Supplementary Material

Integrated microfluidic platform based on potentiometric Sonogel-Carbon sensors for the simultaneous determination of Na^+ and K^+ in untreated human plasma and serum

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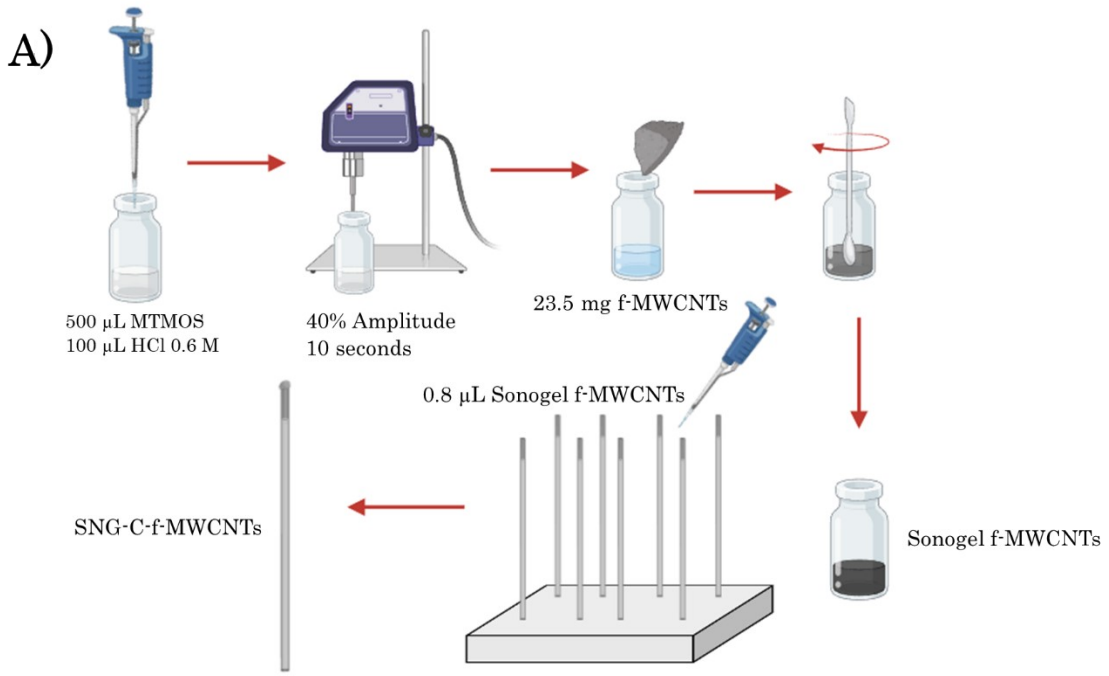
Figure S1. (A) Fabrication of functionalized multi-walled carbon nanotubes and their deposition onto SNG-C electrodes via drop-casting. (B) Preparation of the sodium-selective membrane, including the required amounts of each component. (C) Preparation of the potassium-selective membrane, with the respective quantities of the components.



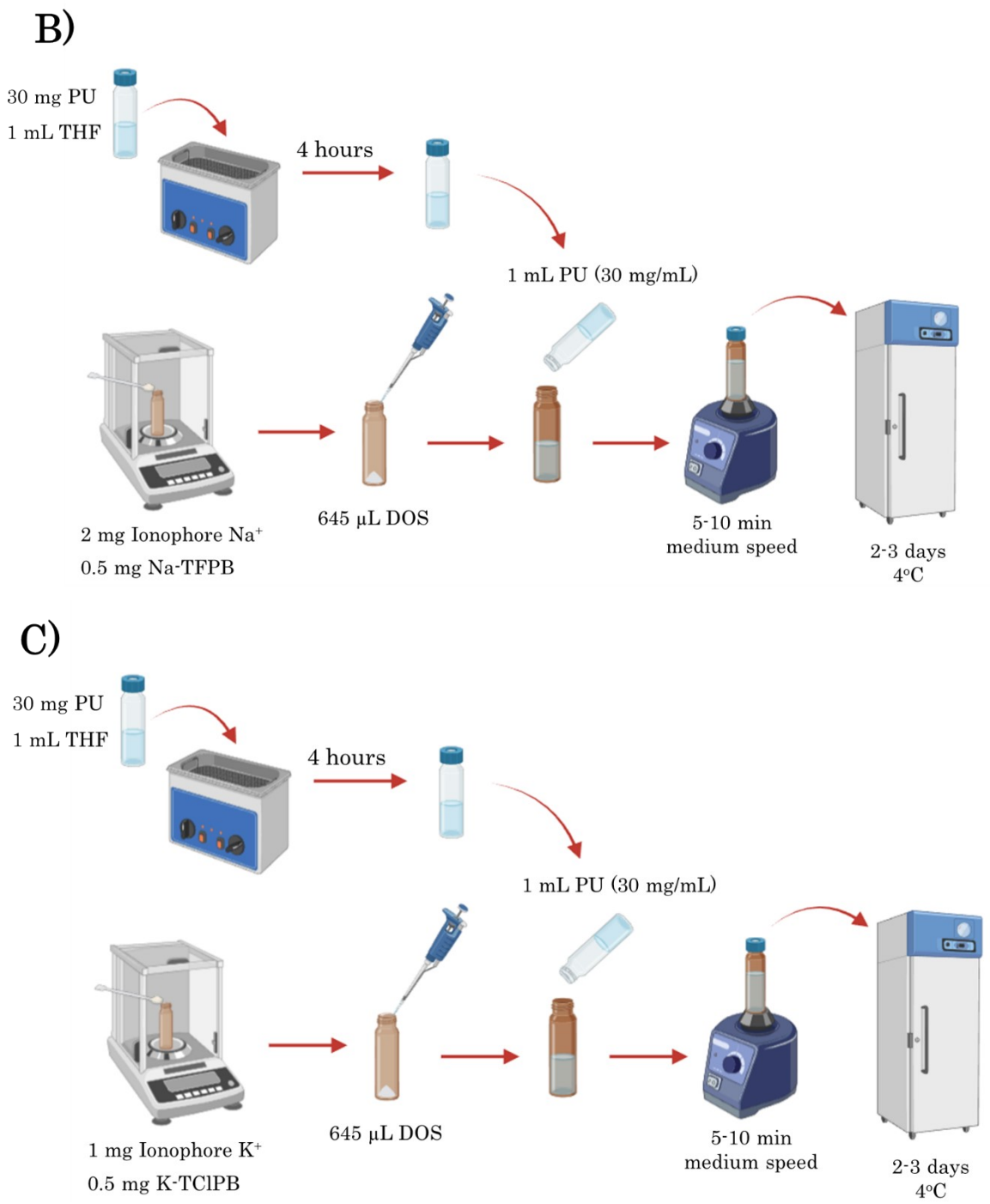


Figure S1 illustrates the fabrication procedures for the sonogel-functionalized multi-walled carbon nanotubes (f-MWCNTs) composite and the ion-selective membranes. The lower panels list the components and their required amounts. For the sonogel-f-MWCNTs, the prepared dispersion is deposited onto the electrode surface by drop-casting. For the sodium- and potassium-selective membranes, the respective solutions are prepared and stored in the refrigerator for 2–3 days to increase viscosity, facilitating their deposition.

