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COORDINATION COMPOUNDS

Behavior of Dodecahydro-*closo*-dodecaborate Anion $B_{12}H_{12}^{2-}$ in Reaction with $Au(Ph_3P)Cl$

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Abstract—The reaction of the anion $B_{12}H_{12}^{2-}$ with $[Au(Ph_3P)Cl]$ in acetonitrile was studied. The nature of the initial cation of the *closo*-dodecaborate and the reagent ratio was shown to affect complexing. The X-ray structures of compounds $Au(Ph_3P)_2[AgB_{12}H_{12}]$ (**I**) and $[Au_9(Ph_3P)_8]B_{24}H_{23}$ (**II**) were determined. Complex **I** is the first example where $B_{12}H_{12}^{2-}$ is coordinated to silver(I) atoms in the face coordination mode. In complex **II**, $B_{12}H_{12}^{2-}$ is oxidized to the dimeric trianion $B_{24}H_{23}^{3-}$, where the two icosahedra are linked by a B—H—B' bridge.

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The documentation concerning the coordination chemistry of cluster boron anions $B_nH_n^{2-}$ (where n = 10, 12) implies that not only these electron-deficient compounds having low donating capacities [1] are coordinated to metal atoms, but they also show a great variety of types of bonding to the metal in coordination compounds. In copper(I) and silver(I) complexes, for example, the *closo*-dodecaborate anion was shown to be capable of forming metal complexes where $B_{12}H_{12}^{2-}$ is involved in the inner coordination sphere via forming 3*c*2*e* (MHB) bonds with metal atoms [2–5] in the same manner as the *closo*-decaborate anion is [6].

Only one gold compound with *closo*-hexaborate anion $B_6H_6^{2-}$, having the composition $[Au_2(Ph_3P)_2(B_6H_6)]$ was described [7, 8]; this compound was prepared by the reaction

$$\begin{aligned}&(Bu_4N)_2B_6H_6 + 2Au(Ph_3P)Cl\\&\to [Au_2(Ph_3P)_2B_6H_6)](\mathbf{III}) + 2(Bu_4N)Cl.\end{aligned} \tag{1}$$

Each Au(I) atom in compound **III** is linked to the triangular face B_3 of the *closo*-hexaborate anion and the phosphorus atom of triphenylphosphine. The terminal hydrogen atoms are presumably uninvolved in gold coordination [7, 8] The IR spectrum of compound **III** features an absorption band at 2473 cm^{-1} associated with the bending vibrations of pendant B—H bonds in $B_6H_6^{2-}$.

Our preliminary studies of reactions of $B_{10}H_{10}^{2-}$ and $B_{12}H_{12}^{2-}$ with $Au(Ph_3P)Cl$ allowed us to isolate the complex $[1\text{-}(Au_3(Ph_3P)_3)B_{10}H_9]$ and complex **II**, respectively [9]. Here, we study the reaction of *closo*-dodecaborate anion $B_{12}H_{12}^{2-}$ with $Au(Ph_3P)Cl$ in acetonitrile, study the effect of the nature of the cation on the initial *closo*-dodecaborate and the reagent ratio on the product composition, and solve the structure of the products.

EXPERIMENTAL

Syntheses

Dodecahydro-*closo*-dodecaboratosilver(I) $[Ag_2B_{12}H_{12}]$ was prepared according to [10].

Chloro(triphenylphosphine)gold(I) $Au(Ph_3P)Cl$ was prepared by reacting $[HAuCl_4]$ with Ph_3P as described elsewhere [11].

Bis(triphenylphosphine)gold(I) catena-(μ^2 -dodecahydro-*closo*-dodecaborate $\{(Au(Ph_3P)_2)(AgB_{12}H_{12})\}_n$ (I). To a solution containing 0.1 mol of $Au(Ph_3P)Cl$ in acetonitrile + benzene (20 mL), added was a solution of 0.1 mole of $[Ag_2B_{12}H_{12}]$ in 20 mL of acetonitrile. The Au^+ to $B_{12}H_{12}^{2-}$ ratio in the reaction mixture was 1 : 1. The resulting clear reaction solution was allowed to stand in the dark for 12 h. Crystals of prismatic habit were forming upon isothermal evaporation of solvents. Yield of compound **I** was about 80%.

