conformations required for tetradentate binding in square-planar, tetrahedral, and pentacoordinate geometries in addition to PNP and PNN binding modes. Clearly the tetrahedral complexes (Cu(I) and Ag(I)) are very labile even with this relatively rigid tetradentate chelating agent (only 4 of the 44 nonhydrogen chelate atoms are sp^3). It is likely that this rapid inversion process can be stopped by locking the conformation of the en backbone, and experiments along these lines are in progress and promise to provide unusual examples of optically stable tetrahedral metal complexes.

The substitution of one imine in the Cu(en=P_2) cation by *t*-BuNC affords a very unusual example of an in situ preparation of a large chelate ring; there is little precedence for metal complexes of this structure. This substitution pattern is a nice illustration of the domination of geometric effects, i.e., preference for tetrahedral geometry, over electronic effects, i.e., N vs. P donors. This view is reinforced by observed lability of the [Cu(tn=P_2)(*t*-BuNC)]ClO_4 complex relative to the en analogue. The pentacoordinate complexes undergo ligand exchange at rates which are extremely fast and which limit mechanistic insight. Lastly, the electrochemical results are very satisfying, particularly with nickel wherein it is seen that three different oxidation states are accessible; future work along these lines will define the salient geometric and electronic features of the reduced species.

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this work. We also thank The Australian National University Computer Services Centre for the use of their facilities. Acknowledgment is also due to Ms. Janet Hope and Dr. G. A. Lawrence for electrochemical measurements and Dr. G. B. Robertson for use of X-ray equipment.

Registry No. **1**, 74684-87-0; **2**·CH_2Cl_2, 74709-78-7; **3**, 74709-80-1; **4**, 74709-82-3; **5**, 74724-74-6; **6**, 74709-84-5; **7**, 74709-86-7; **8**, 74709-88-9; **9**, 74709-89-0; PCHO, 50777-76-9; en, 107-15-3; tn, 109-76-2.

Supplementary Material Available: Listings of microanalytical results, structure factor tables, and bond lengths and angles in phenyl groups, anions, and solvents of crystallization (46 pages). Ordering information is given on any current masthead page.

Contribution from the Baker Laboratory of Chemistry, Cornell University, Ithaca, New York 14853,
and the Institut für Physikalische Chemie, Universität Wien, Wien A-1090, Austria

Magnetic Behavior and Structural Chemistry of $RERu_3B_2$ Borides[1]

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New ternary metal borides [RE,Y]Ru_3B_2 have been prepared and found to crystallize with the $CeCo_3B_2$ type of structure. Magnetic susceptibilities were determined over a temperature range extending from 1.8 to 1100 K. At higher temperatures (>300 K) typical RE^{3+} paramagnetic Curie–Weiss behavior was found for most of the compounds. With the exception of [Ce,Sm]Ru_3B_2 the experimentally obtained effective paramagnetic moments are in good agreement with Hund's rule values for free RE^{3+} ions. The magnetic properties of the ceric rare-earth compounds [Pr,Nd,Sm]Ru_3B_2 are characterized by a Van Vleck paramagnetism of closely spaced multiplets. The susceptibility of $CeRu_3B_2$ is described by the analytical expression $\chi_M = (0.025/T) + 0.6 \times 10^{-3}$ cm^3 mol^{-1} (T = 1.8–300 K); μ_{eff} = 0.45 μ_B corresponds to a high percentage of Ce^{4+} (82%). Ferromagnetic ordering was found for [Pr,Nd,Gd,Tb,Dy,Ho,Er,Tm]Ru_3B_2 at low temperatures; ordering temperatures were in the range 5–83 K. No superconductivity was found on heat-treated samples for temperatures as low as 1.8 K.

Introduction

Compounds of the rare-earth elements with noble metals and boron of the type REM_4B_4 have recently become of major scientific interest, especially in order to study the interaction between superconductivity and long-range magnetic order.[3–8] A close inspection of ternary phase equilibria within RE–[Ru,Rh,Os,Ir]–B systems revealed the existence of several new structure types at lower boron concentration and stimulated our interest in the structural chemistry as well as the magnetic behavior of these new compounds. The subject of the present work is a description of structural and magnetic properties of the new $RERu_3B_2$ series of compounds.

