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ПРОБЛЕМНАЯ СТАТЬЯ

ON THE SAME ELEMENT ISOTOPE MASS NUMBERS (PLEIAD) AND THE CLUSTERS OF ELEMENTS SHARING THE SAME MASS NUMBERS IN THE PERIODIC SYSTEM — THE «CHESHUYA» (FISH SKIN) MODEL

К ВОПРОСУ ОБ ИЗОТОПАХ ОДНОГО ЭЛЕМЕНТА С РАЗНЫМИ МАССОВЫМИ ЧИСЛАМИ И ИЗОТОПАХ РАЗНЫХ ЭЛЕМЕНТОВ С ОДНИМ МАССОВЫМ ЧИСЛОМ В ПЕРИОДИЧЕСКОЙ СИСТЕМЕ ЭЛЕМЕНТОВ: МОДЕЛЬ «ЧЕШУЯ»

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KEYWORDS: elements, isotopes, same element isotope mass numbers (pleiad), different element isotopes sharing the same mass numbers (cluster)

КЛЮЧЕВЫЕ СЛОВА: элементы, изотопы, изотопы одного элемента с разными массовыми числами (плеяда), изотопы различных элементов с одинаковыми массовыми числами (кластер)

ABSTRACT: We graphically characterized the fact that 92 naturally occurring basic elements from the Periodic system, and defined by the different atomic number (number of protons), represent the unique population of 1507 simple substances of different isotopes where the isotopes of the same element share the same number of protons and different number of neutrons. We use the term «pleiad» for all the isotopes of the same atomic number, i.e, element. All elements have isotopes starting with hydrogen ($^{1-3}$H), peak up with indium having 35 different isotopes (mass numbers $^{106-121,123}$In), and close up with uranium having 15 isotopes ($^{227-240}$U). All the isotopes of all the elements that share the same mass number with a certain member of the pleiad were named the «element cluster». Thus, the element cluster of the shortest span is $^{1-3}$H having three hydrogen's and one helium (3 H, 1 He), where ^{3}H and ^{3}He share the same mass numbers. The largest element cluster span was observed for tin ($^{108-130,132}$Sn) comprising 216 different isotopes (1 Ru, 4 Rh, 10 Pd, 16 Ag, 20 Cd, 33 In, 31 Sn, 29 Sb, 24 Te, 16 I, 14 Xe, 7 Cs, 6 Ba, 4 La, 1 Ce). Some isotopes have one, two, or even three varieties with the same mass number what, when presented graphically, gave the impression of the fish skin (Russian «cheshuya») where the isotopes became virtually interdigitated in intriguing patterns. The results are discussed relative to the Gestalt phenomena in biology, possible biological classification of the Periodic system, and bioelement/trace element (B/TE) interactions.

РЕЗЮМЕ: Авторы графически охарактеризовали тот факт, что 92 основных природных химических элемента Периодической системы, опреде-

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ляемые атомным номером (числом протонов), представлены набором из 1507 разных изотопов, где изотопы одного элемента имеют одинаковое число протонов, но разное число нейтронов. Авторы использовали термин «плеяда» для совокупности изотопов с одним атомным номером, т.е. одного элемента. Изотопы имеются у всех элементов, от водорода с тремя (^{1-3}H) до урана с 15 изотопами ($^{227-240}U$). Наибольшее количество изотопов имеется у индия: 35 с массовыми числами 106—121 и 123. Совокупность всех изотопов элемента и изотопов из других плеяд, совпадающих с ними по массе, названа «элементным кластером». Так, у водорода наименьший элементный кластер, включающий 3 изотопа водорода (^{1-3}H) и 1 изотоп гелия (^{3}He). Наибольший элементный кластер наблюдается у олова ($^{108-130,132}Sn$) и включает 216 различных изотопов (1 Ru, 4 Rh, 10 Pd, 16 Ag, 20 Cd, 33 In, 31 Sn, 29 Sb, 24 Te, 16 I, 14 Xe, 7 Cs, 6 Ba, 4 La, 1 Ce). Некоторые изотопы имеют не одну, а две или даже три разновидности одной массы, что в графическом представлении напоминает рыбью чешую. Результаты обсуждаются с точки зрения восприятия системы как целостного образа, возможной биологической классификации Периодической системы, а также взаимодействия биоэлементов/микроэлементов.

