510(k) SUBSTANTIAL EQUIVALENCE DETERMINATION
DECISION SUMMARY
ASSAY AND INSTRUMENT

I Background Information:

A 510(k) Number
k200544

B Applicant
Diamond Diagnostics Inc.

C Proprietary and Established Names
SmartLyte® Plus Electrolyte Analyzer Na+/K+/Cl-/Ca++/Li+

D Regulatory Information

Product Code(s)	Classification	Regulation Section	Panel
JGS	Class II	21 CFR 862.1665 - Sodium Test System	CH - Clinical Chemistry
CGZ	Class II	21 CFR 862.1170 - Chloride test system	CH - Clinical Chemistry
JFP	Class II	21 CFR 862.1145 - Calcium test system	CH - Clinical Chemistry
JIH	Class II	21 CFR 862.3560 - Lithium test system	TX - Clinical Toxicology
JJE	Class I	21 CFR 862.2160 - Discrete photometric chemistry analyzer for clinical use	CH - Clinical Chemistry

II Submission/Device Overview:

A Purpose for Submission:
New Device

B Measurand:
Sodium, Potassium, Chloride, Calcium, Lithium

C Type of Test:
Quantitative, Ion Selective Electrodes

III Intended Use/Indications for Use:

A Intended Use(s):

See Indications for Use below.

B Indication(s) for Use:

The SmartLyte® Plus is an automated, microprocessor-controlled analyzer which utilizes ion-selective electrodes for the measurement of sodium, potassium, chloride, calcium and lithium in Serum, Sodium Heparin Plasma, and Venous Whole Blood, as well as measurement of sodium, potassium and chloride in pre-diluted Urine samples.

The SmartLyte® Plus Sodium Assay is intended to measure sodium in whole blood, serum, plasma, and urine on the SmartLyte® Plus Electrolyte Analyzer. Measurements obtained by this device are used to monitor electrolyte balance in the diagnosis and treatment of aldosteronism (excessive secretion of the hormone aldosterone), diabetes insipidus (chronic excretion of large amounts of dilute urine, accompanied by extreme thirst), adrenal hypertension, Addison's disease (caused by destruction of the adrenal glands), dehydration, inappropriate antidiuretic hormone secretion, or other diseases involving electrolyte imbalance.

The SmartLyte® Plus Potassium Assay is intended to measure potassium in whole blood, serum, plasma, and urine on the SmartLyte® Plus Electrolyte Analyzer. Measurements obtained by this device are used to monitor electrolyte balance in the diagnosis and treatment of diseases conditions characterized by low or high blood potassium levels.

The SmartLyte® Plus Chloride Assay is intended to measure the level of chloride in whole blood, serum, plasma, and urine on the SmartLyte® Plus Electrolyte Analyzer. Chloride measurements are used in the diagnosis and treatment of electrolyte and metabolic disorders such as cystic fibrosis and diabetic acidosis.

The SmartLyte® Plus Calcium Assay is intended to measure ionized calcium levels in whole blood, plasma, and serum on the SmartLyte® Plus Electrolyte Analyzer. Calcium measurements are used in the diagnosis and treatment of parathyroid disease, a variety of bone diseases, chronic renal disease and tetany (intermittent muscular contractions or spasms).

The SmartLyte® Plus Lithium Assay is intended to measure lithium (from the drug lithium carbonate) in whole blood, plasma, and serum on the SmartLyte® Plus Electrolyte Analyzer. Measurements of lithium are used to assure that the proper drug dosage is administered in the treatment of patients with mental disturbances, such as manic-depressive illness (bipolar disorder).

For in-vitro diagnostic use only.

