

This article was downloaded by:

On: 23 January 2011

Access details: *Access Details: Free Access*

Publisher *Taylor & Francis*

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Journal of Coordination Chemistry

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713455674>

A Potential Model for Metal-Peptide Interactions

Aleksander Kufelnickp^a; Mirosława Świątek^a; Andrzej Vogt^b; Jacek Skarzewski^c

^a Institute of Chemistry, Medical Academy of Łódź, Łódź, Poland ^b Faculty of Chemistry, University of Wrocław, Wrocław, Poland ^c Institute of Organic Chemistry, Biochemistry and Biotechnology, Technical University, Wrocław, Poland

To cite this Article Kufelnickp, Aleksander , Świątek, Mirosława , Vogt, Andrzej and Skarzewski, Jacek(1998) 'A Potential Model for Metal-Peptide Interactions', *Journal of Coordination Chemistry*, 43: 1, 21 – 30

To link to this Article: DOI: 10.1080/00958979808022867

URL: <http://dx.doi.org/10.1080/00958979808022867>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

THE COBALT(II)-N,N'- DIGLYCYLETHYLENEDIAMINE-DIOXYGEN SYSTEM

A Potential Model for Metal-Peptide Interactions

ALEKSANDER KUFELNICKI^{a,*}, MIROSLAWA ŚWIĄTEK^a, ANDRZEJ
VOGT^b, JACEK SKARŻEWSKI^c,

^a*Institute of Chemistry, Medical Academy of Łódź, 1 Muszyński Str., 90-151 Łódź, Poland;* ^b*Faculty of Chemistry, University of Wrocław, 14 Joliot-Curie Str., 50-383 Wrocław, Poland;* ^c*Institute of Organic Chemistry, Biochemistry and Biotechnology, Technical University, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland*

(Received 10 December 1996)

In order to investigate hitherto undescribed dioxygen interactions in the cobalt(II)-DGEN system (DGEN: *N,N'*-diglycylethylenediamine, 1,8-diamino-3,6-diaza-2,7-octanedione) all the equilibria possible under an oxygen-free atmosphere had to be reexamined. Two new equilibria have been confirmed by potentiometric and spectrophotometric measurements: $M + L + H \rightleftharpoons MLH$ and $M + 2L \rightleftharpoons ML_2$. Unlike Co(II)-dipeptide systems, metal-promoted deprotonation of the amide group has not been observed. The ML_2 species may act as an "active" complex, able to take up dioxygen in a partially reversible way (reversibility up to 50%). The reaction mechanism is similar to that known for diamines. The structure of the bridging unit in the oxygenated μ -peroxo- μ -hydroxodicobalt(III) complexes has been confirmed by volumetric and spectroscopic experiments.

Keywords: diglycylethylenediamine; cobalt(II); dioxygen uptake

INTRODUCTION

Although the formation as well as metal promoted amide deprotonation equilibria in aqueous solutions of DGEN with copper(II) [1, 2] and nickel(II) [1, 3-5] have been described comprehensively, reactions in the cobalt(II) system

* Author for correspondence.

were studied only by Sun Bai and Martell. [1, 6] The formation constant for ML^{2+} was determined ($\log \beta_{110} = 3.30$), no amide proton displacement being observed. On the other hand, interaction with dioxygen has not been reported.

It seemed interesting to study this system if the oxygenation reaction is possible in the case of DGEN despite the absence of metal promoted amide deprotonation, since participation of the amide nitrogen is considered as the necessary condition of dioxygen uptake in analogous Co(II)-peptide systems. [7] The composition and structure of some deprotonated cobalt(II)-amide complexes as the "active" forms in oxygenation reactions have been extensively studied in previous papers. [8-10]

EXPERIMENTAL

Reagents

DGEN·2HCl and DGEN·2HBr were prepared using the Cottrell and Gill method [11] and standard peptide methodology, [12] respectively. In the second case, ethylenediamine was acylated with *p*-nitrophenylcarbobenzyloxyglycinate and the purified product was subsequently deprotected using a solution of HBr in acetic acid. The crude salts were recrystallized from ethanol. Both final products gave acceptable spectroscopic and elemental analyses. A stock solution of cobalt(II) nitrate (POCh Gliwice) was standardized with disodium versenate in the presence of murexide. The remaining reagents (nitric acid, sodium hydroxide, potassium nitrate) were also POCh Gliwice products of the highest analytical purity.