Octakis(triphenylphosphine)nonagold(I) tricosahydrotetracosaborate $[Au_9(Ph_3P)_8]B_{24}H_{23}$ (II). To a solution of 0.1 mole of $[Ag_2B_{12}H_{12}]$ in 20 mL of acetonitrile, added was a solution of $Au(Ph_3P)Cl$, taken in an excess, in acetonitrile + benzene (20 mL). After the reagents were combined, a white precipitate (AgCl) was gradually forming. The reaction solution was allowed to stand in the dark for 5 h. Light-orange crystals of prismatic habit coated with a reduced finely divided silver layer were isolated from the reaction mixture. The yield of compound **II** did not exceed 50%.

Elemental Analyses

Analysis for carbon and hydrogen was carried out on a CHINS-3 FA 1108 Elemental Analyzer (Carlo Erba). Boron was determined by atomic absorption spectroscopy on PerkinElmer spectrophotometers model 2100 equipped with an HGA-700 electrothermal atomizer [12]. Silver and gold were determined on AAS-303 in acetylene–air flame.

For $C_{36}H_{48}AgAuB_{12}P_2$ anal. calcd., %: H, 4.95; B, 13.27; C, 44.24; Ag, 11.04; Au, 20.15.

For compound **I** found, %: H 4.78; B 12.58; C 44.12; Ag, 10.69; Au, 20.08.

For $C_{144}H_{167}Au_9B_{24}P_8$ anal. calcd., %: H, 4.03; B, 6.21; C, 41.40; Au, 42.43.

For compound **II** found, %: H, 3.91; B, 6.12; C, 41.10; Au, 42.24.

IR Spectra

IR spectra for compounds **I** and **II** were recorded as Nujol mulls on an Infralum FT-02 (Lumex) spectrophotometer in the range 600–4000 cm^{-1} with resolution of 1 cm^{-1}.

For compound **I**: ν(BH) 2475; $\nu(BH)_{MHB}$ 2342, 2150; δ(BBH) 1070 cm^{-1}.

For compound **II**: ν(BH) 2515; $\nu(BH)_{BHB}$ 1875; δ(BBH) 1054 cm^{-1}.

^{11}B NMR Spectra

^{11}B NMR spectra of solutions of complexes **I** and **II** in acetonitrile were recorded on a Bruker AC 200 spectrometer at a frequency of 64.297 MHz with internal deuterium stabilization relative to external boron trifluoride etherate. ^{11}B NMR data for complex **II** are found in [9].

X-ray Crystallography

Diffraction intensity arrays were obtained from crystals of complexes **I** and **II** on Bruker AXS P4 and Bruker AXS SMART 1000 automated diffractometers (λMoK_α, graphite monochromator, ω scans) at 297(2) and 120(2) K, respectively. Program packages XSCANS [13] (for complex **I**) and SMART and SAINT [14] (for complex **II**) were used in collecting and processing *I*(*hkl*) data sets. The correction for absorption was applied using the MULTISCAN method [15, 16]. The structures were solved by a direct method (SHELXS97 [17]). Non-hydrogen atoms were refined in the anisotropic approximation. The positions of the H atoms of polyhedral anions were found from difference synthesizes and then idealized. The coordinates of H atoms of Ph_3P molecules were calculated. All H atoms were refined using the rider model with isotropic thermal parameters as $U_j(H) = 1.2U_{eq}$ of the relevant non-hydrogen atom. The least-squares fits were carried out using software SHELXL97 [17]. Selected crystallographic data for compounds **I** and **II**, the parameters of the X-ray diffraction experiment, and structure refinement parameters are listed in Table 1; some bond lengths and bond angles are found in Table 2.

