Synthesis and Structure−Activity Relationship of Novel Antitumoral Platinum Xanthate Complexes

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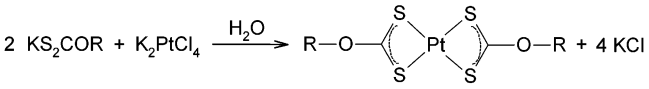
To establish structure−activity relationships, derivatives of a recently described sulfur-containing antitumoral platinum complex, bis(*O*-ethyldithiocarbonato)platinum(II), named thioplatin, were analyzed. Twenty different bis(*O*-alkyldithiocarbonato)platinum(II) complexes were synthesized and tested for cytotoxic activity in a panel of six human tumor lines. Derivatives with up to 7-fold increased activity compared to thioplatin and up to 25-fold more activity than cisplatin were identified. Bis(*O*-alkyldithiocarbonato)platinum(II) complexes with short *n*-alkyl chains such as methyl, ethyl, propyl, and butyl were found to be superior to compounds with long *n*-alkyl chains such as hexyl, octyl, and decyl. Complexes derived from secondary xanthates displayed significantly higher activity than those derived from primary xanthates with the same number of C atoms. Like thioplatin, all tested platinum complexes were more active at pH 6.8 than at pH 7.4. A pH of 6.8 and lower has been frequently found in solid tumors because of the tendency of tumor cells to undergo anaerobic fermentation. Drugs with such pH-dependent antitumoral activity have an improved therapeutic index compared to drugs that are active irrespective of pH.

Introduction

Chemotherapy is still indispensable for the treatment of cancer. Despite advances in surgery and radiotherapy, mortality remained virtually unchanged for most cancers in the decades before discovery of cisplatin [cisdiamminedichloroplatinum(II)], which was a major step forward in the treatment of cancers of, for example, ovary, lung, and testis. Today, platinum compounds remain an important component of chemotherapeutic regimens. All platinum compounds in clinical use are derivatives of cisplatin with two amino groups in the cis position.[1,2]

Recently a platinum complex based on sulfur as complex-forming atoms, bis(*O*-ethyldithiocarbonato)-platinum(II), named thioplatin, with antitumoral activity against a number of human tumor lines was described.[3] Surprisingly, it was found that thioplatin displayed significantly higher cytotoxicity when tumor cells were cultivated in media of pH 6.8 compared to media of pH 7.4. Because in solid tumors a pH of 6.8 and lower has been frequently observed,[4] an improved therapeutic index with thioplatin could be expected. Indeed, thioplatin displayed antitumoral activity on human tumors xenotransplanted in nude mice, which was comparable to cisplatin, yet a significantly lower toxicity on kidneys, small intestines, and white blood cell count was encountered.[3] The question which functional groups of thioplatin determine cytotoxicity and pH dependence of antitumor activity has not been answered yet. To get an impression of the structure−activity relationships, we synthesized analogues of thioplatin and studied their cytotoxic effect in a panel of human cancer lines in vitro. The effects of variations in the alkyl group of thioplatin on both cytotoxicity and the ratio of efficacy at pH 6.8 and 7.4 were studied.

Scheme 1. Synthesis of Platinum Xanthate Complexes



Chemistry

Compounds **1**−**21** were synthesized as illustrated in Scheme 1. Alkylxanthates ROC(S)S$^-$ were reacted with K_2PtCl_4 using water as a solvent. All platinum xanthates were found to be insoluble in water and were collected as a precipitate. For the synthesis of xanthates published procedures were used. The appropriate alcohols were deprotonated with a base such as KOH or with KH to form alcoholates, followed by addition of CS_2.[5,6] Yields ranged from 75% to 99%.

Structures of bis(*O*-alkyldithiocarbonato)platinum(II) complexes **1**−**21** were verified by ^{1}H, ^{13}C, and ^{195}Pt NMR, IR, and UV spectroscopy and by mass spectrometry. With one exception, combustion analysis (C, H, S) results agreed with the calculated values within a range of ±0.3%. The structures of methyl, propyl, butyl, and cyclohexyl derivatives were confirmed by X-ray analysis. As described for bis(*O*-ethyldithiocarbonato)platinum-(II), all four metal complexes possess a chelate structure in which the central platinum atom is coordinated by four sulfur atoms in a square-planar geometry.[6,8]

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All platinum(II) complexes formed yellow crystals, which were stable at room temperature in the presence of light and air for several weeks. They were insoluble in water, slightly soluble in DMSO or acetone (1−3 mg/mL), and soluble in $CHCl_3$. All derivatives were crystallized from acetone or acetone/$CHCl_3$ solutions. While being rather unstable in DMSO, the complexes proved to be stable when dissolved in $CHCl_3$ or acetone over a period of 1−2 months when stored at 4 °C.

Results and Discussion

It was of interest whether the antitumoral spectrum of bis(*O*-alkyldithiocarbonato)platinum(II) complexes was similar for all derivatives or whether variations in the *n*-alkyl chain would affect specificity. The cytotoxic activity of the newly synthesized bis(*O*-alkyldithiocarbonato)platinum(II) complexes was determined in a panel of human tumor cell lines with cisplatin as a standard. We chose cell lines from tumor types that are clinically accessible to therapy with standard platinum complexes of the diamino type such as cisplatin and carboplatin like lung cancer (Calu-6) and cell lines from tumor types that poorly respond to cisplatin like melanoma (SK-MEL 25) or mammary cancer (MCF-7).

We synthesized bis(*O*-alkyldthiocarbonato)platinum-(II) complexes from xanthates with three different classes of substituents: (i) xanthates with linear *n*-alkyl substituents starting with methyl and ending with decyl (**1**−**8**); (ii) branched molecules with xanthates derived from primary alcohols (**9**−**14**); (iii) xanthates derived from secondary alcohols (**15**−**21**). In no cases were heterosubstitutents introduced into the hydrocarbon chains. The structures of the tested derivatives are displayed in Table 1.

Cytotoxicity and Structure−Activity Relationship. We determined the antitumoral activity of compounds **1**−**21** in tissue culture media of pH 6.8 and 7.4. Tissue culture cells produce lactic acid that is released to the growth medium. As a result, predominantly in the case of rapidly growing tumor cells, the pH of the culture medium is endowed with a constant shift to acidity. Even for open culture systems in which the pH is buffered by a 5% CO_2 atmosphere, which is in balance with $NaHCO_3$ in the medium, frequently a lowering of the pH by up to 0.5 occurs within 16 h. Because cytotoxic activity of the compounds at defined pH conditions was one of the main parameters to be determined, we incubated the cells for only 2 h with the test compounds, followed by 24−96 h of incubation with regular, inhibitor-free medium of pH 7.4. In previous experiments with thioplatin, we had observed that such short incubation periods were sufficient to induce cytotoxicity (unpublished results). The substances were serially diluted in tissue culture medium of the desired pH. Since all derivatives were insoluble in water, a solvent had to be used in which all compounds were soluble to an acceptable extent and that was miscible with water. Acetone turned out to be suitable, since the tumor lines tolerated this solvent in concentrations up to 5%. After mixing of stock solutions with medium, stable solutions were obtained probably because of adsorption of the compounds to serum albumin. After incubation, surviving cells were stained with crystal violet and the optical density was measured in an ELISA reader. The concentration that was needed to reduce the cell number by 50% (IC_{50}) was determined from dose−response curves for each compound. Results are listed in Table 1. To enable a better overview, the results are also displayed graphically in Figure 1. The cell number was reduced by less than 50% by some compounds at the highest concentration that could be applied because of limited solubility in acetone. For these compounds, the maximum concentration that was applied is indicated.