INTRODUCTION

Human search for the basic elements (principles, components) of the Universe is known since ancient times in both West (fire, earth, air, water,) and East (fire, earth, metal, water, wood) natural philosophy tradition. It took almost two centuries since the emergence of modern chemistry in the 18th century until all the naturally occurring elements were identified at the beginning of the 20th century, and the search for artificial transuranium new elements is still relentlessly pursued.

Mendeleev (1869) was the first to envisage elements identity by observing how their intricate qualities depended periodically upon the element weight. His point of view allows us to observe elements as strictly defined discrete individualities. What distinguished Mendeleyev from the others was his ability to grasp that the known elements fitted into a scheme that was predetermined since the elements were not being arranged to make a periodic table, but fit the periodic table (Emsley, 2001). Almost 1000 models of the Periodic system has been developed ever since (Mazuris, 1974), including one by the first author of this paper (Momcilovic, 2008).

It was Morley (1913) who first observed that the periodic arrangement of elements was dependent upon the atomic number (the number of protons in the nucleus) instead on the element atomic weight. The later discovery of isotopes, i.e., the elements of the same atomic number (number of protons), but different mass numbers, reflected the importance of the different number of neutrons in the nucleus having the constant number of protons. Fajans suggested that all the isotopes of the same element should be called pleiad (cit Scerri, 2007), the term we would use in the same sense in this paper. The emerged controversy if, in fact, the isotopes were themselves the elements, was resolved by Paneth (1962) on essentially the semantic grounds by declaring that the atomic number defines the basic element whereas the isotopes were defined as simple substances. It was (incorrectly) assumed that there is no chemical difference between the isotopes of the same element (Scerri, 2007).

Today, the leading, albeit reductionistic, paradigm that attempts to provide the explanation of chemical reaction based on electronic configuration alone has been challenged (Pyykko, 1979). Thus, the nuclear physics view the isotopes in a new light of what is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes, and what is the origin of the many simple patterns that emerge in studies of heavy nuclei. That would require theoretical and experimental investigations of isotopes with unusual neutron-to-proton ratios where the nuclei which are typically not found on Earth, are called exotic or rare (Dean, 2007).

The aim of this paper is to address the specific problem of different element isotopes having the same mass number (element cluster) and to outline their graphic characteristic in a novel way. Indeed, that isotopes of different elements may have identical mass numbers is a confounding factor in any mass spectroscopy analytical technique. Since there are difference between the physical and chemical methods capacity in rendering the Periodic system and its constituent parts, the question arises about the role of biology in such rendering because of the gestalt phenomena; the phenomenon where the characteristics of the whole system can not be deduced by knowing the characteristics of the parts of such a system (Ball, 2004).

MATERIAL AND METHODS

The data from the table of isotopes in the Handbook of Chemistry and Physics Heath (1965—1966) form the basis of this paper. Data were organized such that elements were arranged in a sequence following the increase of the element atomic number. Every element was presented as a series of known isotopes distinguished by their mass numbers. Such arrangement, i.e., all the isotopes of an element, was named ‘pleiad’ as discussed in the Introduction. That allows us to compare side by side the isotopes of different elements, i.e., different atomic number (number of protons) but which, nevertheless, have the same mass number (number of neutrons). Thus, all the mass numbers shared among the isotope of one element with all the other identical mass number from the other elements and their isotopes is named «elemental cluster». Since some elements may have two or even three isotopes of the same mass number, the graphic presentation of such a data gave a visual impression of interlocking fish skin (*cheshuya* in the Russian). The «Cheshuya» (fish skin) model of mass number pattern of isotopes within an element (pleiad) and between the elements (element cluster) allows for the new insight into the «fabric» of the Universe.

First we graphically presented the sequence of the «pleiad», i.e., the isotopes, of all the naturally occurring elements — from hydrogen to uranium. All the element clusters were presented in the tabular form. Then we graphically displayed the individual element isotope «clusters» for every of the flowing 40 elements: Silver (Ag), Aluminum (Al), Arsenic (As), Gold (Au), Boron (B), Barium (Ba), Beryllium (Be), Bismuth (Bi), Cadmium (Cd), Calcium (Ca), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Gallium (Ga), Germanium (Ge), Mercury (Hg), Iodine (I), Potassium (K), Lanthanum (La), Lithium (Li), Magnesium (Mg), Manganese (Mn), Molybdenum (Mo), Sodium (Na), Nickel (Ni), Phosphorus (P), Lead (Pb), Platinum (Pt), Rubidium (Rb), Antimony (Sb), Selenium (Se), Silicon (Si), Tin (Sn), Strontium (Sr), Titanium (Ti), Thallium (Tl), Vanadium (V), Wolfram/Tungsten (W), Zinc (Zn), and Zirconium (Zr). Those forty elements comprise the multielement profile of hair and whole blood in our study of human depression (Momcilovic et al., 2006).