Figure S2: Fabrication of the Ag/AgCl reference electrode made in the lab in order to make continuous flow calibrations and measurements with the real samples.

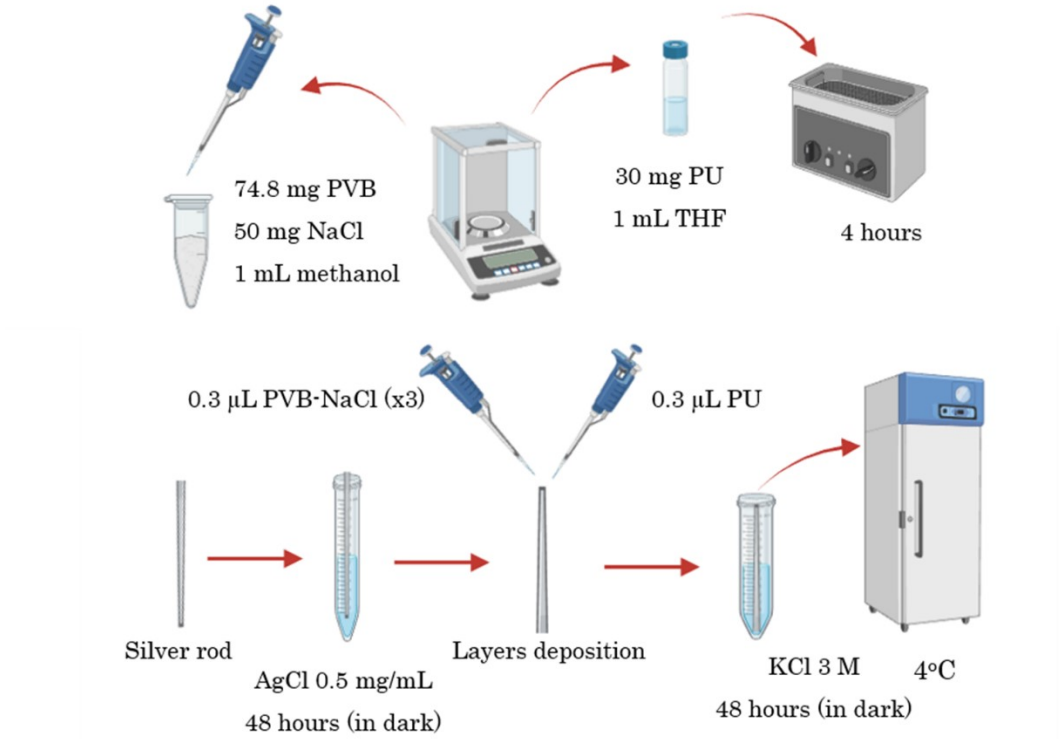


Figure S2 illustrates the procedure to fabricate a pseudo-reference Ag/AgCl electrode. The lower part lists the components and their required amounts for the reference electrode. Specific volumes of these solutions are deposited onto a polished silver rod, which has been previously immersed in AgCl, and the electrode is finally stored in 3 M KCl.

Figure S3: Sensitivity degradation of the sensor over time. The plot shows the gradual decrease in sensitivity as a function of days in use, allowing for the estimation of the sensor's average operational lifetime before performance is significantly affected.