Table 1. Selected crystallographic data, details of experiment, and refinement factors for compounds **I** and **II**

Parameter	**I**	**II**
Formula weight	971.19	2070.19
Crystal system	Monoclinic	Monoclinic
Space group, *Z*	$P2_1/c$, 4	$C2/c$, 8
a, Å	12.711(3)	30.556(3)
b, Å	23.256(4)	16.1407(16)
c, Å	14.759(4)	32.958(3)
β, deg	104.99(2)	116.646(2)
V, Å^3	4214.4(17)	14528(2)
ρ_{calc}, g/cm^3	1.531	1.893
μ_{Mo}, mm^{-1}	4.043	9.187
Crystal size, mm	0.45 × 0.30 × 0.22	0.30 × 0.25 × 0.10
θ range, deg	$1.75 < \theta < 27.00$	$1.76 < \theta < 24.00$
Number of reflections		
measured	11311	53017
unique (*N*) [R_{int}]	9190 [0.0347]	11310 [0.1687]
observed ($I > 2\sigma(I)$) (N_o)	6527	3889
GOOF	1.016	0.774
*R*1, *wR*2 for N_o	0.0617, 0.1570	0.0461, 0.0663
*R*1, *wR*2 for *N*	0.0918, 0.1833	0.1719, 0.0843
$\Delta\rho_{max}/\Delta\rho_{min}$, e/Å^3	1.522/–2.715	1.432/–1.065

The crystallographic data for compound **I** have been deposited with the Cambridge Structural Database (CCDC No. 723647). Data for compound **II** are available from the Cambridge Structural Database (Refcode KIYZAU).

RESULTS AND DISCUSSION

A method for preparing a gold(I) complex of the *closo*-hexaborate anion $[Au_2(Ph_3P)_2(B_6H_6)]$ by reac-

Table 2. Selected bond lengths (d) and bond angles (ω) in the structure of complex **I**

Bond	d, Å
Au(1)–P(1)	2.338(2)
Au(1)–P(2)	2.3405(19)
Ag(1)–H(12)#1	2.09
Ag(1)–H(10)#1	2.29
Ag(1)–H(9)#1	2.49
Ag(1)–B(1)	2.498(11)
Ag(1)–B(12)#1	2.528(11)
Ag(1)–B(10)#1	2.614(11)
Ag(1)–B(2)	2.630(13)
Ag(1)–B(9)#1	2.738(11)
Ag(1)–H(1)	1.95
Ag(1)–H(2)	2.21
Angle	**ω, deg**
B(1)H(1)Ag(1)	107
B(2)H(2)Ag(1)	100
B(9)H(9)Ag(1)#2	91
B(10)H(10)Ag(1)#2	94
B(12)H(12)Ag(1)#2	100

Note: Atoms related to the initial atoms via symmetry transformations: #1 $x, -y + 3/2, z + 1/2$; #2 $x, -y + 3/2, z - 1/2$.

tion(1) using $(Bu_4N)_2B_6H_6$ and $Au(Ph_3P)Cl$ as the reagents is described in [6]. Our studies have shown that it is impossible to prepare a gold(I) complex of $B_{12}H_{12}^{2-}$ by a similar reaction of $(Bu_4N)_2B_{12}H_{12}$ with $Au(Ph_3P)Cl$ in acetonitrile, since an isothermal evaporation of the reaction mixture leads to the isolation of the least soluble compound ($Au(Ph_3P)Cl$) in colorless crystals. Therefore, we chose $[Ag_2B_{12}H_{12}]$ and $Au(Ph_3P)Cl$ for preparing gold complexes of the *closo*-dodecaborate anion. The reaction scheme was presumed to be as follows:

$$[Ag_2B_{12}H_{12}] + 2Au(Ph_3P)Cl \rightarrow [Au_2(Ph_3P)_2B_{12}H_{12}] + 2AgCl. \tag{2}$$