RESULTS AND DISCUSSION

All elements have isotopes starting with hydrogen ($^{1-3}$H), peak up with indium having 35 different isotopes (mass numbers $^{106-121,123}$In), and end up with uranium having 15 isotopes ($^{227-240}$U) (Fig.1). All the elements share some number of isotopes with the other surrounding elements having the same mass number and what we name «element cluster». Thus, the element cluster of the shortest span is $^{1-3}$H having three hydrogen's and one helium (3 H, 1 He), where ^{3}H and ^{3}He share the same mass numbers. The largest element cluster span was observed for tin ($^{108-130,132}$Sn) comprising 216 different isotopes (1 Ru, 4 Rh, 10 Pd, 16 Ag, 20 Cd, 33 In, 31 Sn, 29 Sb, 24 Te, 16 I, 14 Xe, 7 Cs, 6 Ba, 4 La, 1 Ce) (Table 1). Some isotopes have one, two, or even three varieties with the same mass number what, when presented graphically, gave the impression of the fish skin (Russian «cheshuya») where the isotopes became interlocked in intriguing patterns (Fig.2). If we define all the respective basic and simple elements as shown in Figure 1, then there is no visible explaining principle on how and why the number of isotopes vary from element to element and why there are no some isotopes which may be expected to occur. Essentially, such a sequence of basic and simple elements may be viewed as an elementome (analogous to genome) where the sequence is known, but not the principles of its functional organization. New insight in these puzzling problems is expected by the study of exotic or rare elements (Dean, 2007).

The results demonstrated that element clusters may, indeed, be confounding factor in the mass spectra analysis. Perhaps, more intriguing, is that such element clusters can give us new insight into the bioelement/trace element (B/TE) interactions. Except for iodine, the heaviest known essential B/TE, all the other B/TE's are much lighter. However, lithium, one of the lightest B/TE is the powerful anti thyroid agent affecting the iodine, i.e., is the heaviest B/TE. One of the great mysteries in biology and medicine is how the multicellular body with its different organs secures the control over the flow of the mass and energy in the metabolism under the prevailing conditions when the elements may simply percolate into the surrounding tissue structures. Moreover, the mass of the elements appears to be critical for the sensitivity and specificity of ionic channels, gates, and pores so essential for the function of any cell of living beings (Elinder, Arhem, 2004).

Interestingly enough, the essential bioelements and especially the major bioelements (Na, K, O, H, N, C, P, and S) have fewer isotopes than the nonessential elements having the larger atomic numbers. Thus, the energy cost of metabolic handling of heavier than iodine elements is not only higher but would also tip off the delicate mechanism of cellular mechanism/s to distinguish among the large number of isotopes of the same mass number, since the choice to select the right one may be too confusing. That brought up another puzzling question on how the unity of the bioelements of the body can be so precisely tuned up in the midst of the diversity of both intrinsic and extrinsic factors within the body and around it.

Apparently, the Gestalt phenomena, i.e., that the whole cannot be deduced by analyzing its parts (Keller, 1985), is a crucial difference between the respective world of physics and chemistry and that of the biology and life. Epistemologically, there is no essential difference between the Gestalt phenomena in biology of life and uncertainty principle of the quantum physics. That bring us to the question of contextuality in order to explain the mutual relationships between the different components of the system, and why they vary unpredictably to a great extent if the context is not known or understood. We may only wonder if it is, indeed, the single element effect what we are studying or is it the consequence of the particular «team work» of elements comprising any given elemental cluster. Perhaps, some biological experiments need to be performed by administering the strictly controlled composition of defined isotope/s to study their biological implications; thus far we only know that the biological effects of deuterium and tritium are different from that of simple hydrogen.

Further the more, it's intriguing to speculate that, like there are 15 isotopes of uranium, but only ^{235}U is the important one for the nuclear fission weapon, that there may be some other isotopes of certain elements, or clusters of elements, which may have some, as yet unknown, biological characteristics of similar significance.

