# Application Sheet

Laboratory Name

**Test Name: Folate III**

| REF | Σ | SYSTEM |
|---|---|---|
| **07559992** 160 | 100 | MODULAR ANALYTICS E170<br>**cobas e** 411<br>**cobas e** 601<br>**cobas e** 602 |

For USA: Elecsys Folate III Assay

## Intended use

Binding assay for the in vitro quantitative determination of folate in human serum. The binding assay is intended for use on Elecsys and **cobas e** immunoassay analyzers. Folic acid measurements are used in the diagnosis and treatment of anemias.

## Summary

Nutritional and macrocytic anemias can be caused by a deficiency of folate. This deficiency can result from diets devoid of raw fruits, vegetables or other foods rich in folic acid, as may be the case with chronic alcoholics, drug addicts, the elderly or persons of low socioeconomic status, etc. In addition, low serum folate during pregnancy has been associated with neural tube defects in the fetus.[1] Dietary deficiency and malabsorption are the major causes of folate deficiency in humans.[2] Folate is necessary for normal metabolism, DNA synthesis and red blood cell regeneration. Untreated deficiencies may lead to megaloblastic anemia.
Since a deficiency of either vitamin $B_{12}$ or folate can cause megaloblastic anemia, it is advisable to determine the concentration of both vitamin $B_{12}$ and folate in order to properly diagnose the etiology of anemia.
Radioassays were first reported for folate in 1973.[3,4,5,6]
The majority utilize $^{125}$I-folate radiolabeled tracers and natural binding proteins (milk binding protein, folate binding protein). The various commercial assays differ in their free versus bound separation techniques and choice of specimen pretreatment.
The Elecsys Folate assay employs a competitive test principle using natural folate binding protein (FBP) specific for folate. Folate in the sample competes with the added folate (labeled with biotin) for the binding sites on FBP (labeled with ruthenium complex[a)]).

a) Tris(2,2'-bipyridyl)ruthenium(II)-complex ($Ru(bpy)_3^{2+}$)

## Test principle

Competition principle. Total duration of assay: 27 minutes.

- 1st incubation: By incubating 25 µL of sample with the folate pretreatment reagents 1 and 2, bound folate is released from endogenous folate binding proteins.
- 2nd incubation: By incubating the pretreated sample with the ruthenium labeled folate binding protein, a folate complex is formed, the amount of which is dependent upon the analyte concentration in the sample.
- 3rd incubation: After addition of streptavidin-coated microparticles and folate labeled with biotin, the unbound sites of the ruthenium labeled folate binding protein become occupied, with formation of a ruthenium labeled folate binding protein-folate biotin complex. The entire complex becomes bound to the solid phase via interaction of biotin and streptavidin.
- The reaction mixture is aspirated into the measuring cell where the microparticles are magnetically captured onto the surface of the electrode. Unbound substances are then removed with ProCell/ProCell M. Application of a voltage to the electrode then induces chemiluminescent emission which is measured by a photomultiplier.
- Results are determined via a calibration curve which is instrument-specifically generated by 2-point

calibration and a master curve provided via the reagent barcode.

## Reagents - working solutions

The reagent rackpack (M, R1, R2) and the pretreatment reagents (PT1, PT2) are labeled as FOL III.

| | |
|---|---|
| PT1 | Pretreatment reagent 1 (white cap), 1 bottle, 4 mL: Sodium 2-mercaptoethanesulfonate (MESNA) 40 g/L, pH 5.5. |
| PT2 | Pretreatment reagent 2 (gray cap), 1 bottle, 5 mL: Sodium hydroxide 25 g/L. |
| M | Streptavidin-coated microparticles (transparent cap), 1 bottle, 6.5 mL: Streptavidin-coated microparticles 0.72 mg/mL; preservative. |
| R1 | Folate binding protein~$Ru(bpy)_3^{2+}$ (gray cap), 1 bottle, 9 mL: Ruthenium labeled folate binding protein 75 µg/L; human serum albumin (stabilizer); borate/phosphate/citrate buffer 70 mmol/L, pH 5.5; preservative. |
| R2 | Folate~biotin (black cap), 1 bottle, 8 mL: Biotinylated folate 17 µg/L; biotin 120 µg/L; human serum albumin (stabilizer); borate buffer 100 mmol/L, pH 9.0; preservative. |

## Precautions and warnings

For in vitro diagnostic use.
Exercise the normal precautions required for handling all laboratory reagents.
Disposal of all waste material should be in accordance with local guidelines.
Safety data sheet available for professional user on request.
For USA: For prescription use only.
This kit contains components classified as follows in accordance with the Regulation (EC) No. 1272/2008:

Danger

| | |
|---|---|
| H290 | May be corrosive to metals. |
| H314 | Causes severe skin burns and eye damage. |