AgCl formation was expected to remove silver from the reaction system and to shift the reaction toward a suggested gold(I) complex of the anion $B_{12}H_{12}^{2-}$. However, it appeared that reaction (2) did not occur, and depending on the reagent ratio, the reaction of $[Ag_2B_{12}H_{12}]$ with $Au(Ph_3P)Cl$ may be described as follows:

$$[Ag_2B_{12}H_{12}] + Au(Ph_3P)Cl \rightarrow [Au(Ph_3P)_2][AgB_{12}H_{12}]\ (\mathbf{I}), \tag{3}$$

$$[Ag_2B_{12}H_{12}] + 9Au(Ph_3P)Cl \rightarrow (AgCl/Ag^0)\downarrow + [Au_9(Ph_3P)_8]B_{24}H_{23}\ (\mathbf{II}). \tag{4}$$

For the equimolar reagent ratio, AgCl was not formed, and the combination of physicochemical methods allowed us to identify the reaction product with compound **I** (Scheme 3). Elemental analysis showed both silver(I) and gold(I) atoms in complex **I**. In the IR spectrum of compound **I**, in the region of the boron–hydrogen stretches there are a strong band ν(BH) due to "free" BH groups at 2475 cm^{-1} and two broadened medium-intensity bands (~2342 and 2150 cm^{-1}), which are associated with the stretching vibrations $\nu(BH)_{MHB}$. A similar pattern is observed in the IR spectra of $Cat[AgB_{12}H_{12}]$ anionic complexes [4]. In the region where the vibrations of phenyl rings of triphenylphosphine molecules appear (600–1600 cm^{-1}), the IR spectrum of complex **I** is an analogue of the spectrum of the precursor $Au(Ph_3P)Cl$.

Crystals of compound **I** were isolated from the reaction solution, and their structure was solved by X-ray crystallography. Complex I represents a coordination polymer built of $[AgB_{12}H_{12}]_n^{n-}$, anionic chains which are extended along axis c (Fig. 1a) and $[Au(Ph_3P)_2]^+$ complex cations (Fig. 1b). The atom Ag(1) is coordinated by the edge B(1)–B(2) of one $B_{12}H_{12}^{2-}$ anion and the face B(9)B(10)B(12) of the other anion. Ag–B(H) bond lengths with $B_{12}H_{12}^{2-}$ polyhedra are nonequivalent: Ag(1)–B(1) (2.498(11) Å) is far shorter than Ag(1)–B(2) bond lengths (2.630(13) Å), and Ag(1)–B(12) (2.528(11) Å) is shorter than Ag(1)–B(10) (2.614(11) Å) and Ag(1)–B(9) (2.738(11) Å). The longest bond Ag(1)–B(9) in Fig. 1a is indicated by a dashed line.

In the complex cation $[Au(Ph_3P)_2]^+$, the atom Au(1) has a nearly linear coordination: angle P(1)Au(1)P(2) is 170.91(7)°; Au(1)–P bond lengths are 2.338(2) and 2.341(2) Å. Molecular stacking in a crystal in the projection along axis c is shown in Fig. 1c.

closo-Hydroborate anions, by virtue of their geometric specificity, can be coordinated to metal atoms by various edges and/or faces of their boron cages, giving rise to a great many position isomers, specifically mirror isomers [18]. In compound **I**, two enantiomers cocrystallize in a polymer chain: 1-2, 8-9-12 and 1-2, 9-10-12 isomers (Fig. 2). Compound **I** may be classified with $Cat[AgB_{12}H_{12}]$ complexes where Cat = $Au(Ph_3P)_2^+$. As distinct from the $Cat[AgB_{12}H_{12}]$ complexes described in [3–5] (where Cat = $[(NaphCH_2)Ph_3P]^+$, $NBzlEt_3^+$), compound **I** is the first example where the anion $B_{12}H_{12}^{2-}$ is coordinated simultaneously by an edge to one silver(I) atom and by a face to another silver(I) atom.