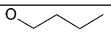
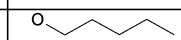
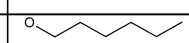
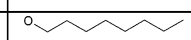
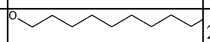
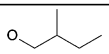
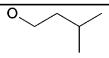
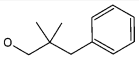
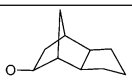
The first series contains the *n*-alkyl homologues **1**−**8**. Increasing activity was obtained with elongation of the alkyl chain from two to four C atoms. The methyl derivative **1** was not in exact line with this observation because it was somewhat more active than the ethyl derivative **2**. Further elongation of the chain resulted in a decrease of activity. Finally, the *n*-decyl derivative **8** almost completely lacked activity at the highest dose tested.

Elongation of chain length seems to have two opposing effects on activity; up to four C atoms, activity increased but then decreased when the molecule was enlarged further. Increasing activity apparently correlates with the positive inductive effect (+I effect) of the *n*-alkyl group of the corresponding xanthate ligand. An indicator of this effect is the decreasing acidity of xanthates with longer *n*-alkyl residues. The pK_a values of methyl xanthate, ethyl xanthate, and butyl xanthate were determined as 2.29, 2.74, and 3.03, respectively.[9] Therefore, platinum complexes of a weaker acid are probably more accessible to protonation at a slightly acidic pH. Protonation should result in destabilization of the complex and in increasing reactivity. Higher reactivity should result in stronger platination of DNA and, as a consequence, in increased cytotoxicity.

To execute cell killing, platinum complexes are thought to react with DNA in the nucleus. Therefore, transport through the plasma membrane is a crucial step. Cisplatin and carboplatin enter the cell via active transport. Such mechanism is endowed with a high chance for the development of resistance due to mutations in the transport system. Small lipids such as synthetic ceramides with side chains of three C atoms can passively pass the plasma membrane independent of active transport. More lipophilic lipids with, for example, 16 C atom side chains stick to the membrane and are unable to enter the cell. A similar mechanism may account for the reduced cytotoxicity of bis(*O*-alkyldthiocarbonato)platinum(II) complexes with alkyl chains longer than four C atoms. Derivative **8** with $n = 10$ has two highly lipophilic chains that can serve as membrane anchors. We speculate that this derivative sticks to the plasma membrane. As a consequence, it might no longer be able to interact with DNA, and therefore, it was found to be almost nontoxic at the highest dose we were able to test.

The complexes with primary, branched alkyl systems **9**−**14** were found to be less toxic than their *n*-homologous. In general, higher IC_{50} values were found. Within this series the IC_{50} value of the branched propyl system **10** is lower or equal to those of the branched butyl systems (**11**, **12**), which are significantly more cytotoxic than the compounds carrying a tertiary group (**13**, **14**). Again, similar to the case for *n*-alkyl homologues, the

Table 1. Cytotoxic Activity of Compounds **1**−**21** and Cisplatin

		$IC_{50} \pm SD$ [a] [μM]											
Cell line		**MCF-7**		**Calu-6**		**LXF-289**		**SK-MEL-25**		**SK-OV-3**		**KB**	
Compound	structure	pH 6.8	pH 7.4	pH 6.8	pH 7.4	pH 6.8	pH 7.4	pH 6.8	pH 7.4	pH 6.8	pH 7.4	pH 6.8	pH 7.4
Cisplatin	$(NH_3)_2PtCl_2$	108 ± 27	160 ± 30	16 ± 1.0	25 ± 5.7	113 ± 22.3	83 ± 23.0	78 ± 3.3	90 ± 25.0	64 ± 0.7	90 ± 27.7	55 ± 2.0	52 ± 3.3
1		7 ± 1.0	19 ± 4.4	11 ± 2.9	21 ± 5.6	39 ± 9.5	102 ± 19.3	14 ± 5.0	80 ± 25.9	26 ± 2.4	47 ± 2.9	20 ± 1.0	49 ± 2.0
2		12 ± 0.2	47 ± 5.3	21 ± 3.9	24 ± 0.9	45 ± 8.0	91 ± 24.9	21 ± 3.0	56 ± 6.2	86 ± 3.2	98 ± 16.5	18 ± 4.0	58 ± 5.0
3		4 ± 1.0	9 ± 3.0	7 ± 1.1	21 ± 0.9	37 ± 9.0	49 ± 5.0	10 ± 1.5	21 ± 1.9	45 ± 27.0	50 ± 1.0	12 ± 1.0	38 ± 3.0
4		7 ± 5.1	25 ± 4.9	7 ± 0.8	19 ± 2.0	24 ± 4.0	39 ± 9.0	10 ± 1.0	22 ± 1.0	33 ± 6.0	90 ± 6.0	16 ± 2.0	32 ± 5.0
5		10 ± 4.0	34 ± 3.8	9 ± 3.6	15 ± 5.4	38 ± 3.5	62 ± 15.5	19 ± 0.6	32 ± 4.8	31 ± 1.5	66 ± 18.0	16 ± 2.0	25 ± 3.0
6		44 ± 5.5	47 ± 25.5	23 ± 7.3	37 ± 2.7	>91	>91	37 ± 3.3	70 ± 10.2	102 ± 13.0	130 ± 7.0	64 ± 4.0	>91
7		31 ± 12	31 ± 11.6	23 ± 13.2	56 ± 9.1	30 ± 10.6	83 ± 1.7	56 ± 13.2	>83	>83	>83	>83	>83
8		24 ± 9.8	30 ± 27.0	>76	>76	38 ± 15.0	53 ± 9.0	>76	>76	>76	>76	>76	>76
9		95 ± 6.1	90 ± 32.7	17 ± 1.0	33 ± 9.2	>102	>102	64 ± 12.3	85 ± 5.1	95 ± 13.3	67 ± 8.2	33 ± 8.2	72 ± 11.0
10		27 ± 5.0	23 ± 12.2	9 ± 0.4	10 ± 2.6	19 ± 2.2	37 ± 3.8	15 ± 4.5	21 ± 9.3	32 ± 10.1	61 ± 19.4	30 ± 10.1	47 ± 12.0
11		19 ± 1.3	27 ± 7.7	9 ± 0.6	19 ± 1.2	19 ± 1.5	44 ± 0.4	17 ± 0.6	32 ± 5.4	23 ± 7.0	35 ± 2.3	31 ± 2.0	39 ± 4.0
12		23 ± 5.0	40 ± 7.7	6 ± 1.0	21 ± 1.0	23 ± 8.0	71 ± 8.8	20 ± 1.7	35 ± 3.8	24 ± 5.0	21 ± 14.0	35 ± 4.0	19 ± 2.0
13		62 ± 6.7	>86	25 ± 5.2	27 ± 4.8	59 ± 18.8	75 ± 16.5	72 ± 18.2	83 ± 9.6	>86	>86	>96	>96
14		>50	>50	10 ± 2.2	17 ± 9.6	>50	>50	>50	>50	>50	>50	>50	>50
15		3 ± 0.9	7 ± 3.0	6 ± 0.6	10 ± 0.6	10 ± 1.7	30 ± 0.4	6 ± 0.4	12 ± 1.5	14 ± 2.1	33 ± 8.0	6 ± 0.4	10 ± 0.9
16		5 ± 0.2	6 ± 1.5	3 ± 0.4	5 ± 0.4	8 ± 1.3	10 ± 0.8	5 ± 0.2	9 ± 0.4	8 ± 1.5	5 ± 0.6	4 ± 0.6	5 ± 0.4
17		7 ± 0.5	9 ± 0.5	9 ± 0.2	9 ± 0.7	15 ± 2.7	18 ± 2.5	10 ± 0.2	11 ± 0.2	18 ± 0.9	34 ± 1.5	5 ± 0.5	7 ± 1.3
18		11 ± 0.8	21 ± 1.0	3 ± 0.4	7 ± 1.2	37 ± 1.4	44 ± 0.8	7 ± 1.0	12 ± 3.7	17 ± 2.9	19 ± 4.1	6 ± 0.6	20 ± 2.9
19		5 ± 0.4	10 ± 0.4	3 ± 0.2	5 ± 0.2	37 ± 0.6	38 ± 1.0	5 ± 0.6	9 ± 1.7	17 ± 1.5	26 ± 6.8	14 ± 2.9	24 ± 3.7
20		5 ± 0.2	9 ± 1.5	3 ± 0.4	8 ± 2.0	6 ± 1.8	12 ± 1.1	3 ± 0.7	8 ± 2.4	9 ± 2.2	12 ± 1.6	6 ± 0.2	9 ± 0.7
21		32 ± 6.0	>38	8 ± 0.8	18 ± 10.0	>38	>38	>38	>38	>38	>38	>77	>77