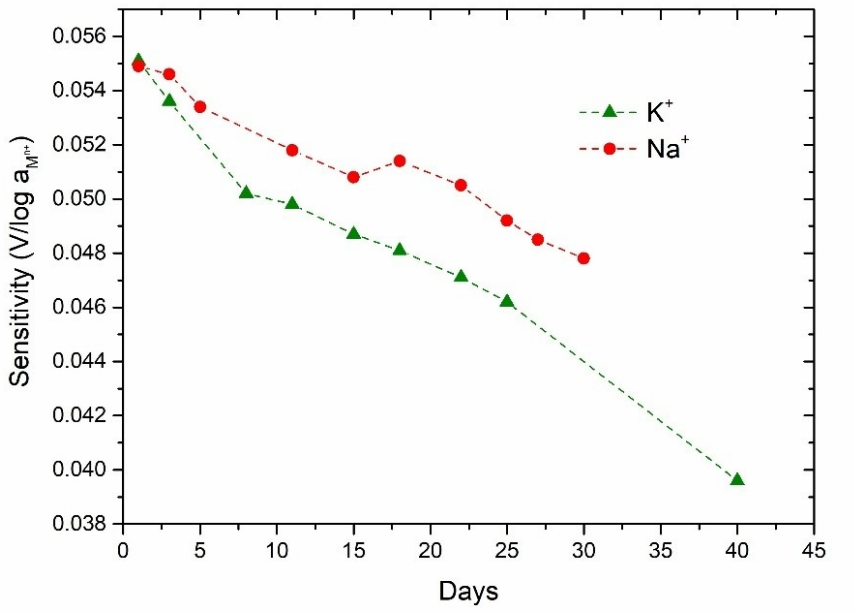
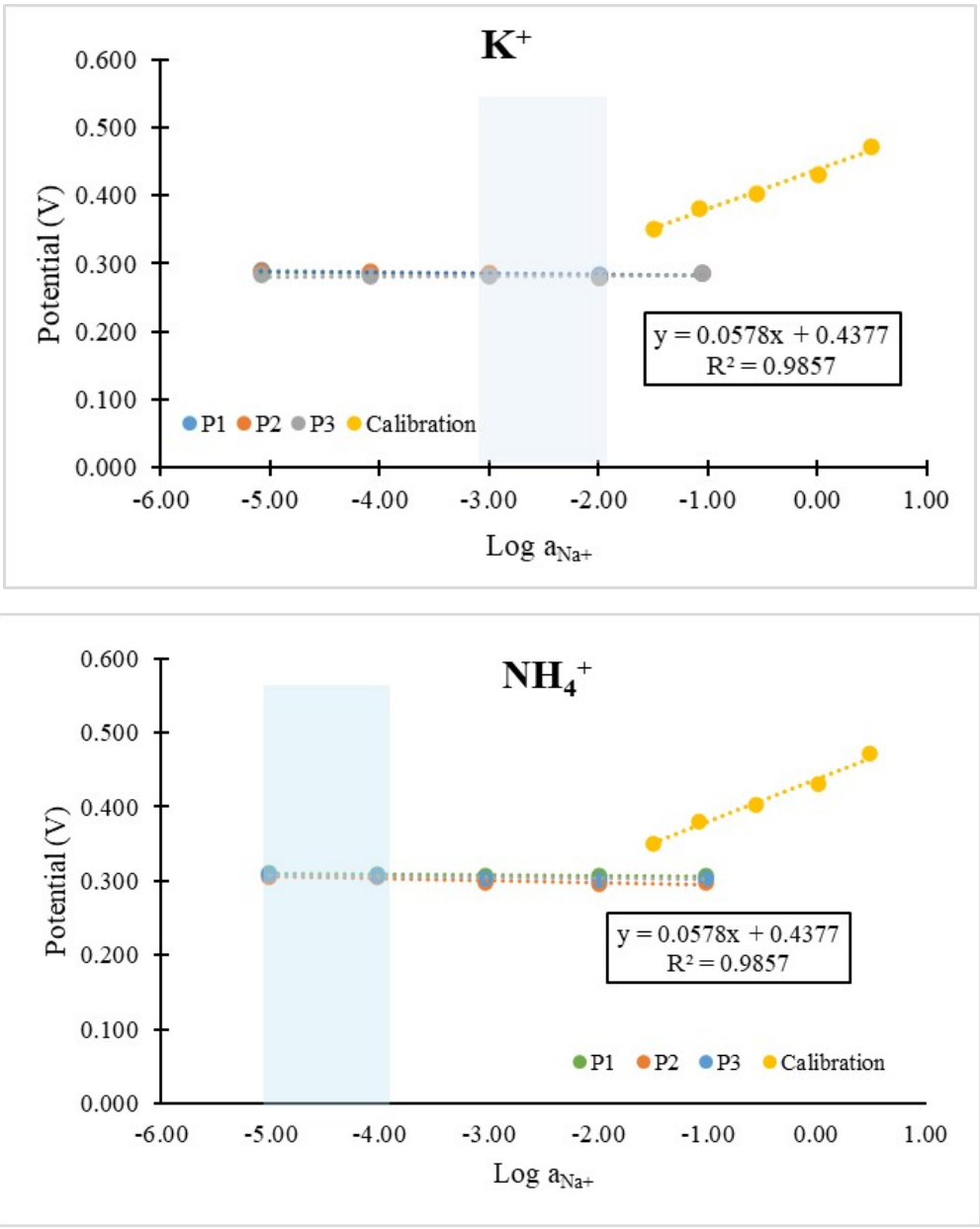
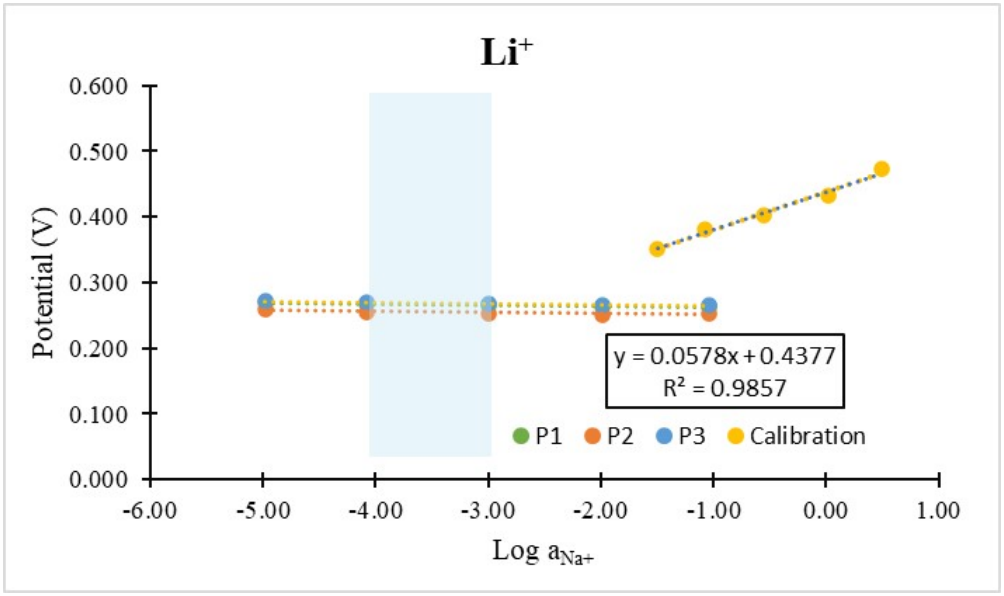
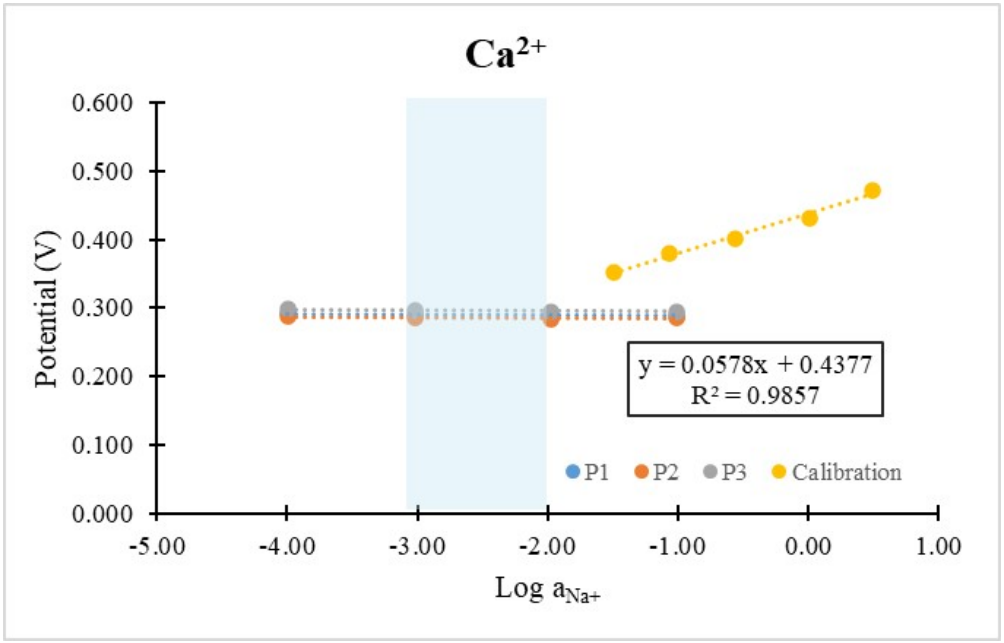