The X-ray crystallography and IR spectroscopic data taken together imply that the coordination of

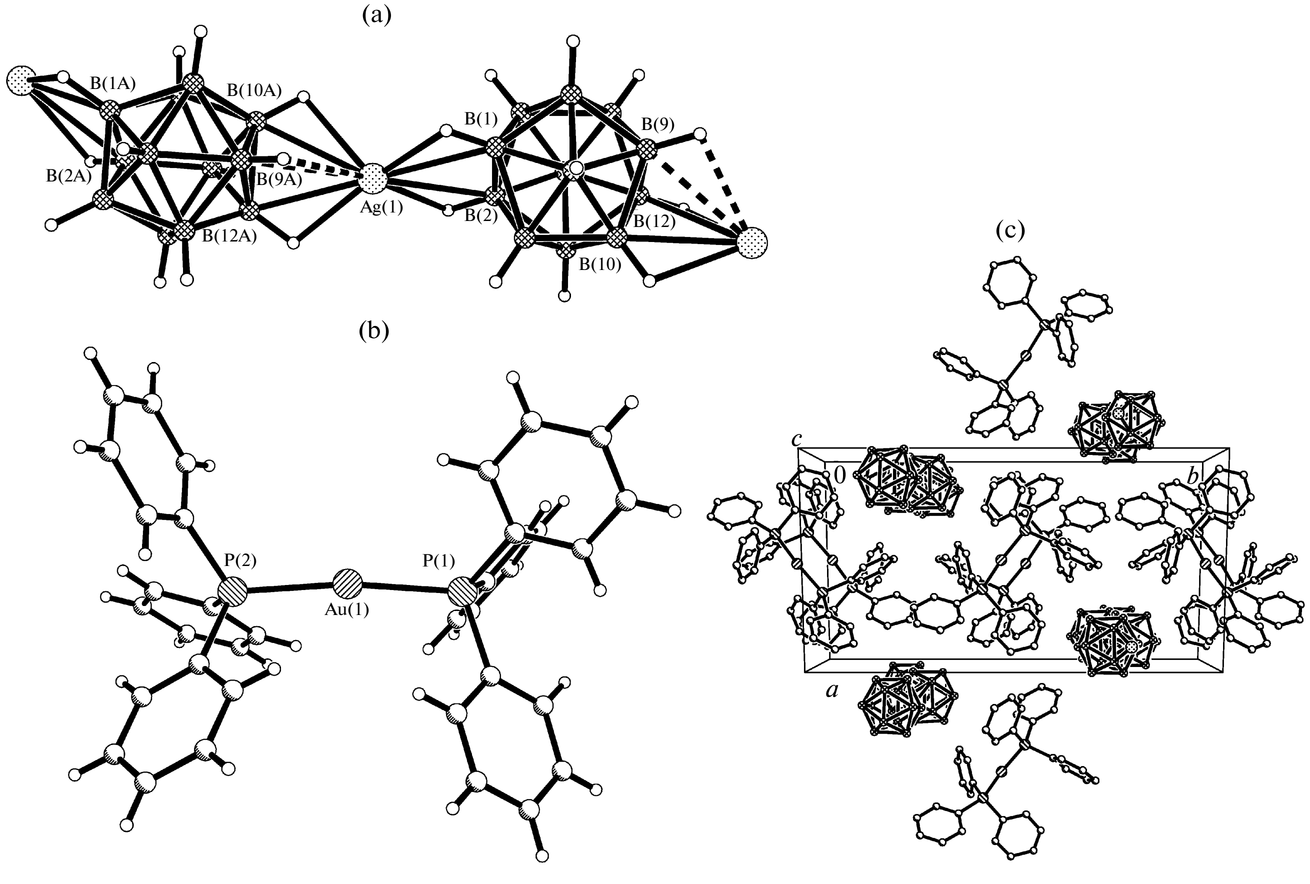

Fig. 1. Crystal structure of compound **I**: (a) a fragment of an $[AgB_{12}H_{12}]_n^{n-}$ chain (the anionic part), (b) $[Au(Ph_3P)_2]^+$ (the cationic part), and (c) projection along axis *c* (H atoms are omitted).

