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SOME PROPERTIES AND THERMAL DECOMPOSITION OF YTTRIUM AND LANTHANIDE BENZOHYDROXAMATES

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Abstract

The conditions of formation and some properties of yttrium and lanthanide benzohydroxamates were studied.

Simultaneous TG-DTG-DTA studies under non-isothermal conditions were carried out in air atmosphere in the temperature range 20–1000°C. The IR spectra and X-ray patterns of some thermal decomposition products were recorded.

Keywords: benzohydroxamates, lanthanides(III)

Introduction

The hydroxamic acids, RC(O)NHOH, behave as chelating agents, coordinating to metal ions via the two oxygen atoms. The hydroxamates of iron(III) are the best-known such compounds [1–5]. They are usually red, which facilitates quantitative determination of the content of hydroxamic acid or iron(III) in solution. Iron(III) benzohydroxamate is likewise the best-known complex of benzohydroxamic acid with metal ions [6–8]. Molybdenum(VI) benzohydroxamate has been widely described [9–15]. The benzohydroxamates of chromium(III) [16–18], gallium(III) [5, 19], cobalt(III) [18, 20] and indium(III) [21] are also known. We have not found any reference to benzohydroxamates of yttrium(III) or the lanthanides(III).

The aim of this paper is to report on the preparation of rare earth benzohydroxamates in the solid state, their properties and their thermal decompositions in an atmosphere of air.

Experimental

Materials

Benzohydroxamic acid (>98%; Merck, Germany), HCl (p.a. 36% solution), $NH_3{\cdot}H_2O$ (p.a. 25% solution), Lu_2O_3 (99.9%; POCh Gliwice, Poland), Y_2O_3

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(99.9%), La_2O_3 (99.5%), $Ce(NO_3)_3{\cdot}6H_2O$ (99%), Pr_6O_{11} (99.5%), Nd_2O_3 (99.9%), Sm_2O_3 (99%), Gd_2O_3 (99.5%; prepared in our laboratory), Eu_2O_3 (99.9%), Tb_4O_7 (99.9%), Dy_2O_3 (99.9%; Koch Light Laboratories Ltd., England), Ho_2O_3 (99%), Tm_2O_3 (99%; Riedel-de Haën, Germany), Er_2O_3 (99.9%) and Yb_2O_3 (99.9%; Fluka AG, Buchs GS, Switzerland) were used.

Benzohydroxamates of Y(III) and lanthanides(III) (without Pm) were prepared by adding a 0.03 M solution of the metal chloride (Ce(III) was used as nitrate) to a hot 0.1 M solution of benzohydroxamic acid. The resulting mixture was adjusted to pH 5.5 with $NH_3{\cdot}H_2O$ solution. The precipitate formed was heated in the mother liquor for 1 h, filtered off, washed with hot water to remove Cl^- and NH_4^+, and dried at 35°C to constant weight. The compounds obtained were characterized via methods of elemental analysis. The analysis are presented in Table 1.

Methods

IR spectra of benzohydroxamic acid and of its complexes with yttrium and the lanthanides were recorded with a Specord M80 spectrophotometer within the range 4000–400 cm^{-1}, with a sensitivity of ± 2 cm^{-1}. Samples were prepared as KBr discs.

Table 1 The results of the elemental analysis of Y(III) and lanthanide benzohydroxamates and their solubility at water at 25°C ($L = C_7H_6NO_2^-$)