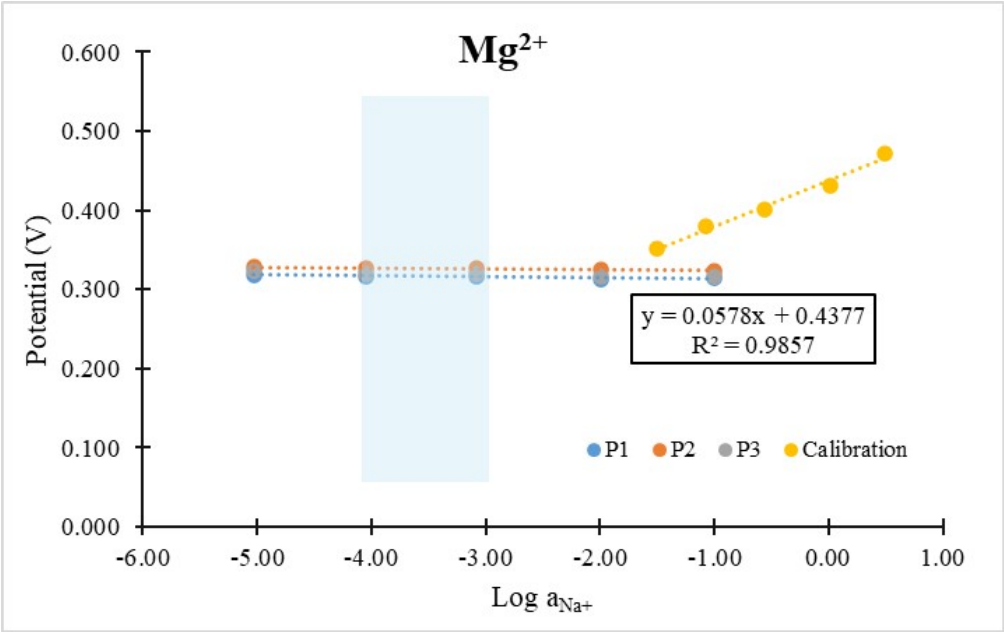
Figure S3 shows the sensitivity of the sodium (Na^+) and potassium (K^+) potentiometric sensors over a period of 40 days, demonstrating the stability of the sensors under storage conditions. Both sensors maintain a high and relatively constant sensitivity throughout the measurement period, with only slight decreases observed after approximately 25–30 days. These results indicate good long-term operational stability and suggest that the sensors can provide reliable measurements over extended periods, which is critical for practical biomedical applications.

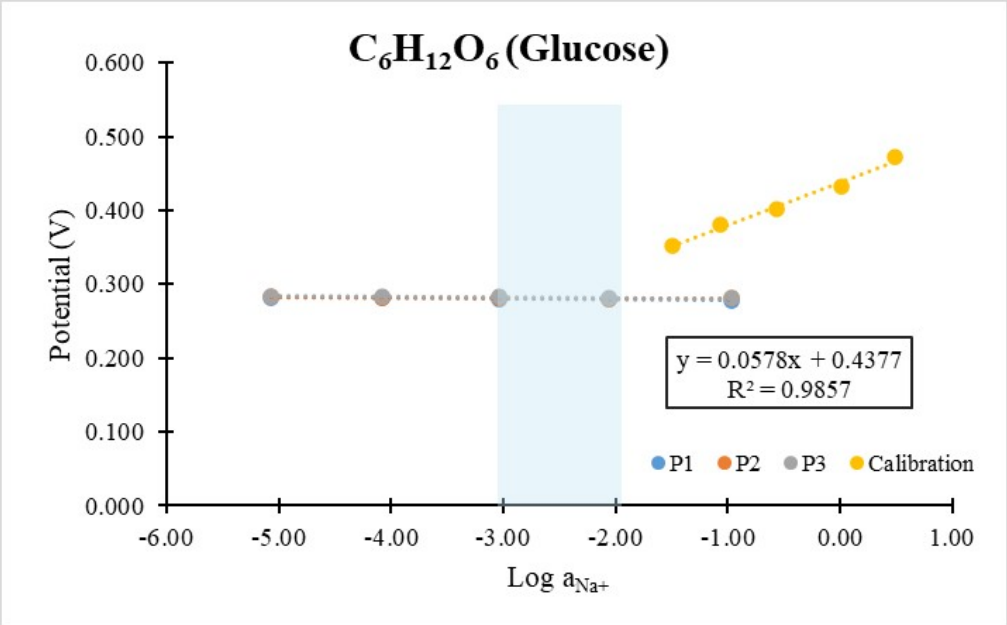
Figure S4: Selectivity study of the potentiometric sodium sensor against the most common blood interferents. The blue box indicates the typical physiological concentration range of each interferent, highlighting the sensor's ability to discriminate the analytical signal under real conditions.