[a] IC_{50} for these compounds were determined from dose response curves at pH 6.8 and pH 7.4, respectively. Values are the mean of four separate assays ± SD.

number of C atoms determines activity. An optimum is reached with four C atoms (**4**, **10**), and with five or more C atoms cytotoxicity is reduced. Compounds **13** and **14** with tertiary groups were only slightly toxic.

Secondary alkyl systems **15**−**21** displayed the highest activity of all compounds. When compared with the corresponding *n*-alkyl systems (**3** and **15**; **5** and **16**) 2- to 3-fold reduced IC_{50} values were obtained. This effect

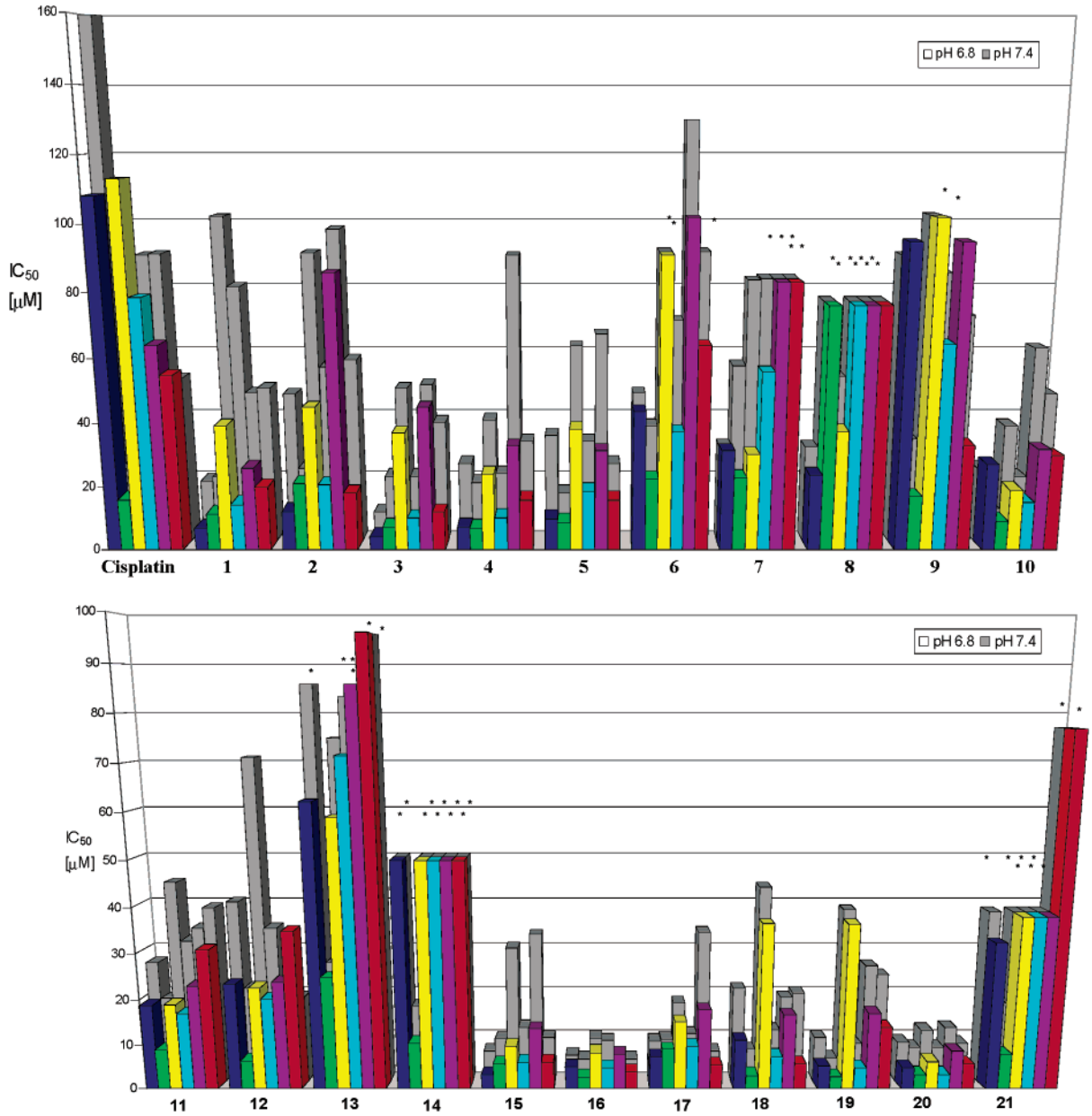


Figure 1. Cytotoxic activity on human cancer cell lines. Shown are IC_{50} values for cytotoxicity in MCF-7 (blue), Calu-6 (green), LXF-289 (yellow), SK-MEL-25 (light blue), SK-OV-3 (violet), and KB (red) cells at pH 6.8. Bars in the background indicate IC_{50} values obtained in the corresponding cell line at pH 7.4. Exact values and SD are indicated in Table 1. The asterisk (∗) indicates that more than 50% of the cells survived at the highest concentration applied.

is most obvious with **6** and **20**. The secondary cyclohexyl derivative was approximately 10-fold more cytotoxic than the corresponding *n*-hexyl derivative.

As with the linear derivatives, activity increased with the number of C atoms from four to five and six (**18**−**20**). In the case of a larger cyclic system with 10 C atoms (**21**), cell killing was quenched almost completely as for the case with the *n*-decyl substituent (**8**).