Experimental Section

Starting materials were 99.7% crystalline boron from Ventron GmbH, Karlsruhe, BRD, 99.9% rare-earth-metal ingots from Ventron GmbH, and 99.9% Ru powder from Degussa, Hanau, BRD. Powders of the elements and filings of the RE metals were compacted in steel dies without the use of binders or lubricants. The pellets (~1 g) were arc melted on a water-cooled copper hearth by using a nonconsumable tungsten electrode in a Ti/Zr-gettered argon atmosphere. The melted buttons were subsequently heat treated in a high-vacuum furnace (24 h at 1400 °C, ~5×10^{-4} Pa) on a boron nitride substrate and finally quenched in high-purity argon.

Ytterbium-containing samples were reacted in evacuated silica tubes (2 × 24 h at 1200 °C, ~10^{-1} Pa). For protection against the silica walls the pellets were wrapped in molybdenum foil. Precise lattice parameters and standard deviations were evaluated by a least-squares refinement procedure[9] on X-ray diffraction data obtained from De-

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(1) Dedicated to Professor H. Bittner on the occasion of his 60th birthday.

(2) (a) Baker Laboratory. (b) Institut für Physikalische Chemie.

(3) Matthias, B. T.; Corenzwitt, E.; Vandenberg, J. M.; Barz, H. E. *Proc. Natl. Acad. Sci. USA* **1977**, *74*, 1334, 1336.

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0020-1669/80/1319-3316$01.00/0

Table I. Crystallographic and Magnetic Data of Ternary Borides MRu_3B_2 (M = Y, RE, Th, U)

compd	a (±0.004), Å	c (±0.002), Å	V, Å^3	c/a	ordering temp, K	asym Curie temp, K	μ_{eff}^{exptl}, μ_B	μ_{eff}^{theor} (RE^{3+}), μ_B
$CeRu_3B_2$	5.523	2.991	79.0	0.542			1.24^a	2.54
$PrRu_3B_2$	5.532	3.015	79.9	0.545	5	51	3.70	3.58
$NdRu_3B_2$	5.538	3.010	79.9	0.543	39	61	3.63	3.62
$SmRu_3B_2$	5.514	3.010	79.3	0.546			1.70^a	1.65^a
$GdRu_3B_2$	5.493–5.505	3.024–3.015	79.0–79.1	0.551–0.548	10	65	8.04	7.94
$TbRu_3B_2$	5.485	3.014	78.5	0.550	83	145	9.81	9.72
$DyRu_3B_2$	5.474	3.016	78.3	0.551	50	105	10.78	10.63
$HoRu_3B_2$	5.466	3.017	78.1	0.552	25	50	10.47	10.60
$ErRu_3B_2$	5.461	3.016	77.9	0.552	32	130	9.54	9.60
$TmRu_3B_2$	5.454	3.010	77.5	0.552	27	185	7.69	7.68
$YbRu_3B_2$	5.454	3.003	77.4	0.551		0	4.49	4.54

compd	a (±0.004), Å	c (±0.002), Å	V, Å^3	c/a	χ_g(300 K), cm^3/g
$LuRu_3B_2$	5.439	3.016	77.2	0.554	7.2×10^{-7} ^{b}
YRu_3B_2	5.471	3.027	78.4	0.553	7.8×10^{-7} ^{b}
$ThRu_3B_2$	5.528	3.070	81.2	0.555	5.8×10^{-7} ^{b}
URu_3B_2	10.950	5.934	616.1	0.542	2.0×10^{-6} ^{b}
single cryst	10.9531	5.9353	616.7	0.542	
UOs_3B_2	11.048	5.948	627.8	0.539	1.3×10^{-6} ^{b}

^{a} Values at 293 K. ^{b} Practically temperature independent.

bye–Scherrer films as well as from diffractometer readings, by using filtered Cr Kα and Cu Kα radiation.