Physical Measurements

Potentiometric measurements were carried out by means of a PHM-85 precision pH meter (Radiometer) equipped with a combined GK2401C electrode and T801 temperature sensor. The indicating glass electrode was standardized with buffer solutions, phthalate ($pH_{20} = 4.00 \pm 0.02$) and phosphate ($pH_{20} = 6.50 \pm 0.02$, obtained from concentrated Radiometer solution). The glass electrode was calibrated on the $pH = f(-\log[H^+])$ scale by the method of Irving. [13] Calculations of formation constants from the potentiometric measurements were carried out using the SUPERQUAD program purchased from Protonic Software (Leeds, U.K.). Volumetric measurements were made in an isobaric measurement system of our own design, [14] provided with a double walled reaction vessel. Electronic absorption spectra were measured on a Specord M40 (Zeiss) spectrophotometer with a thermostatted cell compartment. The pH measurements

TABLE I Equilibrium constants β_{MLH} in the cobalt (II)—DGEN system under oxygen-free conditions; $\mu = 0.1$ (KNO_3), 25°C .

Constant	Present work	Literature
$\log \beta_{011}$	8.20 ± 0.01	$8.22^1; 8.33^2; 8.39^3; 8.51^4$
$\log \beta_{012}$	15.67 ± 0.01	$15.70^1; 16.00^2; 16.10^3; 16.32^4$
$\log \beta_{110}$	3.30 ± 0.01	3.30^1
$\log \beta_{111}$	10.54 ± 0.02	
$\log \beta_{120}$	5.13 ± 0.04	

in the internal spectrophotometric titrations under oxygen atmosphere were carried out by means of a N517 MERA (Wroclaw) pH-meter with a combined OSH-10-10 electrode for measurements at a semi-micro scale. The titrant was added with a microsyringe (Hamilton Bonaduz AG, Switzerland). Spectroscopic curves were digitalized by means of an EMG 777D programmable graphic calculator (Hungary). Determination of stability constants on the basis of spectrophotometric titrations was accomplished by the EQUID program (kindly supplied by Dr. A. Liwo [15]) and for comparison by HYPERQUAD (Protonic Software). ESR spectra of solutions of μ -superoxodicobalt complexes were recorded on a ESP 300E Bruker spectrometer at room temperature.

RESULTS AND DISCUSSION

Potentiometric and Spectrophotometric Data under Oxygen-free Atmosphere

The two protonation constants of DGEN at 25°C , $\mu = 0.1$ (KNO_3) and then the formation constants of complexes under oxygen-free atmosphere¹¹¹ have been determined for various metal concentrations (within the range $3.33 \times 10^{-3} - 1.0 \times 10^{-2}$ mol dm⁻³) and various L:M values. The results of SUPERQUAD least-squares refinement procedures are presented in Table I and illustrated by an exemplary species distribution diagram (Figure 1). Attempts to detect metal promoted amide deprotonation resulted in rejection of all the estimated equilibrium constants. Moreover, during the titrations in the presence of cobalt, the molar neutralization coefficient did not exceed $a = 2$ and at pH > 8.5 precipitation of $\text{Co}(\text{OH})_2$ has been observed.