The striking difference in activity between primary and secondary alkyl derivatives could be due to the electron-donating effect of secondary systems, which should favor protonation of the ligand. As a consequence of protonation, secondary xanthate complexes might be more accesseble to nucleophilic attacks at a slightly acidic pH. Furthermore, we cannot exclude that primary and secondary alcohol derivatives differ in reactivity with cellular platinum detoxifying agents such as glutathione.[11,12]

It would be desirable to also test platinum complexes with tertiary xanthates (e.g., $^{-}S_2COC(CH_3)_3$, *tert*-butyl xanthate). Yet tertiary xanthates were found to be extremely unstable in aqueous environments.[10] So far, we were unable to synthesize such platinum complexes.

The second compound-specific parameter of interest was the pH dependence of cytotoxic activity. We found IC_{50} values at pH 6.8 being lower than at pH 7.4 (Figure 2) as a general feature of all bis(*O*-alkyldthiocarbonato)-platinum(II) complexes analyzed in this study. In case of the *n*-alkyl derivatives, an inverse correlation between chain length and the ratio of the activity at pH 6.8 to the activity at 7.4 could be observed. For compound **1** with one C atom, we determined a mean ratio of 2.84. This value declined to 1.33 for **8** with 10 C atoms. Preferential activity at pH 6.8 inversely coincides with cytotoxicity in the *n*-alkyl sequence for molecules with one to six C atoms. This statement is not true for

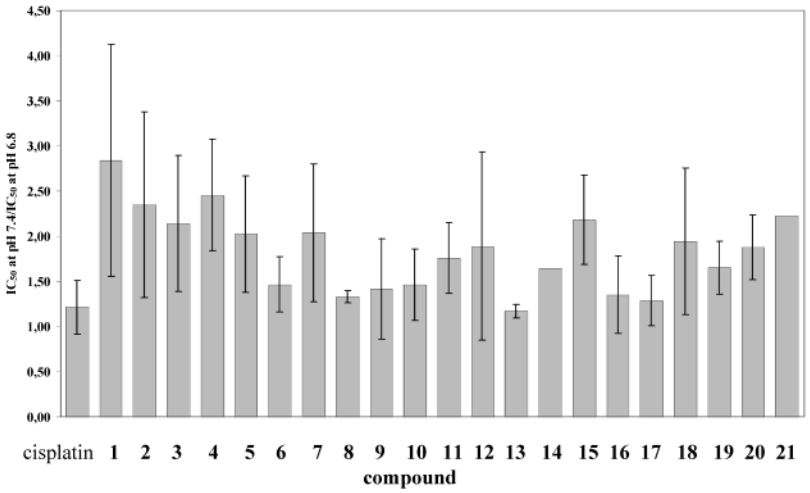


Figure 2. Mean values ± SD of (IC_{50} at pH 7.4)/(IC_{50} at pH 6.8) for all six human tumor cell lines tested. IC_{50} values at both pH conditions were obtained in five cell lines for **9**, four cell lines for **6**, three cell lines for **13** and **7**, two cell lines for **8**, and one cell line for **14** and **21**.

the secondary xanthate derivatives **15**−**21**. In this group **15**, **16**, and **20** share almost equal cytotoxicity, yet there is a significant difference in the (pH 6.8)/(pH 7.4) activity quotient. While this value was 2.18 ± 0.49 for **15**, it was somewhat lower (1.88 ± 0.36) for **20** (the most active compound) and as low as 1.35 ± 0.43 for **16.** The difference between **15** and **16** is significant at $p = 0.033$ (T test). It can be speculated that the +I effect of the corresponding ligand determines the pH ratio. As mentioned above, the +I effect reduces the acidity of the corresponding xanthic acid. For isopropyl xanthate, a pK_a comparable to methylxanthate was found.[9] In the case of *n*-alkyl xanthic acids, a decrease in acidity was observed when the alkyl chain was elongated. Therefore, chemical reactivity of platinum complexes should increase with chain length at both pH 6.8 and pH 7.4. For complexes with low reactivity, protonation should be significantly less efficient than for complexes of high reactivity. Therefore, **5** and **6** are still cytotoxic at pH 7.4 and relatively low (pH 7.4)/(pH 6.8) activity ratios of 2.03 and 1.46 were obtained. For compounds **1** and **2**, ratios of 2.84 and 2.35 were found and cytotoxicity was significantly reduced at pH 7.4. This effect became more obvious with the secondary alcohol derived xanthate complexes **15** and **16**. Compound **16** had almost similar activity at both pH conditions. In contrast, **15**, which is a complex of a probably more acidic xanthic acid was found to be 2.18-fold more active at pH 6.8 than at pH 7.4.

It is a general feature of cisplatin and its derivatives that cytotoxicity is correlated with the growth rate of target cells. Rapidly dividing cells are in general highly sensitive, independent of their state of malignancy. As a consequence, severe side effects on bone marrow cells and on gut epithelia arise.[11] This feature of cisplatin becomes obvious when the most rapidly growing cell line from our panel, Calu-6 (doubling time of 14−16 h), is compared with the slowly growing MCF-7, LXF-289, and SK-MEL-25 lines (doubling times of 32−48 h). In Calu-6, an IC_{50} of 25 μM was found, while in the slowly growing lines, values between 78 and 113 μM were determined. In contrast, most of the bis(*O*-alkyldithiocarbonato)platinum(II) complexes displayed similar IC_{50} values in Calu-6 and MCF-7. In some cases an even lower IC_{50} was found in slowly growing MCF-7 cells. Clear exceptions are **9**, **13**, **14**, and **21**. These compounds have a spectrum of activity similar to that of cisplatin; Calu-6 is by far the most sensitive cell line. Yet these compounds show reduced cytotoxic activity in the remaining lines. Thus, the latter compounds apparently lack some features important for the broad antitumoral activity compared with the other derivatives. The underlying mechanism remains to be explored. In this respect, compounds **14** and **21** could serve as controls in evaluating the differences between thioplatin and cisplatin. Irrespective of these open questions, we clearly demonstrated that compounds **15**, **16**, and **20** exceed the activity of cisplatin and, in addition, are more active at pH 6.8, conditions found frequently in tumor tissue.

Experimental Section

Cell Lines. Calu-6 (adenocarcinoma, lung), SK-MEL-25 (melanoma), MCF-7 (mammary carcinoma), LXF-289 (adenocarcinoma, lung), SK-OV-3 (adenocarcinoma, ovary), and KB (squameous cell carcinoma, head and neck) were obtained from ATCC and were cultivated according to the instructions of the supplier at 37 °C, 5% CO_2 atmosphere, and 100% relative humidity.

Control of pH. To obtain culture conditions at pH 6.8, media containing 1.3 g of $NaHCO_3$/L was prepared. To each 50 mL of fetal calf serum, which was used as an additive, 1 mL of 1 N HCl was added to neutralize $NaHCO_3$. After incubation for 30 min in a 5% CO_2 atmosphere, a pH of 6.8 was obtained in the cultures. This pH was stable for at least 12 h for all cell lines at the cell density used in this study.

A pH of 7.4 was obtained with medium containing 2.2 g of $NaHCO_3$/L.

Cytotoxicity Assay. For in vitro experiments, stock solutions of the platinum complexes in acetone were prepared (1 mg/mL). Because of poor solubility, stock solutions of lower concentration were used with some compounds: **3**, 0.25 mg/mL; **4**, 0.25 mg/mL; **12**, 0.90 mg/mL; **13**, 0.68 mg/mL; **15**, 0.57 mg/mL; **17**, 0.50 mg/mL. Acetone was applied in tissue culture up to a concentration of 5%. At this concentration, cellular growth rates remained unaffected (not shown). A maximum concentration of 50 μg/mL could be applied for compounds with a solubility of at least 1 mg/mL. For compounds with lower solubility, the maximum dose was accordingly lower.