Susceptibility measurements in the range 80–1100 K were performed with a pendulum susceptibility meter by using a compensation Faraday method[10] under N_2 below 300 K and under high-purity argon in the range 300–1100 K. At low temperatures 1.8 K < T < 80 K a Faraday balance[11] under helium with Spectrosil silica buckets and Cahn Electrobalance recording was used. An ac induction method as described elsewhere[12] was employed for determination of superconducting critical temperatures.

No Eu or Pm samples were prepared.

Results and Discussion

I. Structure Determination. Powder patterns of alloy samples with a boron content of ~30 atom % indicated compound formation with the approximate formula MRu_3B_2 (M = Y, Th, RE). Except for lanthanum, for which no compound formation was observed at or above 1000 K, the samples of all the rare-earth members, Y, and Th were found to be well crystallized and single phase (or nearly so) for the following nominal composition (in atom %): M, 17; Ru, 50; B, 33. The Debye–Scherrer photographs were characterized by pronounced similarity and could be indexed completely with a hexagonal unit cell (see Table I). The formula and the lattice parameters, as well as the powder intensities, indicate structural analogy of the MRu_3B_2 borides with the structure type of $CeCo_3B_2$ (ordered $CaCu_5$ type[13]).

Recently the crystal structure of URu_3B_2 was solved from single-crystal four-circle diffractometer data and found to have a low-symmetry, fourfold superstructure ($a = 2a^*$, $c = 2c^*$) of the $CeCo_3B_2$ cell.[14] Superstructure reflections, however, were very faint and were not discernible from ordinary powder photographs; i.e., deviation from higher symmetry ($CeCo_3B_2$) was rather small. Similar behavior seemed to be conceivable for the isotypic [Y,Th,RE]Ru_3B_2 series of compounds, despite the fact that no deviations from $CeCo_3B_2$ symmetry were found from the powder photographs. So far as the size factor is concerned, the similar alloying behavior of uranium in combination with noble metals and boron is comparable to that of the smallest RE members.[15,16]

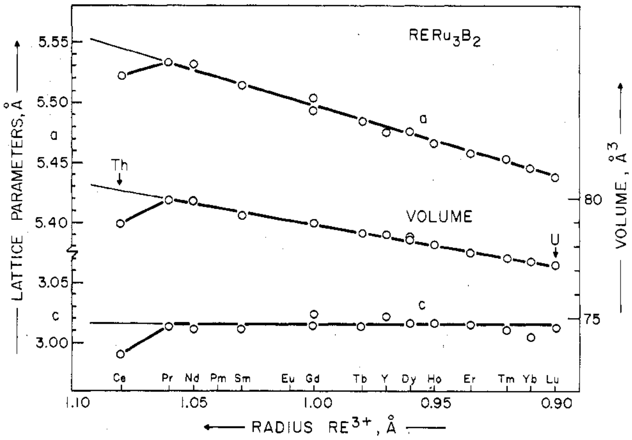

Figure 1. Lattice parameters and volumes of [RE,Y,Th,U]Ru_3B_2 borides vs. $R_{RE}{}^{3+}$ ($CaCu_5$-type subcell parameters).

In order to decide whether the URu_3B_2- or the $CeCo_3B_2$-type structure is adopted, we prepared Weissenberg photographs from an $ErRu_3B_2$ single crystal. High Laue symmetry 6/*mmm*, no observed extinctions, unit cell parameters, and reflection intensities obtained from single-crystal layer patterns (axis [001]) clearly indicate a $CeCo_3B_2$ structure type for $ErRu_3B_2$ (space group *P6/mmm*, No. 191). An evaluation of the powder diagram of $ErRu_3B_2$ is presented in Table II; it shows excellent agreement between observed and calculated intensities. From the smooth linear dependency of lattice parameters vs. RE size, the $CeCo_3B_2$-type structure seems likely to be adopted throughout the complete $RERu_3B_2$ series of compounds. Confirmation, however, would be desirable for each of the remaining RE members by detailed single-crystal studies.

For most of the compounds, only small changes in lattice parameters with composition were observed in multiphase alloys, indicating narrow homogeneity regions. $GdRu_3B_2$ was an exception (see Table I). Linear dependence of lattice parameters and unit cell volume was found from a graph against corresponding values of the RE^{3+} ionic radii (see Figure 1). The usefulness of this graph in revealing valency dif-

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(10) SUS 10, susceptibility measuring device, A. Paar KG, Graz, Austria.