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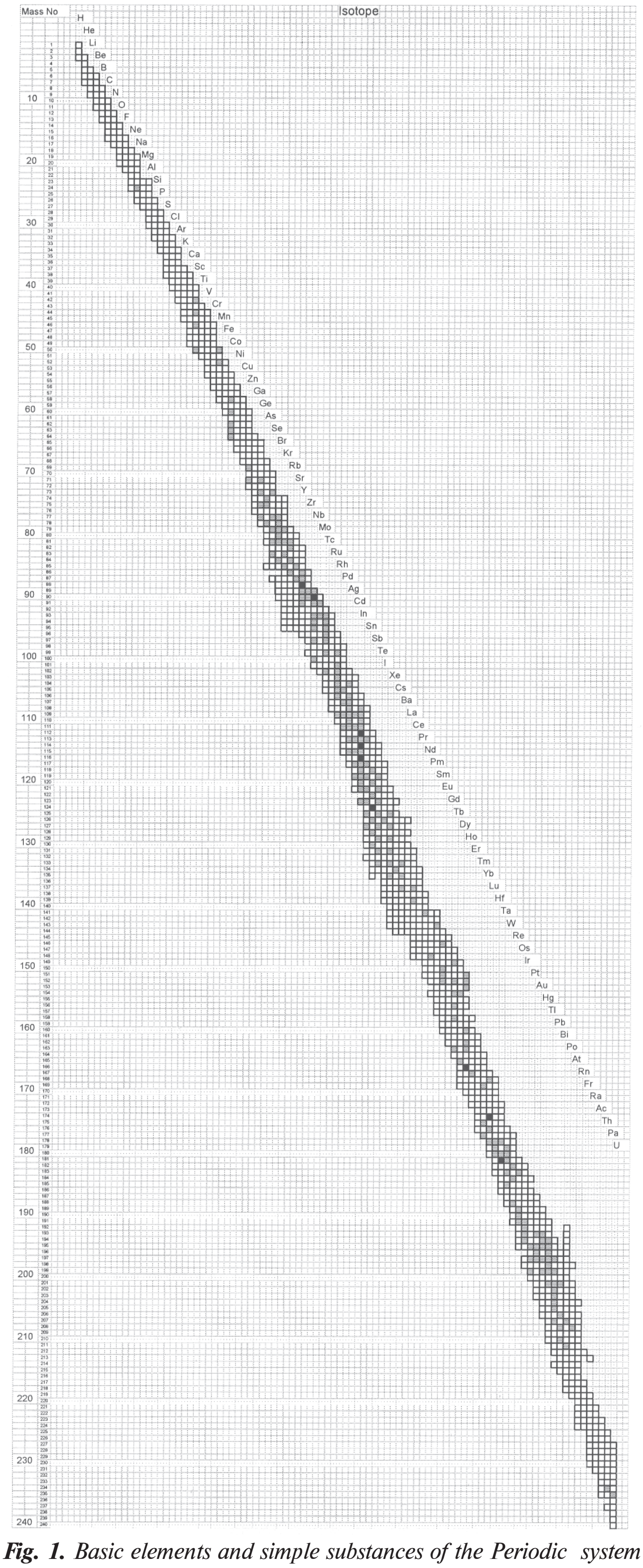


Fig. 1. *Basic elements and simple substances of the Periodic system*

□ isotope mass number, ■ two isotopes of the same element sharing the same mass number,
■ three isotopes of the same element sharing the same mass number