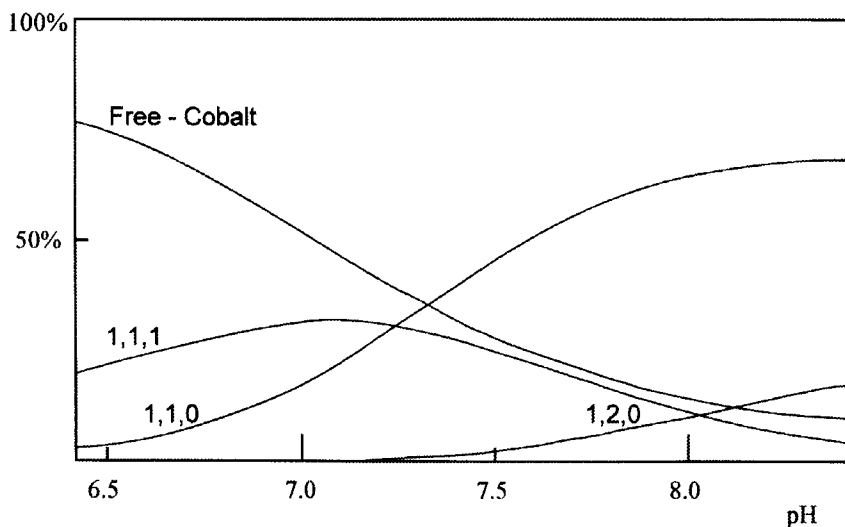


FIGURE 1 Species distribution diagram for the cobalt (II)—DGEN equilibrium system; $C_{Co} = 8.33 \times 10^{-3} \text{ mol dm}^{-3}$, $C_L = 1.67 \times 10^{-2} \text{ mol dm}^{-3}$, $\mu = 0.1 \text{ (KNO}_3\text{)}$, 25°C .



Spectrophotometric titrations of Co(II)-DGEN under an oxygen-free atmosphere (Figure 2) were also carried out at various total metal concentrations and various L:M values. Relatively low values of the molar absorption coefficients at $ca 20 \times 10^3 \text{ M}^{-1} \text{ cm}^{-1}$ (originating from the mainly *quasi*-octahedral ligand field transition ($4T_{1g} \rightarrow 4T_{1g}(P)$) with admixture of transitions to doublet states) induced the use of higher total cobalt concentrations ($3 - 6 \times 10^{-2} \text{ mol dm}^{-3}$).

The highest curves (without precipitation) were obtained at $a = 1.5 - 2$. Addition of base was accompanied by a distinct rise in absorbance together with a slight blue shift of the maximum.

Volumetric and Spectroscopic Data under Oxygen Atmosphere

Titration were carried out at L:M = 0.5:1, 1:1, 1.5:1, 2:1, 2.5:1 and 3:1. Dioxygen uptake in the Co(II)-DGEN system occurs at pH = 8 to 9 (an exemplary titration is shown in Figure 3). Within that pH range, as follows from Figure 1, the concentration of Co(DGEN)_2 begins to increase.

In addition, the dependence of total oxygen uptake on ligand to metal ratio (determined in various titrations) showed an inflection at $C_L:C_{Co} \approx 2$. Then, amounts of dioxygen bound per 1 mmol Co at higher L:M values did slightly