(11) Young, J. E., Jr. Ph.D. Thesis, Cornell University, 1971.

(12) Fisher, W. G. Ph.D. Thesis, Cornell University, 1978.

(13) Kuz'ma, Yu. B.; Kripyakevich, P. I.; Bilonishko, N. S. *Dopov. Akad. Nauk Ukr. RSR, Ser. A: Mat. Tekh. Nauki* **1969**, *10*, 939.

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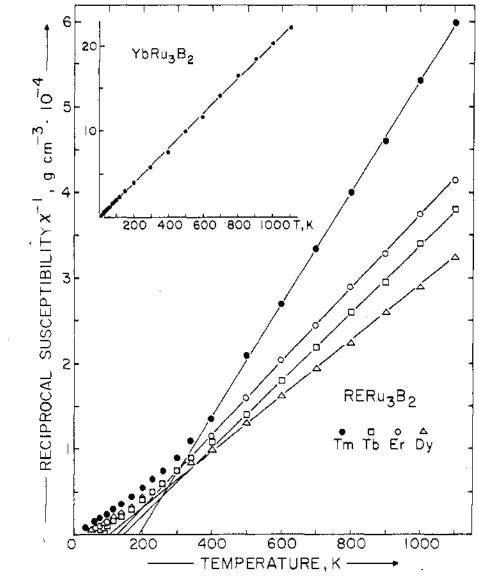

Figure 2. Reciprocal gram-susceptibility vs. temperature for RERu$_3$B$_2$ borides (RE = Tb, Dy, Er, Tm, Yb).

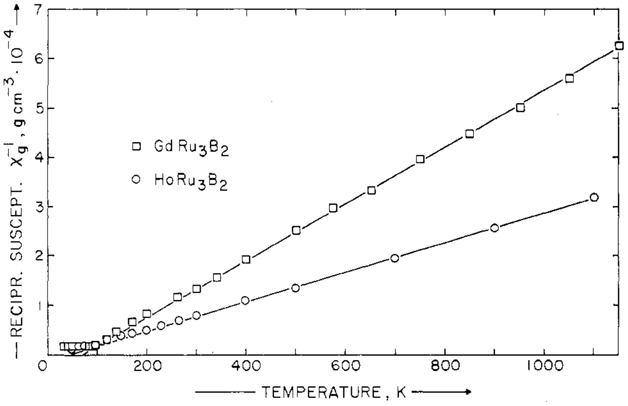

Figure 3. Reciprocal gram-susceptibility vs. temperature for [Gd,-Ho]Ru$_3$B$_2$.

ferences is shown in the case of YbRu$_3$B$_2$, yielding trivalency of Yb, as well as in the case of CeRu$_3$B$_2$, where the small lattice parameters indicate the Ce^{4+} type of behavior. (See also section II, Magnetic Properties.)

According to the classification scheme of ternary transition-metal borides[17] based upon boron–boron aggregation, the structural chemistry of RERu$_3$B$_2$ borides is characterized by isolated boron atoms in tetrakaidecahedral Ru$_6$RE$_3$ coordination. Ru–Ru distances ($a/2$, R_{Ru} = 1.34 Å) range from 2.72 (LuRu$_3$B$_2$) to as much as 2.76 Å for PrRu$_3$B$_2$. Ru–Ru distances derived from extrapolated (Figure 1) lattice parameters for hypothetical "LaRu$_3$B$_2$" (a = 5.575, c = 3.02 Å) greatly exceed the sum of metal radii. Hence, a decisive size factor may explain the upper stability limit of RERu$_3$B$_2$-type borides as being located near PrRu$_3$B$_2$. Despite the larger volume of ThRu$_3$B$_2$ compared to that of the Pr compound, its Ru–Ru distances (2.76 Å) are well within the above-mentioned range (due to a slightly larger c/a ratio). In this context, it is interesting to note that the CeCo$_3$B$_2$-type related series REIr$_3$B$_2$[14] exhibits a much larger c/a ratio compared to RERu$_3$B$_2$. The smaller a axis of LaIr$_3$B$_2$ yields Ir–Ir distances close to the sum of Ir-metal radii (Ir–Ir (LaIr$_3$B$_2$) = 2.76, R_{Ir} = 1.36 Å). On the other hand, no LaRh$_3$B$_2$[14] has been found so far (R_{Rh} = R_{Ru}).