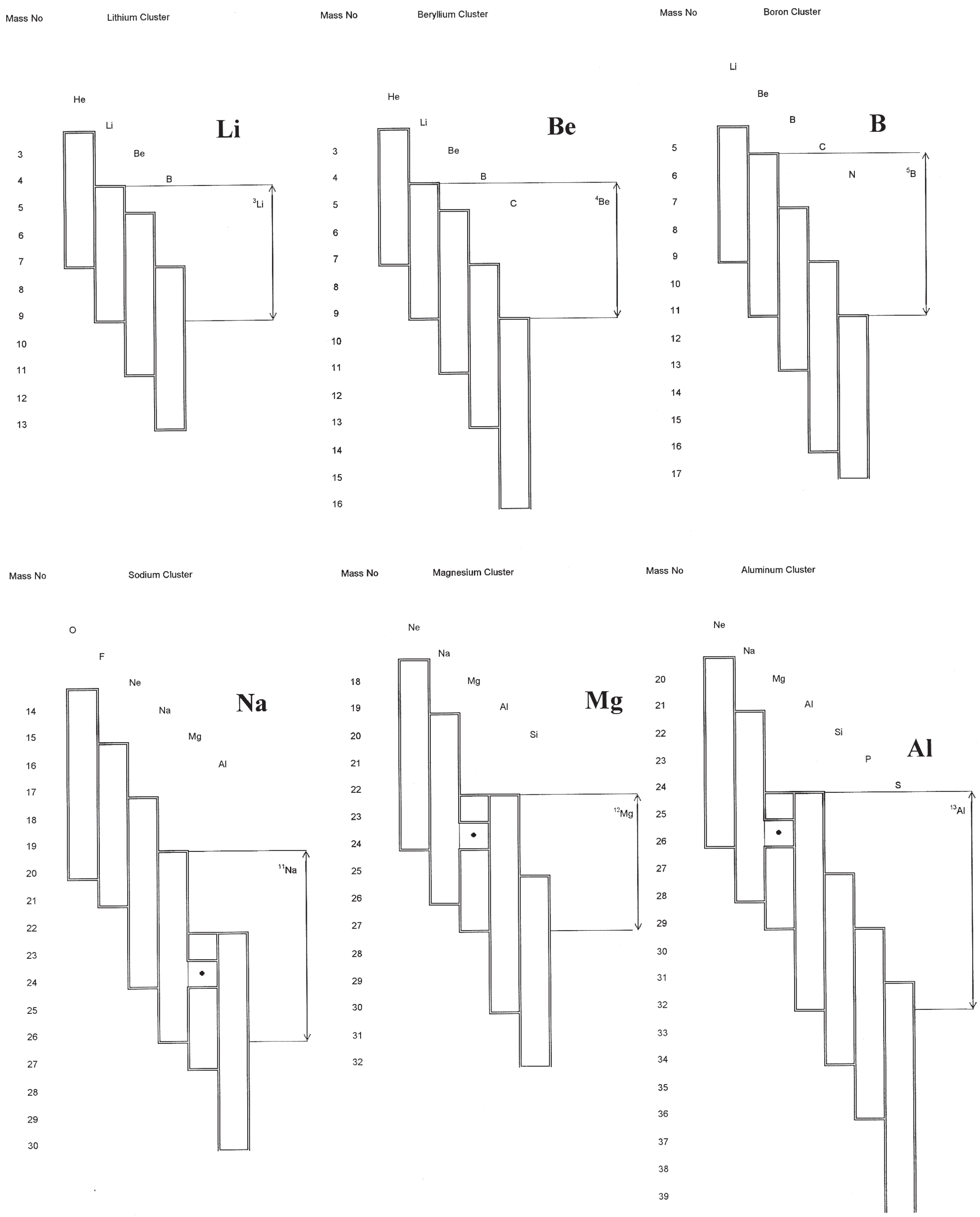
Fig. 2. Isotopic clusters of some elements

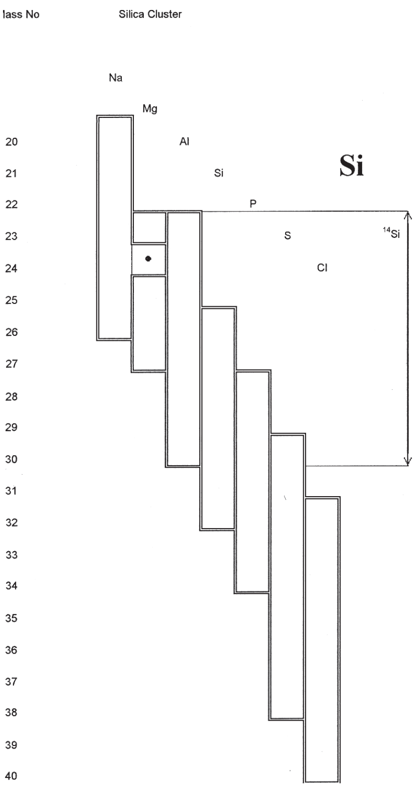
Single isotope;