C Special Conditions for Use Statement(s):

Rx - For Prescription Use Only

D Special Instrument Requirements:

SmartLyte® Plus Electrolyte Analyzer $Na^+/K^+/Cl^-/Ca^{++}/Li^+$

IV Device/System Characteristics:

A Device Description:

The SmartLyte® Plus Electrolyte Analyzer $Na^+/K^+/Cl^-/Ca^{++}/Li^+$ is an automated, microprocessor-controlled analyzer which utilizes ion-selective electrodes for the measurement of sodium, potassium, chloride, ionized calcium and lithium in serum, sodium heparin plasma and venous whole blood, as well as measurement of sodium, potassium and chloride in prediluted urine samples. The analyzer self-calibrates using Diamond Diagnostics Fluid Pack (k013850) every 4 hours throughout the day or on request.

B Principle of Operation:

The SmartLyte® Plus Electrolyte Analyzer $Na^+/K^+/Cl^-/Ca^{++}/Li^+$ measures sodium, potassium and chloride in whole blood, serum, plasma, and urine and ionized calcium and lithium in whole blood, serum, and plasma, using ion selective electrode technology. The flow-through sodium electrode contains a glass tube, specially formulated to be sensitive to sodium ions. The flow-through potassium, chloride, ionized calcium, and lithium electrodes incorporate a neutral carrier ionophore membrane. The potential of each electrode is measured relative to a fixed, stable voltage established by the silver/silver chloride reference electrode. An ion selective electrode develops a voltage that varies with the concentration of the ion to which it responds. The relationship between the voltage developed and the concentration of the sensed ion is logarithmic.

C Instrument Description Information:

1. Instrument Name:
   SmartLyte® Plus Electrolyte Analyzer $Na^+/K^+/Cl^-/Ca^{++}/Li^+$

2. Specimen Identification:
   Specimen (sample type and patient) should be identified by manually entering the information via the touchscreen.

3. Specimen Sampling and Handling:
   Sodium heparin venous whole blood from syringe, evacuated collection tubes or cup can be aspirated by positioning the sample over a probe for all analytes.

4. Calibration:
   The SmartLyte® Plus analyzer performs a 2-point calibration (3-point calibration if lithium) every 4 hours. The software also permits calibration on demand. A 1-point calibration is performed automatically with each measurement.

5. Quality Control:
   Diamond Diagnostics controls (k033063) are the recommended quality control material to be used daily.

V Substantial Equivalence Information:

A Predicate Device Name(s):
GemLyte Electrolyte Analyzer $Na^+/K^+/Cl^-/Ca^{++}/Li^+$

B Predicate 510(k) Number(s):
k082462

C Comparison with Predicate(s):

Device & Predicate Device(s):	k190947	k082462
Device Trade Name	SmartLyte® Plus Electrolyte Analyzer $Na^+/K^+/Cl^-/Ca^{++}/Li^+$	GemLyte Electrolyte Analyzer
General Device Characteristic Similarities		
Intended Use/Indications For Use	For the measurement of sodium, potassium, chloride, calcium, and lithium	Same
Measurement Method	Ion selective electrodes	Same
Sample Matrix	Venous whole blood, Sodium Heparin plasma, serum, and urine	Same
Calibration	Automatic and on demand.	Same
Measurement Range, Blood	Na^+: 40-200 mmol/L K^+: 1.5 -15.0 mmol/L Cl^-: 50-200 mmol/L Ca^{2+}: 0.3-5.0 mmol/L Li^+: 0.2-5.5 mmol/L	Same
Measurement Range, Urine	Na^+: 3-300 mmol/L K^+: 5-120 mmol/L Cl^-: 15-300 mmol/L	Same
General Device Characteristic Differences		
Analyzer Output	5" touchscreen color display 4 USB ports	32-character, 2-line alphanumeric display 2 USB ports
USB Ports	Four	Two
Analysis time	30 sec	57 sec
Sample Results Storage	10000	1000
Program Flow	Multi-level menu structure	Single level menu

VI Standards/Guidance Documents Referenced:

CLSI EP05-A3: Evaluation of Precision Performance of Quantitative Measurement Procedures; Approved Guideline – Third Edition.

CSLI EP06-A Evaluation of the Linearity of Quantitative Measurement Procedures: A Statistical Approach; Approved Guideline.