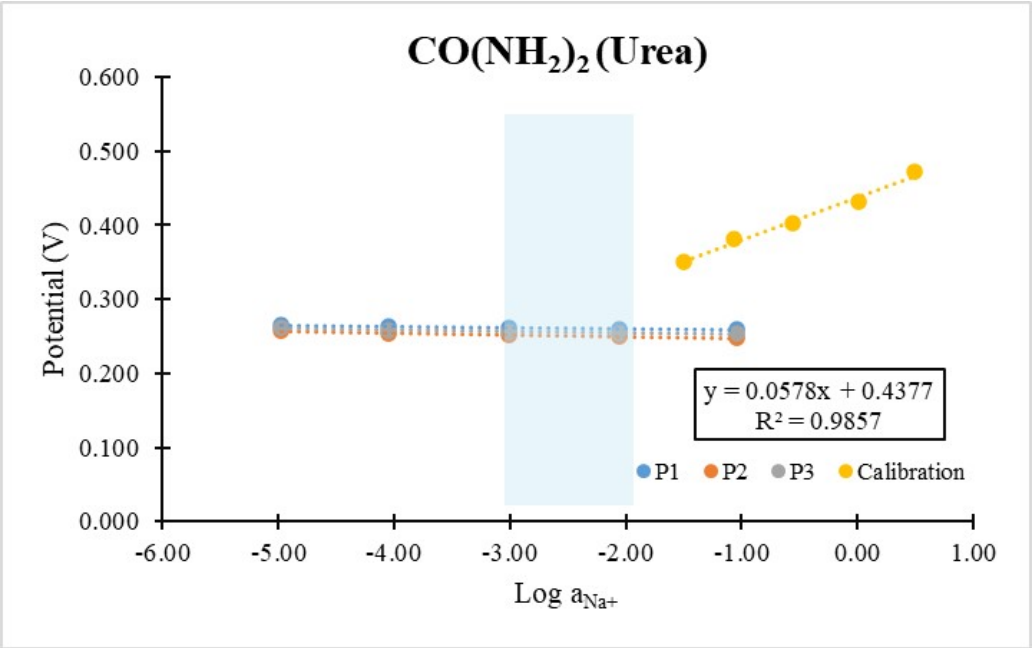


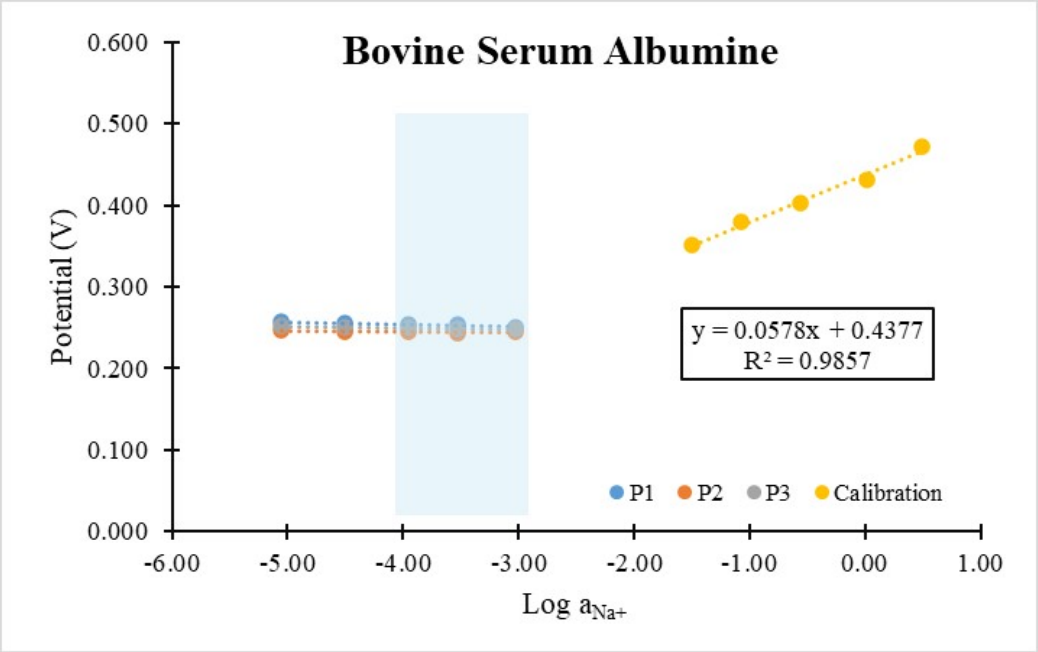

Li+
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Potential (V)
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
Log a Na+
y = 0.0578x + 0.4377
R² = 0.9857
P1
P2
P3
Calibration

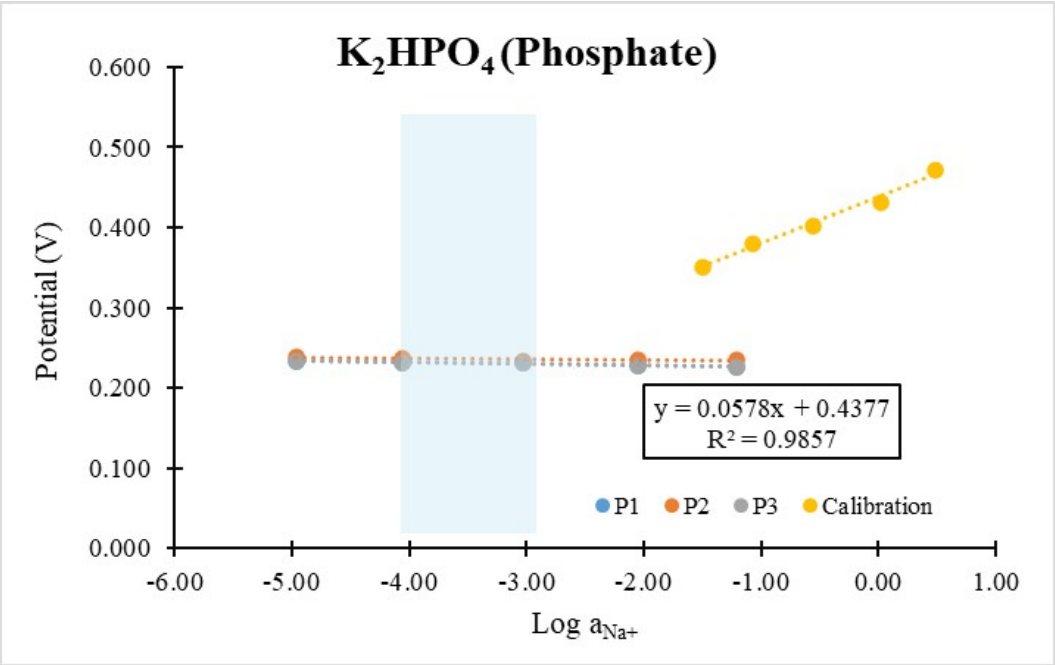

Ca2+
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Potential (V)
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
Log a Na+
y = 0.0578x + 0.4377
R² = 0.9857
P1
P2
P3
Calibration


Mg2+
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Potential (V)
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
Log aNa+
y = 0.0578x + 0.4377
R² = 0.9857
P1
P2
P3
Calibration


C6H12O6 (Glucose)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Potential (V)
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
Log aNa+
y = 0.0578x + 0.4377
R² = 0.9857
P1
P2
P3
Calibration

