

Redox-Active Antineoplastic Ruthenium Complexes with Indazole: Correlation of in Vitro Potency and Reduction Potential

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6·2(CH₃)₂CO

Elemental Analyses

Compound	Anal. calcd. for	calcd. [%]				found [%]			
		C	H	N	Cl	C	H	N	Cl
Trisindazolium [hexachlororuthenate(III)]	$C_{21}H_{21}N_6Cl_6Ru$	37.58	3.15	12.52	31.69	37.30	3.34	12.55	31.65
Bisindazolium [pentachloro(1 <i>H</i> -indazole)ruthenate(III)]	$C_{21}H_{20}N_6Cl_5Ru$	39.74	3.18	13.24	27.93	40.01	3.24	13.01	28.31
Indazolium <i>trans</i> - [tetrachlorobis(1 <i>H</i> -indazole)ruthenate(III)]	$C_{21}H_{19}N_6Cl_4Ru$	42.16	3.20	14.05	23.70	41.97	3.03	13.78	23.92
<i>mer</i> -Trichlorotris(1 <i>H</i> -indazole)ruthenium(III)	$C_{21}H_{18}N_6Cl_3Ru \cdot 2C_4H_8O$	49.33	4.85	11.90	15.06	49.23	4.58	12.04	15.16
<i>trans</i> -[Dichlorotetra(1 <i>H</i> -indazole)ruthenium(III)] chloride	$C_{28}H_{24}N_8Cl_3Ru$	49.46	3.56	16.48	15.64	49.63	3.70	16.73	15.85
<i>trans</i> -[Dichlorotetra(1 <i>H</i> -indazole)ruthenium(II)]	$C_{28}H_{24}N_8Cl_2Ru$	52.18	3.75	17.39	11.00	52.46	3.59	17.17	10.92

Details of the crystal structures of **5·2CH₃OH** and **6·2(CH₃)₂CO**

The crystal structure of **5·2CH₃OH** consists of the cations *trans*-[Ru^{III}Cl₂(ind)₄]⁺, Cl[−] anions and methanol solvent molecules. The Ru atom in **5·2CH₃OH** is coordinated octahedrally by four indazole ligands in equatorial plane and two chloride ligands in axial positions. The Ru–N bond lengths are in the range 2.069(5)–2.071(3) Å, whereas Ru–Cl1 and Ru–Cl2 are significantly longer at 2.3285(9) and 2.3338(9) Å, correspondingly. A propeller-like arrangement of the *trans*-tetraindazole core, formed by a tilting of the indazole rings with respect to the RuN₄ plane to reduce the mutual repulsions, is characteristic for the cation in **5·2CH₃OH**. All of the indazole rings are essentially planar. The pitch of the four indazole planes varies between 20.2 and 38.5°. The *trans*-coordinated indazole ligands are almost parallel to one another. The dihedral angle is small and does not exceed 5.6°. Interestingly, in two of them the N–N bonds are *trans*, while in the other two these bonds are *cis* to each other. Torsion angles in **5·2CH₃OH** are as follows: Cl1–Ru–N1–C1 = −38.5(3)°; Cl1–Ru–N5–N6 = −33.3(3)°; Cl1–Ru–N7–N8 = −25.3(3)°; Cl1–Ru–N3–N4 = −20.2(3)°.

The unit cell of **6·2(CH₃)₂CO** contains two crystallographically independent complexes along with two molecules of acetone. Like in **5·2CH₃OH**, the coordination geometry about Ru(II) is a distorted octahedron of four nitrogen atoms of the indazole ligands and two chlorides. While the Ru–N bond lengths (Ru1–N1 2.0640(13), Ru1–N3 2.0638(14), Ru2–N5 2.0668(15) and Ru2–N7 2.0535(14) Å) are only slightly shorter than those in **5·2CH₃OH**, the Ru1–Cl1 at 2.4120(9) and Ru2–Cl2 at 2.4236(7) Å are noticeably longer. This can be attributed to the effect of the ruthenium oxidation state. The arrangement of the indazole ligands is also similar, tending to minimize steric crowding between them. The opposite *trans*-coordinated indazole ligands are nearly parallel to each other in both crystallographically independent molecules (the dihedral angles vary from 0.1 to 5.6°). The relevant torsion angles in **6·2(CH₃)₂CO** are as follows: Cl1–Ru–N1–N2 = 40.16(10)°; Cl1–Ru–N3–N4 = 26.28(9)°; Cl2–Ru2–N7–N8 = −20.66(10)°; Cl2–Ru2–N5–C15 = 3.01(12)°.

Thus, X-ray diffraction study has shown that the reduction of **5** is accompanied by a lengthening of the Ru–Cl bonds by 0.08–0.09 Å. This is presumably the consequence of the lowering of the positive charge of the central metal ion.