Cells were plated in 96-well plates at a density of 2×10^6 cells/plate. In the case of SK-OV-3, 1×10^6 cells/plate were seeded. One day later, the culture medium was replaced by medium of the desired pH. After equilibration in a 5% CO_2

atmosphere, test compounds were added in quadruplicate. Serial 1:2 dilutions were prepared directly in the plates using multichannel pipets. The resulting concentrations were 50, 25, 12.5, 6.25, 3.1, 1.6, and 0.8 μg/mL. After incubation for 2 h at 37°C, the culture medium was discharged and replaced with 100 μL of a fresh, drug-free medium of pH 7.4. Cultures were incubated until untreated controls had grown confluent (between 24 and 96 h, depending on growth rate). Cells were fixed with 3% formaldehyde and stained with 1% crystal violet. The amount of bound crystal violet, which corresponds to the number of live cells, was determined in an Antos 2001 ELISA reader at 550 nm. In the cases of MCF-7 and KB, which formed nonhomogeneous growth patterns in the plates, the dye was eluted with 200 μL of ethanol/1% acetic acid before the absorbance was determined. IC_{50} values were taken from dose−response curves.

Chemistry. Instrumentation. Melting points were determined in open capillaries with a Büchi electrothermal melting point apparatus and are not corrected. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Brucker AC 300 instrument operating at 300 and 75 MHz, respectively. Chemical shifts (δ) are given in parts per million (ppm) relative to tetramethylsilane as internal reference. The following abbreviations are used to describe peak patterns when appropriate: s (singlet), d (doublet), t (triplet), q (quartet), p (pentet), m (multiplet), c (centered). ^{195}Pt NMR spectra were recorded in $CDCl_3$ on a Brucker DRX 300 instrument operating at 107 MHz with K_2PtCl_4 as internal reference. Infrared spectra were recorded on a Brucker Vector 22 in KBr. The following abbreviations are used to describe the peak intensity: w (weak), m (medium), s (strong). UV spectra were recorded on a Hewlett-Packard HP 8452 A spectrophotometer in CH_2Cl_2 as solvent. The absorption maxima λ_{max} are reported in nm, and the extinction coefficient ϵ is reported in $dm^{-3}\ mol^{-1}\ cm^{-1}$. Mass spectra were obtained with a JEOL JMS-700 instrument (FAB, positive mode; matrix was *m*-nitrobenzyl alcohol). Combustion analysis (C, H, S) was performed on an Elementar vario EL, and the results were within ±0.3% of the theoretical values.

All commercially available chemicals were used as received (solvents in p.a. quality).

Platinum Compounds. All alkylxanthates were prepared according to published procedures.[5,6] Xanthates were purified by crystallization or precipitation from acetone/diethyl ether or pentane. Colorless to bright-yellow crystals or solids were obtained. Potassium (or sodium) alkylxanthates (KS_2COR or NaS_2COR) were reacted with dipotassium tetrachloroplatinate(II) (K_2PtCl_4). A solution of 3.6 mmol of potassium alkylxanthate in 5 mL of water was added to 1.2 mmol of K_2PtCl_4 dissolved in 10 mL of water. Immediate precipitation of a yellow solid could be observed. In the cases of alkylxanthates with long carbon chains, the reaction progressed only slowly. The mixture was stirred overnight at room temperature. The precipitate was filtered, washed three times with distilled water, and was crystallized from acetone/chloroform. Remaining solvent was removed in vacuo at 10^{-3} Torr for 1−2 days. The isolated yields ranged between 73% and 99%.

The following compounds have been described but were only incompletely characterized: $Pt(S_2COR)_2$ with R = methyl,[8] ethyl,[8] *n*-propyl,[13] isopropyl,[14] *n*-butyl,[12] *n*-pentyl.[12]

Cisplatin, $PtCl_2(NH_3)_2$, was purchased from Bristol Myers as a solution of 0.5 mg/mL (Platinex). Thioplatin was obtained from Antisoma, London.

Bis(*O*-methyldithiocarbonato)platinum(II) (1):[8] yield 86%; mp 130 °C (dec); ^{1}H NMR δ 4.21 (s, 3H, CH_3); ^{13}C NMR δ 58.29 (OCH_3), 236.32 (CS_2); ^{195}Pt NMR δ −4254; IR (KBr) 2939 (w), 1622 (w), 1458 (s), 1429 (m), 1290 (s), 1184 (m), 1066 (m), 1025 (s), 947 (m) cm^{-1}; MS (FAB+) *m*/*z* 370, 392, 408, 409 (M^+), 410; UV [nm (ϵ)] λ 250 (35 800), 306 (5600), 358 (5900), 448 (3000). Anal. ($C_4H_6O_2S_4Pt$) C, H, S. Crystal system: monoclinic; *C*2/*m*; a = 10.8852(3) Å, b = 6.9265(2) Å, c = 6.2468(2) Å, α = 90°, β = 97.779(1)°, γ = 90°. Distances: Pt1−S2, 2.3159(8) Å; Pt1−S, 1, 2.3281(8) Å. Angles: S1−Pt1−S1#1, 180.0°; S1−Pt1−S2#1, 104.80(3)°; S1−Pt1−S2, 75.20-(3)°.

Bis(*O*-ethyl-dithiocarbonato)platinum(II) (2):[7,8] ^{1}H NMR δ 1.51 (t, ^3J = 7 Hz, 6H, CH_3), 4.63 (q, ^3J = 7 Hz, 4H, CH_2); ^{13}C NMR δ 13.71 (CH_3), 69.08 (OCH_2), 234.90 (CS_2); ^{195}Pt NMR δ −4213; IR (KBr) 2983 (w), 2935 (w), 1627 (w), 1464 (w), 1395 (s), 1370 (s), 1286 (s), 1116 (s), 1019 (s), 853 (m) cm^{-1}; MS (FAB+) *m*/*z* 436, 437 (M^+), 438, 439, 440; UV [nm (ϵ)] λ 250 (34 400), 304 (5400), 358 (6100), 448 (3100). Anal. ($C_6H_{10}O_2S_4$-Pt) C, H, S.

Bis(*O*-propyldithiocarbonato)platinum(II) (3):[13] yield 91%; mp 155 °C; ^{1}H NMR δ 1.05 (t, ^3J = 7.3 Hz, 3H, CH_3), 1.93 (m, 2H, CH_2), 4.56 (t, ^3J = 6.6 Hz, 2H, OCH_2); ^{13}C NMR δ 10.19 (CH_3), 21.59 (CH_2), 74.50 (OCH_2), 235.20 (CS_2); ^{195}Pt NMR δ −4220; IR (KBr) 2966 (w), 2931 (w), 2874 (w), 1627 (w), 1465 (w), 1405 (m), 1314 (m), 1281 (s), 1239 (m), 1025 (s), 929 (m); MS (FAB+) *m*/*z* 176, 289, 307, 423, 465, 466 (M^+); UV [nm (ϵ)] λ 250 (32 400), 306 (5300), 360 (6100), 448 (3200). Anal. ($C_8H_{14}O_2S_4Pt$) C, H, S. Crystal system: triclinic; $P\bar{1}$; a = 5.7785(3) Å, b = 6.6477(4) Å, c = 9.3271(5) Å, α = 85.657-(1)°, β = 79.479(1)°, γ = 79.030(1)°. Distances: Pt1−S1, 2.3322-(12) Å; Pt1−S2, 2.3377(10) Å. Angles: S1−Pt1−S1#1, 180.0°; S1−Pt1−S2#1, 104.88(4)°; S1−Pt1−S2, 75.12(4)°.