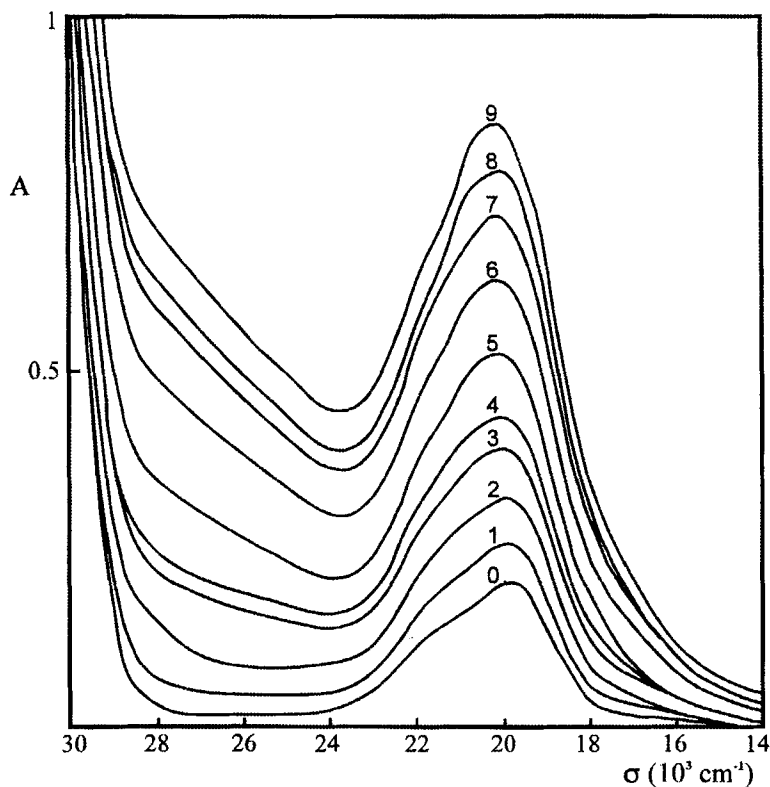


FIGURE 2 Spectrophotometric titration in the cobalt (II)-DGEN system; $C_{Co} = 0.0357 \text{ mol dm}^{-3}$, $C_L = 0.0713 \text{ mol dm}^{-3}$, $\mu = 1.0$ (KNO_3), 25°C ; number of moles of sodium hydroxide added per mole of ligand, α : 0-0.0, 1-0.111, 2-0.259, 3-0.416, 4-0.515, 5-0.729, 6-0.841, 7-0.963, 8-1.152, 9-1.285.

exceed 0.5 mmol. The average number of mmol of OH^- per 1 mmol O_2 resulting from all the experiments under O_2 atmosphere amounted to 9.

The electronic spectra of the oxygen complex (Figure 4) have been recorded at the same concentrations of ligand and metal and at various initial pH values (8 to 12) corresponding to particular points of the volumetric titration. The temperature was lowered to $\approx 0^\circ\text{C}$ in order to inhibit the irreversible autoxidation reaction.

Kinetic data concerned with the first-order autoxidation showed that the half-lives, $t_{0.5}$, were particularly long in basic medium. When the initial pH (before adding the cobalt(II) solution) was ~ 13 , the value of $t_{0.5}$ exceeded 80 minutes, whereas at $\text{pH}_{\text{initial}} \sim 9$ the $t_{0.5}$ values were lower than 15 minutes. The electronic absorption spectra of the μ -superoxidicobalt(III) complex were obtained after mono-electronic oxidation of the peroxo bridge to a superoxo bridge, (4).

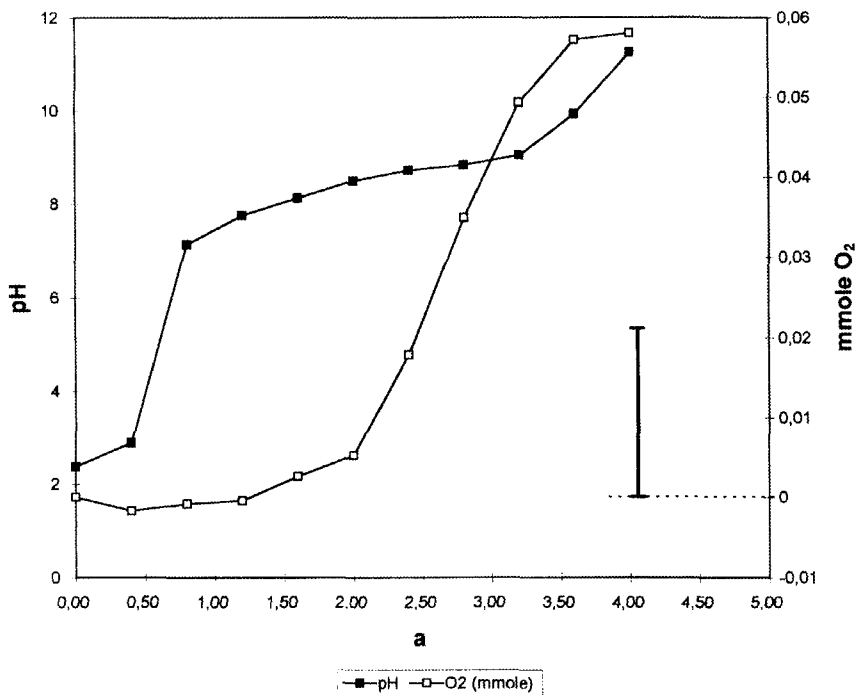
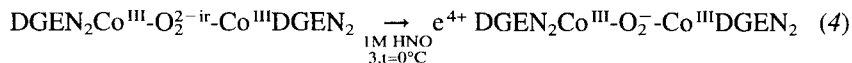