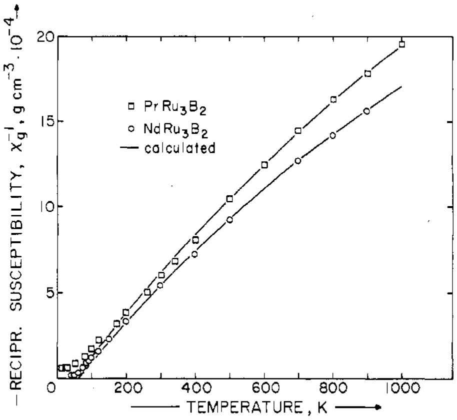

Figure 4. Reciprocal gram-susceptibility vs. temperature for [Pr,-Nd]Ru$_3$B$_2$ and calculated least-squares fit to eq 2.

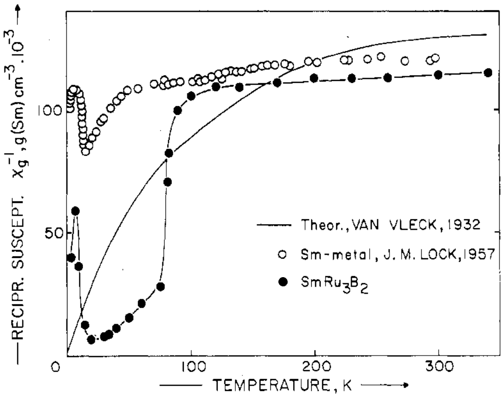

Figure 5. Reciprocal gram-susceptibility vs. temperature for SmRu$_3$B$_2$. For comparison with values obtained by Lock[19] (Sm metal) as well as the theoretical values by Van Vleck[18] (free Sm^{3+}) the SmRu$_3$B$_2$ values have been based on the Sm metal content.

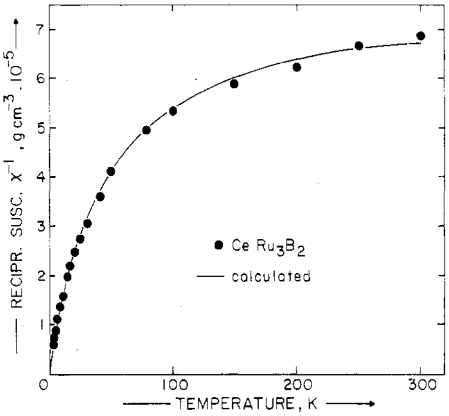

Figure 6. Reciprocal gram-susceptibility vs. temperature for CeRu$_3$B$_2$ and calculated least-squares fit to eq 2.

II. Magnetic Properties. The results of the magnetic measurements are summarized in Figures 2–7 and in Table I. The magnetic susceptibility of the Y, Lu, and Th as well as the U compounds was found to be practically independent of temperature, and thus [Y,Lu,U,Th]Ru$_3$B$_2$ and UOs$_3$B$_2$ can be regarded as Pauli paramagnets.

A. Paramagnetic Behavior. Most of the remaining RERu$_3$B$_2$ borides exhibited normal paramagnetic behavior and adhered closely to the Curie–Weiss law (Figures 2 and 3) over the major portion (300–1100 K) of the measured temperature region. For the heavier rare-earth alloys, Gd → Yb, a linear dependence of the reciprocal gram-susceptibility χ_g (cm^3 g^{-1})

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[17] Rogl, P.; Nowotny, H. *J. Less-Common Met.* **1978**, *61*, 39.

