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Review of Elementary Crystallographic Cells of Important Intermediate Phases in Golden Alloys

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ABSTRACT: *Pure gold is rarely used, mainly from its low mechanical properties, first of all the strength and hardness, but the toughness is however on a high level. For improving the strength and hardness the gold shold be alloyed with different metals, while some metalloids (as aluminium and silicon) have shown detrimental effect (dramatically reduced the toughness)Golden alloys have found a wide application in jewel making but also in other fields, as for coins, in stomatology, etc. Depending from the kind of usage, those alloys are produced but before they should be alloyed with proper metal(s). Many casting and/or mechanical properties of golden alloys are known, but their crystallographic characteristics still are not well known, even to metallurgists and specialists in production of those alloys. Further, after applying a kind of heat treatment (either the hardness is increased or not), some changes in crystallographic structure of golden alloys are subjected to change. Here will be presented the elementary cells of different crystallographic structures in most known gold binary alloys, which are important for usage.*

Key words: *gold alloys, intermediate phases, elementary cells*

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I. INTRODUCTION

For common golden jewel binary alloys, great number of constitutional diagrams and their crystallographic structures and elementary cells are known [1]. For other ternary, those diagrams still were not fully investigated [2,3], also the kind of phases from complex golden alloys. There are a lot of gold binary alloys but their elementary cells still are not well known, so an exactly explanation sometimes could not be found out in the literature.Gold is able to make alloys with many elements from group of metals or metalloids. In all occasions, and for further understanding the phases which appeared through the entire alloying system, the constitutional diagram is, of course, irreplaceable diagram [4,5]. The most popular gold alloys in trade and to ordinary people are known as 14, 16 and 18 karat gold.An unusual way for showing the possibility about forming of an alloy from gold and another metal/metalloid is shown in Fig. 1. In this figure one can find only a brief information if any metal or metalloid is soluble in gold or not [1,6]. The kind of solid solution or intermetallic compound which appears in Fig. 1. is usable only for description of the purpose. It is far away that such representation can replace the using of a constitutional diagram.

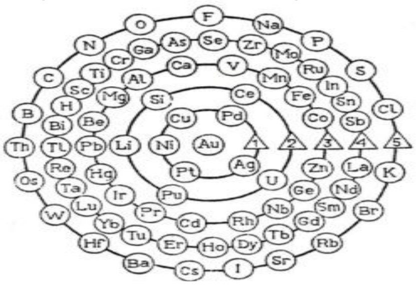


Fig.1. Schematic representation of solubility of different elements in gold [1]

in which means:1-full solubility of elements in gold; 2-full insolubility of an element in gold; 3-limitedsolubility of gold in elements; 4-limited solubility of elements in gold, and 5-limited mutual solubility between gold and elementsFurther informations from this kind of diagram cold not be taken.

II. KONCEPT OF ELEMENTARY CELL:

Elementary cell is commonly used in crystallography, metallography or science of materials. The concept of elementary cell is strongly defined by axes x,y,z and their intersections a, b, c and angles between them α, β and γ, as shown in Fig. 2b).

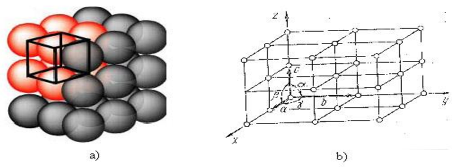


Fig. 2.- Gathering of atoms in crystal a) and elementary cell b)

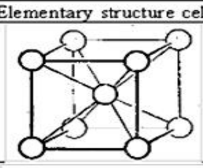
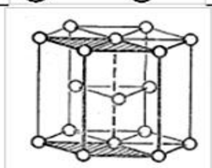
The crystal classes fall into seven crystal systems, with greater number of unit cells. Every phase has own unit cell.