FIGURE 3 A plot of pH changes and quantity of dioxygen uptake vs a (molar neutralization coefficient); $C_{Co} = 3.33 \times 10^{-3} \text{ mol dm}^{-3}$, $C_L = 6.67 \times 10^{-3} \text{ mol dm}^{-3}$, $\mu = 0.1$ (KNO_3), $\sim 0^\circ\text{C}$. The vertical segment shows the amount of oxygen evolved upon acidification of the solution at the end of the titration.

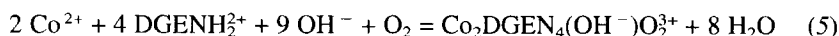


The MLCT band $d\pi(\text{Co}) \rightarrow \pi^*_v(\text{O}_2^-)$, characteristic of μ -superoxo species, occurred at $13.9 \times 10^3 \text{ cm}^{-1}$ (Figure 5). In the ESR spectrum, the paramagnetic μ -superoxodicobalt species in acidic solution gave a radical signal ($g_{\text{iso}} = 2.034$) with a well resolved 15-line hyperfine structure of $A_{\text{iso}} = 1.2 \text{ mT}$ (Figure 6).

The formation constant of CoDGEN^{2+} (Table I) is identical with the one reported by Sun Bai and Martell, [3] but the constants for other complexes (CoDGENH^{3+} and $\text{Co}(\text{DGEN})_2^{2+}$) have not been previously evaluated. From the two possible structures of CoDGEN^{2+} (I,II), structure I seems to be more probable than the square-planar structure II. In the latter case the formation of ML_2 would be excluded. In addition, the *quasi*-octahedral structure of the complexes was evidenced by the ligand field spectra observed in the spectrophotometric titrations (Figure 2). Consequently, the protonated MLH complex may be presented as III. (Scheme I)

The results of EQUID and HYPERQUAD fitting procedures for the absorbance curves measured under oxygen-free conditions confirmed the model found from the potentiometric titrations, although the standard deviations in $\log \beta$ were higher. The rise in molar absorption coefficients of the species is in the order CoDGEN^{2+} , CoDGENH^{3+} and $\text{Co}(\text{DGEN})_2^{2+}$, determined by deconvolution of the spectra (Figure 7), and corresponds to the increase in ligand field strength of the complexes.

The dioxygen uptake data indicate the overall reaction with oxygen to be similar to that for diamines. [16, 17]



The oxygenation equilibrium then may be written as in (6).