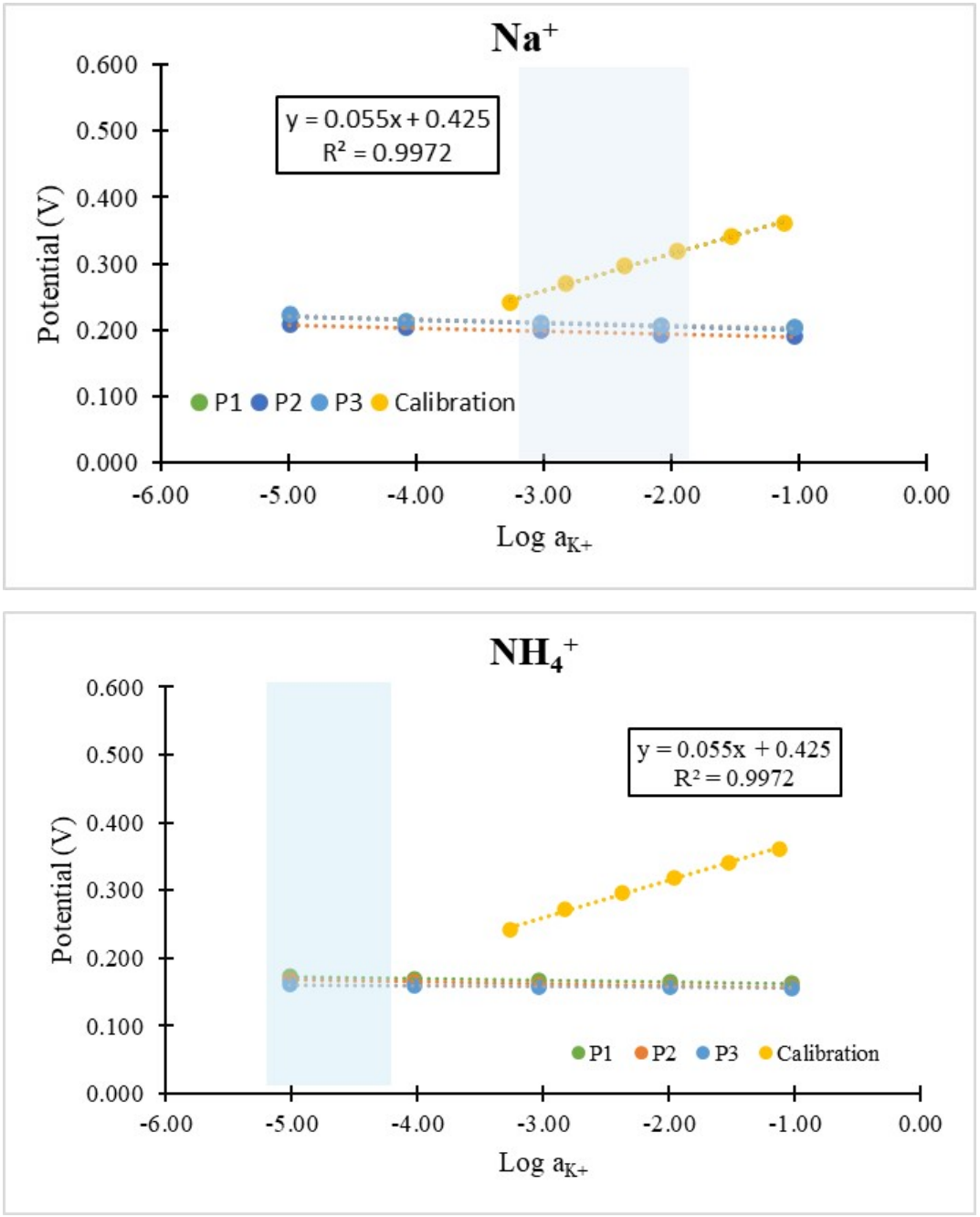

CO(NH2)2 (Urea)
Potential (V)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
Log aNa+
y = 0.0578x + 0.4377
R² = 0.9857
P1
P2
P3
Calibration

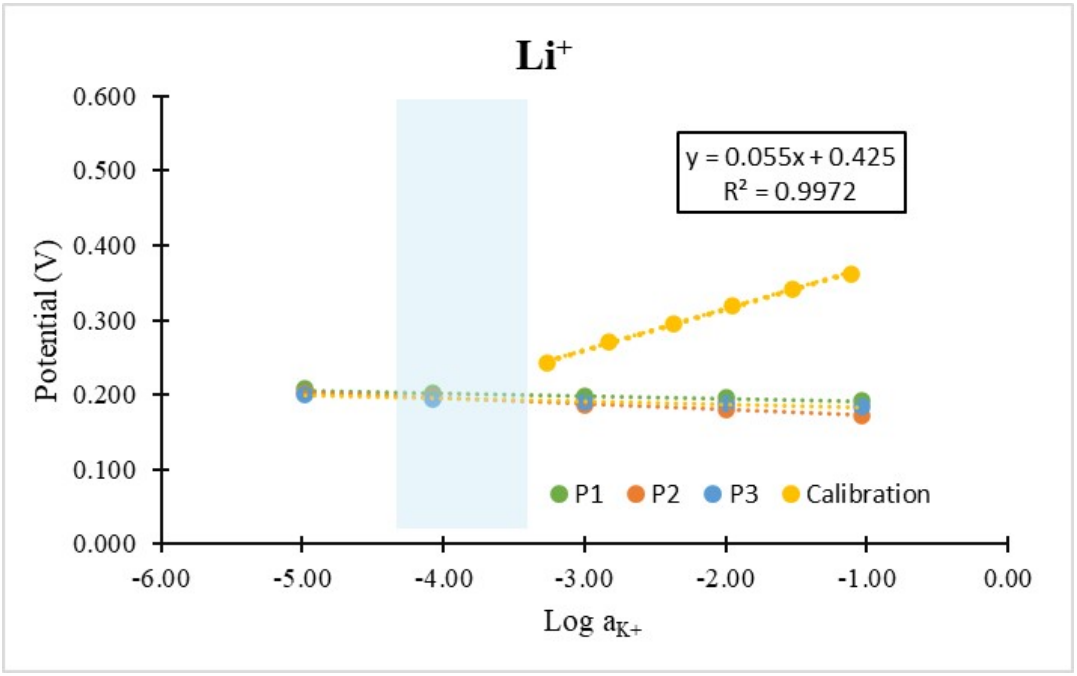

Bovine Serum Albumine
Potential (V)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
Log aNa+
y = 0.0578x + 0.4377
R² = 0.9857
P1
P2
P3
Calibration