Complex	%Ln		%C		%H		%N		Solubility/
	found	calc.	found	calc.	found	calc.	found	calc.	mol dm^{-3}
$YL_3{\cdot}H_2O$	17.21	17.44	49.49	48.84	3.92	3.88	8.25	8.14	$5.3{\cdot}10^{-5}$
$LaL_3{\cdot}H_2O$	24.99	24.60	43.90	44.60	3.48	3.54	7.32	7.43	$1.4{\cdot}10^{-5}$
Ce_6OL_{17}	26.86	26.52	45.00	45.08	3.34	3.22	7.28	7.51	$1.1{\cdot}10^{-5}$
$PrL_3{\cdot}H_2O$	24.21	24.87	44.65	44.44	3.62	3.53	7.61	7.41	$1.7{\cdot}10^{-5}$
$NdL_3{\cdot}H_2O$	24.60	25.26	44.40	44.21	3.60	3.51	7.56	7.37	$2.5{\cdot}10^{-5}$
$SmL_3{\cdot}H_2O$	26.29	26.04	43.33	43.75	3.44	3.47	7.22	7.29	$5.3{\cdot}10^{-5}$
$EuL_3{\cdot}H_2O$	26.08	26.30	43.96	43.60	3.49	3.46	7.33	7.27	$7.3{\cdot}10^{-5}$
$GdL_3{\cdot}H_2O$	26.63	26.93	43.71	43.22	3.47	3.43	7.28	7.20	$10.2{\cdot}10^{-5}$
$TbL_3{\cdot}H_2O$	27.10	27.18	43.20	43.08	3.43	3.42	7.20	7.18	$6.0{\cdot}10^{-5}$
$DyL_3{\cdot}H_2O$	27.27	27.61	43.35	42.82	3.44	3.40	7.23	7.14	$4.9{\cdot}10^{-5}$
$HoL_3\,H_2O$	27.85	27.92	42.75	42.64	3.39	3.38	7.12	7.11	$4.8{\cdot}10^{-5}$
$ErL_3{\cdot}H_2O$	28.41	28.16	42.12	42.50	3.34	3.37	7.00	7.08	$3.3{\cdot}10^{-5}$
$TmL_3{\cdot}H_2O$	28.55	28.40	42.13	42.35	3.34	3.36	7.00	7.06	$2.6{\cdot}10^{-5}$
$YbL_3{\cdot}H_2O$	29.07	28.88	41.79	42.07	3.30	3.34	6.96	7.01	$2.5{\cdot}10^{-5}$
$LuL_3{\cdot}H_2O$	28.62	29.12	42.66	41.93	3.39	3.33	7.12	6.99	$1.6{\cdot}10^{-5}$

Simultaneous TG-DTG-DTA curves under non-isothermal conditions were obtained with a Paulik-Paulik-Erdey Derivatograph Q-1500D. Samples (100 mg) were heated in platinum crucibles (φ 9 mm) at 20–1000°C in air atmo-sphere at a heating rate of 10°C min^{-1}. The reference material was α-Al_2O_3 in a platinum crucible.

X-ray diffraction patterns of the intermediates of thermal decomposition were recorded by the Debye-Scherrer method, using a DRON-2 diffractometer with Ni-filtered CuK_α radiation.

The solubilities of the complexes in water at 25°C were examined spectrophotometrically with the use of arsenazo III.

Results and discussion

The complexes of benzohydroxamic acid with yttrium(III) and the lanthanides were prepared as solid, roentgenographically amorphous compounds, with colours characteristic of yttrium(III) and the lanthanide(III) ions (except for the europium complex, which is cream-coloured, and the cerium compound, which is brown). The general formula of the prepared compounds is $Ln(C_7H_6NO_2)_3\cdot H_2O$, where *Ln*= Y(III), La(III), Pr(III), Nd(III), Sm(III)-Lu(III). Under the applied preparation conditions, cerium forms a complex of undetermined composition. Polarographic analysis shows that about 15% of the cerium ions present are tetravalent. We suggest the formula $Ce(III)_5Ce(IV)O(C_7H_6NO_2)_{17}$. *Its composition is* confirmed by elemental analysis. All of the complexes are slightly soluble in water (Table 1).

The IR spectra of the yttrium and lanthanide benzohydroxamates were recorded and compared with those of benzohydroxamic acid. Table 2 lists the most important bands and their assignments (in this Table, the following notation of the vibrations modes is used: ν – stretching vibration, δ – deformation vibration, β – in-plane deformation vibration, γ – out-of-plane deformation vibration, C_{Ar} – aromatic carbon atom).

During heating, the benzohydroxamates of yttrium and the lanthanides decompose in several steps. The thermal data on the particular decomposition stages are listed in Tables 3–5. Some typical TG, DTG and DTA curves are given in Figs 1 and 2.