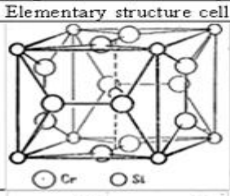
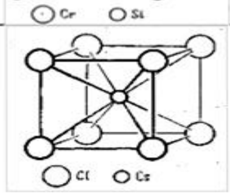
III. STRUCTURES OF ELEMENTARY CELLS:

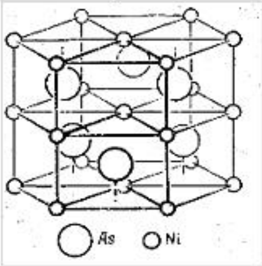
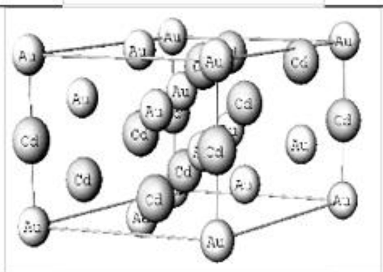
For serios metallurgical analyzing of an alloy, the exact structure of an elementary cell should be known. Those cells for almost gold binary alloys are reviewed in table as follows [4,6].

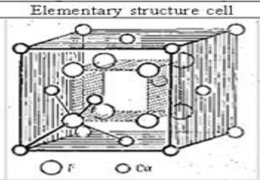
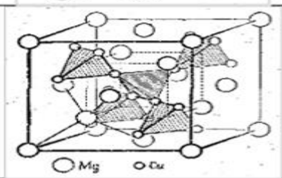
Table 1. Important structures of intermetallic compounds in binary gold alloys

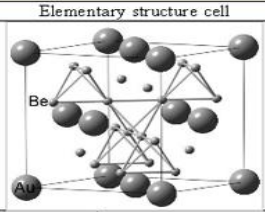
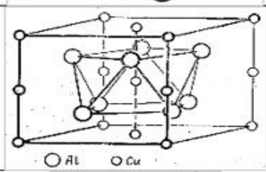
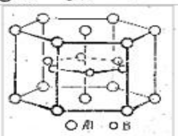
(designation is provided according to International Crystallography Organization)

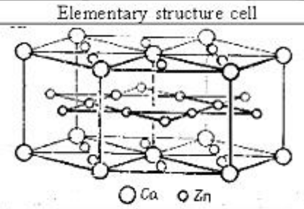
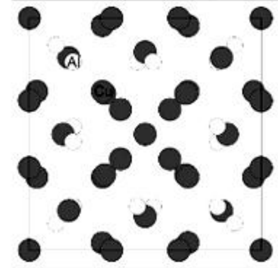
Structure type	Elementary structure cell	Phase
A2 (type W)		β-$AlAu_4$
A3 (type W)		ε-AuCd α_2-Au_3Cd Au_3Ga Au_3Hg Au_4In ε-AuSb β-Au_4Sn ε-$AuZn_8$

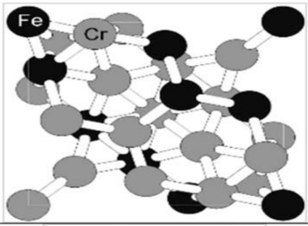
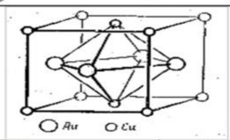
Structure type	Elementary structure cell	Phase
A15 (type Cr_3Si)		$AuNb_3$ $AuTa_3$ $AuTi_3$ AuV_3 $AuZr_3$
B2 (type CsCl)		AuCd AuCs AuDy AuEr AuGd AuHo AuLu AuMg AuMn AuNd AuPr AuSc AuSm AuTb AuTm AuY

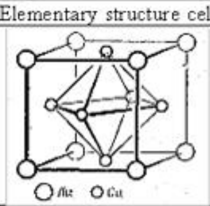
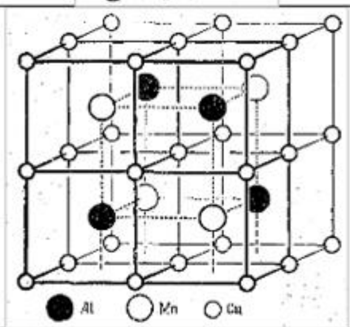
Structure type	Elementary structure cell	Phase
$B8_1$ (type NiAs)		AuSn
B19 (type AuCd)		AuCd AuTi