CLSI EP07-A3 Interference Testing in Clinical Chemistry; Approved Guideline – Third Edition.

CLSI EP17-A2 Evaluation of Detection Capability for Clinical Laboratory Measurement Procedures; Approved Guideline – Second Edition.

VII Performance Characteristics (if/when applicable):

A Analytical Performance:

1. Precision/Reproducibility:
   Within run precision was evaluated using three sodium heparin venous whole blood, serum, sodium heparin plasma, urine samples, and controls for each analyte. Sample concentrations spanned across the measuring range for each analyte. Each sample was measured 30 times consecutively in one day without calibration between measurements. The results are summarized below.

Within-run precision, sodium heparin venous whole blood (mmol/L)

Sample 1	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	103.35	2.717	81.15	0.6546	0.542
%CV	0.47	1.19	0.88	0.45	0.69
N	30	30	30	30	30

Sample 2	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	139.28	3.575	105.22	1.0644	0.9842
%CV	0.47	1.38	0.72	1.47	1.24
N	30	30	30	30	30

Sample 3	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	163.33	7.177	139.91	1.6935	1.5573
%CV	0.59	0.35	0.61	1.16	1.83
N	30	30	30	30	30

Within- run precision, sodium heparin plasma (mmol/L)

Sample 1	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	108.63	2.533	83.20	0.5028	0.4120
%CV	0.29	0.62	0.33	0.42	0.79
N	30	30	30	30	30

Sample 2	Na^+	K^+	Cl^-	Ca^{2+}	Li^+
Mean	135.42	3.327	107.73	1.3297	1.0684
%CV	0.32	0.46	0.35	0.30	1.81
N	30	30	30	30	30

Sample 3	Na^+	K^+	Cl^-	Ca^{2+}	Li^+
Mean	167.73	6.885	140.93	1.6685	1.7837
%CV	0.43	0.54	0.52	0.46	0.88
N	30	30	30	30	30

Within-run precision, serum (mmol/L)

Sample 1	Na^+	K^+	Cl^-	Ca^{2+}	Li^+
Mean	115.13	2.610	76.24	0.4503	0.5612
%CV	0.82	1.20	0.62	0.74	0.89
N	30	30	30	30	30

Sample 2	Na^+	K^+	Cl^-	Ca^{2+}	Li^+
Mean	132.48	4.167	103.41	1.0923	1.1763
%CV	0.15	0.27	0.32	0.37	0.86
N	30	30	30	30	30

Sample 3	Na^+	K^+	Cl^-	Ca^{2+}	Li^+
Mean	162.35	6.859	131.02	1.5722	2.2646
%CV	0.27	0.51	0.29	0.43	0.97
N	30	30	30	30	30

Within-run precision, urine (mmol/L)

		Na^+	K^+	Cl^-
Sample 1	**Mean**	62.61	28.811	90.38
	%CV	1.64	0.51	1.06
	N	30	30	30
Sample 2	**Mean**	108.92	46.644	139.83
	%CV	0.87	0.26	0.68
	N	30	30	30
Sample 3	**Mean**	248.66	171.262	151.70
	%CV	0.65	0.56	0.61
	N	30	30	30

Total precision

Total precision was evaluated using three sodium heparin venous whole blood, serum, sodium heparin plasma, urine, and control samples for each analyte. Samples concentrations spanned the measuring range. Samples were measured twice a day in duplicate for ten consecutive days resulting in n=40 replicates per sample using multiple reagents lots. Venous whole blood samples were tested over 2-hour time period since the analytes measured are not stable in sodium heparin venous whole blood for long periods of times. The results are summarized below.