Table II. Powder Diffraction Data for $ErRu_3B_2$ ($CeCo_3B_2$-Type Structure)[a]

	$10^4(\sin^2\theta)$		intens			$10^4(\sin^2\theta)$		intens	
hkl	obsd	calcd	obsd	calcd	*hkl*	obsd	calcd	obsd	calcd
100	267	266	vvw	7	321	5701	5701	vw	10
001	654	653	vw$^-$	5	222	5805	5802	vw$^+$	17
110	800	797	vvw	4	003	*b*	5880	*b*	0
101	918	919	st	77	312	*b*	6067	*b*	0
200	1064	1063	vst	100	103	6142	6146	vw$^-$	5
111	1445	1450	m	46	411	6234	6233	vw	11
201	1719	1716	vw	10	500	*b*	6642	*b*	0
210	*b*	1860	*b*	1	113	6679	6677	vw$^-$	6
300	*b*	2391	*b*	1	402	6860	6864	vw	15
211	2517	2513	w	33	203	*b*	6943	*b*	1
002	2616	2616	vw$^-$	9	330	*b*	7174	*b*	0
102	*b*	2879	*b*	1	501	7291	7296	vw$^-$	5
301	3043	3045	vw	14	420	7438	7439	vw	16
220	3189	3188	w$^-$	19	322	*b*	7661	*b*	1
112	*b*	3410	*b*	1	213	7738	7740	vw	11
310	*b*	3454	*b*	0	331	7826	7827	vw$^-$	6
202	3671	3676	w	28	421	8095	8093	vvw	3
221	3846	3842	vvw	2	412	*b*	8193	*b*	1
311	4107	4107	vw	15	510	*b*	8236	*b*	0
400	4259	4251	vw$^-$	11	303	8278	8271	vw$^-$	7
212	*b*	4473	*b*	1	511	8891	8890	vw	15
401	4897	4904	vvw	2	223	*b*	9068	*b*	2
302	*b*	5004	*b*	0	502	*b*	9256	*b*	0
320	*b*	5048	*b*	0	313	9331	9334	w	20
410	*b*	5580	*b*	0	600	9558	9565	w	21

[a] The material is the alloy $Er_{0.17}Ru_{0.50}B_{0.33}$ (arc melted). The method used was powder X-ray diffraction in a Debye–Scherrer camera with Ni-filtered Cu Kα radiation. $I = mF^2(1 + \cos^2 2\theta)/(\sin^2\theta\cos\theta)$ was normalized to the strongest reflection with the intensity 100. The space group is $P6/mmm$-D_{6h}^1, No. 191. Lattice parameters are $a = 5.461$ (3) and $c = 3.016$ (2) Å. One Er atom in (1a) 0, 0, 0, three Ru atoms in (3g) $^1/_2$, 0, $^1/_2$, and two B atoms in (2c) $^1/_3$, $^2/_3$, 0. [b] Not observed.

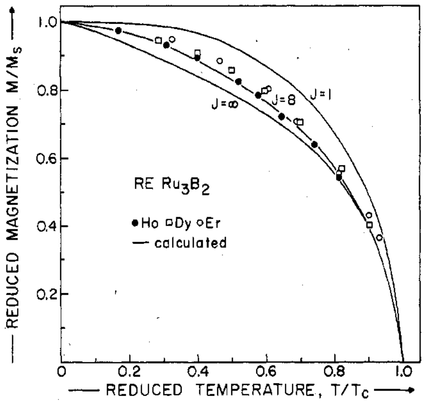

Figure 7. Reduced magnetization vs. reduced temperature for [Dy,Ho,Er]Ru_3B_2 borides.

vs. temperature was found above ferromagnetic ordering temperatures, T_{Curie}. Paramagnetic moments per formula unit, calculated from the Curie–Weiss constant $\mu_{eff} = 2.83C^{1/2}\ \mu_B$, and extrapolated Curie–Weiss temperatures Θ_p [$\chi_M = C/(T - \Theta_p)$] are listed in Table I. $YbRu_3B_2$ (Figure 2) exhibits ideal paramagnetic behavior, as its Θ_p is found to be zero. The paramagnetic moment derived for $YbRu_3B_2$ is very close to the theoretical value[18] for Yb^{3+} in perfect agreement with lattice parameters and volume, as discussed in section I (Figure 1).

