TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.: 3,846,243

Government or Corporate Employee: Natl Academy of Sciences

Supplementary Corporate Source (if applicable): Natl Research Council, Wash, DC

NASA Patent Case No.: A2C-10,469-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES ☒ NO ☐

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Woerner

Enclosure
Automated Analysis of Oxidative Metabolites

Figure 1

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The diagram includes:
- Colorimeter 660 nm
- Colorimeter 618 nm
- Recorder
- Waste
- Dialyzer 25°
- Water Bath 37°
- Sample Pick-Up
- 100% Oxygen
- Color Forming Reagent
- Proportioning Pump
- Phenol-Disodium Tartrate: H₂O 1:6
- 0.02% CuSO₄
- 0.04% NaK Tartrate
- 2% Na₂CO₃
- 0.1 N NaOH

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Filed Aug. 18, 1972
4 Sheets-Sheet 1

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JAMES C. FLETCHER
ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Nov. 5, 1974

3,846,243

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PATENT
WITH OXYGEN

WITHOUT OXYGEN

FIG. 5.

FIG. 6.
AUTOMATED ANALYSIS OF OXIDATIVE METABOLITES

James C. Fletcher, Administrator of the National Aeronautics and Space Administration, with respect to an Invention of Raymond L. Furner, Birmingham, Ala.

Filed Aug. 18, 1972, Ser. No. 281,908
Int. Cl. C12K 1/00
U.S. Cl. 195—103.5 R

3,846,243

3 Claims

ABSTRACT OF THE DISCLOSURE

An automated system for the study of drug metabolism is disclosed. The system monitors the oxidative metabolites of aromatic amines and of compounds which produce formaldehyde on oxidative dealkylation. It includes color developing compositions suitable for detecting hydroxylated aromatic amines and formaldehyde.

The invention described herein was made by a Research Associate of National Academy of Sciences while under contract with the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or thereafter.

BACKGROUND OF THE INVENTION

Field of the invention

An automated system for the study of drug metabolism.

Description of the prior art

The metabolism of aniline to p-aminophenol by oxidative microsomal enzymes has been studied in considerable detail by numerous investigators. Previous methods for studying oxidative metabolism required that the enzyme, substrate and cofactors be mixed in a flask and placed in a constant temperature water bath for incubation. Time of incubation was generally an arbitrary unit varying from 5 minutes to an hour or more depending on the substrate.

Termination of the oxidative metabolism was accomplished by extracting the metabolite with an organic solvent. The solvent also inactivated the oxidative enzymes.

An aliquot of the organic solvent was transferred to another vessel containing an alkaline mixture containing phenol. The metabolite was then re-extracted into the other vessel containing an alkaline mixture containing phenol to form a blue color with an absorption maximum near 620 m\(^\mu\). Although this extraction procedure has been made more sensitive by increasing the phenol concentration in the alkaline extract, it has a number of inherent inconvenient and disadvantageous procedures; namely, it requires the use of heavy and unpleasant procedures; namely, it requires the use of heavy and unpleasant procedures.

The system described herein resolves these disadvantages and disadvantages; namely, it requires an ether extraction; transfer steps have been completely eliminated; a method for using a minimal amount of valuable cofactor has been provided; an aluminum sample plate has been devised that keeps the enzyme suspension cold until analysis actually is begun; the time between the start of incubation and recording of results has been made uniform; time required for one analysis has been reduced to 20 minutes plus 2 minutes for each additional sample or duplicate. A multiplicity of operations can be performed inexpensively, accurately, with a high degree of reproducibility and with the results automatically recorded while the analyses are being performed.

The prior art method for measuring the formaldehyde had a number of inherently inconvenient and disadvantageous procedures; namely, it required the use of heavy metals for the precipitation of proteins; it was time consuming, requiring about 1½ hours for a single sample; it required at least five individual transfers or additions of reagents; it required a water bath for incubation during the color forming phase, and close attention to the duration of the color forming phase. These numerous steps increase the potential for error. The use of heavy metals is messy at best since special care is required in the cleaning of the analytical glassware.

SUMMARY OF THE INVENTION

The present invention relates to a system for the automatic analysis of drug metabolites which consists of mixing the drug with an amount of enzyme and cofactor in the presence of 100% oxygen to form the metabolite, dialyzing the so-formed solution against phosphate buffer and developing color by adding a suitable reagent to the recipient stream of the dialysis.
BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic flow diagram illustrating a novel system for automatically analyzing drug metabolites and protein content in incubation mixtures.

FIG. 2 is a side view of a water gravity pump for introducing 100% oxygen at a low, steady pressure into the system described in FIG. 1.

FIG. 3 is a perspective view of a gravity fed cofactor dispensing system.

FIGS. 4A, 4B and 4C illustrate the dual pipette pickup assembly in action. FIG. 4A shows the resting buffer pickup position. FIG. 4B shows both pipettes raised out of the buffer. FIG. 4C illustrates the enzyme-cofactor pickup position.

FIG. 5 is a plot of peaks in systems with and without oxygen representing diffusion of oxygen from buffer into sample.

FIG. 6 is a perspective view of a solid aluminum sample plate.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to a procedure for monitoring the hepatic metabolites of aromatic amines such as aniline and compounds which form formaldehyde on oxidative dealkylation such as ethylmorphine and p-nitroanisole.

The system as shown schematically in FIG. 1 is first flushed with buffer which is introduced through pipettes 1 and 2 and with phenol solution through line 12 until it reaches equilibrium, normally about 30 minutes. To calibrate the system, samples containing 10 μg./ml of freshly prepared p-aminophenol or formaldehyde in distilled water (with or without protein) are introduced into the system via pipette 2 from a conventional sampler system 18, later described in detail. In the initial phase of development when metabolism was studied the complete incubation mixture was previously prepared in an ice bath near 0° C. and placed in sample cups on the sample plate 20. In the next sample was to be inserted. Following this procedure, the cup placed on the turntable of a sample changer. The suspension homogenate used in the incubation mixture was previously prepared in an ice bath near 0° C. and placed in sample cups on the sample plate 40. The oxygen separates the sample into segments, facilitates mixing, helps to eliminate deposit formation in the lines, and insures uniform reaction of the sample with enzyme. Oxygen to sample ratio is about 0.31 by volume.

The rat liver homogenate used in the incubation mixture was prepared by placing five grams of rat liver in a vessel containing 10 ml. 1.15% KCl and homogenized for about 10.5 minutes (time depends upon coil length and flow rate). During the period the substrate is metabolized in water bath 6 maintained at 37° C. Time in the coil is about 10.5 minutes (time depends upon coil length and flow rate). During the period the substrate is metabolized the oxygenated sample containing the metabolite is forced through the continuous flow dialyzer 7 maintained at 25° C. and equipped with a standard membrane.

Dialysis is against oxygenated buffer provided by lines 8 and 9 with a flow rate identical to the oxygenated sample. The metabolite dialyzes across the membrane is carried out of the dialyzer by the buffer. The dialyzed sample containing protein exits to waste via line 11. The dialysate containing the metabolite is reacted with a suitable color forming reagent provided by line 12 and the mixture allowed to incubate for approximately 6 minutes in reaction coil 10 and 1 minute in coil 17.

The color forming reagent is selected according to the metabolite being analyzed. p-Aminophenol requires IN NaOH containing 5% phenol to form a blue color at room temperature with an absorption maximum near 620 μm. Formaldehyde requires a reagent prepared as follows: 150 gm. ammonium acetate, 3 ml. glacial acetic acid, 2 ml. acetylace tone diluted to 400 ml. with distilled water. When combined with formaldehyde this reagent yields a bright yellow color with an absorption maximum near 412 μm. In the analysis of formaldehyde the color forming coil is 10 μm. and the dialyzed sample containing protein is 412 μm.

Time for color formation is about 6 minutes. After the heating bath the colored material is passed through the air-cooled coil 17 before proceeding to a de-bubbler and the flow cell in the colorimeter 24. Cooling prevents overloading the de-bubbler by contracting the gas bubble. Percent transmission is monitored on the colorimeter 28 with the colorimeter is recorded on a strip chart recorder 14. Concentration of the metabolite is proportional to the log of the peak height.
In FIG. 2 there is shown a method for introducing oxygen into the system without distorting the bubble pattern. This consists of a water gravity pump having a flask 2A with the flask about half filled with water and with pure oxygen standing over the water. Additional water can now be introduced by siphon action from flask 2B so that oxygen from flask 2A is forced out through the lines 5 and 9. In this way a very gentle but controlled positive pressure can be maintained on the oxygen lines so that bubbles are introduced into the system in a regular and uniform fashion.

FIG. 3 illustrates a gravity fed dispenser for cofactor-substrate which feeds into the dual pipette pickup assembly shown in FIGS. 4A, B and C, both of which are at the sample pickup location 18 in FIG. 1. Cofactor-substrate solution is placed in the 1000 ml. container 25 equipped with a stop-cock 26 for passage of liquid, a stop-cock 27 in the internal pressure equilibration arm, an air tight stopper 28 and a 4-inch delivery barrel 29. After the delivery barrel 29 is placed in opening 30 (FIG. 4) and allowed to rest on the ledge 31, the stop-cocks 26 and 27 are opened allowing cofactor-substrate solution to spill into trough 32. As the level of liquid rises an equilibrium of hydrostatic pressure is reached which prevents further flow from 25 until the liquid level is decreased by withdrawal through pipette 1. Thus, the reservoir is continually refilled, but does not overflow; the cofactor-substrate is used only for each sample and is not continuously introduced into the system.

Pipette 1 is in a continual exhaust state and therefore it must be in liquid to avoid introduction of air bubbles into the system. When it is not in the cofactor-substrate trough 32, it is in the buffer trough 34.

Pipette 2 is in buffer trough 35 or in a sample cup 18A in the sample changer. Buffer is presented to trough 34 by inflow line 16. Excess buffer overflows into spillover chamber 36 and hence through the waste exit 37. The buffer supply 16A to trough 35 is standard on existing equipment and is partially obscured by the cofactor substrate-buffer reservoir.

The sequence of steps is clearly shown in FIGS. 4A, B and C which show the successive stages of the movements of the two pipettes.

The sample plate 33 (see also FIG. 6) is made of solid aluminum for high thermal conductivity. The center well 33A of the aluminum plate is deep enough to accept ice, frozen CO$_2$, or other material to maintain a desirable temperature in the sample cup 18A. When cooled with ice, the solutions in the sample cup are maintained between 0.5 and 1.5°C. A microswitch lever on the sample changer is bent so that the sample plate turns freely until a stop pin in a stop pin hole 38 engages the microswitch lever and interrupts the cycle.

FIG. 5 shows the results obtained with oxygen and without oxygen. The broken line shows the result without oxygen wherein the oxidative metabolism of aniline appeared as small twin peaks. The system did not respond to increased cofactor concentrations or increased tissue concentrations. The peaks coincide with sample extermities, so it was reasoned that the buffer might have contributed to metabolism by permitting some factor to diffuse out or permitting another factor to diffuse in. It was found that this difficulty could be solved by adding 100% oxygen to the system to replace the standard air bubbles and, as the solid line shows, a single sharp peak is achieved by the addition of oxygen. The method of adding the oxygen without distorting the bubble pattern of the system was previously described in conjunction with FIG. 2.

While I have illustrated a preferred mode of practicing the present invention, it will be understood that the invention may be practiced otherwise than illustrated here. Various changes may be made and will occur to those skilled in the art without departing from the underlying idea of this invention within the scope of the appended claims.

I claim:

1. A method for the continuous-flow analysis of oxidative metabolites of aromatic amines and of compounds which produce formaldehyde on oxidative dealkylation consisting essentially of the steps of:
   (1) combining a fluid stream comprising a substrate-cofactor in a phosphate buffer with a rat liver homogenate comprising oxidative microsomal enzymes,
   (2) dividing the resulting mixture into a first stream for determining the quantity of protein and into a second stream for metabolizing the substrate and for determining the quantity of metabolite generated during such metabolism,
   (3) diluting said first stream with phosphate buffer,
   (4) aerating said diluted first stream,
   (5) reacting said aerated first stream with a color forming reagent for protein,
   (6) colorimetrically determining the amount of protein,
   (7) intermittently adding small aliquots of 100% oxygen to said second stream,
   (8) incubating said oxygenated second stream at a controlled temperature to promote the formation of metabolite by enzyme action on said substrate,
   (9) dialyzing said second stream against phosphate buffer, and
   (10) colorimetrically determining the concentration of metabolite after reacting the dialysate with a color forming reagent for said metabolite.

2. The method of claim 1 wherein said substrate consists essentially of aniline.

3. The method of claim 2 wherein the metabolite color forming reagent is 1 normal NaOH containing 5% phenol.

4. The method of claim 1 wherein the metabolite color forming reagent consists essentially of 150 g. ammonium acetate, 3 ml. glacial acetic acid, and 2 ml. acetylacetone in 400 ml. distilled water.

5. The method of claim 4 wherein the metabolite color forming reagent consists essentially of 1% CuSO$_4$, 0.4% sodium potassium tartrate, and 2% Na$_2$CO$_3$ and which is 0.1 N with NaOH mixed with a phenol-cloicale-water solution in the ratio of 1:6.

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