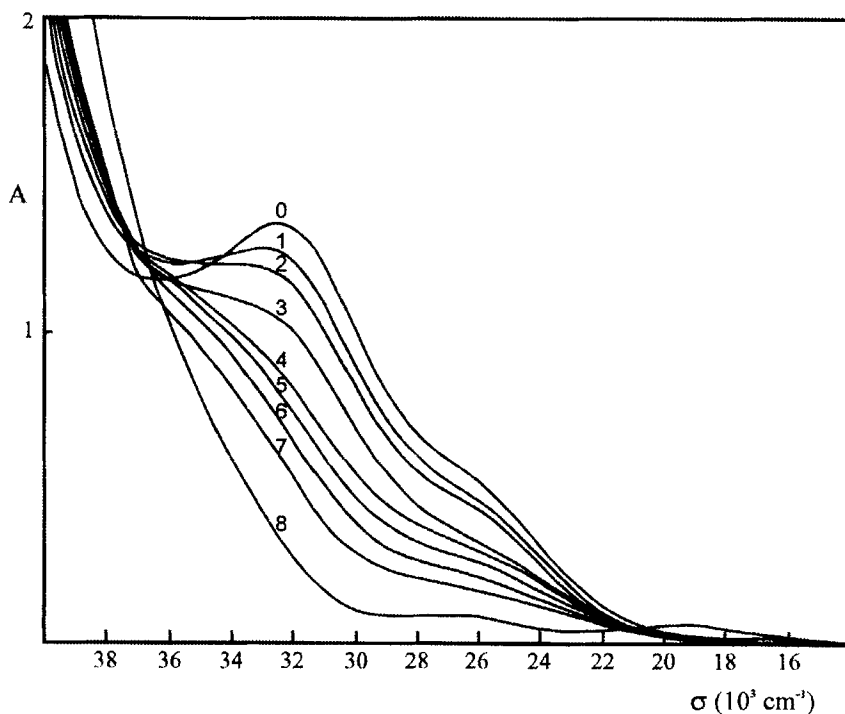


FIGURE 4 Electronic absorption spectra of the μ -peroxo- μ -hydroxodicobalt (III) complex with DGEN taken soon after oxygenation (curve 0) and after 1-20 min, 2-30 min, 3-40 min, 4-1 h, 5-1 h 30 min, 6-2 h, 7-3 h, 8-24 h; path length = 0.1 cm, $C_{\text{Co}} = 3.33 \times 10^{-3} \text{ mol dm}^{-3}$, $C_{\text{L}} = 1.0 \times 10^{-2} \text{ mol dm}^{-3}$, $\text{pH}_{\text{initial}} = 12.66$, $C_{\text{NaOH}} = 2.72 \times 10^{-2} \text{ mol dm}^{-3}$.

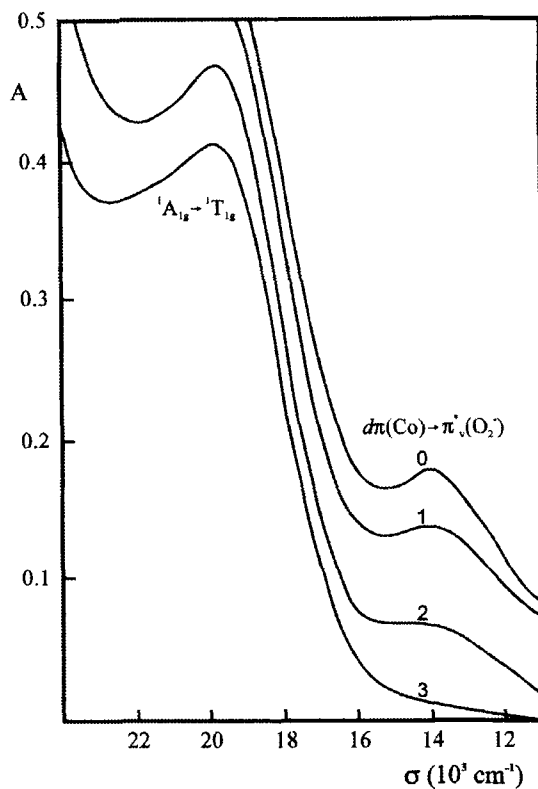


FIGURE 5 Absorption spectrum of the cobalt (II)-DGEN μ -superoxo- μ -hydroxo complex; 0—soon after mono-electron oxidation of the dioxygen bridge, 1—after 20 min, 2—after 40 min, 3—after 90 min; path length = 0.1 cm, $C_{Co} = 3.33 \times 10^{-3} \text{ mol dm}^{-3}$, $C_L = 1.0 \times 10^{-2} \text{ mol dm}^{-3}$.