Bis(*O*-butyldithiocarbonato)platinum(II) (4):[12] yield 91%; mp 146 °C; ^{1}H NMR δ 0.98 (t, ^3J = 7.7 Hz, 3H, CH_3), 1.48 (m, 2H, CH_2), 1.88 (m, 2H, CH_2), 4.60 (t, ^3J = 6.6 Hz, 2H, OCH_2); ^{13}C NMR δ 13.51 (CH_3), 18.91 (CH_2), 30.05 (CH_2), 72.90 (OCH_2), 235.17 (CS_2); ^{195}Pt NMR δ −4219; IR (KBr) 2956 (w), 2931 (w), 2864 (w), 1627 (w), 1466 (w), 1407 (m), 1355 (m), 1288 (s), 1125 (m), 1029 (s), 1014 (s), 911 (m), 897 (m) cm^{-1}; MS (FAB+) *m*/*z* 155, 176, 308, 329, 493 (M^+), 494, 495; UV [nm (ϵ)] λ 250 (39 300), 304 (6400), 358 (7400), 448 (3800). Anal. ($C_{10}H_{18}O_2S_4Pt$) C, H, S. Crystal system: triclinic; $P\bar{1}$; a = 5.7543(1) Å, b = 6.7466(1) Å, c = 10.7487(3) Å, α = 73.594-(1)°, β = 77.591(1) °, γ = 79.749(1)°. Distances: Pt1−S1, 2.3312(11) Å; Pt1−S2, 2.3175(12) Å. Angles: S1−Pt1−S1#1, 180.0°; S1−Pt1−S2#1, 104.89(4)°; S1−Pt1−S2, 75.11(4)°.

Bis(*O*-pentyldithiocarbonatoplatinum(II) (5):[12] yield 83%; mp 109 °C; ^{1}H NMR δ 0.94 (t, ^3J = 7 Hz, 3H, CH_3), 1.41 (m, 4H, CH_2), 1.90 (m, 2H, CH_2), 4.59 (t, ^3J = 6.6 Hz, 2H, OCH_2); ^{13}C NMR δ 13.83 (CH_3), 22.15 (CH_2), 22.28 (CH_2), 27.77 (CH_2), 73.20 (OCH_2), 235.14 (CS_2); ^{195}Pt NMR δ −4219; IR (KBr) 2958 (w), 2928 (w), 2856 (w), 1628 (w), 1462 (w), 1401 (w), 1282 (s), 1126 (w), 1025 (m), 915 (w) cm^{-1}; MS (FAB+) *m*/*z* 154, 307, 381, 451, 520, 521 (M^+), 522, 523, 879, 1042 (M^+_{Dimer}); UV [nm (ϵ)] λ 254 (52 100), 304 (8400), 360 (9400), 448 (4500). Anal. ($C_{12}H_{22}O_2S_4Pt$) C, H, S.

Bis(*O*-hexyldithiocarbonato)platinum(II) (6): yield 90%; mp 84 °C; ^{1}H NMR δ 0.89 (m, 6H, CH_3), 1.28−1.44 (m, 10H, CH_2), 1.82−1.91 (m, 4H, CH_2), 4.56 (t, ^3J = 6.5 Hz, 4H, OCH_2); ^{13}C NMR δ 13.93, 22.42, 25.28, 28.04, 31.21, 73.21 (OCH_2), 235.12 (CS_2); ^{195}Pt NMR δ −4219; IR (KBr) 2952 (m), 2916 (m), 2852 (m), 1637 (w), 1468 (m), 1402 (m), 1297 (s), 1279 (s), 1129 (w), 1018 (s), 908 (m); MS (FAB+) *m*/*z* 380, 381, 382, 404, 405, 406, 407, 464, 465, 466, 467, 548, 549, 550 (M^+), 551, 552, 553, 1097, 1098, 1099, 1100 (M^+_{Dimer}); UV [nm (ϵ)] λ 252 (37 300), 306 (5800), 360 (6800), 448 (3300). Anal. ($C_{14}H_{26}O_2S_4$-Pt) C, H, S.

Bis(*O*-octyldithiocarbonato)platinum(II) (7): yield 98%; mp 95 °C; ^{1}H NMR δ 0.89 (t, ^3J = 7 Hz; 3H, CH_3), 1.21−1.49 (m, 10H, CH_2), 1.89 (m, 2H, CH_2), 4.59 (t, ^3J = 6.6 Hz, 2H, OCH_2); ^{13}C NMR δ 14.06 (CH_3), 22.60, 25.62, 28.08, 29.02, 29.04, 31.71, 73.23 (OCH_2), 235.13 (CS_2); ^{195}Pt NMR δ −4219; IR (KBr) 2954 (w), 2922 (w), 2852 (w), 1633 (w), 1465 (w), 1403 (w), 1282 (s), 1024 (m), 914 (w) cm^{-1}; MS (FAB+) *m*/*z* 289, 307, 329, 380, 381, 391, 433, 460, 604, 605 (M^+), 606, 607, 1210 (M^+_{Dimer}), 1211, 1212; UV [nm (ϵ)] λ 252 (37 800), 304 (5300), 358 (6000), 448 (2000). Anal. ($C_{18}H_{34}O_2S_4Pt$) C, H, S.

Bis(*O*-decyldithiocarbonato)platinum(II) (8): yield 99%; mp 93 °C; ^{1}H NMR δ 0.87 (t, 6H, CH_3), 1.26−1.45 (m, 28H, CH_2), 1.87 (m, 4H, CH_2), 4.56 (t, ^3J = 6.5 Hz, 4H, OCH_2); ^{13}C NMR δ 14.08, 22.65, 25.61, 28.08, 29.05, 29.25, 29.38, 29.45, 31.85, 73.22 (OCH_2), 235.15 (CS_2); ^{195}Pt NMR δ −4219; IR

(KBr) 2954 (s), 2922 (s), 2849 (s), 1633 (w), 1468 (s), 1404 (s), 1287 (s), 1155 (m), 1030 (s), 1017 (s), 914 (s) cm^{-1}; MS (FAB+) *m/z* 482, 521, 613, 660, 661, 662 (M^+), 663, 664, 665; UV [nm (ϵ)] λ 250 (40 000), 304 (6400), 360 (7500), 448 (3600). Anal. ($C_{22}H_{42}O_2S_4Pt$) C, H, S.