$B_{12}H_{12}^{2-}$ anions to Ag(I) atoms is via long and short three-center two-electron bonds (MHB). This is evidenced by the values of Ag–H(B) (1.95–2.49 Å) and Ag–B(H) (2.498(11)–2.738(11) Å) bond lengths and AgHB bond angles (90.8°–106.8°) (Table 2) and by the appearance in the IR spectrum of two bands arising from $\nu(BH)_{MBH}$ and having peaks at 2342 cm^{-1} ($\Delta\nu$ = 133 cm^{-1}) and 2150 cm^{-1} ($\Delta\nu$ = 325 cm^{-1}), which refer to longer and shorter Ag–H(B) contacts, respectively.

The study of the behavior of the *closo*-dodecaborate anion in a greater excess of $Au(Ph_3P)Cl$ with respect to $[Ag_2B_{12}H_{12}]$ (where the ratio of $Au(Ph_3P)Cl$ to $[Ag_2B_{12}H_{12}]$ was 9 : 1) produced a radically different complex $[Au_9(Ph_3P)_8]B_{24}H_{23}$ (**II**). In this case, precisely as implied by reaction (2), AgCl is produced to then enter a redox reaction where Ag^+ is reduced to Ag^0 and Au^+ to $Au^{0.33+}$ and where $B_{12}H_{12}^{2-}$ is oxidized to $B_{24}H_{23}^{3-}$ (Scheme 4). Among other reasons, the formation of degradation products of $B_{12}H_{12}^{2-}$ is responsible for the low yield of compound **II**.

Complex **II** contains a nonanuclear gold cluster (Fig. 3b), which constitutes the cationic part of the complex. The counterion (Fig. 3a) is the dimeric centrosymetrical trianion $B_{24}H_{23}^{3-}$. B–H and B···B' distances in the B–H–B' bridge are 1.08 and 2.154 Å,

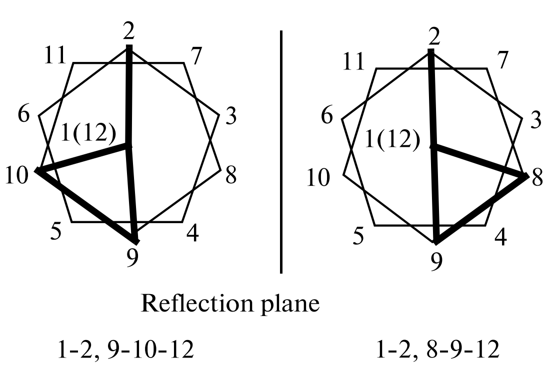

Fig. 2. Schematics of enantiomers 1-2, 8-9-12 and 1-2, 9-10-12 that cocrystallize in the crystal of complex **I** (top view).