The cerium complex decomposes violently above 150°C and an undefined product is formed at 210°C. The next stage of thermal decomposition begins at 300°C and probably yields unstable $Ce(CO_3)_2$ (mass loss: observed 49.0%, theoretical 50.76%). The compound decomposes above 370°C, and CeO_2 is formed at 530°C.

The hydrated complexes of yttrium and the lanthanides (La, Pr–Lu) lose their water molecules in continuous mode at 50–150°C, without sharp endothermic effects in the DTA curves. This indicates that the water present in the compounds is loosely bound. The stability of the anhydrous complexes increases insignificantly along the lanthanide series.

Table 2 Frequencies of the maxima of the IR spectra of benzohydroxamic acid and of Y and lanthanide benzohydroxamates (cm^{-1})

Acid	Y	La	Ce	Pr	Nd	Sm	Eu	Assignment
3296s	3288m	3248m		3256m	3256m	3264m	3256m	νC=O*, νOH from H_2O**
3056m	3080m	3050m	3060m	3056m	3056m	3054m	3066m	νNH, νC$_{Ar}$–H
2768s								νOH
1648s								νC=O (amide I band)
	1620s	1620s		1620s	1620s	1620s	1620s	δHOH
1612s	1604s	1604s	1604s	1604s	1604s	1604s	1604s	νC$_{Ar}$–C$_{Ar}$, βC$_{Ar}$–C$_{Ar}$
1572s								
1564s	1568s	1568s	1568s	1568s	1568s	1568s	1568s	βNH+νCN (am. II band)
1556s	1532m	1538m	1536m	1534m	1535m	1533m	1532m	νNO
1488m	1484m	1484m	1484m	1484m	1484m	1488m	1484m	νC$_{Ar}$–C$_{Ar}$, βC$_{Ar}$–C$_{Ar}$
1432m								δOH
1402m								
	1342	1343m	1345m	1340m	1340m	1340m	1343m	νCO
1328m								βOH
1313m	1312m	1308m	1308m	1308m	1308m	1308m	1308m	νCN+βNH (am. III band)
1160m	1156s	1156s	1156s	1156s	1156s	1156s	1156s	βC$_{Ar}$H
	1056m	1052m	1052m	1052m	1052m	1056m	1056m	νCO
1040m								
1024m	1024m	1024m	1024m	1024m	1024m	1024m	1024m	νC–N(H)
	916m	912m	912m	912s	912s	912m	912s	νNO
896m								νN–O(H)
825w								
800m								γOH
785m	784m	784m	784m	784m	784m	784m	784m	γNH
703m								βO=CN (amide IV band)
688s	692s	696s	692s	692s	692s	692s	692s	γNH (amide V band), γC$_{Ar}$–C$_{Ar}$
528m								γC=O (amide VI band)
	470w	450w	448w	448w	448w	448w	453w	νLn–O

Table 2 Continued

Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Assignment
3248m	3264m	3288m	3264m	3248m	3272m	3312m	3320m	νC=O*, νOH from H_2O**
3060m	3060m	3055m	3070m	3060m	3060m	3065m	3080m	νNH, νC_{Ar}–H
								νOH
								νC=O (amide I band)
1620s	1620s	1620s	1620s	1620s	1620s	1620s	1620s	δHOH
1604s	1604s	1604s	1604s	1604s	1604s	1604s	1606s	νC_{Ar}–C_{Ar}, βC_{Ar}–C_{Ar}
1568s	1568s	1568s	1568s	1568s	1568s	1568s	1568s	βNH+νCN (am. II band)
1530m	1528m	1533m	1532m	1532m	1524m	1532m	1532m	νNO
1484m	1484m	1484m	1484m	1480m	1484m	1484m	1484m	νC_{Ar}–C_{Ar}, βC_{Ar}–C_{Ar}
								δOH
1335m	1344m	1346m	1343m	1347m	1333m	1347m	1350m	νCO
								β OH
1308m	1312m	1312m	1308m	1308m	1308m	1312m	1308m	νCN+βNH (am. III band)
1156s	1156s	1156s	1156s	1156s	1156s	1156s	1156s	$\beta C_{Ar}H$
1056m	1056m	1056m	1056m	1060m	1060m	1060m	1060m	νCO
1024m	1024m	1024m	1024m	1024m	1024m	1024m	1024m	νC–N(H)
916s	916s	916s	916s	916s	916s	920s	920s	νNO
								νN–O(H)
								γOH
784m	784m	784m	784m	784m	784m	784m	784m	γNH
								βO=CN (amide IV band)
692s	692s	692s	692s	692s	692s	692s	692s	γNH (amide V band),
								γC_{Ar}–C_{Ar}
								γC=O (amide VI band)
456w	472w	470w	480w	480w	476w	476w	486w	νLn–O