Bis(*O*-(cyclopropyl)methyldithiocarbonato)platinum-(II) (9): yield 89%; mp 113 °C (dec); ^{1}H NMR δ 0.42 (m_c, 4H, CH_2), 0.72 (m_c, 4H, CH_2), 1.35 (m_c, 2H, CH), 4.41 (d, ^3J = 7.5 Hz, 2H, OCH); ^{13}C NMR δ 3.97 (2 × CH_2), 9.14 (CH), 78.14 (OCH), 234.93 (CS_2); ^{195}Pt NMR δ −4214; IR (KBr) 2996 (w), 1637 (m), 1420 (w), 1355 (m), 1286 (s), 1246 (m), 1041 (m), 991 (m) cm^{-1}; MS (FAB+) *m/z* 289, 307, 329, 489, 490 (M^+), 491; UV [nm (ϵ)]: λ 252 (43 700), 304 (5800), 358 (6500), 450 (1800). Anal. ($C_{10}H_{14}O_2S_4Pt$) C, H, S.

Bis(*O*-isobutyldithiocarbonato)platinum(II) (10): yield 91%; mp 191 °C; ^{1}H NMR δ 1.04 (d, ^3J = 6.6 Hz, 6H, CH_3), 2.23 (m, 1H, CH), 4.37 (d, ^3J = 6.6 Hz, 2H, OCH_2); ^{13}C NMR δ 18.82 (2 × CH_3), 27.65 (CH), 78.70 (OCH_2), 235.23 (CS_2); ^{195}Pt NMR δ −4222; IR (KBr) 2961 (w), 2871 (w), 1629 (w), 1462 (w), 1404 (w), 1282 (s), 1034 (m), 958 (w) cm^{-1}; MS (FAB+) *m/z* 155, 176, 307, 329, 381, 443, 451, 460, 482, 492, 493 (M^+), 494, 495; UV [nm (ϵ)] λ 250 (38 600), 304 (4000), 358 (6600), 450 (2700). Anal. ($C_{10}H_{18}O_2S_4Pt$) C, H, S.

Bis(*O*-(2-methyl)butyldithiocarbonato)platinum(II) (11): yield 85%; mp 141 °C; ^{1}H NMR δ 0.96 (t, ^3J = 6.6 Hz, 3H, CH_3), 1.03 (d, ^3J = 7 Hz, 3H, CH_3), 1.29 (m, 1H, CH_2), 1.53 (m, 1H, CH_2), 1.99 (m, 1H, CH_2), 4.39 (dd, ^3J = 6.6 Hz, ^2J = 10 Hz, 1H, OCH_2), 4.47 (dd, ^3J = 5.9 Hz, ^2J = 10 Hz, 1H, OCH_2); ^{13}C NMR δ 11.11 (CH_3), 16.18 (CH_3), 25.74 (CH), 34.00 (CH_2), 77.42 (OCH_2), 235.23 (CS_2); ^{195}Pt NMR δ −4221; IR (KBr) 2963 (w), 2929 (w), 2876 (w), 1629 (w), 1457 (w), 1402 (m), 1283 (s), 1153 (w), 1037 (m), 930 (w) cm^{-1}; MS (FAB+) *m/z* 155, 176, 307, 380, 381, 451, 520, 521 (M^+), 522, 523, 1042 (M^+_{Dimer}); UV [nm (ϵ)] λ 252 (40 800), 306 (8200), 358 (9400), 448 (5600). Anal. ($C_{12}H_{22}O_2S_4Pt$) C, H, S.

Bis(*O*-(3-methyl)butyldithiocarbonato)platinum(II) (12): yield 96%; mp 145 °C; ^{1}H NMR δ 0.97 (d, ^3J = 6.6 Hz, 6H, CH_3), 1.79 (m, 3H, CH + CH_2), 4.63 (t, ^3J = 6.6 Hz, 2H, OCH_2); ^{13}C NMR δ 22.29 (CH_3), 24.86, 36.61, 71.75 (OCH_2), 235.08 (CS_2); ^{195}Pt NMR δ −4219; IR (KBr) 2959 (w), 2871 (w), 1634 (w), 1461 (w), 1404 (w), 1286 (s), 1025 (m), 911 (w) cm^{-1}; MS (FAB+) *m/z* 155, 176, 307, 391, 392, 460, 520, 521 (M^+), 522, 523, 1042; UV [nm (ϵ)] λ 252 (29 100), 304 (4400), 358 (4900), 448 (2000). Anal. ($C_{12}H_{22}O_2S_4Pt$) C, H, S.

Bis(*O*-(2,2-dimethyl)propyldithiocarbonato)platinum-(II) (13): yield 99%; mp 218 °C (dec); ^{1}H NMR δ 1.03 (s, 18H, CH_3), 4.24 (s, 4H, CH_2); ^{13}C NMR δ 26.26 (CH_3), 31.81 (C_q), 81.90 (OCH_2), 235.36 (CS_2); ^{195}Pt NMR δ −4222; IR (KBr) 2958 (s), 2908 (w), 2868 (w), 1626 (w), 1476 (w), 1404 (m), 1380 (s), 1300 (s), 1282 (s), 1258 (s), 1199 (s), 1061 (s), 1046 (s), 1019 (s), 951 (s), 931 (s) cm^{-1}; MS (FAB+) *m/z* 252, 289, 307, 427, 460, 482, 521, 522 (M^+), 523, 524; UV [nm (ϵ)] λ 250 (38 800), 306 (6000), 360 (6700), 448 (2600). Anal. ($C_{12}H_{22}O_2S_4Pt$) C, H, S.

Bis(*O*-(2,2-dimethyl-3-phenylpropyldithiocarbonato)-platinum(II) (14): yield 99%; mp 187 °C; ^{1}H NMR δ 1.03 (s, 12H, CH_3), 2.67 (s, 4H, CH_2), 4.21 (s, 4H, CH_2), 7.11 (m, 4H, PhH), 7.21−7.33 (m, 6H, PhH); ^{13}C NMR δ 24.28 (CH_3), 35.31 (CH_2), 44.70 (CH_2), 79.37 (OC), 126.51 (C_{Ph}), 128.21 (C_{Ph}), 130.45 (C_{Ph}), 137.14 ($C_{q,Ph}$), 235.23 (CS_2); ^{195}Pt NMR δ −4226; IR (KBr) 3025 (w), 2961 (w), 1636 (w), 1471 (w), 1399 (m), 1377 (m), 1286 (s), 1266 (s), 1253 (s), 1044 (s), 937 (w); MS (FAB+) *m/z* 427, 467, 468, 469, 470, 471, 503, 525, 558, 672, 673, 674 (M^+), 675, 676; UV [nm (ϵ)]: λ 250 (48 700), 306 (8300), 360 (9100), 448 (2000). Anal. Calcd ($C_{24}H_{30}O_2S_4Pt$): C, 42.78; H, 4.49. Found: C, 42.04; H, 4.46.

Bis(*O*-isopropyldithiocarbonato)platinum(II) (15): yield 93%; mp 159 °C; ^{1}H NMR δ 1.52 (d, ^3J = 6.2 Hz, 6H, CH_3), 5.44 (sept, ^3J = 6.2 Hz, 1H, OCH); ^{13}C NMR δ 21.61 (2 × CH_3), 79.08 (OCH), 233.95 (CS_2); ^{195}Pt NMR δ −4190; IR (KBr) 2980 (w), 2929 (w), 1627 (w), 1446 (w), 1362 (s), 1287 (s), 1082 (s), 1007 (m), 897 (w) cm^{-1}; MS (FAB+) *m/z* 154, 289, 307, 380, 381, 422, 421, 423, 464, 465 (M^+), 466, 467; UV [nm (ϵ)] λ 252 (29 500), 304 (4700), 358 (5700), 448 (2800). Anal. ($C_8H_{14}O_2S_4Pt$) C, H, S.