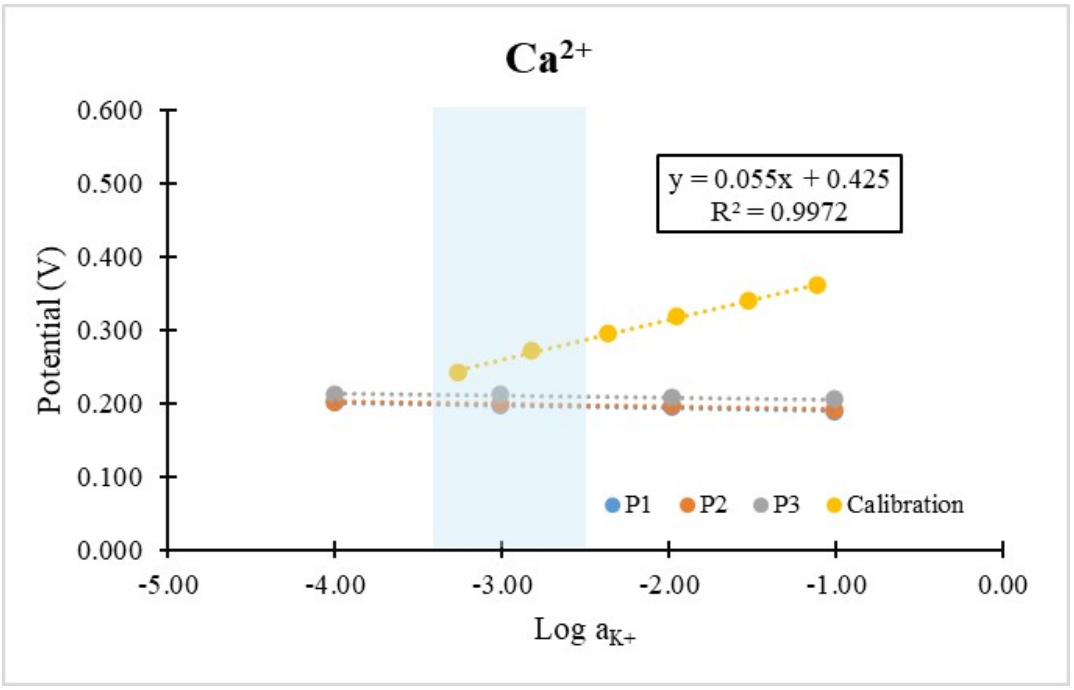


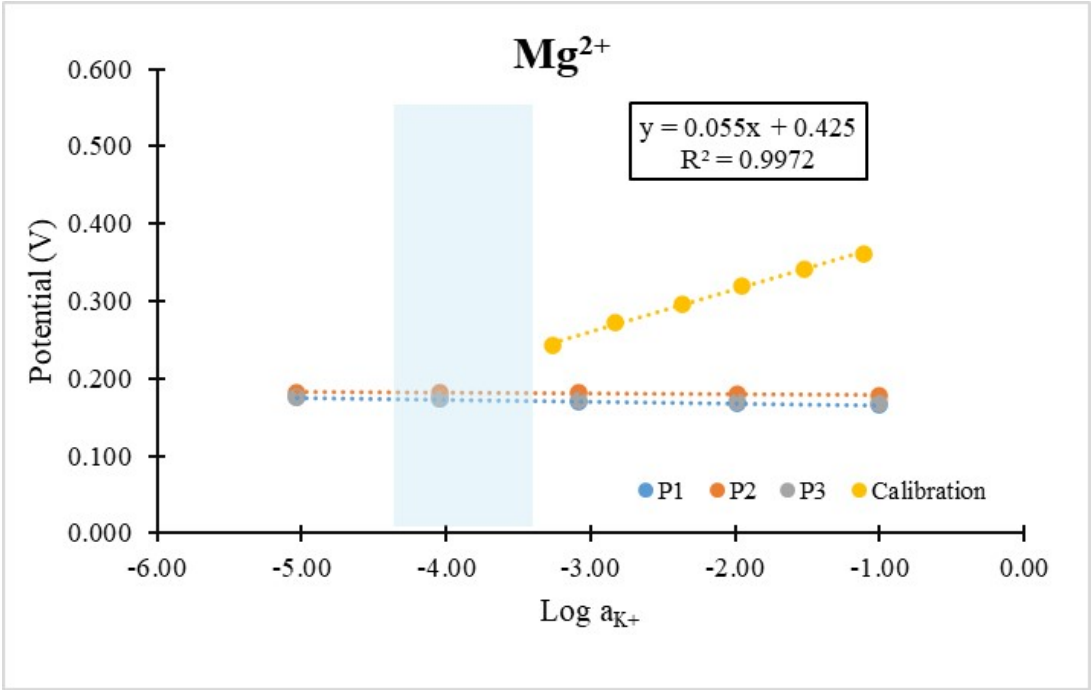
In Figure S4, the results of the selectivity study for the sodium potentiometric sensor are presented. The sensor potential is plotted against the logarithm of the activity of each interfering ion, and a calibration line for sodium is also shown. A horizontal line indicates that the sensor does not respond to the presence of the interferents, demonstrating the high selectivity of the sodium sensor under the tested conditions.

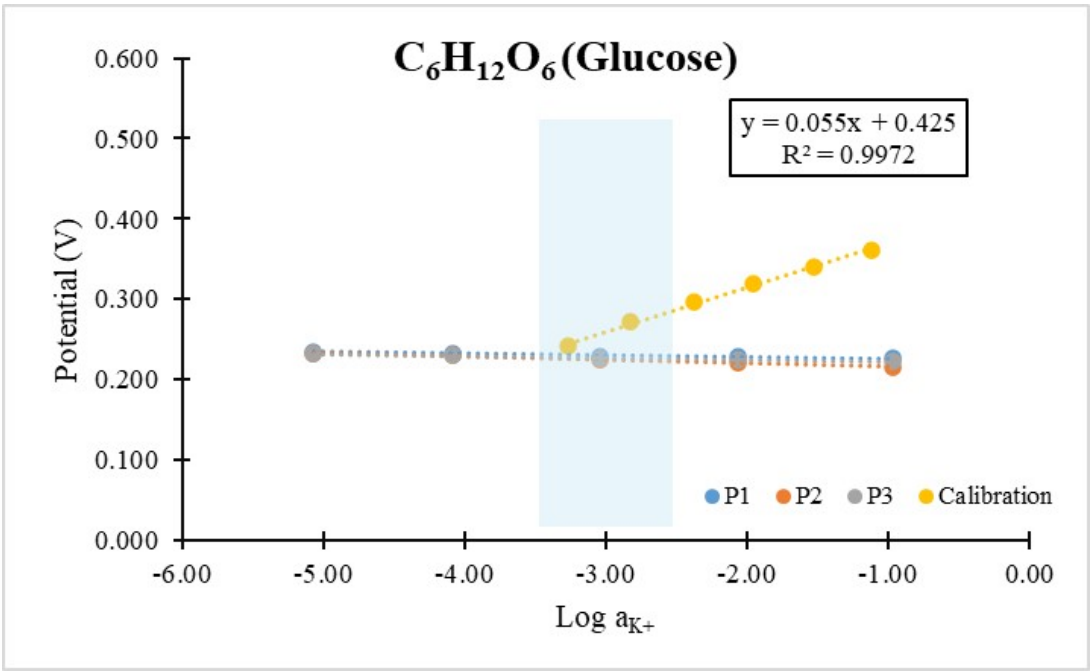
Figure S5: Selectivity study of the potentiometric potassium sensor against the most common blood interferents. The blue box indicates the typical physiological concentration range of each interferent, highlighting the sensor's ability to discriminate the analytical signal under real conditions.




Li+
y = 0.055x + 0.425
R² = 0.9972
Potential (V)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
Log a K+
P1
P2
P3
Calibration


Ca2+
y = 0.055x + 0.425
R² = 0.9972
Potential (V)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
Log a K+
P1
P2
P3
Calibration


Mg2+
y = 0.055x + 0.425
R² = 0.9972
Potential (V)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
Log a K+
P1
P2
P3
Calibration


C6H12O6 (Glucose)
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R² = 0.9972
Potential (V)
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0.500
0.400
0.300
0.200
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0.000
-6.00
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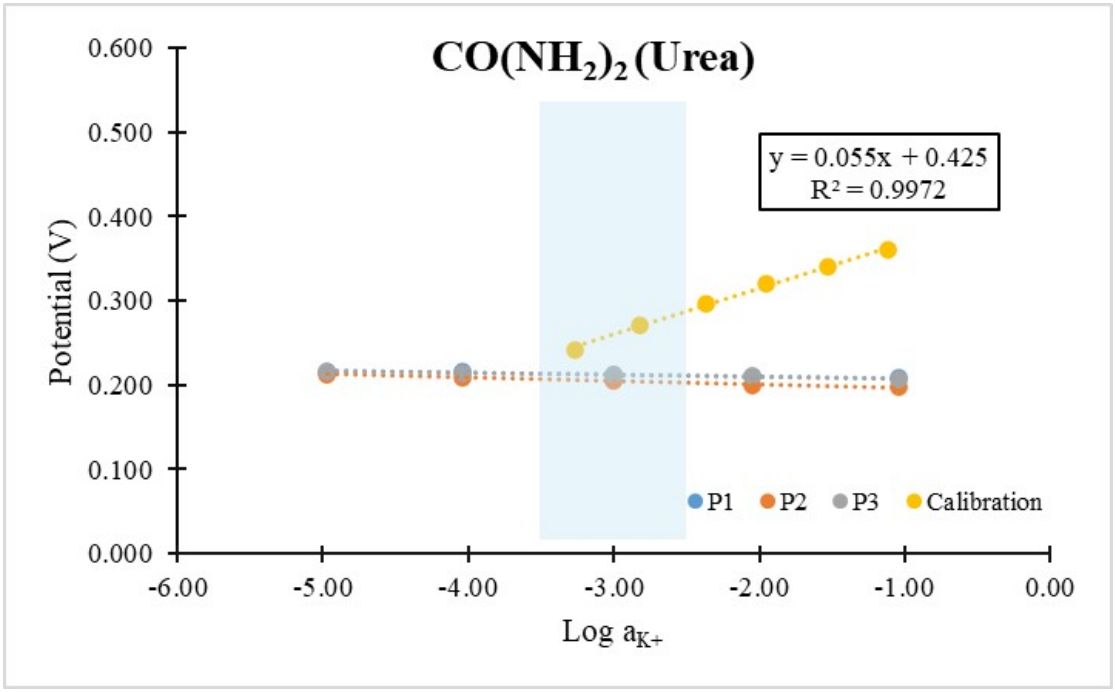
-3.00
-2.00
-1.00
0.00
Log a K+
P1
P2
P3
Calibration