(s – strong, m – medium, w – weak; * – for acid, ** – for complexes)

Decomposition of the complexes begins at 160–180°C. In the first step of decomposition, unstable solid products are formed. The IR spectra of these compounds were recorded (Table 6). The crystallization water vibrations and the CO group vibrations disappear too. The range of metal-oxygen vibrations (500–400 cm^{-1}) is distinctly changed. The aromatic structures in the compounds are retained: we observed the stretching and deformation vibrations of the aro-

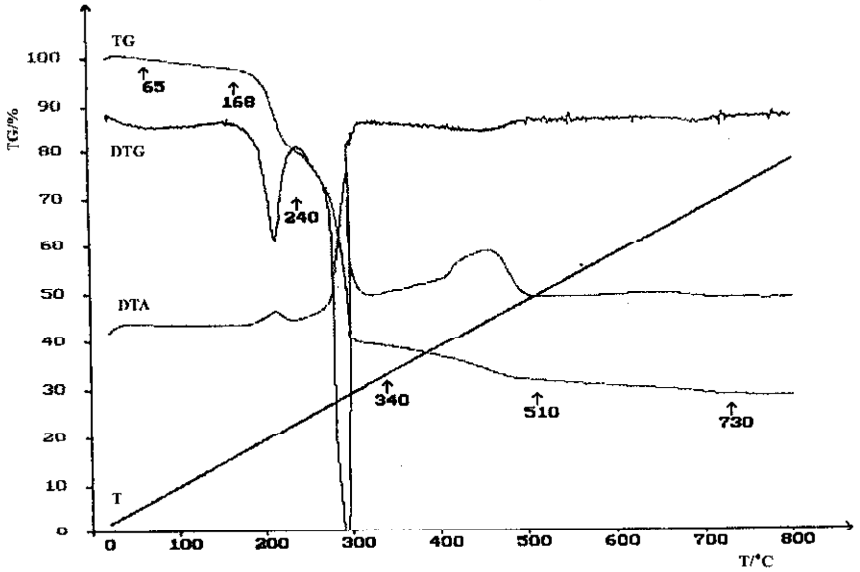

Fig. 1 TG, DTG and DTA curves of samarium(III) benzohydroxamate. Heating rate 10°C min^{-1}

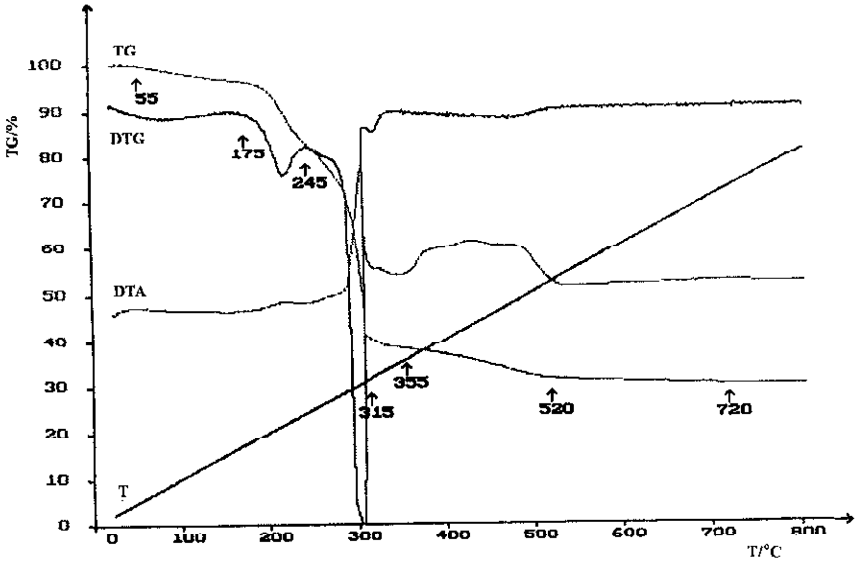

Fig. 2 TG, DTG and DTA curves of erbium(III) benzohydroxamate. Heating rate 10°C min^{-1}