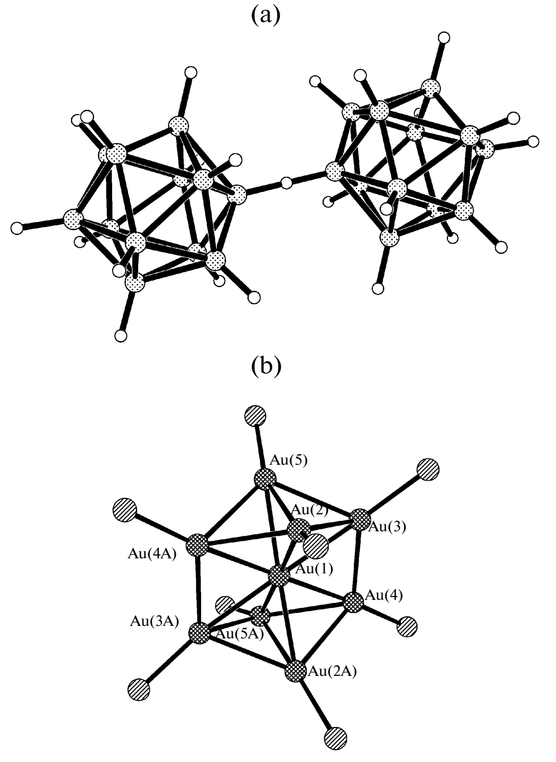

Fig. 3. Crystal structure of compound **II**: (a) $[B_{24}H_{23}]^{3-}$ (anionic part) and (b) $[Au_9(Ph_3P)_8]^{3+}$ (cationic part).

respectively in match with theoretical calculations [19]. The existence of the trianion $B_{24}H_{23}^{3-}$ in complex **II** is unambiguously identified by ^{11}B NMR and IR spectroscopy [9].

Compounds of the cation $[Au_9(Ph_3P)_8]^{3+}$ and anion $[B_{24}H_{23}]^{3-}$ with other counterions are known in the literature. The oxidation of $B_{12}H_{12}^{2-}$ to yield trianion $[B_{24}H_{23}]^{3-}$ was described as early as in 1969 [20]; $Na_3[B_{24}H_{23}]$ was obtained by electrolysis of a solution of $Na_2B_{12}H_{12}$ in acetonitrile at 1.5 V:

$$2B_{12}H_{12}^{2-} \longrightarrow B_{24}H_{23}^{3-} + H^+ + 2\bar{e}.$$

Based on the data of elemental analysis and IR and NMR spectroscopy, a link by a bridging hydrogen atom between the two $B_{24}H_{23}^{3-}$ icosahedra in $B_{12}H_{11}$ was suggested [20].

Later [21], the X-ray diffraction structure of the trianion $[B_{24}H_{23}]^{3-}$ was determined. The angle BHB' between the icosahedra was 128.2°, whereas in complex **II**, the B–H–B' bridge is strictly linear (in terms of symmetry).

Polynuclear gold clusters with triphenylphosphine and its derivatives are described in [22]. Nonanuclear gold clusters are mostly prepared by the reduction of mononuclear gold(I) complexes. Specifically, the reduction of $Au(Ph_3P)NO_3$ by $NaBH_4$ produced the complex $[Au_9(Ph_3P)_8](NO_3)_3$ [23]. Other reducing agents are also useful for preparing $[Au_9(Ph_3P)_8]^{3+}$, for example, the titanium complex $[Ti(\eta\text{-}C_5H_5Me)_2]$ [24]. In our case, the reducing agent is likely to be the initial *closo*-dodecaborate anion $B_{12}H_{12}^{2-}$.

To summarize, we may say that having studied the behavior of the *closo*-dodecaborate anion $B_{12}H_{12}^{2-}$ in reaction with $Au(Ph_3P)Cl$, we found a number of features of the complexing process. We have found that $Cat_2B_{12}H_{12}$ salts of organic cations ($Cat^+ = Ph_4P^+$, Bu_4N^+) do not react with $Au(Ph_3P)Cl$ in acetonitrile, whereas the use of $[Ag_2B_{12}H_{12}]$ as the precursor *closo*-dodecaborate and variation of the reagent ratio produce fundamentally different products. The equimolar ratio of $[Ag_2B_{12}H_{12}]$ to $Au(Ph_3P)Cl$ yields a silver(I) complex that is the first example where the *closo*-dodecaborate anion is coordinated to silver(I) atoms in the face coordination. The reaction of $[Ag_2B_{12}H_{12}]$ with an excess of $Au(Ph_3P)Cl$ generates ideal conditions for preparing $[B_{24}H_{23}]^{3-}$ and $[Au_9(Ph_3P)_8]^{3+}$, whereas the preparation of the aforementioned cation and anion individually requires applying more severe conditions. Both complexes contain gold atoms, which are however not linked to the cluster boron anion.