CO(NH2)2 (Urea)
y = 0.055x + 0.425
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Potential (V)
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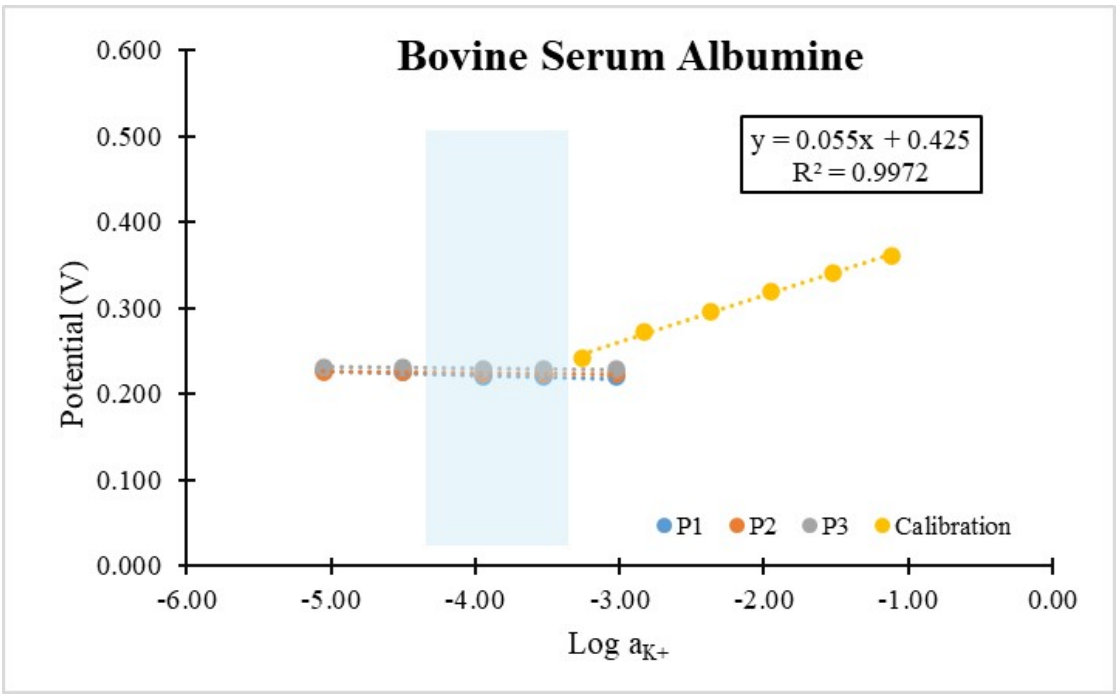
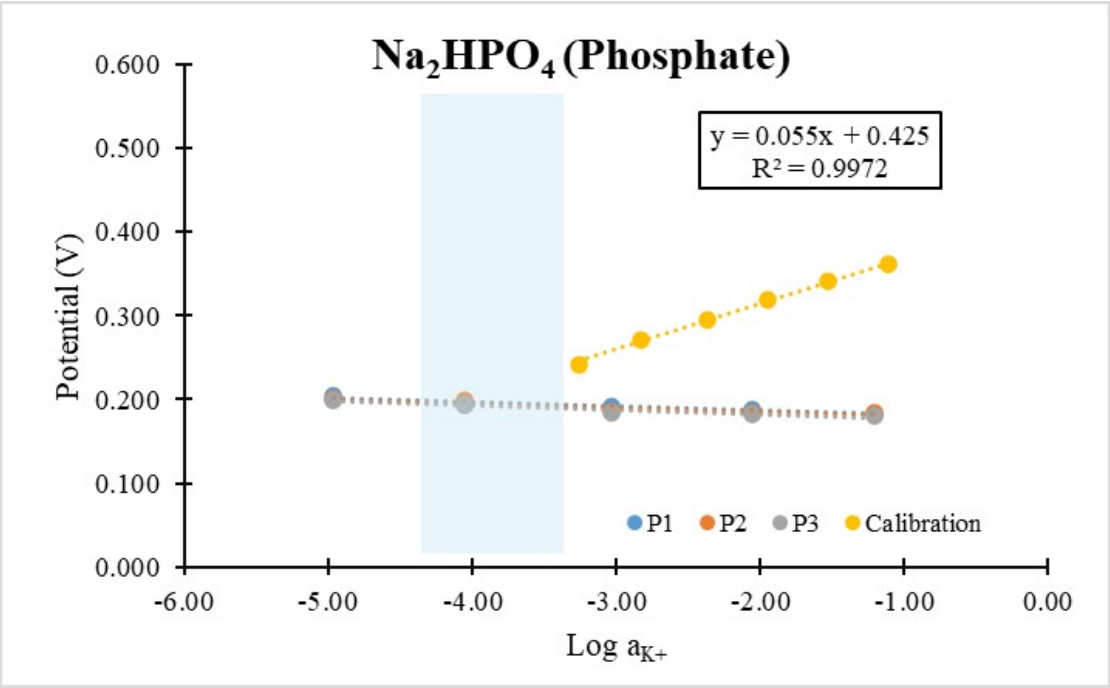
-1.00
0.00
Log aK+
P1
P2
P3
Calibration


Bovine Serum Albumine
y = 0.055x + 0.425
R² = 0.9972
Potential (V)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
Log aK+
P1
P2
P3
Calibration



In Figure S5, the results of the selectivity study for the potassium potentiometric sensor are presented. The sensor potential is plotted against the logarithm of the activity of each interfering ion, and a calibration line for sodium is also shown. A horizontal line indicates that the sensor does not respond to the presence of the interferents, demonstrating the high selectivity of the sodium sensor under the tested conditions.