Table 3 Thermal data of the dehydration and decomposition process at 20–300°C of Y and lanthanide benzohydroxamates in air atmosphere, ($L = C_7H_6NO_2^-$)

Complex	T_{range}/°C	Mass loss/%		Product*	T_{rangeI}/°C	Mass loss/%	T_{rangeII}/°C	Mass loss/%
		calc.	found					
$YL_3 \cdot H_2O$	55–155	3.49	3.2	YL_3	175–250	23.4	255–320	61.0
$LaL_3 \cdot H_2O$	60–150	3.19	2.9	LaL_3	160–235	22.7	238–320	51.5
Ce_6OL_{17}					145–210	39.3		
$PrL_3 \cdot H_2O$	60–150	3.17	2.9	PrL_3	165–240	22.2	245–315	53.7
$NdL_3 \cdot H_2O$	50–147	3.16	3.2	NdL_3	160–240	21.1	243–315	55.8
$SmL_3 \cdot H_2O$	65–150	3.13	3.0	SmL_3	168–240	20.7	243–310	55.2
$EuL_3 \cdot H_2O$	50–145	3.11	3.2	EuL_3	170–245	20.2	248–310	53.3
$GdL_3 \cdot H_2O$	50–145	3.08	3.0	GdL_3	170–245	20.0	248–325	53.5
$TbL_3 \cdot H_2O$	50–140	3.08	3.2	TbL_3	170–247	20.3	250–325	55.1
$DyL_3 \cdot H_2O$	50–140	3.06	3.2	DyL_3	175–245	19.7	248–310	55.5
$HoL_3 \cdot H_2O$	55–145	3.05	3.2	HoL_3	177–247	19.3	250–315	53.7
$ErL_3 \cdot H_2O$	55–145	3.04	3.0	ErL_3	175–245	18.6	248–310	53.6
$TmL_3 \cdot H_2O$	60–150	3.03	3.1	TmL_3	180–250	18.5	255–315	53.5
$YbL_3 \cdot H_2O$	55–150	3.00	3.0	YbL_3	170–245	17.9	250–315	52.7
$LuL_3 \cdot H_2O$	50–140	3.00	3.1	LuL_3	175–240	17.9	245–310	52.0

T_{rarge} – temperature range of dehydration
T_{rargeI} – temperature range of I stage of decomposition
T_{rargeII} – temperature range of II stage of decomposition
* Product of dehydration

Table 4 Thermal data of the decomposition process above 300°C of Y and lanthanide benzohyroxamates in air atmosphere

Compound of lanthanide	$T_{range IV}$/ °C	Mass loss*/ %	$T_{range V}$/ °C	Mass loss/%		Product	T_{final}/ °C	Mass loss/%		Final product
				calcd.	found			calcd.	found	
Y	325–345	65.8	385–555	75.58	75.7	$Y_2O_3 \cdot 2C$	~780	77.91	78.2	Y_2O_3
La			345–545	65.84	65.8	$La_2O_3 \cdot 5C$	~880	71.15	70.7	La_2O_3
Ce	300–360	49.0 $[Ce(CO_3)_2]$	368–530	67.37	67.0	CeO_2	530	67.37	67.0	CeO_2
Pr			355–590	66.78	66.7	$Pr_6O_{11} \cdot 9C$	~850	70.00	69.8	Pr_6O_{11}
Nd			345–525	67.37	67.3	$Nd_2O_3 \cdot 3C$	~760	70.53	70.3	Nd_2O_3
Sm			340–510	66.67	66.4	$Sm_2O_3 \cdot 3C$	~730	69.79	69.5	Sm_2O_3
Eu			335–490	66.44	66.4	$Eu_2O_3 \cdot 3C$	~730	69.55	69.3	Eu_2O_3
Gd			345–520	66.89	66.9	$Gd_2O_3 \cdot 2C$	~720	68.95	69.3	Gd_2O_3
Tb			355–505	67.52	67.4	$Tb_4O_7 \cdot C$	~780	68.03	68.3	Tb_4O_7
Dy	312–330	57.8	355–520	66.27	66.2	$Dy_2O_3 \cdot 2C$	~720	68.31	68.7	Dy_2O_3
Ho	320–335	56.2	365–520	66.50	66.4	$2Ho_2O_3 \cdot 3C$	~720	68.02	68.1	Ho_2O_3
Er	315–337	56.3	355–520	65.77	65.9	$Er_2O_3 \cdot 2C$	~720	67.79	67.5	Er_2O_3
Tm	318–350	57.5	380–535	66.05	66.2	$2Tm_2O_3 \cdot 3C$	~700	67.56	67.4	Tm_2O_3
Yb	318–355	57.7	385–550	66.11	66.5	$Yb_2O_3 \cdot C$	~650	67.11	66.9	Yb_2O_3
Lu	315–345	55.2	370–570	66.89	67.5	Lu_2O_3	570	66.89	67.5	Lu_2O_3