Bis(*O*-(1-ethyl)propyldithiocarbonato)platinum(II) (16): yield 90%; mp 92 °C; ^{1}H NMR δ 0.97 (t, ^3J = 7.4 Hz, 12H, CH_3), 1.78−1.86 (m, 8H, CH_2), 5.12 (m_c, 2H, OCH); ^{13}C NMR δ 9.50 (2 × CH_3), 26.51 (2 × CH_2), 88.89 (OCH), 234.79 (CS_2); ^{195}Pt NMR δ −4190; IR (KBr) 2968 (w), 2935 (w), 1638 (w), 1457 (w), 1385 (m), 1370 (m), 1304 (s), 1287 (s), 1103 (w), 1017 (m) cm^{-1}; MS (FAB+) *m/z* 380, 381, 450, 451, 452, 520, 521 (M^+), 522, 523, 1042 (M^+_{Dimer}), 1043; UV [nm (ϵ)] λ 252 (44 600), 304 (6400), 358 (7300), 446 (2300). Anal. ($C_{12}H_{22}O_2S_4Pt$) C, H, S.

Bis(*O*-(1,2,2-trimethyl)propyldithiocarbonato)platinum-(II) (17): yield 88%; mp 170 °C (dec); ^{1}H NMR δ 0.98 (s, 18H, CH_3), 1.38 (d, ^3J = 6.4 Hz, 6H, CH_3), 5.05 (q, ^3J = 6.4 Hz, 2H, CH); ^{13}C NMR δ 14.80 (CH_3), 25.56 ((CH_3)$_3$), 34.99 (C_q), 89.61 (OCH), 234.46 (CS_2); ^{195}Pt NMR δ −4195; IR (KBr) 2964 (m), 2870 (w), 1628 (w), 1441 (w), 1370 (s), 1291 (s), 1118(w), 1075 (m), 1045 (m), 1015 (m), 873 (m) cm^{-1}; MS (FAB+) *m/z* 307, 381, 405, 466, 547, 548, 549, 550 (M^+), 551, 552, 553, 668, 1099 (M^+_{Dimer}); UV [nm (ϵ)] λ 252 (38 800), 304 (5700), 358 (6800), 446 (2400). Anal. ($C_{14}H_{26}O_2S_4Pt$) C, H, S.

Bis(*O*-cyclobutyldithiocarbonato)platinum(II) (18): yield 79%; mp 155 °C; ^{1}H NMR δ 1.71 (m_c, 2H, CH_2), 1.93 (m_c, 2H, CH_2), 2.37−2.44 (m, 4H, CH_2), 2.45−2.57 (m, 4H, CH_2), 5.35 (p, ^3J = 6.4 Hz, 2H, OCH); ^{13}C NMR δ 13.55 (CH_2), 30.10 (2 × CH_2), 77.23 (OCH), 233.31 (CS_2); ^{195}Pt NMR δ −4210; IR (KBr) 2990 (w), 2942 (w), 1637 (w), 1364 (m), 1278 (s), 1261 (s), 1126 (m), 1126 (m), 1040 (m), 1014 (m), 885 (m) cm^{-1}; MS (FAB+) *m/z* 307, 460, 489, 490 (M^+), 491, 492, 979, 980 (M^+_{Dimer}); UV [nm (ϵ)] λ 252 (45 700), 306 (6900), 362 (7700), 450 (3100). Anal. ($C_{10}H_{14}O_2S_4Pt$) C, H, S.

Bis(*O*-cyclopentyldithiocarbonato)platinum(II) (19): yield 75%; mp 156 °C (dec); ^{1}H NMR δ 1.63−1.71 (m, 4H, CH_2), 1.72−1.86 (m, 4H, CH_2), 1.96−2.10 (m, 8H, CH_2), 5.58 (m, 2H, OCH); ^{13}C NMR δ 23.80 (2 × CH_2), 32.81 (2 × CH_2), 88.02 (OCH), 233.95 (CS_2); ^{195}Pt NMR δ −4196; IR (KBr) 2960 (w), 2924 (w), 1637 (w), 1429 (w), 1369 (m), 1331 (m), 1282 (s), 1156 (m), 1020 (m), 925 (m) cm^{-1}; MS (FAB+) *m/z* 307, 329, 460, 517, 518 (M^+), 519; UV [nm (ϵ)]: λ 252 (39 400), 304 (5400), 360 (6300), 448 (1900). Anal. ($C_{12}H_{18}O_2S_4Pt$) C, H, S.

Bis(*O*-cyclohexyldithiocarbonato)platinum(II) (20): yield 97%; mp 162 °C (dec); ^{1}H NMR δ 1.28−1.85 (m, 16H, CH_2), 1.95−2.07 (m, 4H, CH_2), 5.15 (m, 2H, OCH); ^{13}C NMR δ 23.30 (CH_2), 24.87 (CH_2), 31.14 (CH_2), 83.66 (OCH), 233.84 (CS_2); ^{195}Pt NMR δ −4189; IR (KBr) 2935 (m), 2856 (m), 1626 (w), 1448 (m), 1377 (m), 1281 (s), 1241 (m), 1151 (m), 1033 (m), 1018 (s), 993 (m), 907 (m), 882 (m) cm^{-1}; MS (FAB+) *m/z* 460, 482, 544, 545, 546 (M^+), 547, 548; UV [nm (ϵ)] λ 252 (36 800), 304 (5800), 360 (7200), 448 (3200). Anal. ($C_{14}H_{22}O_2S_4Pt$) C, H, S. Crystal system: monoclinic; space group $P2_1/c$; a = 10.3154(4) Å, b = 9.4968(3) Å, c = 18.6967(7) Å, α = 90°, β = 100.118(1)°, γ = 90°. Distances: Pt1−S2, 2.3182(7) Å; Pt1−S1, 2.3200(7) Å; Pt1−S1#1, 2.3237(6) Å. Angles: S1−Pt1−S1#1, 177.19(3)°; S1−Pt1−S2#1, 104.67(2)°; S1−Pt1−S2, 74.94-(2)°.

Bis(*O*-exo/exo-tricyclo[5.2.1.0^{2,6}]dec-9-yldithiocarbonato)platinum(II) (21): yield 87%; mp 172 °C; ^{1}H NMR δ 0.90−1.08 (m, 4H), 1.13−1.32 (m, 2H), 1.38−1.52 (m, 4H), 1.60−1.97 (m, 10H), 2.10 (m_c, 2H), 2.35 (m_c, 2H), 4.94 (m, 2H, OCH); ^{13}C NMR δ 27.70, 29.66, 31.60, 31.89, 38.82, 39.57, 42.43, 46.19, 47.21, 87.42 (OC), 233.82 (CS2); ^{195}Pt NMR δ −4195; IR (KBr) 2948 (m), 2860 (m), 1623 (w), 1473 (w), 1441 (w), 1369 (m), 1306 (s), 1265 (s), 1156 (m), 1034 (m), 957 (m) cm^{-1}; MS (FAB+) *m/z* 252, 307, 482, 529, 562, 589, 590, 613, 648, 649, 650 (M^+), 651, 652, 653; UV [nm (ϵ)]: λ 252 (43 600), 306 (6200), 360 (7500), 450 (2200). Anal. ($C_{22}H_{30}O_2S_4Pt$) C, H, S.

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