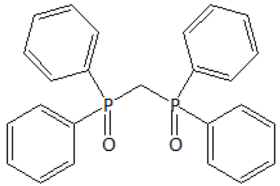
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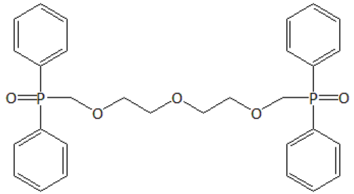
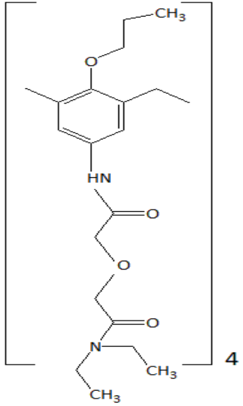
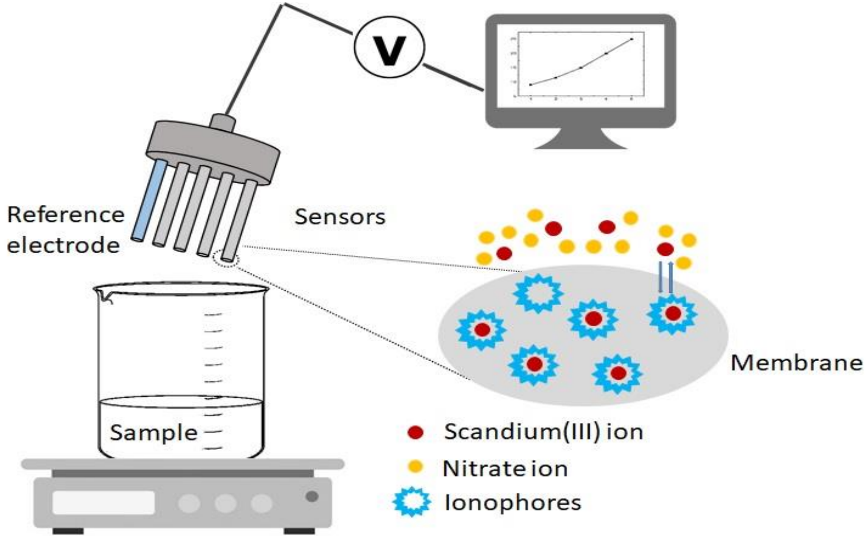