$T_{rangeIV}$ – temperature range of I stage of decomposition
$T_{rangeII}$ – temperature range of II stage of decomposition
T_{final} – temperature of product formation
*Found mass loss

matic ring. Additionally, the distinct bands at 1408–1408 cm^{-1} (strong), 857–850 cm^{-1} (medium) and 720 cm^{-1} (medium), ascribed to vibration of the carbonate ion appear in the IR spectra.

Table 5 DTG and exothermic DTA peaks on decomposition of Y and lanthanide benzohydroxamates in air atmosphere ($L = C_7H_6NO_2^-$)

Complex	DTG_{max}/ °C						DTA_{max}/ °C			DTA_{range}/°C
$YL_3 \cdot H_2O$	95	225	310	330		490	228	315	340	405–550
$LaL_3 \cdot H_2O$	100	203	300			485	203	302		380–540
Ce_6OL_{17}		205		353	390		207			340–530
$PrL_3 \cdot H_2O$	75	210	290			485	212	295		375–580
$NdL_3 \cdot H_2O$	75	210	300			480	211	301		370–515
$SmL_3 \cdot H_2O$	80	213	295			455	213	297		360–500
$EuL_3 \cdot H_2O$	80	218	301			450	220	303		350–485
$GdL_3 \cdot H_2O$	75	215	300			470	215	301		360–510
$TbL_3 \cdot H_2O$	85	220	304			465	220	306		365–500
$DyL_3 \cdot H_2O$	82	222	305	316		~450	222	307	320	370–510
$HoL_3 \cdot H_2O$	85	222	307	320		~450	222	310	325	370–520
$ErL_3 \cdot H_2O$	85	220	307	320		~460	220	309	325	365–520
$TmL_3 \cdot H_2O$	90	225	304	330		~470	225	309	340	400–540
$YbL_3 \cdot H_2O$	90	222	304	330		~480	222	308	340	385–540
$LuL_3 \cdot H_2O$	85	222	304	327		~480	222	307	330	375–535

This stage of decomposition is accompanied by the combustion of some products of degradation and a slight exothermic effect is exhibited in the DTA curve (Table 5).

When heated above 240–250°C, the compounds decompose very violently and the organic moiety undergoes combustion. The DTA curve reveals a very sharp and strong exothermic effect (Table 5). This stage of decomposition is completed above 310°C and the solid products formed are stable up to 335–350°C in the cases of La and the light lanthanide compounds (from Pr to Tb). In the cases of Y and the heavy lanthanide salts (from Dy to Lu), the solid products of degradation formed at 310–315°C immediately decompose and the compounds then obtained are stable up to 355–385°C.