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REFERENCES

1. *The Chemistry of Inorganic Hydrides. Collected Works*, Ed. by N. T. Kuznetsov (Nauka, Moscow, 1990) [in Russian].
2. N. Chaozhou, M. Yilin, and S. Cuifang, Acta Chim. Sin. **43** (5), 411 (1985).
3. V. V. Drozdova, E. A. Malinina, N. T. Kuznetsov, et al., Zh. Neorg. Khim. **51** (11), 1832 (2006) [Russ. J. Inorg. Chem. **51** (11), (2006)].
4. E. A. Malinina, V. V. Drozdova, N. T. Kuznetsov, et al., Zh. Neorg. Khim. **53** (7), 1105 (2008) [Russ. J. Inorg. Chem. **53** (7), (2008)].
5. O. Volkov, Ch. Hu, and P. Paetzold, Z. Anorg. Allg. Chem. **631** (6–7), 1107 (2005).
6. V. V. Drozdova, E. A. Malinina, N. T. Kuznetsov, et al., Zh. Neorg. Khim. **53** (2), 238 (2008) [Russ. J. Inorg. Chem. **53** (2), (2008)].
7. T. Chaper and W. Preetz, Chem. Ber. **130**, 405 (1997).

8. T. Chaper, C. Näther, and W. Preetz, Z. Naturforsch. B **54**, 345 (1999).
9. E. A. Malinina, V. V. Drozdova, N. T. Kuznetsov, et al., Dokl. Akad. Nauk **414** (4), 484 (2007).
10. N. T. Kuznetsov, G. S. Klimchuk, and O. A. Kanaeva, Zh. Neorg. Khim. **20** (10), 2557 (1975).
11. *Handbuch der praeparativen anorganischen Chemie*, Ed. by G. Brauer (Ferdinand Enke, Stuttgart, 1975–1981; Mir, Moscow, 1985).
12. L. I. Ochertyanova, K. Yu. Zhizhin, V. N. Mustyatsa, et al., Neorg. Mater. **40** (1), 188 (2004).
13. *XSCANS Software Package. Version 2.2* (Bruker AXS, Madison, WI, 1996).
14. *SMART (control) and SAINT (Integration) Software. Version 5.0* (Bruker AXS, Madison, 1997).
15. R. H. Blessing, Acta Crystallogr. Sect. A **51** (1), 33 (1995).
16. G. M. Sheldrick, *SADABS. Program for Scaling and Correction of Area Detector Data* (Univ. of Göttingen, Göttingen, 1997).
17. G. M. Sheldrick, *SHELXS97 and SHELXL97. Programs for the Solution and Refinement of Crystal Structures* (Univ. of Göttingen, Göttingen, 1997).
18. V. V. Drozdova, E. A. Malinina, and N. T. Kuznetsov, Zh. Neorg. Khim. **54** (12), 2029 (2009) [Russ. J. Inorg. Chem. **54** (12), (2009)].
19. A. M. Mebel, K. Najafian, O. P. Charkin, and R. von Schleyer, J. Mol. Struct.: Theochem **187**, 461 (1999).
20. R. J. Wiersema and R. L. Middaugh, Inorg. Chem. **8** (10), 2074 (1969).
21. O. Volkov, Ch. Hu, U. Kolle, and P. Paetzold, Z. Anorg. Allg. Chem. **631**, 1909 (2005).
22. *Modern Supramolecular Gold Chemistry*: *Gold–Metal Interactions and Applications*, Ed. by A. Laguna (Wiley-VCH, Weinheim, 2008).
23. F. Cariati and L. Naldini, J. Chem. Soc., Dalton Trans., No. 20, 2286 (1972).
24. P. J. Dyson and D. M. P. Mingos, *Gold: Progress in Chemistry, Biochemistry and Technology*, Ed. by H. N. Y. Schmidbaur (Wiley, New York, 1999).