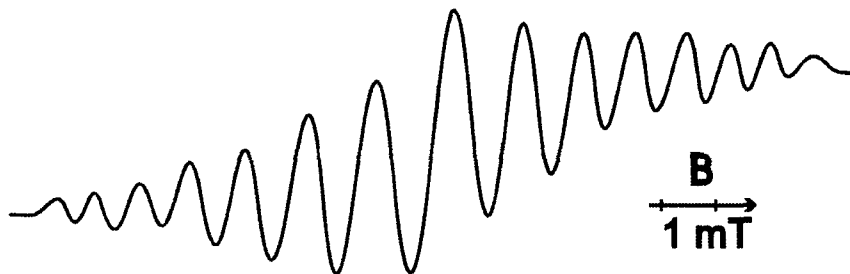
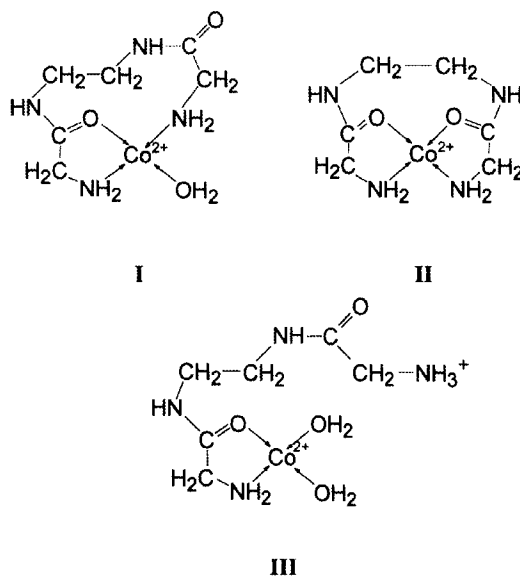


FIGURE 6 ESR spectrum of μ -superoxo- μ -hydroxo species in the Co(II)-DGEN- O_2 system; $T = 295 \text{ K}$, $C_{Co} = 3.33 \times 10^{-3} \text{ mol dm}^{-3}$, $C_L = 1.0 \times 10^{-2} \text{ mol dm}^{-3}$.



The presence of an additional hydroxo bridge has been confirmed by the electronic spectra of the oxygenated complex (Figure 4). Besides the isolated peak at $\sim 32 \times 10^3 \text{ cm}^{-1}$ due to the π^*_h (in-plane) $\rightarrow d\sigma^*(\text{Co})$ component, a shoulder at $\sim 25 \times 10^3 \text{ cm}^{-1}$ due to a much weaker π^*_v (out-of-plane) $\rightarrow d\sigma^*(\text{Co})$ transition has been observed. This type of spectrum is characteristic of

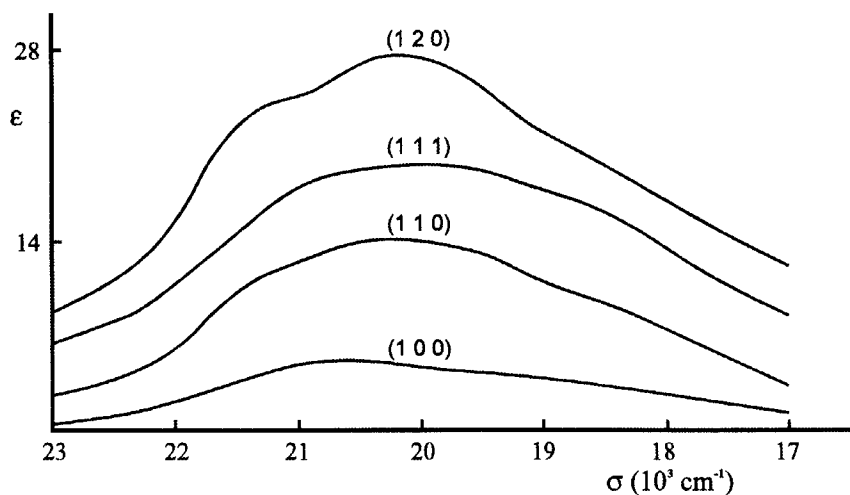
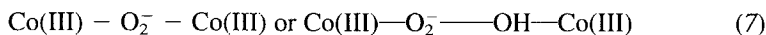