All solid intermediates obtained above 310°C have undefined composition. Their IR spectra exhibit intense vibrations of CO_3^{2-} (1408–1400, 850–840 and 720–718 cm^{-1}), and several medium and weak bands (at 1548–1520, 1510–1500,

Table 6 The comparison of the frequencies [cm^{-1}] of IR spectra of Ce, Gd, Dy, Tm benzohydroxamates (BENZ) and their thermal decomposition products (TDP) formed at 210–250°C

Ce		Pr		Gd		Dy		Tm		Assignment	
BENZ	TDP 210°C	BENZ	TDP 240°C	BENZ	TDP 240°C	BENZ	TDP 250°C	BENZ	TDP 250°C	40°C	>200°C
		3256m		3248m		3288m		3272m		νOH	–
3060m	3080m	3056m	3060w	3060m	3060w	3055m	3055w	3060m	3060w	$\nu NH+\nu C_{Ar}-H$	
		1620s		1620s		1620s		1620s		δHOH	
1604s	1596s	1604s	1596s	1604s	1604s	1604s	1600s	1604s	1598s	$\nu+\beta C_{Ar}-C_{Ar}$	
1568s		1568s		1568s	1572s	1568s	1556s	1568s	1560s	$\beta NH+\nu CN$	
1536m	1536s	1534m	1532s	1530m	1540s	1533m	1534s	1524m	1530s	νNO	νNO, νC=N
1484m	1500m	1484m	1512s	1484m	1480m	1484m	1480m	1484m	1480m	$\nu+\beta C_{Ar}-C_{Ar}$	
	1416s		1404s		1404s		1408s		1404s	–	CO_3^{2-}
1345m		1340m		1335m		1346m		1333m		νCO	–
1308m	1305m	1308m	1304m	1308m	1304m	1312m	1304m	1308m	1304m	$\nu CN+\beta NH$	
1156s	1166w	1156s	1156w	1156s	1156m	1156s	1160m	1156s	1160m	$\beta C_{Ar}-H$	
	1072w		1072w				1068w		1065w		
1052m		1052m		1056m		1056m		1060m		νCO	–
1024m	1024m	1024m	1024m	1024m	1024m	1024m	1024m	1024m	1024m	νC–N(H)	
912m		912s	910w	916s	912m	916s	912m	916s	912m	νNO	
	848w		850w		848w		857w		850w	–	CO_3^{2-}
784m		784m	785w	784m	784m	784m	784w	784m	784m	γNH	
	716m		720m		720m		720m		720m		CO_3^{2-}
692s	684m	692s	690m	692s	688m	692s	688s	692s	690m	$\gamma NH, \gamma C_{Ar}-C_{Ar}$	
	560w				540w						
448w	se	338w	se	456w	470w	470w	se	476w	se	νLn–O	

(s – strong, m – medium, w – weak, se – several weak bands)

1080–1070 and 980 cm^{-1}), probably due to an organic residue. Roentgenographic analysis shows that all mentioned intermediates of the thermal decomposition are amorphous.

When heating is continued the formation of new intermediates is observed. The X-ray patterns contain very distinct peaks. We identify these products as mixtures of lanthanide oxides with a residue of organic carbon. The contents of carbon in the light lanthanide oxides are greater than those in the heavy lanthanide oxides. The carbon burns out continuously and the pure lanthanide oxides are formed. It is impossible to determine exactly the temperature of the end of decomposition. The temperature of oxide formation generally decreases along the lanthanides series, from 880°C for La to 570°C for Lu (except for CeO_2, which is formed at the lowest temperature, 530°C). The thermal decomposition of yttrium benzohydroxamate approximates to that of a heavy lanthanide complex, but the temperature of Y_2O_3 formation fits into the range for the light lanthanide group.

Conclusions

The benzohydroxamates of yttrium and the lanthanides obtained under the conditions described above are solid, roentgenographically amorphous compounds that are slightly soluble in water. Their general formula is $Ln(C_7H_6NO_2)_3 \cdot H_2O$, where *Ln*= Y(III), La(III), Pr(III), Nd(III), Sm(III)-Lu(III). On being heated in air atmosphere, the complexes decompose in several steps. In the first stage of degradation, the anhydrous compounds are formed. It was impossible to determine the compositions of the other intermediates formed above 200°C. The oxides of yttrium and the lanthanides are the final products of thermal dissociation.

Cerium benzohydroxamate is an anhydrous compound. Its composition is difficult to determine. When heated, it decomposes in three steps, forming CeO_2 as final product.

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