**Prevention:**

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| P280 | Wear protective gloves/ protective clothing/ eye protection/ face protection. |

**Response:**

| | |
|---|---|
| P301 + P330 + P331 | IF SWALLOWED: Rinse mouth. Do NOT induce vomiting. |
| P303 + P361 + P353 | IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower. |
| P304 + P340 + P310 | IF INHALED: Remove person to fresh air and keep comfortable for breathing. Immediately call a POISON CENTER or doctor/physician. |
| P305 + P351 + P338 | IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. |
| P390 | Absorb spillage to prevent material damage. |

Product safety labeling primarily follows EU GHS guidance.
Contact phone: 1-800-428-2336

All human material should be considered potentially infectious. All products derived from human blood are prepared exclusively from the blood of donors tested individually and shown to be free from HBsAg and antibodies to HCV and HIV. The testing methods applied were FDA-approved or cleared in compliance with the European Directive 98/79/EC, Annex II, List A.

However, as no testing method can rule out the potential risk of infection with absolute certainty, the material should be handled with the same level of care as a patient specimen. In the event of exposure, the directives of the responsible health authorities should be followed.[7,8]
Avoid foam formation in all reagents and sample types (specimens, calibrators and controls).

## Reagent handling

The reagents in the kit have been assembled into a ready-for-use unit that cannot be separated.
All information required for correct operation is read in from the respective reagent barcodes.

## Storage and stability

Store at 2-8 °C.
Do not freeze.
Store the Elecsys reagent kit **upright** in order to ensure complete availability of the microparticles during automatic mixing prior to use.

| Stability: | |
|---|---|
| unopened at 2-8 °C | up to the stated expiration date |
| after opening at 2-8 °C | 8 weeks |
| on the analyzers | 2 weeks or 4 weeks when stored alternatively in the refrigerator and on the analyzer, with the total time on-board the analyzer not exceeding 10 x 8 hours |

## Specimen collection and preparation

**Note: Hemolysis may significantly increase folate values due to high concentrations of folate in red blood cells. Therefore, hemolyzed samples are not suitable for use in this assay. Samples for folate determinations should be collected from fasting persons.**

Only the specimens listed below were tested and found acceptable.
Serum collected using standard sampling tubes or tubes containing separating gel.
Serum: Stable for 2 hours at 15-25 °C, 2 days at 2-8 °C, 4 weeks at (-15)-(-25) °C. Freeze only once. Protect from light. Store the samples at 2-8 °C if they cannot be measured immediately.
The sample types listed were tested with a selection of sample collection tubes that were commercially available at the time of testing, i.e. not all available tubes of all manufacturers were tested. Sample collection systems from various manufacturers may contain differing materials which could affect the test results in some cases. When processing samples in primary tubes (sample collection systems), follow the instructions of the tube manufacturer.
Samples should not subsequently be altered with additives (biocides, anti-oxidants or substances possibly changing the pH of the sample) in order to avoid erroneous folate recovery.
Centrifuge samples containing precipitates before performing the assay.
Do not use heat-inactivated samples.
Ensure the samples, calibrators and controls are at 20-25 °C prior to measurement.
Due to possible evaporation effects, samples, calibrators and controls on the analyzers should be analyzed/measured within 2 hours.

## Materials provided

See “Reagents – working solutions” section for reagents.

## Materials required (but not provided)

- REF 07560001190, Folate III CalSet, for 4 x 1.0 mL
- REF 03183971122, Diluent Universal, 2 x 36 mL sample diluent

- General laboratory equipment
- MODULAR ANALYTICS E170 or **cobas e** analyzer

Accessories for MODULAR ANALYTICS E170, **cobas e** 601 and **cobas e** 602 analyzers:

- REF 04880340190, ProCell M, 2 x 2 L system buffer
- REF 04880293190, CleanCell M, 2 x 2 L measuring cell cleaning solution
- REF 03023141001, PC/CC-Cups, 12 cups to prewarm ProCell M and CleanCell M before use
- REF 03005712190, ProbeWash M, 12 x 70 mL cleaning solution for run finalization and rinsing during reagent change
- REF 03004899190, PreClean M, 5 x 600 mL detection cleaning solution
- REF 12102137001, AssayTip/AssayCup Combimagazine M, 48 magazines x 84 reaction vessels or pipette tips, waste bags
- REF 03023150001, WasteLiner, waste bags
- REF 03027651001, SysClean Adapter M

Accessories for all analyzers:

- REF 11298500160, ISE Cleaning Solution/Elecsys SysClean, 5 x 100 mL system cleaning solution

In addition, other suitable control material can be used.