FIGURE 7 Molar absorption coefficients of the various cobalt (II)-DGEn complexes found in the equilibrium mixture; $C_{\text{Co}} = 0.0357 \text{ mol dm}^{-3}$, $C_{\text{L}} = 0.1420 \text{ mol dm}^{-3}$.

dibridged μ -peroxo- μ -hydroxo fragments (enhanced planarity of the $\text{Co}(\text{O}_2, \text{OH})\text{Co}$ unit). [18, 19] Confirmation of the bridging mode in the Co-DGEN-O_2 adduct came from the Vis/NIR spectrum of the μ -superoxodocobalt(III) complex. The intensity of the MLCT band was relatively low (even lower than the neighbouring d^6 quasi-octahedral d-d band of cobalt(III); $^1A_{1g} \rightarrow ^1T_{1g}$), just as in the case of other planar dibridged systems. [18, 19]

The 15-line hyperfine structure of the ESR spectrum is due to a symmetrical interaction of the unpaired electron of the O_2^- radical with the two ^{59}Co nuclei ($I = 7/2$). The small values of A_{iso} as compared with the oxygen-free complexes indicate that the unpaired electron density is mainly shifted towards π^* orbitals of the coordinated dioxygen group. Thus the following structure notation may be justified for the studied complex.1



References

- [1] K. Sun Bai, and A.E. Martell, *J. Am. Chem. Soc.*, **91**, 4412 (1969).
- [2] M. Briellman, and A.D. Zuberbühler, *Helv. Chim. Acta*, **65**, 46 (1982).
- [3] K. Sun Bai, and A.E. Martell, *Inorg. Chem.*, **9**, 1126 (1970).
- [4] T. Kaden, *Helv. Chim. Acta*, **54**, 625 (1971).
- [5] R. Pearson, and G.K. Pagenkopf, *Inorg. Chem.*, **17**, 1799 (1978).
- [6] *Stability Constants Database SQUERY*© 1993 (IUPAC and Academic Software, Leeds, U.K.).
- [7] I. Sóvágó, *Metal Complexes of Peptides and Their Derivatives*, In: *Biocoordination Chemistry: Coordination Equilibria in Biologically Active Systems*, (K. Burger, Ellis Horwood, Chichester, 1990).
- [8] A. Vogt, A. Kufelnicki, and B. Jeżowska-Trzebiatowska, *Polyhedron*, **9**, 2567 (1990).
- [9] A. Kufelnicki, and M. Świątek, *Polish J. Chem.*, **67**, 1345 (1993).
- [10] A. Kufelnicki, M. Świątek and A. Vogt, *Polish J. Chem.*, **69**, 206 (1995).
- [11] T.L. Cottrell and J.E. Gill, *J. Chem. Soc.*, 129 (1947).
- [12] J. Skarżewski and J. Mlochowski, *J. Chem. Research (S)*, 64 (1988); *J. Chem. Research (M)*, 552 (1988).
- [13] M. Meloun, J. Havel and E. Högfeldt, *Computation of Solution Equilibria: A Guide to Methods in Potentiometry, Extraction, and Spectrophotometry*, (Ellis Horwood, Chichester, 1988).
- [14] A. Kufelnicki, *Polish J. Chem.*, **62**, 19 (1988).
- [15] J. Kostrowicki and A. Liwo, *Comput. Chem.*, **11**, 195 (1987).
- [16] S. Fallab, *Angew. Chem.*, **79**, 500 (1967).
- [17] S. Petri, *Roczniki Chem.*, **46**, 355 (1972).
- [18] A.B.P. Lever and H.B. Gray, *Acc. Chem. Res.*, **11**, 348 (1978).
- [19] A. Kufelnicki, *Polish J. Chem.*, **65**, 269 (1991).