M4


M5

Ligands

Visual appearance of the developed sensor

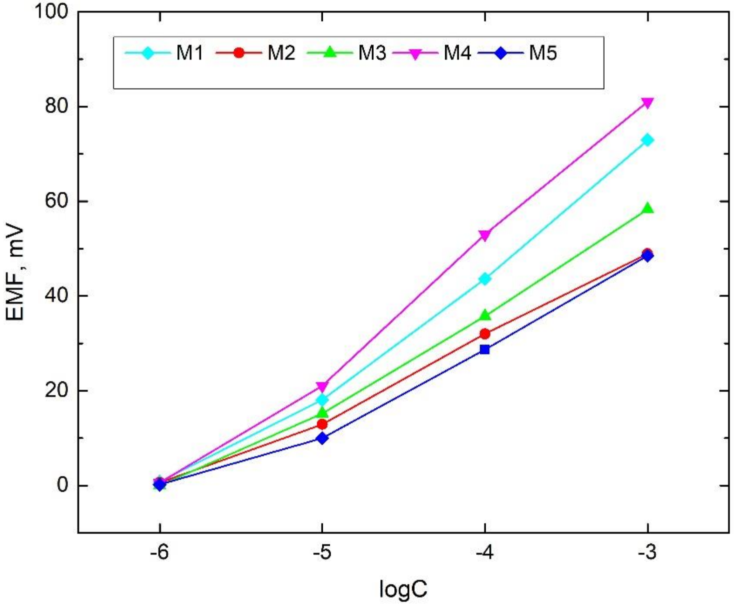


Electrochemical cell

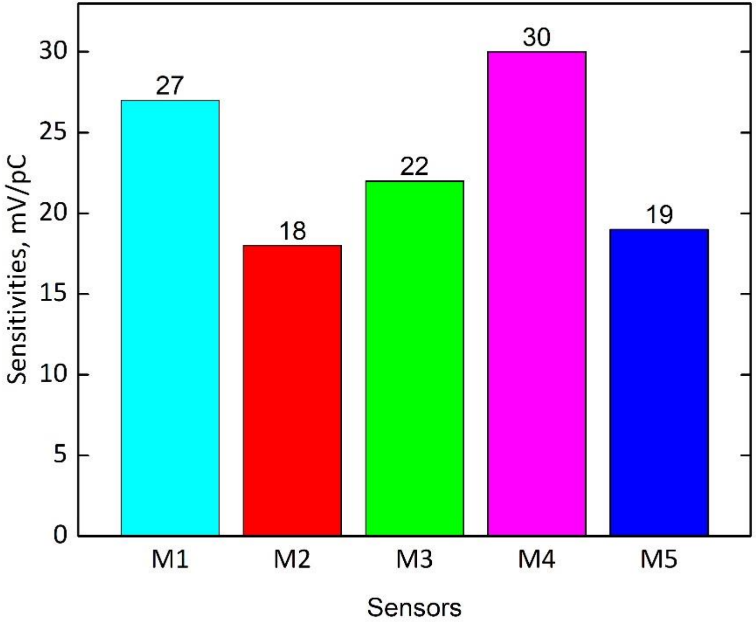
Cu |Ag| AgCl, KCl$_{sa}$t |sample solution| membrane |NaCl,0.01M| AgCl |Ag| Cu

Results

Calibration was performed at 10^{-7} to 10^{-2}M of each ion
The linear part of each sensor function plot (10^{-5} to 10^{-3}M)



Potentiometric response curve for scandium at pH=2



Sensitivity values of the sensors to scandium ion at pH=2

Results

Selectivity coefficient values of the sensors towards scandium, $\pm 0.2 logK^{pot}_{Sc,Me}$.

Sensors	La^{3+}	Eu^{3+}	Gd^{3+}	Lu^{3+}
M1	-2.0	-2.2	-0.9	-1.3
M2	-2.3	-2.7	-0.2	-0.1
M3	-2.3	-3.0	-2.1	-2.8
M4	-1.3	-1.9	-1.3	-1.9
M5	-1.1	-0.1	+0.6	-0.3

Detection limits (in $\pm 0.2 pC_{Sc^{3+}}$) of sensors, at $pH = 2$

Sensors	M1	M2	M3	M4	M5
LOD	5.4	5.8	5.0	5.1	5.5

Bi-ionic potential method (BIP)

$$logk^{pot}_{IJ} = \left(\frac{z(I)F \times (E(J) - E(I))}{2.302 \times R \times T} + log\left(\frac{a(I)}{a(J)^{z(I)/z(J)}} \right) \right)$$

z= charge of ion

a=activity

E=electrode potential

I=primary ion

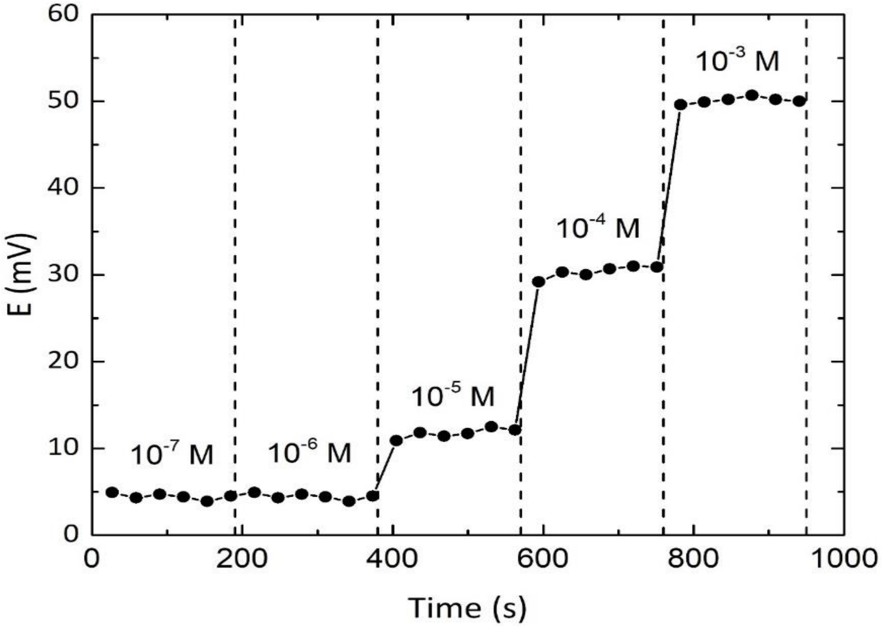
J=interfering ion

K=selectivity coefficient

F=Faraday constant

The more negative the log(k), the more selective is the sensor toward ion I

Results



Dynamic response curve of the sensor M5 for step changes in scandium concentration

Conclusion

- The first potentiometric sensors for scandium ions
- Phosphine oxides and diamides of organic acids are effective ligands for scandium sensing
- Sensors showed pronounced sensitivity and selectivity for Sc^{3+} detection at pH 2
- The lower detection limits of approximately 0.4 mg/l of Sc^{3+} were achieved
- Promising analytical tool – alternative to the conventional methods


Thank You!