## Assay

For optimum performance of the assay follow the directions given in this document for the analyzer concerned. Refer to the appropriate operator's manual for analyzer-specific assay instructions.
Resuspension of the microparticles takes place automatically prior to use. Read in the test-specific parameters via the reagent barcode. If in exceptional cases the barcode cannot be read, enter the 15-digit sequence of numbers.
MODULAR ANALYTICS E170, **cobas e** 601 and **cobas e** 602 analyzers: PreClean M solution is necessary.
Bring the cooled reagents to approximately 20 °C and place on the reagent disk (20 °C) of the analyzer. Avoid foam formation. The system automatically regulates the temperature of the reagents and the opening/closing of the bottles.

## Calibration

Traceability: This method has been standardized against the WHO International Standard NIBSC code: 03/178.
Every Elecsys reagent set has a barcoded label containing specific information for calibration of the particular reagent lot. The predefined master curve is adapted to the analyzer using the relevant CalSet.
*Calibration frequency:* Calibration must be performed once per reagent lot using fresh reagent (i.e. not more than 24 hours since the reagent kit was registered on the analyzer). Renewed calibration is recommended as follows:

- after 1 month (28 days) when using the same reagent lot
- after 7 days (when using the same reagent kit on the analyzer)
- as required: e.g. quality control findings outside the defined limits

## Quality control

At least once daily run solutions at two levels of a quality control material with known concentrations.

Refer to Brown Clinic Quality Control Requirements, Rules and Reviews Policy

Refer to Brown Clinic Quatliy Control Specialty and Subspecialty Policy

## Calculation

The analyzer automatically calculates the analyte concentration of each sample (either in nmol/L or ng/mL).

Conversion factors: nmol/L x 0.44 = ng/mL
ng/mL x 2.27 = nmol/L

## Limitations - interference

Do not use hemolyzed samples.
The assay is unaffected by icterus (bilirubin < 496 µmol/L or < 29 mg/dL), lipemia (Intralipid < 1500 mg/dL), biotin (< 86.1 nmol/L or < 21 ng/mL), IgG < 16 g/L, IgA < 4.0 g/L and IgM < 10 g/L.
Criterion: Recovery within ± 10 % of initial values for samples > 4-20 ng/mL and ≤ 0.4 ng/mL deviation of initial values for samples 2.0-4.0 ng/mL. Hemolysis may significantly increase folate values due to high concentrations of folate in red blood cells. Therefore, hemolyzed samples are not suitable for use in this assay.
Samples should not be taken from patients receiving therapy with high biotin doses (i.e. > 5 mg/day) until at least 8 hours following the last biotin administration.
No interference was observed from rheumatoid factors up to a concentration of 1000 IU/mL.
In vitro tests were performed on 16 commonly used pharmaceuticals and in addition on human erythropoietin. No interference with the assay was found.
It is contraindicated to measure samples of patients receiving therapy with certain pharmaceuticals, e.g. methotrexate or leucovorin, because of the cross-reactivity of folate binding protein with these compounds.
Samples with extremely high total protein concentrations (e.g. patients suffering from Waldenström's macroglobulinemia) are not suitable for use in this assay, since they may lead to the formation of protein gel in the assay cup. Processing protein gel may cause a run abort. The critical protein concentration is dependent upon the individual sample composition.
In rare cases, interference due to extremely high titers of antibodies to analyte-specific antibodies, streptavidin or ruthenium can occur. These effects are minimized by suitable test design.
For diagnostic purposes, the results should always be assessed in conjunction with RBC folate, the patient’s medical history, clinical examination and other findings.

## Limits and ranges

**Measuring range**
2.0 - 20.0 ng/mL or 4.54 - 45.4 nmol/L (defined by the Limit of Quantitation and the maximum of the master curve). Values below the Limit of Quantitation are reported as < 2.0 ng/mL (< 4.54 nmol/L). Values above the measuring range are reported as > 20.0 ng/mL (> 45.4 nmol/L).

**Lower limits of measurement**
*Limit of Blank, Limit of Detection and Limit of Quantitation*

| | |
|---|---|
| Limit of Blank | = 0.6 ng/mL |
| Limit of Detection | = 1.2 ng/mL |
| Limit of Quantitation | = 2.0 ng/mL |

The Limit of Blank, Limit of Detection and Limit of Quantitation were determined in accordance with the CLSI (Clinical and Laboratory Standards Institute) EP17-A requirements.
The Limit of Blank is the 95$^{th}$ percentile value from n ≥ 60 measurements of analyte-free samples over several independent series. The Limit of Blank corresponds to the concentration below which analyte-free samples are found with a probability of 95 %.
The Limit of Detection is determined based on the Limit of Blank and the standard deviation of low concentration samples. The Limit of Detection corresponds to the lowest analyte concentration which can be detected (value above the Limit of Blank with a probability of 95 %).
The Limit of Quantitation is defined as the lowest amount of analyte in a sample that can be accurately quantitated with a total allowable relative error of ≤ 20 %.
It has been determined using low concentration folate samples.