The susceptibility data for the ceric rare earths (Ce, Pr, Nd, Sm) cannot be described by a simple Curie–Weiss law. Nonetheless, in the case of [Pr,Nd]Ru_3B_2 the deviations of χ_g^{-1} vs. T from linear dependence at the highest temperatures ($T > 800$ K) seem to be typical examples of the temperature-independent Van Vleck type of paramagnetism, consistent with existence of relatively low-lying energy states above the Hund's rule ground state.[18] Therefore, a least-squares fit of the data (>300 K) was made to function 1, where N is the

Table III. Comparison of Molar Susceptibilities $\chi_M(T)$ for Different Nd and Pr Compounds

compd	χ_M, cm^3 mol^{-1}	μ_{eff}^{exptl}, μ_B	ref
Nd metal	$1.366/(T - 4.3) + 0.721 \times 10^{-3}$	3.3	19
Nd_2O_3	$1.684/(T + 68) + 0.60 \times 10^{-3}$	3.67	20
$NdRu_3B_2$	$1.65/(T - 61) + 0.66 \times 10^{-3}$	3.62	this work
$PrRu_3B_2$	$1.72/(T - 51) + 0.54 \times 10^{-3}$	3.58	this work

$$\chi_M = \frac{N(\mu_{eff}^2)}{3k_B(T + \Delta)} + N\alpha - \frac{N(e^2)}{6mc^2}\sum_i \overline{R_i^2} + \chi_{Pauli} \quad (1)$$

Avogadro number and k_B is the Boltzmann constant. The first (main) term represents a Curie–Weiss contribution from the ground strate, and the second term is the temperature-independent Van Vleck correction (second-order Zeeman effect), while the third term represents the diamagnetic part. Finally, due to the generally metallic nature of the low-boron-content samples, a fourth term was included to account for the Pauli paramagnetism of the conduction electrons. With use of best-fit parameters μ_{eff}, Θ_p, etc. (see Table II), eq 1 in its analytically simpler form

$$\chi_M = \frac{C}{T + \Delta} + B \quad (2)$$

describes the experimental data fairly well in both cases [Pr,Nd]Ru_3B_2 at temperatures $T > 300$ K, Figure 4. Furthermore, the effective moments, μ_{eff}, so obtained are in excellent agreement with Hund's rule ground states for the free RE^{3+} ions (Table I). Table III gives a comparison of analytical

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(18) Van Vleck, J. H., "The Theory of Electric and Magnetic Susceptibilities"; Clarendon: Oxford, 1932.

(19) Lock, J. M. *Proc. Phys. Soc., London, Sect. B* **1957**, *70*, 566.

expressions for χ_M of various Nd and Pr compounds, as derived by different authors.

For a theoretical calculation of the Van Vleck correction term, multiplet widths for Pr^{3+} and Nd^{3+} were used as compiled by Arajs;[21,22] the diamagnetic core correction was based on Selwood's data.[23] Thus, a simple separation of the experimentally obtained B term $B = \chi_{dia} + \chi_{Van\ Vleck} + \chi_{Pauli}$ yielded a rough estimation for χ_{Pauli}. In both cases [Pr,Nd]Ru_3B_2 the derived values $\chi_{Pauli} \cong 1.0 \times 10^{-6}$ cm^3 g^{-1} are in fair agreement and are found to be of the same order of magnitude as those reported by Arajs[22] for Pr metal (1.15×10^{-6} cm^3 g^{-1}) as well as by Kittel for Ru metal (0.5×10^{-6} cm^3 g^{-1}).

Considering the experimentally obtained paramagnetic effective moments for $RERu_3B_2$ phases (see Table I), excellent agreement is found with Hund's theoretically expected values for free RE^{3+} ions. Therefore, at least at higher temperatures (>300 K), paramagnetic behavior of $RERu_3B_2$ borides is considered to be solely due to the rare-earth atom sublattice. The fact of a negligible paramagnetic contribution of the noble metal–boron sublattice is confirmed by the practically temperature-independent Pauli paramagnetic behavior of zero magnetic moment rare-earth combinations such as [Y,Lu]Ru_3B_2 (see Table I).