Total precision, sodium heparin venous whole blood (mmol/L)

Sample 1	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	103.10	2.72	81.6	0.65	0.52
%CV	0.36	0.63	1.05	1.05	1.60
N	40	40	40	40	40

Sample 2	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	139.34	4.36	106.57	1.07	0.97
%CV	0.38	0.75	0.78	1.83	1.52
N	40	40	40	40	40

Sample	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	163.16	7.14	141.33	1.66	1.51
%CV	0.38	2.44	0.82	1.57	3.33
N	40	40	40	40	40

Total precision, sodium heparin plasma (mmol/L)

Sample 1	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	108.54	2.54	84.19	0.50	0.41
%CV	0.66	1.36	1.42	0.43	0.84
N	40	40	40	40	40

Sample 2	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	135.15	4.10	108.83	1.33	1.06
%CV	0.65	1.53	0.85	0.24	1.67
N	40	40	40	40	40

Sample 3	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	167.16	6.88	142.60	1.67	1.79
%CV	0.94	3.76	1.17	0.54	0.73
N	40	40	40	40	40

Total precision, serum (mmol/L)

Sample 1	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	115.20	2.52	76.81	0.45	0.56
%CV	1.00	1.63	1.44	0.59	0.88
N	40	40	40	40	40

Sample 2	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	132.43	4.95	104.73	1.09	1.18
%CV	0.60	1.20	0.63	0.27	0.89
N	40	40	40	40	40

Sample 3	**Na^+**	**K^+**	**Cl^-**	**Ca^{2+}**	**Li^+**
Mean	161.91	6.82	132.18	1.57	2.27
%CV	0.87	2.69	1.07	0.33	0.88
N	40	40	40	40	40

Total precision, urine (mmol/L)

		Na^+	K^+	Cl-
Sample 1	**Mean**	67.87	31.01	90.97
	%CV	3.97	3.23	2.68
	N	40	40	40
Sample 2	**Mean**	108.77	46.30	137.34
	%CV	1.70	1.66	1.49
	N	40	40	40
Sample 3	**Mean**	250.10	169.93	152.85
	%CV	0.87	0.85	1.22
	N	40	40	40

2. Linearity:

Linearity was evaluated by preparing stock solutions with high concentrations of Na, K, Cl in sodium heparin venous whole blood, serum, sodium heparin plasma, and urine. Linearity for Li and Ca was assessed in pooled sodium heparin venous whole blood, serum, sodium heparin plasma. Linear regression was performed.

The results are summarized below.

Sodium heparin venous whole blood

Parameter	**Slope**	**Intercept**	**R^2**	**Sample range tested (mmol/L)**	**Claimed measuring range (mmol/L)**
Sodium	1.02	-4.52	0.9986	34.3-205.7	40-200
Potassium	1.02	-0.15	0.9990	1.6-16.3	1.7-15.0
Chloride	0.97	12.07	0.9974	55.0-216.7	50-200
ionized Calcium	1.00	-0.09	0.9983	0.4-5.8	0.3-5.0
Lithium	0.97	0.13	0.9977	0.3-4.9	0.2 -5.5

Sodium heparin plasma

Parameter	**Slope**	**Intercept**	**R^2**	**Sample range tested (mmol/L)**	**Claimed measuring range (mmol/L)**
Sodium	1.00	5.29	0.9988	16.8-211.0	40-200
Potassium	1.01	0.07	0.9993	1.4-17.4	1.7-15.0
Chloride	0.97	6.29	0.9997	53.8-190.4	50-200
ionized Calcium	1.01	0.06	0.9970	0.3-5.1	0.3-5.0
Lithium	1.00	-0.08	0.9983	0.3-5.1	0.2 -5.5

Serum

Parameter	**Slope**	**Intercept**	**R^2**	**Sample range tested (mmol/L)**	**Claimed measuring range (mmol/L)**
Sodium	1.01	2.60	0.9990	18.1-207.2	40-200
Potassium	1.02	0.03	0.9992	1.3-16.3	1.7-15.0

Parameter	Slope	Intercept	R^2	Sample range tested (mmol/L)	Claimed measuring range (mmol/L)
Chloride	1.00	1.89	0.9991	20.9-203.0	50-200
ionized Calcium	0.98	-0.22	0.9939	0.1-5.3	0.3-5.0
Lithium	1.03	-0.05	0.9995	0.2-6.7	0.2 -5.5

Urine

Parameter	Slope	Intercept	R^2	Sample range tested (mmol/L)	Claimed measuring range(mmol/L)
Sodium	1.00	2.83	0.9988	1.2-307.9	3-300
Potassium	1.00	-0.48	0.9984	0.5-132.9	5-120
Chloride	1.03	-7.24	0.9987	1.4-353.5	15-300

3. Analytical Specificity/Interference:
The sponsor submitted information to support the interference results included in the labeling which was found to be acceptable.