Structure type	Elementary structure cell	Phase
C1 (type CaF_2)		Al2Au $AuGa_2$ $AuIn_2$
C15 (type CsCl)		Au_2Bi Au_2Na Au_2Pb

Structure type	Elementary structure cell	Phase
$C15_b$ (type $AuBe_5$)		$AuBe_5$ Au_5Ca
C_{16} (type $CuAl_2$)		$AuNa_2$ $AuPb_2$ $AuTh_2$
C32 (type AlB_2)		AuB_2 Au_2Nb Au_2Th

Structure type	Elementary structure cell	Phase
$D2_4$ (type $CaZn_5$)		Au_5Ba Au_5K Au_5Rb Au_5Sr
$D8_3$ (type Cu_9Al_4)		Al_2Au_5 δ-Au_5Cd_8 Au_5Ga Au_5Hg_8 Au_7In_3 γ_1-$AuZn_3$ Au_5Zn_8

Structure type	Elementary structure cell	Phase
$D8_b$ (type CrFe ; σ-фаза)		$AuTa_2$ $AuZr_3$
$L1_0$ (type AuCu)		AuCu

Structure type	Elementary structure cell	Phase
$L1_2$ (type Cu_3Au)		Au_3Cd $AuCu_3$ Au_3Cu $AuMn_3$ Au0 3300 $_3$Pt Au_3Zn
$L2_1$ (type Cu_2AlMn)		$AgAuCd_2$ $AuCuZn_2$ $AgAuZn_2$ Au_5Sr

NOTE: 1- Structure types are designated according to the most known type, for example AuCu, CrFe (σ-phase), etc.;

2- Types of phases are listed according to a,b,c ... order

Phases from ternary, quartenary, etc. alloys are pretty complex in theri nature, also for investigation and/or structure determination, and obviously they need much more knowledge and/or researching activities [6-12].

IV. DISCUSION

For most commercial golden alloys with silver and copper the crystal structures were partialy investigated, while for many other gold-metal (metaloid) alloys such data still are unknown to producers, even to specialists [1,6,8]. During manufacturing processing, as expected, many different kinds of structures will be appeared, as well in golden products. From the constitutional diagram one can find a valuable data about temperature *vs* phase composition or solubility of components etc, but not the informations about crystal type structure(s) [4,5]. Only some constitutional diagrams of binary gold alloys are well investigated. The most of phases or intermetallic compounds in gold-metal system also are not fully examined. Such review of crystal structures will be helpfull for everyone who is engaged in production or quality assessment of gold alloys [8-12]The crystal classes fall into seven crystal systems, with greater number of unit cells. A great number of intermetallic compounds which gold makes with other metals here are briefly listed, according to phases between two elements, structure type and type of elementary structure cell. All elements obviously did not make an intermetallic compound, but great number does. Those elemetary cells of gold-metal/metaloid here are given for next alloying elements: silver, copper, zinc, nickel, cadmium, tin, bismuth, lead, magnesium, manganese, gallium, sodium, potasium, barium, calzium, mercury, tantal, vanadium, zirconium, caesium, dysprosium, erbium, gadolinium, holmium, lutetium, neodymium, praseodymium, samarium, rubudium, terbium, thulium, yttrium and strontium. Details about concentration and temperature regions of those intermetallic compounds could be found at a proper constitutional diagram. For detailed structure determinations of phases from gold-metal(s) systems different methods of investigations should be applied [2,6,12].

V. CONCLUSION

The elementary cells for almost gold alloys are reviewed, where the crystal types are shown for every group of cell, mainly for binary sistems, for main elements which are able to make an intermetallic compound with gold. The designation of important structures, i.e. crystallographic cells of intermetallic compounds in binary gold alloys, is provided according to International Crystallography OrganizationHere collected and shown data will be helpfull for everyone who is engaged in structure determination or sometimes in production of such golden alloy. However, the obtained results should be used for further explanations of physical, chemical or metallurgical properties of gold alloys, neither only for jewelry purposes.

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