The Case of $SmRu_3B_2$ and $CeRu_3B_2$. For both compounds a plot of the reciprocal susceptibility χ_g^{-1} vs. temperature shows remarkable deviations from a simple Curie–Weiss law (Figures 5 and 6). It is interesting to note from Figure 5 how closely the reciprocal gram-susceptibility χ_g^{-1} of $SmRu_3B_2$ follows the temperature dependence shown by pure Sm metal itself. The room-temperature paramagnetic moment μ_{eff} is in excellent agreement with the theoretically expected value for tripositive Sm according to the Van Vleck theory for closely spaced multiplets.[18] Deviations from Van Vleck theory, however, become well pronounced at low temperatures and might be attributed to strong crystal field effects. Similar behavior was found for SmN,[24] SmGa,[25] and recently for Sm[Ir,Os]$_4B_4$.[26]

On the other hand, the susceptibility function χ_g^{-1} vs. T for $CeRu_3B_2$ (Figure 6) reflects the generally ambivalent behavior of cerium as an alloying constituent. χ_g^{-1} vs. T for $CeRu_3B_2$ resembles most the theoretical χ_g^{-1} vs. T for ideally free Sm^{3+} Van Vleck paramagnetism.[18] There is for Sm^{3+} a small Curie contribution $\mu_{eff}^{Sm^{3+}} = 0.84\ \mu_B$, arising from the $J = {}^5/_2$ Hund's rule ground state and a second-order Zeeman effect, due to rather small multiplet splitting. Similarly, the $CeRu_3B_2$ susceptibility curve can be expressed by a least-squares-fitted analytical function $\chi_M = 0.025/T + 0.6 \times 10^{-3}$ cm^3 mol^{-1}. From this, a small paramagnetic moment, $\mu_{eff} = 0.45\ \mu_B$, is derived for $CeRu_3B_2$, yielding a valency of 3.82, suggesting a rather high ratio $Ce^{4+}/Ce^{3+} = 4.55$, in fair agreement with lattice parameters and the volume of the $CeRu_3B_2$ unit cell.

B. Ferromagnetic Behavior. The low-temperature ($T < 300$ K) magnetic behavior of the $RERu_3B_2$ borides (RE = Pr, Nd, Gd, Tb, Dy, Ho, Er, Tm) is characterized by onset of ferromagnetic ordering as indicated by large positive paramagnetic Curie–Weiss temperatures. Values for the ferromagnetic ordering temperature T_c were obtained from Arrott plots (M^2 vs. H/M) and are listed in Table I. The magnetization obtained in a field of 16 kG was in general smaller than the theoretical saturation moment gJ of the free RE^{3+} ion except for [Er,Dy,Ho]Ru_3B_2. Furthermore, except in the case of Ho we observed considerable differences between T_{Curie} and the asymptotic Curie temperatures Θ_p derived from extrapolations of the χ_g^{-1} vs. T plots. This suggests that in these cases magnetic ordering phenomena are more complicated than simple ferromagnetic ordering. Thus, only $HoRu_3B_2$ seems to obey rather closely the complete Brillouin expression for its magnetization ($J = 8$; see Figure 7), whereas remarkable discrepancies are obvious for Dy and Er ($J = {}^{15}/_2$ in both cases; Figure 7). Due to the relatively high ordering temperatures, $T_{Curie} > 20$ K and strong magnetic interaction, superconducting behavior seems to be unlikely and was not found experimentally in measurements as low as 1.8 K, not even in the case of the zero-moment RE combinations. [Th,Lu]Ru_3B_2, however, was not investigated below 80 K.

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Registry No. $CeRu_3B_2$, 74744-14-2; $PrRu_3B_2$, 74744-05-1; $NdRu_3B_2$, 74744-07-3; $SmRu_3B_2$, 74744-01-7; $GdRu_3B_2$, 74744-11-9; $TbRu_3B_2$, 74744-10-8; $DyRu_3B_2$, 74744-15-3; $HoRu_3B_2$, 74744-12-0; $ErRu_3B_2$, 74744-13-1; $TmRu_3B_2$, 74744-04-0; $YbRu_3B_2$, 74744-00-6; $LuRu_3B_2$, 74744-08-4; YRu_3B_2, 74744-03-9; $ThRu_3B_2$, 74744-02-8; URu_3B_2, 74744-09-5; UOs_3B_2, 74744-06-2.

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