4. Assay Reportable Range:

Measuring range in sodium heparin venous whole blood, sodium heparin plasma and serum	Na^+: 40-200 mmol/L K^+: 1.7-15.0 mmol/L Cl^-: 50-200 mmol/L Ca^{2+}: 0.3-5.0 mmol/L Li^+: 0.2-5.5 mmol/L
Measuring range urine	Na^+: 3-300 mmol/L K^+: 5-120 mmol/L Cl^-: 15-300 mmol/L

5. Traceability, Stability, Expected Values (Controls, Calibrators, or Methods):

The SmartLyte® Plus Sodium assay is traceable to a flame emission spectrophotometry reference method, which uses reference materials from the National Institute of Standards and Technology (NIST).

The SmartLyte® Plus Potassium assay is traceable to a flame emission spectrophotometry reference method, which uses reference materials from the NIST.

The SmartLyte® Plus Chloride assay is traceable to a coulometric reference method, which uses reference materials from the NIST.

The SmartLyte® Plus Calcium assay is traceable to a flame emission spectrophotometry reference method, which uses reference materials from the NIST.

The SmartLyte® Plus Lithium assay is traceable flame emission spectrophotometry reference method, which uses reference materials from the NIST.

6. Detection Limit:
Reportable ranges were determined based on the linearity studies for Na^+, K^+, and Cl^- (see Section VII.A.2 above).

The limit of blank (LoB), limit of detection (LoD), and limit of quantitation (LoQ) were determined for ionized calcium and lithium according to CLSI EP17-A2 guideline.

For LoB studies, blank samples were tested on one analyzer with two different reagent lots. Five different blank samples were run in replicates of five on each day for three days for a total of 75 replicates per lot. The LoB was calculated using the non-parametric method.

For LoD studies, samples with low levels of ionized calcium or lithium were prepared and run five times on one analyzer with two different reagent lots. Five different low-level samples were tested in replicates of five on each day for three days for a total of 75 replicates per lot. The results were pooled to calculate the total standard deviation (SDL) per lot. The LoD was calculated using the equation: LoD = LoB + C*p*SD*L*. The maximum value of the LoDs obtained for the two lots was reported as the LoD of the device.

For LoQ studies, five pooled samples with low levels of ionized calcium or lithium were prepared and measured in replicates of five on each day for three days using two diferent reagent lots on one ananlyzer giving a total of 75 replicates per lot. The mean, SD, and bias relative to a reference value was calculated for each sample. These values were used to calculate TE using the equation TE = |Bias| + 2s for each sample and expressed as concentrations relative to the respective reference value for each sample. The LoQ was defined as a Total Error (TE) of 21.6%.

The overall results of LoB, LoD, and LoQ for each matrix are summarized below:

Sodium heparin venous whole blood			
Analyte	**LoB**	**LoD**	**LoQ**
Ca^{2+} (mmol/L)	0.043	0.094	0.295
Li^+ (mmol/L)	0.029	0.077	0.204

Sodium heparin plasma			
Analyte	**LoB**	**LoD**	**LoQ**
Ca^{2+} (mmol/L)	0.035	0.072	0.302
Li^+ (mmol/L)	0.040	0.053	0.174

Serum			
Analyte	**LoB**	**LoD**	**LoQ**
Ca^{2+} (mmol/L)	0.047	0.089	0.299
Li^+ (mmol/L)	0.041	0.079	0.199