## Dilution

Samples with folate concentrations above the measuring range can be diluted manually with Elecsys Diluent Universal. The recommended dilution is 1:2. The concentration of the diluted sample must be > 8.5 ng/mL or 19.3 nmol/L.
After manual dilution, multiply the result by the dilution factor.

## Expected values

Referring to "The American Journal of Clinical Nutrition"[9] serum folate (folic acid) values were found as follows:

| Sex | Age | N | Median | | 2.5th-97.5th percentile | |
|---|---|---|---|---|---|---|
| | years | | nmol/L | ng/mL | nmol/L | ng/mL |
| Both | all | 23345 | 29.5 | 13.0 | 10.4-78.9 | 4.6-34.8 |
| Male | all | 11387 | 27.9 | 12.3 | 10.2-73.0 | 4.5-32.2 |
| Female | all | 11958 | 30.1 | 13.3 | 10.9-84.5 | 4.8-37.3 |
| Both | 4-11 | 3595 | 39.0 | 17.2 | 19.5-85.4 | 8.6-37.7 |
| Both | 12-29 | 6390 | 27.4 | 12.1 | 11.3-61.6 | 5.0-27.2 |
| Both | 20-59 | 8689 | 26.3 | 11.6 | 10.0-70.2 | 4.4-31.0 |
| Both | ≥ 60 | 4671 | 37.6 | 16.6 | 12.7-104 | 5.6-45.8 |

These values were obtained in the USA during the National Health and Nutrition Examination Survey (NHANES), 1999-2004.
The values shown below were performed on samples from an apparently healthy population, using the Elecsys Folate III assay on the **cobas e** 411 analyzer.
The calculation is based on 214 sera (110 men, 104 women). The age range was between 21 and 59 years. Pregnant or lactating women were excluded. The reference population was selected according to normal homocysteine values.

| Country | N | Median | | 2.5th-97.5th percentile | |
|---|---|---|---|---|---|
| | | nmol/L | ng/mL | nmol/L | ng/mL |
| USA | 214 | 26.8 | 11.8 | 10.9 - 54.9 | 4.78 - 24.2 |

*Please note:* These values should only be used as a guideline.
It should be taken into consideration that differences in the expected values may exist with respect to population and dietary status.
Each laboratory should investigate the transferability of the expected values to its own patient population and if necessary determine its own reference ranges.

## Specific performance data

For Known Interfering Substances section refer to package insert.
For Known Non-Interfering Substance refer to package insert.
For Additional Technical Information refer to package insert.

## References

1 Rush D. Folate Supplements Prevent Recurrence of Neural Tube Defects, FDA Dietary Supplement Task Force. Nutrition Reviews 1992;50(1):22-28.
2 Herbert V. Drugs effective in megaloblastic anemias. In Goodman LS and Gilman A (eds): The Pharmacological Basis of Therapeutics, 5th Ed, MacMillan Co, 1975;1324-1349.
3 Dunn RT, Foster LB. Radioassay of serum Folate. Clin Chem 1973;19:1101-1105.

4 Rothenberg SP, DaCosta M, Rosenberg BS. A radioassay for serum Folate: Use of a two phase sequential incubation, ligand-binding system. New Eng J Med 1972;285(25):1335-1339.
5 Gutcho S, Mansbach L. Simultaneous radioassay of serum Folate and folic acid. Clin Chem 1977;23:1609-1614.
6 BIO RAD Quantaphase B-12/Folate Radioassay Instruction Manual. March 1995.
7 Occupational Safety and Health Standards: bloodborne pathogens. (29 CFR Part 1910.1030). Fed. Register.
8 Directive 2000/54/EC of the European Parliament and Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work.
9 Pfeiffer CM, Johnson CL, Jain RB, et al. Trends in blood folate and vitamin B-12 concentrations in the United States, 1988-2004. Am J Clin Nutr 2007;86:718-727.
10 Passing H, Bablok W, Bender R, et al. A general regression procedure for method transformation. J Clin Chem Clin Biochem 1988 Nov;26(11):783-790.

### Alternative method

Refer to Brown Clinic Back-up Testing Policy

### Source document

Reagent Name: Folate III
Method Sheet Version: V1.0 English

## Effective date

Effective date for this procedure:

## Author

Source documentation compiled by Roche Diagnostics

Revised by: Heather J Hall, MBA, MT(ASCP), CG(ASCP)$^{cm}$ Date: 4/9/2018

Approved by: Aaron Shives MD (Signature on file Date: 4/11/2018

## REVIEW – REVISION SUMMARY DOCUMENTATION

Date: By: Revision Summary: