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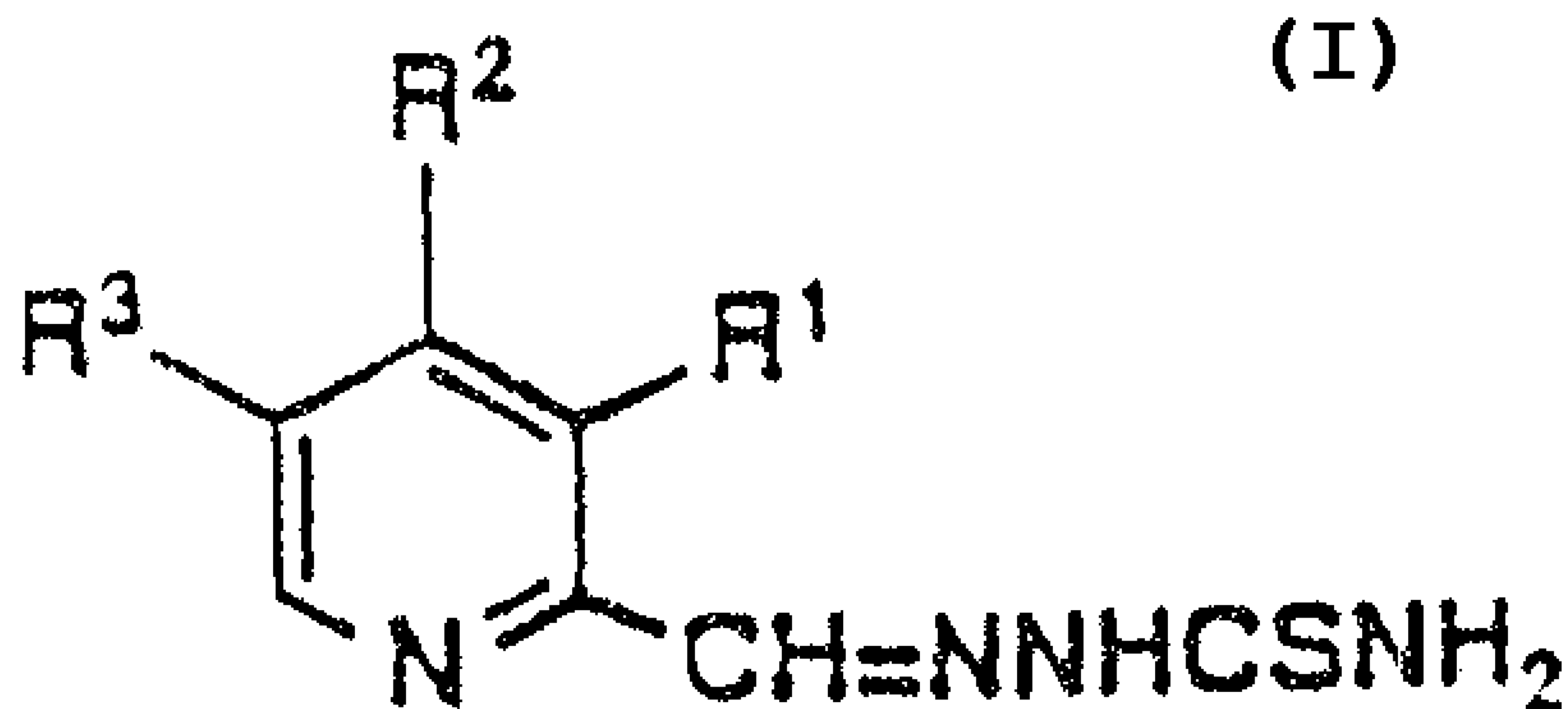
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(54) Titre : AGENTS ANTITUMEURS, A BASE DE 2-FORMYLPYRIDINETHIOSEMICARBAZONE

(54) Title: 2-FORMYLPYRIDINE THIOSEMICARBAZONE ANTITUMOR AGENTS



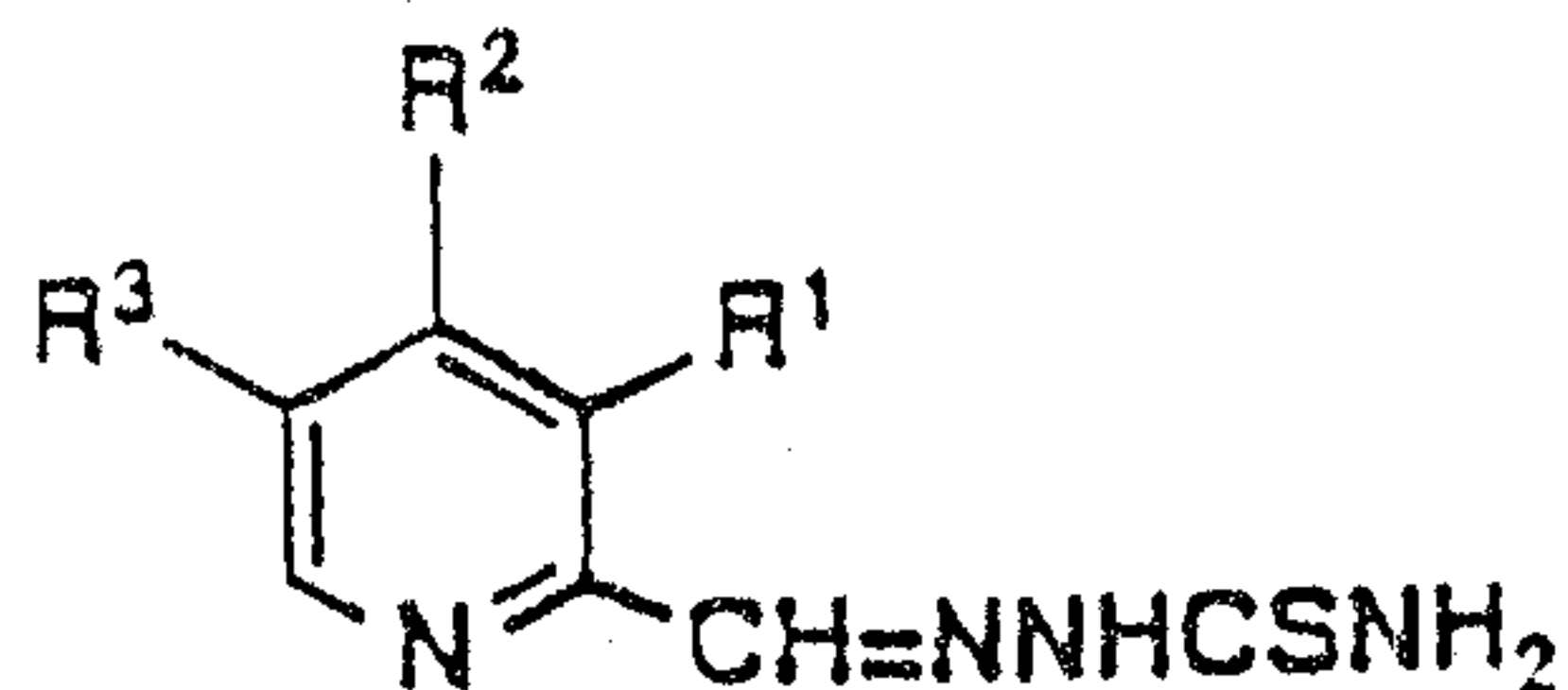
(57) Abrégé/Abstract:

Disclosed is a compound of the formula (See formula I) wherein either (a) R^1 is NHR^4 or NR^4R^5 and R^3 is hydrogen or (b) R^3 is NHR^4 , NR^4R^5 or OH and R^1 is hydrogen; R^2 is hydrogen or C_{1-4} lower alkyl; R^4 is hydrogen, hydroxyl or C_{1-4} lower alkyl; and R^5 is C_{1-4} lower alkyl; provided that R^1 and R^2 cannot both be hydrogen when R^3 is $\text{N}(\text{CH}_3)_2$ or OH ; or a pharmaceutically acceptable salt or hydrate thereof, and its use as an anti-tumor agent.



ABSTRACT OF THE DISCLOSURE

Disclosed is a compound of the formula



wherein either (a) R¹ is NHR⁴ or NR⁴R⁵ and R³ is hydrogen or (b) R³ is NHR⁴, NR⁴R⁵ or OH and R¹ is hydrogen;

5 R² is hydrogen or C₁₋₄ lower alkyl;

 R⁴ is hydrogen, hydroxyl or C₁₋₄ lower alkyl; and

 R⁵ is C₁₋₄ lower alkyl;

provided that R¹ and R² cannot both be hydrogen when R³ is N(CH₃)₂ or OH; or a pharmaceutically acceptable salt or hydrate thereof,
10 and its use as an anti-tumor agent.

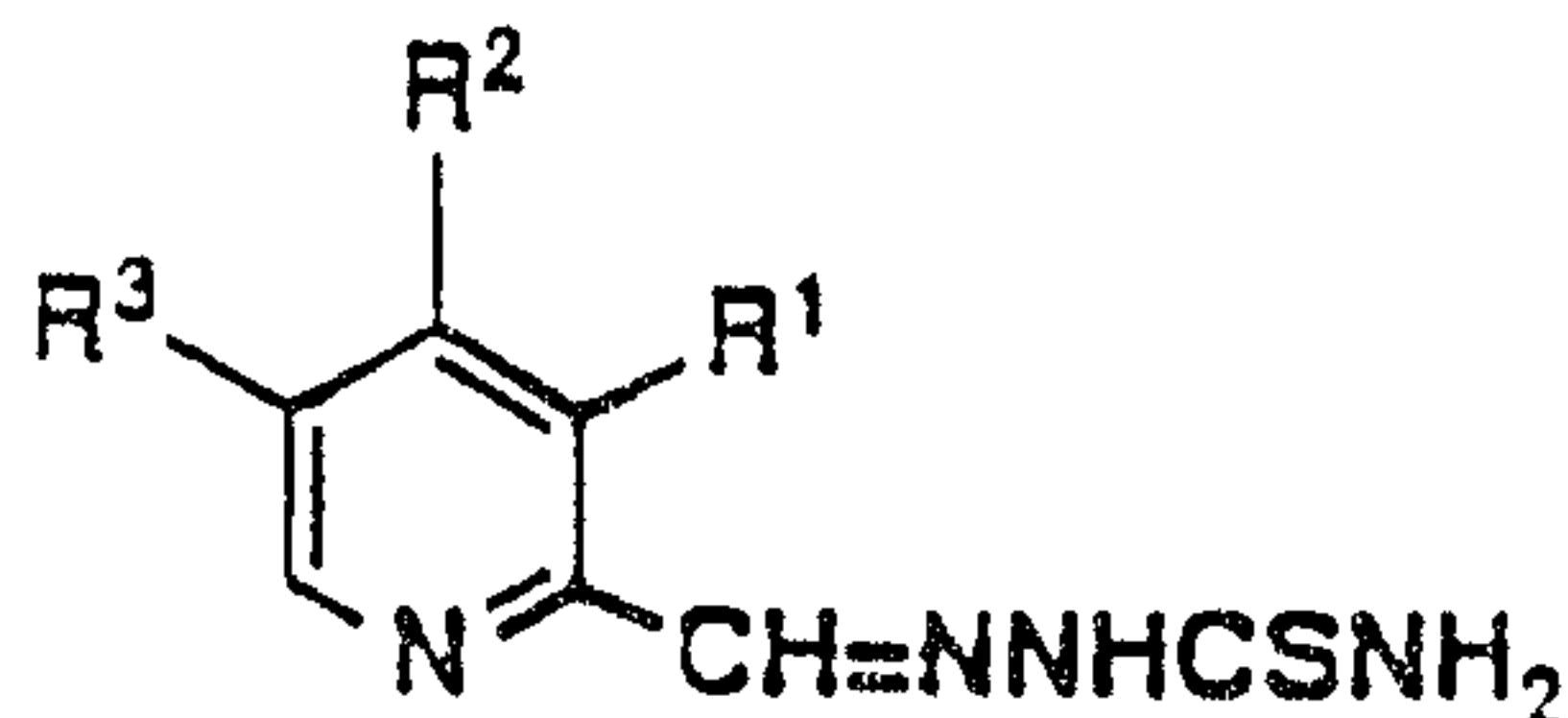
2-FORMYLPYRIDINE THIOSEMICARBAZONE ANTITUMOR AGENTS

Some aspects of the invention were supported in part by U.S. Public Health Service Grant CA-02817 from the National Cancer Institute and support from the Northeast NMR Facility at Yale University insofar as the use of high resolution NMR spectra is concerned that was made possible by a grant from the Chemical Division of the National Science Foundation (Grant No. CHE-7916210).

5-Hydroxy-2-formylpyridine thiosemicarbazone is a well known compound that has been proposed as an anti-neoplastic agent and has received a Phase I trial in cancer patients. This agent was not chose for further development. Representative literature includes DeConti et al., "Clinical and Pharmacological Studies with 5-Hydroxy-2-formylpyridine Thiosemicarbazone", *Cancer Res.*, **1972**, *32*, 1455-62. Similarly, 4-methyl-5-amino-1-formyl-isoquinoline thiosemicarbazone is also well known as manifested by Agrawal et al., "Potential Antitumor Agents. 13. 4-Methyl-5-amino-1-formylisoquinoline thiosemicarbazone", *J. Med. Chem.*, **1976**, *19*, 970-72. Subsequent to this research, others have tried a variety of compounds which may be considered to be analogs of 2-formylpyridine thiosemicarbazones, as shown by the numerous compounds which have been synthesized and tested by French et al., " α -(N)-Formylheteroaromatic Thiosemicarbazones. * * *", *J. Med. Chem.*, **1974**, *17*, 172-81. Among the various compounds reported by French et al. in Table I (page 174) may be mentioned 5-acetylamino-2-formylpyridine thiosemicarbazone (compound 49). A variety of compounds were synthesized with 4-position substitutions, as reported by Agrawal et al., "Potential Antitumor Agents. 14. 4-Substituted 2-Formylpyridine Thiosemicarbazones", *J. Med. Chem.*, **1976**, *19*, 1209-14. This Agrawal et al. research reports on compounds which include 4-dimethylamino-2-formylpyridine thiosemicarbazone (page 1210, compound 5) and 4-piperidino-2-formylpyridine thiosemicarbazone (id., compound 20), 4-pyrrolidinoamino-2-formylpyridine thiosemicarbazone (page 1211, compound 28), 4-

bis(hydroxyethyl)amino-2-formylpyridine thiosemicarbazone (id., compound 30) and structurally more remote forms; in no case is there a disclosure of a 2-formylpyridine thiosemicarbazone in this research of Agrawal et al. that has both one of the 4-
5 position substituents and any substituent on the ring other than one example with a 3-methyl group (id., compound 37). French et al. have also made attempts to work in the field with 4-substitution. French et al. disclose only one compound which may be considered to be a (3 or 5)-substituted-4-methyl-2-
10 formylpyridine thiosemicarbazone, i.e., the 3-species, 3-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone, which is compound 51 and which is found to lack "significant activity." Most of the compounds among the 61 tabulated 2-formylpyridine thiosemicarbazones are indicated as possessing "significant
15 activity," which is designated by an asterisk, as explained on page 175. An isomeric form is disclosed, namely, 3-hydroxy-6-methyl-2-formylpyridine thiosemicarbazone, which is compound 52 and which is also found to lack "significant activity."

In accordance with a first aspect of the invention there are
20 provided compounds of the formula:



wherein either (a) R^1 is NHR^4 or NR^4R^5 and R^3 is hydrogen or (b) R^3 is NHR^4 , NR^4R^5 or OH and R^1 is hydrogen;

R^2 is hydrogen or C_{1-4} lower alkyl;

R^4 is hydrogen, hydroxyl or C_{1-4} lower alkyl; and

5 R^5 is C_{1-4} lower alkyl;

provided that R^1 and R^2 cannot both be hydrogen when R^3 is $N(CH_3)_2$ or OH; or a pharmaceutically acceptable salt or hydrate thereof.

The term " C_{1-4} lower alkyl" refers to alkyl groups of up to four carbon atoms, methyl, ethyl, propyl and butyl; in accordance with
10 a preferred embodiment, C_{1-4} lower alkyl represents methyl.

In one embodiment there are provided compounds wherein R^4 is hydrogen. In a further embodiment there are provided compounds wherein R^2 is hydrogen. In a further embodiment there are provided compounds wherein R^2 is lower alkyl preferably methyl.

15 In accordance with a preferred embodiment, R^4 is hydrogen, i.e., the compounds are 3- and 5-amino-2-formylpyridine thiosemicarbazones. The compounds may be free from further substituents in accordance with one embodiment, i.e., R^2 is hydrogen, or in a second and also preferred embodiment the
20 compounds of the invention are 3- and 5-amino-4-methyl-2-formylpyridine thiosemicarbazones, i.e., R^2 is methyl.

Representative compounds of the invention include 3-amino-2-formylpyridine thiosemicarbazone, 5-amino-2-formylpyridine thiosemicarbazone, 3-amino-4-methyl-2-formylpyridine
25 thiosemicarbazone, 5-amino-4-methyl-2-formylpyridine thiosemicarbazone, and 5-hydroxyamino-4-methyl-2-formylpyridine thiosemicarbazone. It is to be understood that any compound of the invention above or any other aspect should be understood as contemplating any pharmaceutically acceptable salts or hydrates
30 thereof.

A method is provided for the treatment of tumors in mammals, e.g., cats, dogs, rats, mice, monkey and man. All of the compounds of the aforementioned first aspect of the invention are specifically considered to be useful in the treatment of tumors.

For example, all compounds of the first aspect of the invention are useful in the treatment of the L1210 leukemia in mice. Dosages that are contemplated within the scope of the invention are from about 40 to about 100 mg/kg/day.

5 In accordance with a second aspect of the invention there is provided a method for the treatment of tumors in mammals, e.g., cats, dogs, rats, mice, monkey and man, which comprises administration of the compounds 3-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone or 5-hydroxy-4-methyl-2-
10 formylpyridine thiosemicarbazone. For example, among tumors which may be treated in accordance with the second aspect of the invention may be mentioned the treatment of the L1210 leukemia in mice. Dosages that are contemplated within the scope of the invention are from about 4 to about 600 mg/kg/day. As part of
15 this second aspect of the invention there is also provided the novel compound 5-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone.

 The synthesis of the compounds of the first aspect of the invention is described in greater detail in the examples which
20 follow. In general terms, there is first described the synthesis of various 3-amino, 5-amino- and 5-nitro-substituted 2-formylpyridine thiosemicarbazones. Oxidation of 3-nitro-, 5-nitro-, 3-nitro-4-methyl- and 5-nitro-4-methyl-2-picolines with selenium dioxide in refluxing dioxane yielded the corresponding
25 2-formylpyridines. To reduce the nitro groups to amino functions, the aldehydes were protected by conversion to the cyclic ethylene acetals, which were then reduced by catalytic hydrogenation using Pd/C as a catalyst to give the corresponding amino acetals. The resulting compounds were then reacted with
30 thiosemicarbazide in ethanol containing 10% concentrated hydrochloric acid to form the desired thiosemicarbazone hydrochlorides; the free bases were liberated by treatment with aqueous sodium bicarbonate solution. Condensation of 5-nitro-2-formylpyridine and 5-nitro-4-methyl-2-formylpyridine, with
35 thiosemicarbazide in the presence of hydrochloric acid, followed

by treatment with sodium bicarbonate, yielded the corresponding 5-nitro-substituted thiosemicarbazones.

The acetamide and alkylsulfonamide derivatives of 3-amino- and 5-amino-2-formylpyridine thiosemicarbazone were prepared.

5 Acetylation with acetic anhydride in anhydrous pyridine gave
acetamide derivatives which were then condensed with
thiosemicarbazide to produce 5-acetylamino-2-formylpyridine
thiosemicarbazone and 3- and 5-acetylamino-4-methyl-2-
formylpyridine thiosemicarbazones. During the process of acidic
10 hydrolysis of the ethylene acetal groups, some hydrolysis of the
acetamide functions occurred even though reaction conditions were
carefully controlled. The desired pure compounds were obtained
by recrystallization from ethanol or by silica gel
chromatography. Treatment of 2-(1,3-dioxolanyl)-4-methyl-5-
15 aminopyridine with methanesulfonyl chloride or p-toluenesulfonyl
chloride in anhydrous pyridine afforded the corresponding 5-
methanesulfonylamino and p-toluenesulfonylamino derivatives, 2-
(1,3-dioxolanyl)-4-methyl-5-methanesulfonylamino-2-formylpyridine
thiosemicarbazone and 2-(1,3-dioxolanyl)-4-methyl-5-p-toluenesulfonylaminopyridine,
20 respectively, which were then treated with thiosemicarbazide in
the presence of concentrated hydrochloric acid to afford the
corresponding 5-methanesulfonylamino- and 5-p-
toluenesulfonylamino-4-methyl-2-formylpyridine
thiosemicarbazones, 5-methanesulfonylamino-4-methyl-2-
25 formylpyridine thiosemicarbazone and 5-toluenesulfonylamino-4-
methyl-2-formylpyridine thiosemicarbazone.

5-Hydroxyamino-4-methyl-2-formylpyridine thiosemicarbazone was synthesized by hydrogenation of 2-(1,3-dioxolanyl)-4-methyl-5-nitropyridine in ethanol using $\text{Pd}(\text{OH})_2/\text{C}$ as a catalyst under 50 psi of hydrogen to yield the 5-hydroxyamino derivative contaminated with about 10-15% of the corresponding 5-amino derivative. 2-(1,3-Dioxolanyl)-4-methyl-5-hydroxyaminopyridine was easily purified by recrystallization from ethanol. The structure was assigned by NMR, mass spectroscopy and elemental analysis. During the reduction process, the rate of absorption

of hydrogen decreased considerably after the formation of the 5-hydroxyamino derivative, 2-(1,3-dioxolanyl)-4-methyl-5-hydroxyaminopyridine, and the reaction was terminated at this stage. When the reaction was allowed to proceed until the absorption of hydrogen was complete (about 24 h), however, the 5-aminoderivative, 2-(1,3-dioxolanyl)-4-methyl-5-aminopyridine, was obtained in nearly quantitative yield.

Condensation of 2-(1,3-dioxolanyl)-4-methyl-5-hydroxyaminopyridine with thiosemicarbazide in the presence of concentrated hydrochloric acid, followed by treatment with sodium bicarbonate afforded the desired 5-hydroxyamino-4-methyl-2-formylpyridine thiosemicarbazone.

Melting points were determined with a Thomas-Hoover Unimelt apparatus and are uncorrected. ¹H NMR spectra were recorded on a Varian EM-390 90 MHz NMR spectrometer or a Bruker WM-500 500 MHz spectrometer with Me₄Si as the internal reference. The mass spectra (at 70 eV) were provided by the Yale University Chemical Instrumentation Center. TLC was performed on EM precoated silica gel sheets containing a fluorescent indicator. Elemental analyses were carried out by the Baron Consulting Co., Orange, CT. Where analyses are indicated only by symbols of the elements, the analytical results for those elements were within $\pm 0.4\%$ of the theoretical value.

Use of the compound of the present invention is preferably carried out when the compound is in a pharmaceutically acceptable salt form. Acceptable salts include, for example, inorganic acid salts such as hydrochloride and hydrobromide, organic salts such as acetate, tartrate, citrate, fumarate, maleate, toluenesulfonate, methanesulfonate, ethanesulfonate, hydroxymethanesulfonate, and hydroxyethanesulfonate, metal salts such as sodium salt, potassium salt, calcium salt, and aluminum salt, and salts with a base such as triethylamine salt, guanidine salt, ammonium salt, hydrazine salt, quinine salt, and cinchonine salt. The salts are made using procedures that will be readily

apparent to those skilled in the art. Hydrates, which are also contemplated within the scope of the presently claimed invention, can be formulated using principles well known to those of ordinary skill in the art.

5 The presently claimed invention can be formulated as a pharmaceutical composition in accordance with procedures that will be readily apparent to those of ordinary skill in the art. Preferred pharmaceutical compositions are, for example, tablets, including lozenges and granules, caplets, dragées, pills, gelatin
10 capsules, ampuls, and suppositories comprising the active ingredient together with a) diluents, e.g., lactose, dextrose, sucrose, mannitol, sorbitol, cellulose and/or glycine; b) lubricants, e.g., silica, talcum, stearic acid, its magnesium or calcium salt and/or polyethyleneglycol; for tablets also
15 c) binders, e.g., magnesium aluminum silicate, starch paste, gelatin, tragacanth, methylcellulose, sodium carboxymethylcellulose and/or polyvinylpyrrolidone; if desired d) disintegrants, e.g., starches, agar, alginic acid or its sodium salt, or effervescent mixtures; and/or e) absorbents,
20 colorants, flavors and sweeteners. Injectable compositions are preferably aqueous isotonic solutions or suspensions, and suppositories are advantageously prepared from fatty emulsions or suspensions. Said compositions may be sterilized and/or contain adjuvants, such as preserving, stabilizing, wetting or
25 emulsifying agents, solution promoters, salts for regulating the osmotic pressure and/or buffers. In addition, they may also contain other therapeutically valuable substances. Said compositions are prepared according to conventional mixing, granulating or coating methods, respectively, and contain about
30 0.1 to 75%, preferably about 1 to 50%, of the active ingredient.

Suitable formulations for transdermal application include an effective amount of a compound of the invention with a carrier. Advantageous carriers include absorbable pharmacologically acceptable solvents to assist passage through
35 the skin of the host. Characteristically, transdermal devices are in the form of a bandage comprising a backing member, a

reservoir containing the compound optionally with carriers, optionally a rate controlling barrier to deliver the compound to the skin of the host at a controlled and predetermined rate over a prolonged period of time, and means to secure the device to the skin.

The following examples serve to further illustrate the invention.

EXAMPLE I

A mixture of 3-nitropyridine (1.3 g, 9.4 mmol) and selenium dioxide (1.1 g, 9.4 mmol) in 1,4-dioxane (30 mL), containing 0.8 mL of water, was refluxed under an atmosphere of nitrogen for 20 h. The reaction mixture was cooled and filtered to remove the precipitated black selenium. The filtrate was evaporated in vacuo to dryness and the residue was chromatographed on a silica gel column (CH_2Cl_2 , R_f 0.82) to afford 0.32 g (23%) of white crystals of 3-nitropyridine-2-carboxaldehyde: mp 61-62°C (lit. 63°C); ^1H NMR (90 MHz, CDCl_3) δ 7.65 (d, 1H, 5-H, $J_{4,5} = 6.0$ Hz, $J_{5,6} = 4.5$ Hz), 8.32 (d, 1H, 4-H, $J_{4,5} = 6.0$ Hz), 9.05 (d, 1H, 6-H, $J_{5,6} = 4.5$ Hz), 10.31 (s, 1H, 2-CHO).

EXAMPLE II

5-Nitropyridine-2-carboxaldehyde was prepared from the nitro derivative, 2-methyl-3-nitropyridine, by the procedure employed for the synthesis of Example I, except that anhydrous dioxane was used as the solvent and the reaction time was 4 h. Yield: 2.0 g (42%); mp 66-67°C (lit. 66.5-67.5°C); TLC, R_f 0.85 (EtOAc); ^1H NMR (90 MHz, CDCl_3) δ 8.0 (d, 1H, 3-H, $J_{3,4} = 4.5$ Hz), 8.30 (d, 1H, 4-H, $J_{3,4} = 4.5$ Hz), 9.25 (s, 1H, 6-H), 10.45 (s, 1H, 2-CHO).

EXAMPLE III

A mixture of 3-nitropyridine-2-carboxaldehyde (1.50 g, 9.70 mmol), ethylene glycol (7 g, 62 mmol) and p-toluenesulfonic acid monohydrate (60 mg, 0.24 mmol) in toluene (150 mL) was refluxed until the starting material was no longer observed by TLC (CH₂Cl₂/EtOAc, 4:1, v/v). The reaction mixture was cooled and washed with aqueous sodium bicarbonate solution, water, and brine. The organic layer was dried over MgSO₄. The filtrate was evaporated in vacuo to dryness and the residue was chromatographed on a silica gel (120 g) column (CH₂Cl₂/EtOAc, 4:1, v/v, R_f 0.50). The product was 2-(1,3-dioxylanyl)-3-nitropyridine, obtained as almost colorless needles (1.65 g, 87%): mp 65-67°C; ¹H NMR (90 MHz, CDCl₃) δ 4.15 (s, 4H, CH₂CH₂), 6.52 (s, 1H, 2-CH), 7.52 (m, 1H, 5-H), 8.15 (dd, 1H, 4-H, J_{4,6} = 1 Hz), 8.85 (dd, 1H, 6-H, J_{5,6} = 4 Hz, J_{4,6} = 1 Hz). Anal. (C₈H₈N₂O₄) C, H, N.

EXAMPLE IV

2-(1,3-Dioxolanyl)-5-nitropyridine was prepared from 5-nitropyridine-2-carboxaldehyde by the procedure employed for the synthesis of Example III. Yield: 2.0 g (84%); mp 104-105°C; TLC R_f 0.73 (CH₂Cl₂/EtOAc, 1:1, v/v); ¹H NMR (90 MHz, CDCl₃) δ 4.10 (s, 4H, CH₂CH₂), 5.92 (s, 1H, 2-CH), 7.72 (d, 1H, 3-H, J_{3,4} = 8 Hz), 8.50 (dd, 1H, 4-H, J_{3,4} = 8 Hz, J_{4,6} = 2 Hz), 9.42 (d, 1H, 6-H, J_{4,6} = 2 Hz). Anal. (C₈H₈N₂O₄) C, H, N.

EXAMPLE V

A solution of 2-(1,3-dioxolanyl)-3-nitropyridine (1.00 g, 5.1 mmol) in ethanol (100 mL) was hydrogenated overnight in a Parr apparatus at 50 psi of hydrogen in the presence of 10% Pd/C (0.1 g). The reaction mixture was filtered through a Celite-pat and the catalyst was washed with ethanol. The combined filtrate and washings were evaporated in vacuo to dryness and co-evaporated with benzene. The resulting solid was recrystallized

from benzene to afford 0.81 g (96%) of product, 2-(1,3-dioxolanyl)-3-aminopyridine, as white crystals: mp 73-74°C; TLC R_f 0.4 (EtOAc); ^1H NMR (90 MHz, CDCl_3) δ 4.10 (m, 4H, CH_2CH_2), 4.15 (br s, 2H, 3- NH_2 , D_2O exchangeable), 5.80 (s, 1H, 2-CH), 6.90 (m, 2H, 4-H and 6-H), 7.95 (dd, 1H, 5-H). Anal. ($\text{C}_8\text{H}_{10}\text{N}_2\text{O}_2 \cdot 0.1\text{H}_2\text{O}$) C, H, N.

EXAMPLE VI

2-(1,3-Dioxolanyl)-5-aminopyridine was prepared from 2-(1,3-dioxolanyl)-5-nitropyridine by the procedure employed in Example V. Yield: 2.6 g (93%); mp 81-82°C; TLC R_f 0.18 (EtOAc); ^1H NMR (90 MHz, CDCl_3) δ 3.85 (br s, 2H, 5- NH_2 , D_2O exchangeable), 4.05 (m, 4H, CH_2CH_2), 5.72 (s, 1H, 2-CH), 6.95 (dd, 1H, 4-H, $J_{3,4} = 8$ Hz, $J_{4,6} = 2$ Hz), 7.30 (d, 1H, 3-H, $J_{3,4} = 8$ Hz) 8.08 (d, 1H, 6-H, $J_{4,6} = 2$ Hz). Anal. ($\text{C}_8\text{H}_{10}\text{N}_2\text{O}_2$) C, H, N.

EXAMPLE VII

To a solution of 2-(1,3-dioxolanyl)-3-aminopyridine (0.80 g, 4.8 mmol) in 10 mL of ethanol, 8 mL of water and 2 mL of concentrated hydrochloric acid was added 0.48 g (5.3 mmol) of thiosemicarbazide. The mixture was stirred at room temperature overnight and refluxed for 1 h, cooled and filtered. The crude yellow hydrochloride salt was dissolved in 50 mL of hot water and filtered. To the hot filtrate was added 10 mL of 5% sodium bicarbonate solution. The mixture was stirred at room temperature for 1 h, filtered and washed with water, followed by ethanol to yield 3-amino-2-formylpyridine thiosemicarbazone. Yield: 0.72 g (77%); mp 240-241°C dec; MS m/e 194 (M^+); ^1H NMR (90 MHz, $\text{DMSO}-d_6$) δ 6.48 (br s, 2H, 3- NH_2 , D_2O exchangeable), 7.12 (m, 2H, 4-H and 6-H), 7.83 (dd, 1H, 5-H), 8.10 (br s, 2H, CSNH_2 , D_2O exchangeable), 8.10 (s, 1H, 2-CH), 10.95 (s, 1H, NNH , D_2O exchangeable). Anal. ($\text{C}_7\text{H}_9\text{N}_5\text{S}$) C, H, N.

EXAMPLE VIII

5-Amino-2-formylpyridine thiosemicarbazone was prepared from 2-(1,3-dioxolanyl)-5-aminopyridine by the procedure employed for the synthesis of Example VII. Yield: 1.9 g (82%); mp 205-207°C; MS m/e 194 (M^+); ^1H NMR (DMSO- d_6 , 500 MHz) δ 5.60 (br s, 2H, 3-NH₂, D₂O exchangeable), 6.95 (dd, 1H, 4-H, $J_{3,4}$ = 8 Hz, $J_{4,6}$ = 1.5 Hz), 7.65 (s, 1H, 2-CH), 7.75 (d, 1H, 6-H, $J_{4,6}$ = 1.5 Hz), 7.90 (d, 1H, 3-H, $J_{3,4}$ = 8 Hz), 7.85 and 8.10 (two br s, 2H, CSNH₂, D₂O exchangeable), 11.05 (s, 1H, NNH, D₂O exchangeable). Anal. (C₇H₉N₅S·0.4H₂O) C, H, N.

EXAMPLE IX

3-Amino-4-methyl-2-formylpyridine thiosemicarbazone was prepared from 2-(1,3-dioxolanyl)-4-methyl-3-aminopyridine by the procedure employed for the synthesis of Example VII. Yield: 0.5 g (76%); mp 227-228°C; MS m/e 208 (M^+); ^1H NMR (500 MHz, DMSO- d_6) δ 2.25 (s, 3H, 4-CH₃), 6.18 (s, 2H, 3-NH₂, D₂O exchangeable), 7.01 (d, 1H, 5-H, $J_{5,6}$ = 6 Hz), 7.78 (d, 1H, 6-H, $J_{5,6}$ = 6 Hz), 7.90 (s, 2H, CSNH₂, D₂O exchangeable), 8.32 (s, 1H, 2-CH), 11.31 (s, 1H, NNH, D₂O exchangeable). Anal. (C₈H₁₁N₅S·HCl·H₂O) C, H, N.

EXAMPLE X

5-Amino-4-methyl-2-formylpyridine thiosemicarbazone was prepared from 2-(1,3-dioxolanyl)-4-methyl-5-aminopyridine by the procedure employed for the synthesis of Example VII. Yield: 0.64 g (78%); mp 235-236°C; MS m/e 208 (M^+); ^1H NMR (500 MHz, DMSO- d_6) δ 2.10 (s, 3H, 4-CH₃), 5.48 (s, 2H, 5-NH₂, D₂O exchangeable), 7.80 (s, 2H, CSNH₂, D₂O exchangeable), 7.80 (s, 1H, 3-H), 7.95 (s, 1H, 6-H), 8.00 (s, 1H, 2-CH), 11.50 (s, 1H, NNH, D₂O exchangeable). Anal. (C₈H₁₁N₅S·HCl·H₂O) C, H, N.

EXAMPLE XI

A mixture of 5-nitropyridine-2-carboxaldehyde (0.50 g, 3.3 mmol) and thiosemicarbazide (0.36 g, 4 mmol) in 20 mL of 70% aqueous ethanol solution was refluxed for 2 h, cooled and filtered. The yellow precipitate that formed was washed with water and recrystallized from ethanol to give 0.54 g (73%) of product, 5-nitro-2-formylpyridine thiosemicarbazone: mp 215-217°C; ¹H NMR (90 MHz, DMSO-d₆) δ 8.25 (d, 1H, 3-H), 8.35 and 8.55 (two br s, 2H, CSNH₂, D₂O exchangeable), 8.90 (dd, 1H, 4-H), 9.75 (d, 1H, 6-H), 10.15 (s, 1H, 2-CH), 11.95 (s, 1H, NNH, D₂O exchangeable). Anal. (C₇H₇N₅O₂S) C, H, N.

EXAMPLE XII

5-Nitro-4-methyl-2-formylpyridine thiosemicarbazone was prepared from 4-methyl-5-nitropyridine-2-carboxaldehyde by the procedure employed for the synthesis of Example XI. Yield: 0.38 g (88%); mp 220-222°C; ¹H NMR (90 MHz, DMSO-d₆) δ 2.55 (s, 3H, 4-CH₃), 8.12 (s, 1H, 3-H), 8.30 and 8.50 (two br s, 2H, CSNH₂, D₂O exchangeable), 9.15 (s, 1H, 6-H), 9.45 (s, 1H, 2-CH), 11.85 (s, 1H, NNH, D₂O exchangeable). Anal. (C₈H₉N₅O₂S) C, H, N.

EXAMPLE XIII

To a stirred solution of 2-(1,3-dioxolanyl)-5-aminopyridine (2.0 g, 12 mmol) in 15 mL of anhydrous pyridine in an ice bath was added dropwise 2 mL of acetic anhydride at 0.5°C. The reaction mixture was stirred overnight and evaporated in vacuo to dryness. The residue was co-evaporated with ethanol (10 mL) and recrystallized from ethanol to yield 2.1 g (82%) of product, 2-(1,3-dioxolanyl)-5-acetylamino-5-pyridine: mp 145-147°C; ¹H NMR (90 MHz, CDCl₃) δ 2.05 (s, 3H, CH₃), 4.10 (m, 4H, CH₂CH₂), 5.82 (s, 1H, 2-CH), 7.10 (dd, 1H, 4-H, J_{3,4} = 8 Hz, J_{4,6} = 2 Hz), 7.45 (d, 1H, 3-H, J_{3,4} = 8 Hz), 8.40 (br s, 1H, NH, D₂O exchangeable), 8.68 (d, 1H, 6-H, J_{4,6} = 2 Hz). Anal. (C₁₀H₁₂N₂O₃) C, H, N.

EXAMPLE XIV

A mixture of 2-(1,3-dioxolanyl)-4-methyl-3-aminopyridine (500 mg, 2.78 mmol), 5 mL of acetic anhydride and 15 mL of anhydrous pyridine was refluxed overnight and evaporated in vacuo to dryness. The residue was dissolved in CH₂CH₂ (30 mL), washed with 10% sodium bicarbonate, brine, and water, then dried (anhydrous MgSO₄). The solvent was removed and the residue was purified on a silica gel column (CH₂Cl₂/CH₃OH, 10:1, v/v, R_f 0.67) to produce 440 mg (72%) of product, 2-(1,3-dioxolanyl)-4-methyl-3-acetylaminopyridine: mp 77-79°C, ¹H NMR (90 MHz, CDCl₃) δ 2.10 (s, 3H, COCH₃), 2.17 (s, 3H, 4-CH₃), 2.20 (br s, 1H, NH, D₂O exchangeable), 3.95 (m, 4H, CH₂CH₂), 5.70 (s, 1H, 2-CH), 7.15 (d, 1H, 5-H, J_{5,6} = 6 Hz), 8.42 (d, 1H, 6-H, J_{5,6} = 6 Hz). Anal. (C₁₁H₁₄N₂O₃) C, H, N.

EXAMPLE XV

2-(1,3-Dioxolanyl)-4-methyl-5-acetylaminopyridine was prepared from 2-(1,3-dioxolanyl)-4-methyl-5-aminopyridine by the procedure employed for the synthesis of Example XIV. Yield: 0.5 g (82%); mp 98-99°C; TLC, R_f 0.65 (CH₂Cl₂/EtOH, 10:1, v/v); ¹H NMR (90 MHz, CDCl₃) δ 2.08 (s, 3H, COCH₃), 2.15 (s, 3H, 4-CH₃), 4.05 (m, 4H, CH₂CH₂), 5.72 (s, 1H, 2-CH), 7.30 (s, 1H, 3-H), 8.05 (br s, 1H, NH, D₂O exchangeable), 8.58 (s, 1H, 6-H). Anal. (C₁₁H₁₄N₂O₃) C, H, N.

EXAMPLE XVI

A mixture of 2-(1,3-dioxolanyl)-5-acetylaminopyridine (0.60 g, 3.6 mmol), thiosemicarbazide (0.40 g, 4.4 mmol), 1 mL of glacial acetic acid and 10 mL of ethanol was heated with stirring at 50°C for 6 h, cooled and filtered. The acetic acid salt was dissolved in hot water, filtered into 15 mL of 5% sodium bicarbonate solution and the mixture was stirred at room temperature for 1 h. The yellow precipitate that formed was filtered, washed with water, and recrystallized from ethanol

twice to give 0.46 g (54%) of product, 5-acetylamino-2-formylpyridine thiosemicarbazone: mp 215-217°C; ¹H NMR (90 MHz, DMSO-d₆) δ 2.05 (s, 3H, COCH₃), 8.00 (m, 3H, 2-CH, 3-H and 4-H), 8.05 and 8.15 (two br s, 2H, CSNH₂, D₂O exchangeable), 8.80 (d, 1H, 6-H, J_{4,6} = 1.5 Hz), 10.30 (s, 1H, 5-NH, D₂O exchangeable), 11.30 (s, 1H, NNH, D₂O exchangeable). Anal. (C₉H₁₁N₅OS) C, H, N.

EXAMPLE XVII

A mixture of 2-(1,3-dioxolanyl)-4-methyl-3-acetylamino-5-pyridine (0.41 g, 1.9 mmol), thiosemicarbazone (0.2 g, 2.2 mmol), 1 mL of concentrated hydrochloric acid and 10 mL of ethanol was stirred at room temperature overnight. The yellow precipitate (hydrochloride salt) that formed was filtered and washed with water, followed by ethanol. The hydrochloride salt was dissolved in hot water and stirred with 10 mL of 5% sodium bicarbonate solution for 1 h, filtered, and washed with water. The crude product was chromatographed on a silica gel column (CH₂Cl₂/CH₃OH, 4:1, v/v, R_f 0.52) to give 0.21 g (45%) of product, 3-acetylamino-4-methyl-2-formylpyridine thiosemicarbazone: mp 225-227°C; ¹H NMR (90 MHz, DMSO-d₆) δ 2.05 (s, 3H, COCH₃), 2.18 (s, 3H, 4-CH₃), 7.30 (d, 1H, 5-H, J_{5,6} = 6 Hz), 8.14 (d, 1H, 2-CH), 7.90 and 8.30 (two br s, 2H, CSNH₂, D₂O exchangeable), 8.35 (d, 1H, 6-H, J_{5,6} = 6 Hz), 9.71 (s, 1H, 3-NH, D₂O exchangeable), 11.53 (s, 1H, NNH, D₂O exchangeable). Anal. (C₁₀H₁₃N₅OS) C, H, N.

EXAMPLE XVIII

5-Acetylamino-4-methyl-2-formylpyridine thiosemicarbazone was prepared from 2-(1,3-dioxolanyl)-4-methyl-5-acetylamino-5-pyridine by the procedure employed for the synthesis of Example XVII. Yield: 0.42 g (76%); mp 229-231°C; TLC, R_f 0.52 (CH₂Cl₂/CH₃OH, 4:1, v/v); ¹H NMR (90 MHz, DMSO-d₆) δ 2.10 (s, 3H, COCH₃), 2.25 (s, 3H, 4-CH₃), 7.90 (s, 1H, 3-H), 8.05 (s, 1H, 2-CH), 8.05 and 8.35 (two br s, 2H, CSNH₂, D₂O exchangeable),

8.60 (s, 1H, 6-H), 9.62 (s, 1H, 5-NH, D₂O exchangeable), 11.60 (s, 1H, NNH, D₂O exchangeable). Anal. (C₁₀H₁₃N₅OS) C, H, N.

EXAMPLE XIX

To a stirred solution of 2-(1,3-dioxolanyl)-4-methyl-5-aminopyridine (0.8 g, 4.4 mmol) in 10 mL of anhydrous pyridine in an ice bath was added dropwise 0.6 g (5.3 mmol) of methanesulfonyl chloride at 0-5°C. The mixture was stirred at room temperature overnight and evaporated in vacuo to dryness. The residue was co-evaporated with toluene (10 mL) and then partitioned between CH₂CH₂ (30 mL) and water (10 mL). The organic layer was washed with 10% sodium bicarbonate, brine and water, dried with anhydrous MgSO₄, and filtered. The filtrate was concentrated to a small volume and purified on a silica gel column (EtOAc, R_f 0.40) to give 0.68 g of product, 2-(1,3-dioxolanyl)-4-methyl-5-methanesulfonylaminopyridine: mp 128-130°C; ¹H NMR (90 MHz, CDCl₃) δ 2.40 (s, 3H, 4-CH₃), 3.03 (s, 3H, CH₃SO), 4.12 (m, 4H, CH₂CH₂), 5.65 (s, 1H, 2-CH), 7.40 (s, 1H, 3-H), 8.10 (br s, 1H, NH, D₂O exchangeable), 8.52 (s, 1H, 6-H). Anal. (C₁₀H₁₄N₂O₄S) C, H, N.

EXAMPLE XX

2-(1,3-Dioxolanyl)-4-methyl-5-p-toluenesulfonylaminopyridine was prepared from 2-(1,3-dioxolanyl)-4-methyl-5-aminopyridine by a procedure similar to that employed in Example XIX. Yield: 0.75 g (77%); mp 155-156°C; ¹H NMR (90 MHz, CDCl₃) δ 2.05 (s, 3H, ArCH₃), 2.32 (s, 3H, 4-CH₃), 4.10 (m, 4H, CH₂CH₂), 5.70 (s, 1H, 2-CH), 6.50 (br s, 1H, NH, D₂O exchangeable), 7.20-7.40 (m, 5H, ArH and 3-H), 8.20 (s, 1H, 6-H). Anal. (C₁₆H₁₈N₂O₄S) C, H, N.

EXAMPLE XXI

A mixture of 2-(1,3-dioxolanyl)-4-methyl-5-methanesulfonylaminopyridine (0.93 g, 3.6 mmol), thiosemicarbazide (0.37 g, 4.0 mmol) and 10 mL of 5% hydrochloric acid

solution was heated with stirring at 60°C for 4 h and cooled. The yellow precipitate (hydrochloride salt) that formed was filtered and washed with a small amount of water. The hydrochloride salt was then stirred in 10 mL of 1 N NaOH solution for 30 min and filtered. The filtrate was neutralized with dilute acetic acid, filtered, washed with water followed by ethanol to give 0.65 g (63%) of product, 5-methanesulfonylamino-4-methyl-2-formylpyridine thiosemicarbazone: mp 210-212°C; ¹H NMR (90 MHz, DMSO-d₆) δ 2.35 (s, 3H, 4-CH₃), 3.05 (s, 3H, 4-CH₃SO), 8.05 (s, 1H, 3-H), 8.22 (s, 1H, 6-H), 8.30 (s, 1H, 2-CH), 8.15 and 8.35 (two br s, 2H, CSNH₂, D₂O exchangeable), 9.45 (br s, 1H, SO₂NH, D₂O exchangeable), 11.45 (s, 1H, NNH, D₂O exchangeable). Anal. (C₉H₁₃N₅O₂S₂·0.75 H₂O) C, H, N.

EXAMPLE XXII

5-Toluenesulfonylamino-4-methyl-2-formylpyridine thiosemicarbazone was prepared from 2-(1,3-dioxolanyl)-4-methyl-5-p-toluenesulfonylaminopyridine by the procedure employed for the synthesis of Example XXI. Yield: 0.43 g (80%); mp 234-236°C; ¹H NMR (90 MHz, DMSO-d₆) δ 2.12 (s, 3H, ArCH₃), 2.40 (s, 3H, 4-CH₃), 7.30-7.40 (m, 4H, ArH), 8.05 (s, 1H, 3-H), 8.20 (s, 1H, 6-H), 8.30 (s, 1H, 2-CH), 8.35 and 8.55 (two br s, 2H, CSNH₂, D₂O exchangeable), 9.40 (br s, 1H, SO₂NH, D₂O exchangeable), 11.55 (s, 1H, NNH, D₂O exchangeable). Anal. (C₁₅H₁₇N₅O₂S₂) C, H, N.

EXAMPLE XXIII

A solution of 2-(1,3-dioxolanyl)-4-methyl-5-nitropyridine (1.8 g, 8.6 mmol) in ethanol (100 mL) was hydrogenated for 2 h in a Parr apparatus at 50 psi of hydrogen in the presence of 20% Pd(OH)₂/C (0.2 g). The reaction mixture was filtered through a Celite-pat and the catalyst was washed with ethanol. The combined filtrate and washings were evaporated in vacuo to dryness. The residue was recrystallized from ethanol twice to give 1.0 g (60%) of product: mp 180-181°C as white crystals of 2-(1,3-dioxolanyl)-4-methyl-5-hydroxyaminopyridine; MS m/e 167

($M^+ + 1$); ^1H NMR (500 MHz, $\text{DMSO}-d_6$) δ 2.08 (s, 3H, 4- CH_3), 3.90-4.05 (m, 4H, CH_2CH_2), 5.54 (s, 1H, 2-CH), 7.13 (s, 1H, 3-H), 8.18 (s, 1H, 6-H), 8.29 (s, 1H, NH, D_2O exchangeable), 8.45 (s, 1H, OH, D_2O exchangeable). Anal. ($\text{C}_9\text{H}_{12}\text{N}_2\text{O}_3$) C, H, N.

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EXAMPLE XXIV

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5-Hydroxyamino-4-methyl-2-formylpyridine thiosemicarbazone was prepared from 2-(1,3-dioxolanyl)-4-methyl-5-hydroxyaminopyridine by the procedure employed for the synthesis of Example VII. Yield: 0.45 g (77%); mp 197-198°C; MS m/e 224 (M^+); ^1H NMR (90 MHz, $\text{DMSO}-d_6$) δ 2.35 (s, 3H, 4- CH_3), 8.12 (m, 3H, 3-H, 6-H and 2-CH), 8.55 and 8.75 (two br s, 2H, CSNH_2 , D_2O exchangeable), 9.15 (br s, 2H, HONH , D_2O exchangeable), 12.10 (s, 1H, NNH , D_2O exchangeable). Anal. ($\text{C}_8\text{H}_{11}\text{N}_5\text{OS}$) C, H, N.

15

The following discussion relates to the biological activities of the compounds of the first aspect of the invention represented by the experimental work of Examples I-XXIV.

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The tumor-inhibitory properties of the substituted 2-formylpyridine thiosemicarbazones were determined by measuring their effects on the survival time of mice bearing the L1210 leukemia.

EXAMPLE XXV

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5-Hydroxy-2-formylpyridine thiosemicarbazone was used as a standard for comparison with the compounds of the invention which are tested in the following examples. The 5-hydroxy-2-formylpyridine thiosemicarbazone was administered by intraperitoneal injection, beginning 24 hours after tumor implantation with the maximum effective daily dosage being 40 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. (The number of mice tested was in the amount of 5-10 per dosage level). The average percentage change in body weight from onset

to termination of the therapy was +2.0. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, which was determined to be 133.

5 It is noted that while a value of 133 was obtained, in reports by French et al., supra, a value of 268 was reported. The difference may be due to the L1210 leukemia cell lines employed or differences in the schedule of drug administration. Although the compound was administered by intraperitoneal injection starting 24 h after tumor inoculation both in this
10 Example and in the French et al. study, the present Example employed six daily treatments, while French et al. used daily treatments, continued until half the test animals were dead.

EXAMPLE XXVI

15 3-Amino-2-formylpyridine thiosemicarbazone was administered by intraperitoneal injection to mice bearing the L1210 leukemia, beginning 24 hours after tumor implantation, with the maximum effective daily dosage being 40 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. (The number of mice tested was in the amount
20 of 5-10 per dosage level). The average percentage change in body weight from onset to termination of the therapy was -5.9. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 187, which compares favorably with the value for the reference
25 standard used in the test in Example XXV, 5-hydroxy-2-formylpyridine thiosemicarbazone, which has a value of 133.

EXAMPLE XXVII

30 5-Amino-2-formylpyridine thiosemicarbazone was administered by intraperitoneal injection to mice bearing the L1210 leukemia, beginning 24 hours after tumor implantation, with the maximum effective daily dosage being 20 mg/kg. Administration was once per day for a total of six consecutive days to a representative

sample population. (The number of mice tested was in the amount of 5-10 per dosage level). The average percentage change in body weight from onset to termination of the therapy was -2.8. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 140, which compares favorably with the value for the reference standard used in the test in Example XXV, 5-hydroxy-2-formylpyridine thiosemicarbazone, which has a value of 133.

EXAMPLE XXVIII

3-Amino-4-methyl-2-formylpyridine thiosemicarbazone was administered by intraperitoneal injection to mice bearing the L1210 leukemia, beginning 24 hours after tumor implantation, with the maximum effective daily dosage being 20 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. (The number of mice tested was in the amount of 5-10 per dosage level). The average percentage change in body weight from onset to termination of the therapy was -2.8. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 190, which compares favorably with the value for the reference standard used in the test in Example XXV, 5-hydroxy-2-formylpyridine thiosemicarbazone, which has a value of 133.

EXAMPLE XXIX

5-Amino-4-methyl-2-formylpyridine thiosemicarbazone was administered by intraperitoneal injection to mice bearing the L1210 leukemia, beginning 24 hours after tumor implantation, with the maximum effective daily dosage being 20 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. (The number of mice tested was in the amount of 5-10 per dosage level). The average percentage change in body weight from onset to termination of the therapy was -7.0. A value $T/C \times 100$ is calculated, which is the

ratio of the survival time of treated to control animals x 100, and has a value of 138, which compares favorably with the value for the reference standard used in the test in Example XXV, 5-hydroxy-2-formylpyridine thiosemicarbazone, which has a value of 133.

EXAMPLE XXX

5-Hydroxyamino-4-methyl-2-formylpyridine thiosemicarbazone was administered by intraperitoneal injection to mice bearing the L1210 leukemia, beginning 24 hours after tumor implantation, with the maximum effective daily dosage being 10 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. (The number of mice tested was in the amount of 5-10 per dosage level). The average percentage change in body weight from onset to termination of the therapy was -2.7. A value T/C x 100 is calculated, which is the ratio of the survival time of treated to control animals x 100, and has a value of 136, which compares favorably with the value for the reference standard used in the test in Example XXV, 5-hydroxy-2-formylpyridine thiosemicarbazone, which has a value of 133.

The following examples relate to the second aspect of the invention:

EXAMPLES XXXI-XXXII

Fuming sulfuric acid (1500 g, 15.3 mol) was added slowly to 2,4-lutidine (165 mL, 1.43 mol) and cooled in an ice bath with stirring. Potassium nitrate (262.5 g, 2.60 mol) was then added slowly. The reaction mixture was gradually heated to 100°C and maintained at this temperature for 8 h. The reaction mixture was then heated at 120°C for an additional 8 h. After cooling to room temperature, the reaction mixture was poured onto ice (2.5 kg). The solution was neutralized to pH 7 using potassium carbonate and extracted with chloroform (3 x 4 L). The organic

layer was dried over anhydrous Na_2SO_4 and the solvent was evaporated; the remaining solution was distilled under reduced pressure. 3-Nitro-2,4-dimethylpyridine (41.71 g, 0.27 mol, 19%, 37°C/0.24 mm Hg), 5-nitro-2,4-dimethylpyridine (38.18 g, 0.25 mol, 18%, 44°C/0.17 mm Hg) and a mixture of 3- and 5-nitro-2,4-dimethylpyridine (13.74 g, 0.09 mol) were obtained. 3-Nitro-2,4-dimethylpyridine: ^1H NMR (90 MHz, CDCl_3) δ 2.33 (s, 3H, 4- CH_3), 2.53 (s, 3H, 2- CH_3), 7.02 (d, 1H, 5-H, $J_{5,6} = 4.5$ Hz), 8.35 (d, 1H, 6-H, $J_{5,6} = 4.5$ Hz). 5-Nitro-2,4-dimethylpyridine: ^1H NMR (90 MHz, CDCl_3) δ 2.70 (s, 6H, 2- and 4- CH_3), 7.17 (s, 1H, 3-H), 9.10 (s, 1H, 6-H).

EXAMPLE XXXIII

To a solution of 3-nitro-2,4-dimethylpyridine of Example XXXI (31.4 g, 0.21 mol) in 200 mL of absolute ethanol was added 5% Pd-C (2 g). The mixture was hydrogenated under 59 psi of pressure for 2 h. The solution was filtered and the solvent was evaporated in vacuo to give a solid (24.0 g, 98%): mp 48-50°C (lit. 51-53°C). The product, 3-amino-2,4-dimethylpyridine, appeared homogeneous on TLC and by NMR analysis and was used without further purification. ^1H NMR (90 MHz, CDCl_3) δ 2.17 (s, 3H, 4- CH_3), 2.33 (s, 3H, 2- CH_3), 3.60 (s, 2H, 3- NH_2 , D_2O exchangeable), 6.85 (d, 1H, 5-H, $J_{5,6} = 4.5$ Hz), 7.85 (d, 1H, 6-H, $J_{5,6} = 4.5$ Hz).

EXAMPLE XXXIV

5-Amino-2,4-dimethylpyridine was synthesized by methodology used for Example XXXIII except that the starting material was 5-nitro-2,4-dimethylpyridine. Yield: 24.1 g (98%); mp 62-64°C (lit. 66-68°C); ^1H NMR (90 MHz, CDCl_3) δ 2.10 (s, 3H, 4- CH_3), 2.37 (s, 3H, 2- CH_3), 3.33 (s, 2H, 3- NH_2 , D_2O exchangeable), 6.70 (s, 1H, 3-H), 7.79 (s, 1H, 6-H).

EXAMPLE XXXV

To a solution of 3-amino-2,4-dimethylpyridine (25.0 g, 0.21 mol) in 10% sulfuric acid (405 mL) cooled to 0°C by dry ice in acetone with stirring, a solution of sodium nitrite (16.2 g, 0.23 mol) in 160 mL of water was added dropwise at 0.5°C over a period of 7 min. The solution was maintained at 0°C for an additional 15 min and then heated in a steam-bath for 15 min. After cooling to room temperature, the solution was neutralized with K₂CO₃ to pH 7. The product was then extracted with chloroform (3 x 500 mL). The organic layer was dried over anhydrous Na₂SO₄ and the solvent was removed in vacuo. The product was recrystallized from acetone, and the mother liquid was purified by silica gel column chromatography (EtOAc) to afford an additional amount of the pure product, 3-hydroxy-2,4-dimethylpyridine. The total yield was 12.7 g (51%) as a colorless solid: mp 105-106°C (lit. 99-101°C); ¹H NMR (90 MHz, CDCl₃) δ 2.25 (s, 3H, 4-CH₃), 2.50 (s, 3H, 2-CH₃), 6.97 (d, 1H, 5-H, J_{5,6} = 4.5 Hz), 7.95 (d, 1H, 6-H, J_{5,6} = 4.5 Hz), 11.20 (s, 1H, 5-OH, D₂O exchangeable).

EXAMPLE XXXVI

5-Hydroxy-2,4-dimethylpyridine was synthesized by methodology used for Example XXXV except that the starting material was 5-amino-2,4-dimethylpyridine. Yield: 12.6 g (51%) as a colorless solid; mp 146-148°C (lit. 144-146°C); ¹H NMR (90 MHz, CDCl₃) δ 2.20 (s, 3H, 4-CH₃), 2.47 (s, 3H, 2-CH₃), 6.87 (s, 1H, 3-H), 7.97 (s, 1H, 6-H), 11.43 (s, 1H, 5-OH, D₂O exchangeable).

EXAMPLE XXXVII

To a stirred solution of 3-hydroxy-2,4-dimethylpyridine (23.7 g, 0.19 mol) in 130 mL of glacial acetic acid was added dropwise 36 mL of 30% hydrogen peroxide. The reaction mixture was heated to 80°C and two additional portions of 30% hydrogen peroxide (36 mL) were added at 3 h intervals. The solution was

maintained at 80°C for a total of 9 h and the solvent was removed under reduced pressure. The residue was purified by silica gel column chromatography (EtOAc-MeOH, 7:3, v/v) to give 10.3 g (38%) of product, 3-hydroxy-2,4-dimethylpyridine-N-oxide: mp 134-136°C; ¹H NMR (90 MHz, Me₂SO-d₆) δ 2.17 (s, 3H, 4-CH₃), 2.32 (s, 3H, 2-CH₃), 6.94 (d, 1H, 5-H, J_{5,6} = 6 Hz), 7.72 (s, 1H, 6-H, J_{5,6} = 6 Hz); HRMS (FAB) m/z calcd. for C₇H₉NO₂ 140.0711, found 140.0707. Anal. (C₇H₉NO₂) C, H, N.

EXAMPLE XXXVIII

5-Hydroxy-2,4-dimethylpyridine-N-oxide was synthesized by methodology used for Example XXXVII except that the starting material was 5-hydroxy-2,4-dimethylpyridine. Yield: 10.0 g (37%); mp 229°C dec; ¹H NMR (90 MHz, Me₂SO-d₆) δ 2.10 (s, 3H, 4-CH₃), 2.22 (s, 3H, 2-CH₃), 7.07 (s, 1H, 3-H), 7.70 (s, 1H, 6-H); HRMS (FAB) m/z calcd. for C₇H₉NO₂ 140.0711, found 140.0722.

EXAMPLE XXXIX

A mixture of 3-hydroxy-2,4-dimethylpyridine-N-oxide (11.3 g, 81 mmol) and acetic anhydride (200 mL) was heated at 110°C with stirring for 2.5 h. After cooling, the solvent was evaporated under reduced pressure and the residue was purified by silica gel column chromatography (EtOAc-hexane, 1:1, v/v) to yield 13.5 g (74%) of product, 3-acetoxy-4-methyl-2-acetoxymethylpyridine, as a slightly yellow oil. ¹H NMR (90 MHz, CDCl₃) δ 2.20 (s, 3H, 4-CH₃), 2.37 (s, 6H, 2-OCOCH₃), 5.17 (s, 2H, 2-CH₂), 7.15 (d, 1H, 5-H, J_{5,6} = 4.5 Hz), 8.35 (d, 1H, 6-H, J_{5,6} = 4.5 Hz); HRMS (FAB) m/z calcd. for C₁₁H₁₃NO₄ 224.0923, found 224.0935. Anal. (C₁₁H₁₃NO₄) C, H, N.

EXAMPLE XL

5-Acetoxy-4-methyl-2-acetoxymethylpyridine was synthesized by methodology used for Example XXXIX except that the starting material was 5-hydroxy-2,4-dimethylpyridine-N-oxide. Yield:

9.85 g (54%) as a yellow oil. ^1H NMR (90 MHz, CDCl_3) δ 2.15 and 2.25 (two s, 6H, 2- OCOCH_3), 2.35 (s, 3H, 4- CH_3), 5.13 (s, 2H, 2- CH_2), 7.23 (s, 1H, 3-H), 8.23 (s, 1H, 6-H); HRMS (FAB) m/z calcd. for $\text{C}_{11}\text{H}_{13}\text{NO}_4$ 224.0923, found 224.0943. Anal. ($\text{C}_{11}\text{H}_{13}\text{NO}_4$) C, H, N.

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EXAMPLE XLI

To a solution of 3-acetoxy-4-methyl-2-acetoxymethylpyridine (13.5 g, 60 mmol) in 74 mL of glacial acetic acid was added dropwise with stirring 21 mL of 30% hydrogen peroxide. The mixture was heated to 80°C and two additional portions of 30% hydrogen peroxide (21 mL) was added at 3 h intervals. The solution was maintained at 80°C for a total of 9 h. The solvent was evaporated in vacuo and the residue was purified by silica gel column chromatography (EtOAc-MeOH, 7:3, v/v) to give 2.62 g (18%) of product, 3-acetoxy-4-methyl-2-acetoxymethylpyridine-N-oxide: mp > 360°C. The product was used immediately for the next step.

EXAMPLE XLII

A mixture of 3-acetoxy-4-methyl-2-acetoxymethylpyridine-N-oxide (2.77 g, 11.6 mmol) and 54 mL of acetic anhydride was heated with stirring at 110°C for 2.5 h. After cooling, the solvent was evaporated under reduced pressure and the residue was purified by silica gel column chromatography (EtOAc-hexane, 1:1, v/v) to yield 1.54 g (47%) of product, 3-acetoxy-4-methyl-2-diacetoxymethylpyridine, as a yellow oil: ^1H NMR (90 MHz, CDCl_3) δ 2.10-2.40 (m, 12H, 2- $\text{C}(\text{OCOCH}_3)_2$, 3- OCOCH_3 and 4- CH_3), 5.17 (s, 2H, 2- CH_2), 7.20-7.38 (m, 1H, 5-H), 8.37-8.52 (m, 1H, 6-H); HRMS (FAB) m/z calcd. for $\text{C}_{13}\text{H}_{15}\text{NO}_6$ 282.0978, found 282.0990. Anal. ($\text{C}_{13}\text{H}_{15}\text{NO}_6$) C, H, N.

EXAMPLE XLIII

To a slurry of thiosemicarbazide (0.26 g, 2.9 mmol) in 5 mL of conc. HCl and 15 mL of ethanol was added a solution of 3-acetoxy-4-methyl-2-diacetoxymethylpyridine (0.8 g, 2.9 mmol) in 10 mL of ethanol. The reaction mixture was stirred at 50°C for 2 h and the precipitate was filtered after cooling. The yellow solid was recrystallized from aqueous ethanol solution (1:1, v/v) containing 5% conc. HCl to afford 0.25 g (35%) of product 3-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone as the hydrochloride salt: mp 243°C dec; ¹H NMR (500 MHz, Me₂SO-d₆) δ 2.52 (s, 3H, 4-CH₃), 3.80 (br s, 1H, 3-OH, D₂O exchangeable), 7.73 (d, 1H, 5H, J_{5,6} = 4.5 Hz), 8.27 (d, 1H, 6-H, J_{5,6} = 4.5 Hz), 8.35 (s, 1H, 2-CH), 8.66 and 8.88 (two s, 2H, NH₂, D₂O exchangeable), 12.07 (s, 1H, NH, D₂O exchangeable). HRMS (FAB) m/z calcd. for C₈H₁₀N₄OS 211.0654, found 211.0651. Anal. (C₈H₁₀N₄OS·HCl·H₂O) C, H, N.

The hydrochloride was stirred in 10% sodium bicarbonate to yield the free base: mp 227-228°C dec (lit. mp 223-224°C); ¹H NMR (500 MHz, Me₂SO-d₆) δ 2.23 (s, 3H, 4-CH₃), 4.80 (br s, 1H, 3-OH, D₂O exchangeable), 7.26 (d, 1H, 5H, J_{5,6} = 5 Hz), 8.05 (d, 1H, 6-H, J_{5,6} = 5 Hz), 8.20 (s, 2H, NH₂, D₂O exchangeable), 8.35 (s, 1H, 2-CH), 11.80 (s, 1H, NH, D₂O exchangeable).

EXAMPLE XLIV

To a solution of 2-(1,3-dioxolanyl)-4-methyl-3-aminopyridine (0.60 g, 3.3 mmol) in 15 mL of 10% H₂SO₄ at 0°C (ice bath) with stirring was added dropwise a solution of NaNO₂ (0.38 g, 5.5 mmol) in 3 mL of water. The mixture was stirred at 0°C for 15 min and then heated in a steam-bath for 30 min. The resulting solution was evaporated at room temperature under reduced pressure to yield 3-hydroxy-4-methyl-2-formylpyridine as a syrup, which was dissolved in 15 mL of water, decolorized with charcoal and filtered. To the filtrate was added a solution of thiosemicarbazide (0.31 g, 3.3 mmol) in 5 mL of 5% HCl. The

mixture was refluxed for 30 min, cooled and the yellow precipitate was filtered, washed with water, and recrystallized from aqueous ethanol solution (1:1, v/v) containing 5% conc. HCl to afford 0.21 g (30%) of product: the mp and all spectroscopic data were identical with those obtained in Example XLIII.

EXAMPLE XLV

A mixture of 5-acetoxy-4-methyl-2-acetoxymethylpyridine (6.2 g, 4.5 mmol) and 200 mL of conc. HCl was refluxed for 1 h. After cooling, the reaction mixture was evaporated to dryness under reduced pressure and the residue was purified by silica gel column chromatography (EtOAc-MeOH, 7:3, v/v) to give 3.8 g (97%) of product, 5-hydroxy-4-methyl-2-hydroxymethylpyridine: mp 161-162°C; ^1H NMR (90 MHz, $\text{Me}_2\text{SO}-d_6$) δ 2.33 (s, 3H, 4- CH_3), 4.70 (s, 2H, 2- CH_2), 7.67 (s, 1H, 3-H), 8.22 (s, 1H, 6-H); HRMS (FAB) m/z calcd. for $\text{C}_7\text{H}_9\text{NO}_2$ 140.0711, found 140.0736.

EXAMPLE XLVI

Method A. To a solution of 5-hydroxy-4-methyl-2-hydroxymethylpyridine (3.9 g, 28 mmol) in 100 mL of ethanol was added MnO_2 (10.0 g, 0.12 mmol) and the reaction mixture was heated to reflux for 2 h with stirring. The mixture was filtered and the filtrate was concentrated under reduced pressure to 80 mL. Because the aldehyde, 5-hydroxy-4-methyl-2-formylpyridine, is unstable, conc. HCl (8 mL) was added immediately. Thiosemicarbazide (1.5 g, 17 mmol) was added to the aldehyde solution with stirring and the reaction mixture was heated to reflux for 30 min. The precipitate was filtered upon cooling and recrystallized in aqueous ethanol solution (1:1, v/v) containing 5% conc. HCl to afford 3.3 g (81%) of product, 5-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone: mp 229°C; ^1H NMR (500 MHz, $\text{Me}_2\text{SO}-d_6$) δ 2.33 (s, 3H, 4- CH_3), 4.01 (br s, 1H, 5-OH, D_2O exchangeable), 8.02 (s, 1H, 3-H), 8.20 (s, 1H, 6-H), 8.22 (s, 1H, 2-CH), 8.58 (s, 2H, NH_2 , D_2O exchangeable), 12.0 (s, 1H, NH, D_2O exchangeable).

exchangeable). HRMS (FAB) m/z calcd. for $C_8H_{10}N_4OS$ 211.0654, found 211.0671. Anal. ($C_8H_{10}N_4OS \cdot HCl \cdot H_2O$) C, H, N.

The hydrochloride was stirred in 10% sodium bicarbonate to yield the free base: mp 220-222°C dec; 1H NMR (500 MHz, Me_2SO-d_6) δ 2.15 (s, 3H, 4- CH_3), 7.95 (s, 1H, 3-H), 7.97 (s, 1H, 6-H), 8.01 (s, 1H, 2-CH), 8.04 and 8.18 (two s, 2H, NH_2 , D_2O exchangeable), 10.1 (s, 1H, 5-OH, D_2O exchangeable), 12.0 (s, 1H, NH, D_2O exchangeable).

Method B. This compound was also prepared from the corresponding 5-amino derivative, 2-(1,3-dioxolanyl)-4-methyl-5-aminopyridine, via the aldehyde, 5-hydroxy-4-methyl-2-formylpyridine, by the same procedure described for the synthesis of 3-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone. Yield: 0.32 g (46%); the mp and all spectroscopic data were identical with those obtained in Method A.

EXAMPLE XLVII

A mixture of 2,4-dimethyl-3-nitropyridine (5.0 g, 33 mmol) and selenium dioxide (4.5 g, 42 mmol) in anhydrous 1,4-dioxane (100 mL) was refluxed under an atmosphere of nitrogen for 35 h. The reaction mixture was cooled and filtered to remove the precipitated black selenium. The filtrate was evaporated in vacuo to dryness and the residue was chromatographed on a silica gel (120 g) column (CH_2Cl_2 -EtOAc, 10:1, v/v, R_f 0.65) to afford 1.1 g (20%) of white crystals of 4-methyl-3-nitropyridine-2-carboxaldehyde: mp 101-102°C; 1H NMR (90 MHz, $CDCl_3$) δ 2.35 (s, 3H, 4- CH_3), 7.47 (d, 1H, 5-H, $J_{5,6} = 4.5$ Hz), 8.72 (d, 1H, 6-H, $J_{5,6} = 4.5$ Hz), 9.95 (s, 1H, 2-CHO). Anal. ($C_7H_6N_2O_3$) C, H, N.

EXAMPLE XLVIII

4-Methyl-5-nitropyridine-2-carboxaldehyde was prepared from the nitro derivative, 5-nitro-2,4-dimethylpyridine, by the same procedure described for the synthesis of Example XLVII, except

that the reaction time was 4 h. Yield: 6.0 g (55%); mp 82-83°C (lit. 81-82°C); TLC, R_f 0.86 ($\text{CH}_2\text{Cl}_2/\text{EtOAc}$, 3:2, v/v); ^1H NMR (90 MHz, CDCl_3) δ 2.70 (s, 3H, 4- CH_3), 7.90 (s, 1H, 3-H), 9.20 (s, 1H, 6-H), 10.10 (s, 1H, 2-CHO).

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EXAMPLE XLIX

To 0.75 g (14 mmol) of 4-methyl-3-nitropyridine-2-carboxaldehyde in 100 mL of toluene was added 40 mg of p-toluenesulfonic acid monohydrate and 2 mL of ethylene glycol. The reaction mixture was refluxed with stirring, using a Dean-stark trap to remove the water formed during condensation until complete disappearance of the starting material was observed. The mixture was cooled and then washed with 25 mL of 10% NaHCO_3 solution, followed by 25 mL of water. The toluene layer was dried over anhydrous MgSO_4 and the solvent was removed under reduced pressure. The residue was chromatographed on a silica gel (120 g) column ($\text{CH}_2\text{Cl}_2/\text{EtOAc}$, 10:1, v/v, R_f 0.42) to afford 1.1 g (85%) of white crystals of 2-(1,3-dioxolanyl)-4-methyl-3-nitropyridine: mp 46-48°C; ^1H NMR (90 MHz, CDCl_3) δ 2.40 (s, 3H, 4- CH_3), 4.07 (s, 4H, CH_2CH_2), 6.05 (s, 1H, 2-CH), 7.30 (d, 1H, 5-H, $J_{5,6} = 4.5$ Hz), 8.60 (d, 1H, 6-H, $J_{5,6} = 4.5$ Hz). Anal. ($\text{C}_9\text{H}_{10}\text{N}_2\text{O}_4$) C, H, N.

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20EXAMPLE L

2-(1,3-Dioxolanyl)-4-methyl-5-nitropyridine was synthesized by the method of Example XLIX except that the starting material was 4-methyl-5-nitropyridine-2-carboxaldehyde. Yield: 2.3 g (91%); mp 77-79°C; (lit mp 77°C); TLC, R_f 0.74 ($\text{CH}_2\text{Cl}_2/\text{EtOAc}$, 3:2, v/v); ^1H NMR (90 MHz, CDCl_3) δ 2.65 (s, 3H, 4- CH_3), 4.10 (s, 4H, CH_2CH_2), 5.85 (s, 1H, 2-CH), 7.50 (s, 1H, 3-H), 9.12 (s, 1H, 6-H). Anal. ($\text{C}_9\text{H}_{10}\text{N}_2\text{O}_4$) C, H, N.

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EXAMPLE LI

The nitro derivative, 2-(1,3-dioxolanyl)-4-methyl-3-nitropyridine (1.1 g, 5.2 mmol), was dissolved in 200 mL of ethanol and hydrogenated in a Parr apparatus under 50 psi of pressure in the presence of 10% Pd-C (200 mg) for 20 h. After filtration, the filtrate was evaporated under reduced pressure to give the product (0.9 g, 94%) as a syrup, ninhydrin positive 2-(1,3-dioxolanyl)-4-methyl-3-aminopyridine; ¹H NMR (90 MHz, CDCl₃) δ 2.12 (s, 3H, 4-CH₃), 4.05 (m, 4H, CH₂CH₂), 4.10 (br s, 2H, 3-NH₂, D₂O exchangeable), 5.76 (s, 1H, 2-CH), 6.92 (d, 1H, 5-H, J_{5,6} = 4.5 Hz), 7.86 (d, 1H, 6-H, J_{5,6} = 4.5 Hz). Anal. (C₉H₁₂N₂O₂) C, H, N.

EXAMPLE LII

2-(1,3-Dioxolanyl)-4-methyl-5-aminopyridine was synthesized by methodology used for Example LI except that the starting material was 2-(1,3-dioxolanyl)-4-methyl-5-nitropyridine. Yield: 1.2 g (92%); mp 79-80°C; ¹H NMR (90 MHz, CDCl₃) δ 2.15 (s, 3H, 4-CH₃), 3.70 (br s, 2H, 5-NH₂, D₂O exchangeable), 4.10 (m, 4H, CH₂CH₂), 5.70 (s, 1H, 2-CH), 7.15 (s, 1H, 3-H), 8.00 (s, 1H, 6-H). Anal. (C₉H₁₂N₂O₂) C, H, N.

The following examples show the usefulness of the compounds of the second aspect of the invention:

EXAMPLES LIII-LVI

This set of experiments contrasts the use of the compounds 3- and 5-hydroxy-2-formylpyridine thiosemicarbazone with the compounds of the invention which are the corresponding 4-methyl-substituted compounds. Examples LIII and LIV are reference examples, while Examples LV and LVI represent compounds of the invention. In each of these examples, DMSO is used for solubilization.

EXAMPLE LIII: 3-Hydroxy-2-formylpyridine thiosemicarbazone was administered to mice bearing the L1210 leukemia by intraperitoneal injection in DMSO solution as the injection form, beginning 24 hours after tumor implantation, with the optimum daily dosage being 40 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. At least five mice were tested at each dosage level. The average percentage change in body weight from onset to termination of the therapy was +1.5. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 114.

EXAMPLE LIV: 5-Hydroxy-2-formylpyridine thiosemicarbazone was administered to mice bearing the L1210 leukemia by intraperitoneal injection in DMSO solution as the injection form, beginning 24 hours after tumor implantation, with the optimum daily dosage being 40 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. At least five mice were tested at each dosage level. The average percentage change in body weight from onset to termination of the therapy was +1.8. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 132.

EXAMPLE LV: 3-Hydroxy-4-methyl-2-formylpyridine thiosemicarbazone was administered to mice bearing the L1210 leukemia by intraperitoneal injection in DMSO solution as the injection form, beginning 24 hours after tumor implantation, with the optimum daily dosage being 40 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. At least five mice were tested at each dosage level. The average percentage change in body weight from onset to termination of the therapy was +0.5. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 135.

EXAMPLE LVI: 5-Hydroxy-4-methyl-2-formylpyridine thiosemicarbazone was administered to mice bearing the L1210 leukemia by intraperitoneal injection in DMSO solution as the injection form, beginning 24 hours after tumor implantation, with the optimum daily dosage being 40 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. At least five mice were tested at each dosage level. The average percentage change in body weight from onset to termination of the therapy was -7.4. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 138.

EXAMPLES LVII-LIX

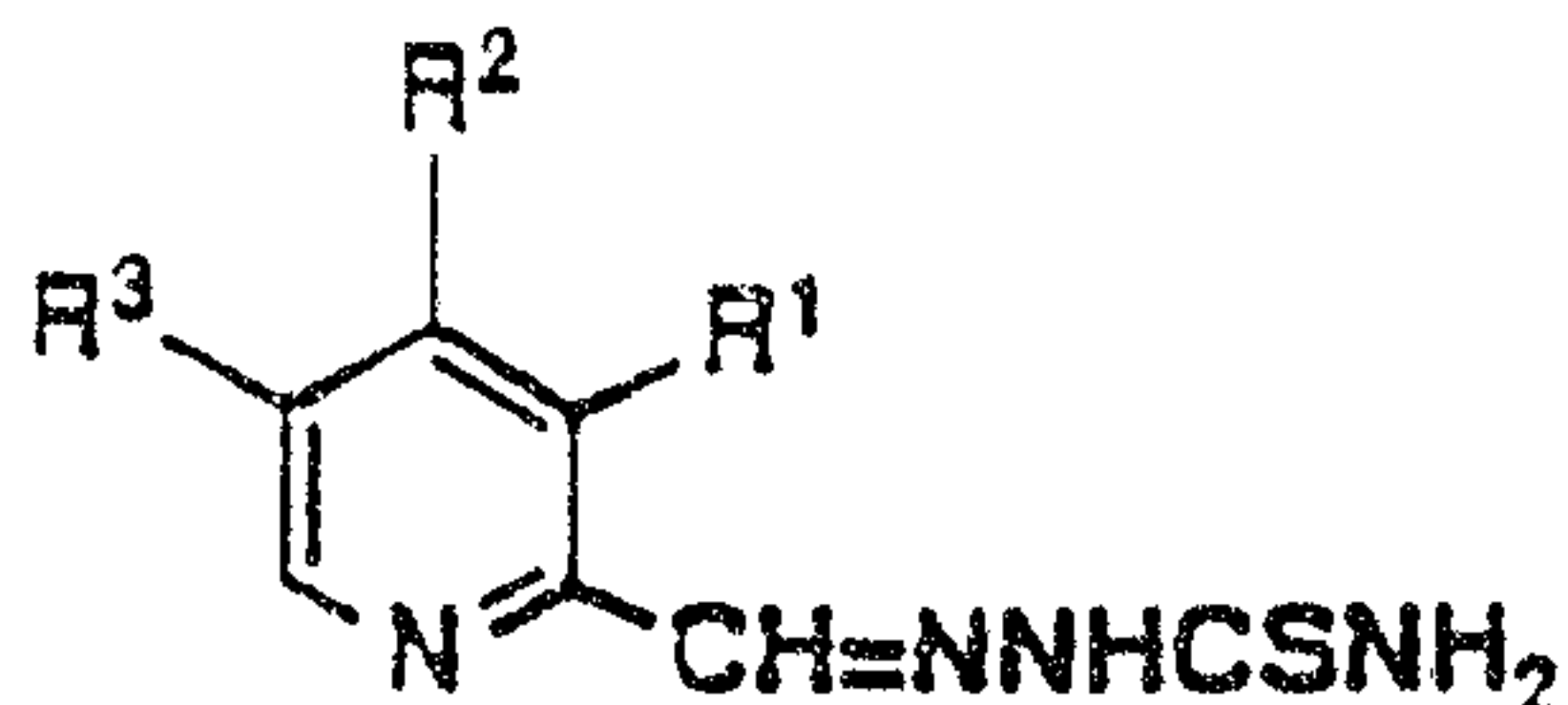
EXAMPLE LVII: 5-Hydroxy-2-formylpyridine thiosemicarbazone was administered to mice bearing the L1210 leukemia by intraperitoneal injection in suspension as the injection form, beginning 24 hours after tumor implantation, with the optimum daily dosage being 60 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. At least five mice were tested at each dosage level. The average percentage change in body weight from onset to termination of the therapy was +4.6. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 146.

EXAMPLE LVIII: 3-Hydroxy-4-methyl-2-formylpyridine thiosemicarbazone was administered to mice bearing the L1210 leukemia by intraperitoneal injection in a suspension as the injection form, beginning 24 hours after tumor implantation, with the optimum daily dosage being 50 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. At least five mice were tested at each dosage level. The average percentage change in body weight from onset to termination of the therapy was +0.9. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 168.

EXAMPLE LIX: 5-Hydroxy-4-methyl-2-formylpyridine thiosemicarbazone was administered to mice bearing the L1210 leukemia by intraperitoneal injection in a suspension as the injection form, beginning 24 hours after tumor implantation, with the optimum daily dosage being 40 mg/kg. Administration was once per day for a total of six consecutive days to a representative sample population. At least five mice were tested at each dosage level. The average change in body weight from onset to termination of the therapy was -3.4. A value $T/C \times 100$ is calculated, which is the ratio of the survival time of treated to control animals $\times 100$, and has a value of 186.

WHAT IS CLAIMED IS:

1. A compound of the formula



wherein either (a) R^1 is NHR^4 or NR^4R^5 and R^3 is hydrogen or (b) R^3 is NHR^4 , NR^4R^5 or OH and R^1 is hydrogen;

R^2 is hydrogen or C_{1-4} lower alkyl;

R^4 is hydrogen, hydroxyl or C_{1-4} lower alkyl; and

R^5 is C_{1-4} lower alkyl;

provided that R^1 and R^2 cannot both be hydrogen when R^3 is $\text{N}(\text{CH}_3)_2$ or OH ; or a pharmaceutically acceptable salt or hydrate thereof.

2. A compound of claim 1 which is 3-amino-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

3. A compound of claim 1 which is 5-amino-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

4. A compound of claim 1 which is 3-amino-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

5. A compound of claim 1 which is 5-amino-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

6. A compound of claim 1 which is 5-hydroxyamino-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

5 7. Use of a compound of claim 1 or a pharmaceutically acceptable salt or hydrate thereof for treating a tumor in a mammal.

8. The use as claimed in claim 7 wherein said compound is 3-amino-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

10 9. The use as claimed in claim 7 wherein said compound is 5-amino-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

15 10. The use as claimed in claim 7 wherein said compound is 3-amino-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

11. The use as claimed in claim 7 wherein said compound is 5-amino-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

20 12. The use as claimed in claim 7 wherein said compound is 5-hydroxyamino-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

13. Use of a compound which is 3- or 5-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof for treating a tumor in a mammal.

25 14. The use as claimed in claim 13 wherein said compound is 5-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

15. The use as claimed in claim 13 wherein said compound is 3-hydroxy-4-methyl-2-formylpyridine thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

16. The compound 5-hydroxy-4-methyl-2-formylpyridine
5 thiosemicarbazone or a pharmaceutically acceptable salt or hydrate thereof.

(I)