7. Assay Cut-Off:
Not applicable.

8. Accuracy (Instrument):
Not applicable.

9. Carry-Over:
   Not applicable.

B Comparison Studies:

1. Method Comparison with Predicate Device:
   Method comparison studies were conducted to demonstrate the correlation of Diamond Diagnostics SmartLyte® Plus Analyzer to the predicate device (GemLyte Electrolyte Analyzer) operated by trained personnel. Contrived samples were less than 10% of all samples tested and were limited to the extreme ends of claimed assay ranges. Slope, intercept, and R^2 were calculated from a linear regression analysis. Results are summarized below.

Sodium Heparin Venous Whole Blood					
	Slope	**Intercept**	**R^2**	**n**	**Concentrations tested (mmol/L)**
Sodium	1.00	0.77	0.9987	109	43.7-198.6
Potassium	0.97	-0.08	0.9953	109	2.1-14.9
Chloride	1.03	-5.35	0.9952	108	51.4-197.8
ionized Calcium	1.00	0.03	0.9983	112	0.3-5.0
Lithium	1.01	0.09	0.9960	110	0.2-5.4

Sodium Heparin Plasma					
	Slope	**Intercept**	**R^2**	**n**	**Concentrations tested (mmol/L)**
Sodium	1.02	-3.04	0.9962	110	40.6-198.5
Potassium	1.00	-0.13	0.9945	125	1.8-14.8
Chloride	0.99	0.33	0.9954	118	52.7-200.1
ionized Calcium	1.03	-0.04	0.9982	113	0.3-4.6
Lithium	0.98	0.12	0.9940	122	0.2-5.3

Serum					
	Slope	**Intercept**	**R^2**	**n**	**Concentrations tested (mmol/L)**
Sodium	1.01	-0.98	0.9959	117	42.5-200.7
Potassium	1.02	-0.23	0.9972	118	1.7-14.85
Chloride	1.01	-1.60	0.9958	125	50.1-198.5
ionized Calcium	1.01	-0.02	0.9963	117	0.3-4.9
Lithium	1.00	0.08	0.9939	109	0.1-5.3

Urine					
	Slope	**intercept**	**R^2**	**n**	**Concentrations tested (mmol/L)**
Sodium	1.01	-2.48	0.9985	117	5.0-290.0
Potassium	1.03	-0.49	0.9984	115	5.4-119.5
Chloride	1.00	2.42	0.9977	118	17.0-297.2

2. Matrix Comparison:
   Not applicable since the performance studies described above were performed using each matrix for which the device is intended to be used.

C Clinical Studies:

1. Clinical Sensitivity:
   Not applicable.

2. Clinical Specificity:
   Not applicable.

3. Other Clinical Supportive Data (When 1. and 2. Are Not Applicable):
   Not applicable.

D Clinical Cut-Off:
Not applicable.

E Expected Values/Reference Range:
The values given in the tables below are from published literature*. Each laboratory or testing site should establish its own range for normal values.

Whole Blood, Serum and Plasma (mmol/L):
Na^+:136 - 145 mmol/L
K^+: 3.5 - 5.1 mmol/L
Cl^-: 97 - 111 mmol/L
Ca^{2+}: 1.0 - 1.30 mmol/L
Li^+: 0.6 - 1.2 mmol/L

Urine (mmol/L):
Na^+: 40 - 220 mmol/L
K^+: 25 - 120 mmol/L
Cl^-: 110 - 250 mmol/L

*Reference: Burtis C, Ashwood E (Eds.), Tietz Textbook of Clinical Chemistry, 2nd Ed., (Philadelphia: W.B. Saunders, Co.,1994) pp.1354-1360,2180-2206.

F Other Supportive Instrument Performance Characteristics Data:
Not applicable.

VIII Proposed Labeling:
The labeling supports the finding of substantial equivalence for this device.

IX Conclusion:
The submitted information in this premarket notification is complete and supports a substantial equivalence decision.