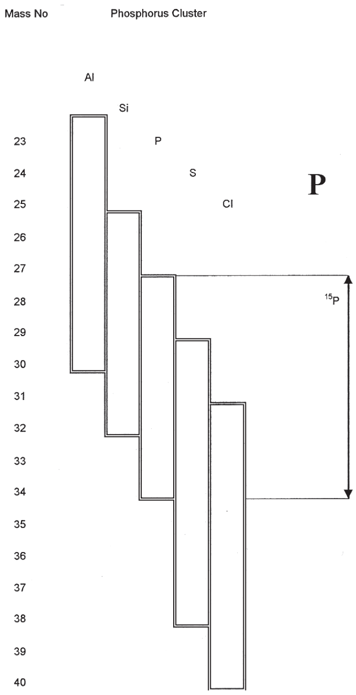
Two isotopes of the same mass number of one element cover the adjacent isotope of the same mass number of a different elements;

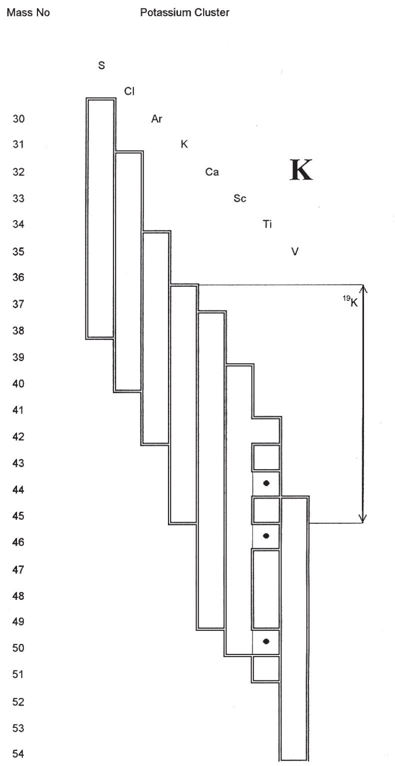
Three isotopes of the same mass number of one element cover the adjacent isotope of the same mass number of two different elements;

x Two isotope of the same mass number where there is no corresponding mass number of the adjacent element.




lass No
Silica Cluster
Na
Mg
Al
Si
P
S
Cl
Si
14Si
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40


Mass No
Phosphorus Cluster
Al
Si
P
S
Cl
P
15P
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40


Mass No
Potassium Cluster
S
Cl
Ar
K
Ca
Sc
Ti
V
K
19K
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
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53
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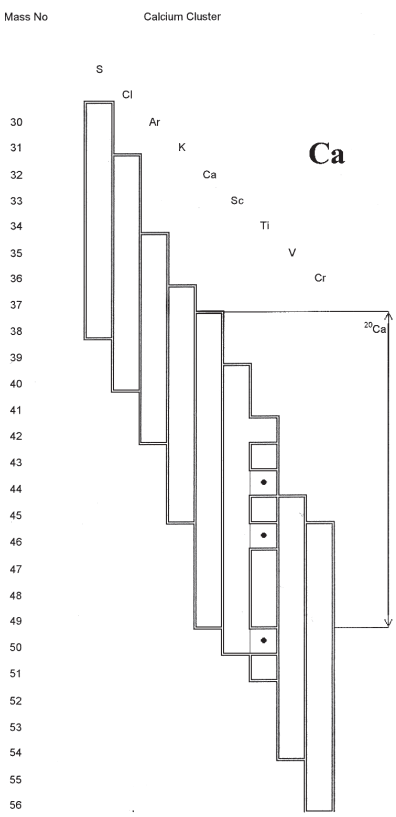
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Calcium Cluster
S
Cl
Ar
K
Ca
Sc
Ti
V
Cr
Ca
20Ca
30
31
32
33
34
35
36
37
38
39
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41
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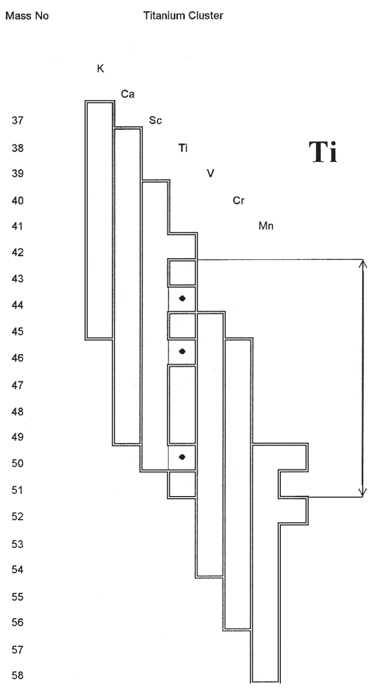
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Titanium Cluster
K
Ca
Sc
Ti
V
Cr
Mn
Ti
37
38
39
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49
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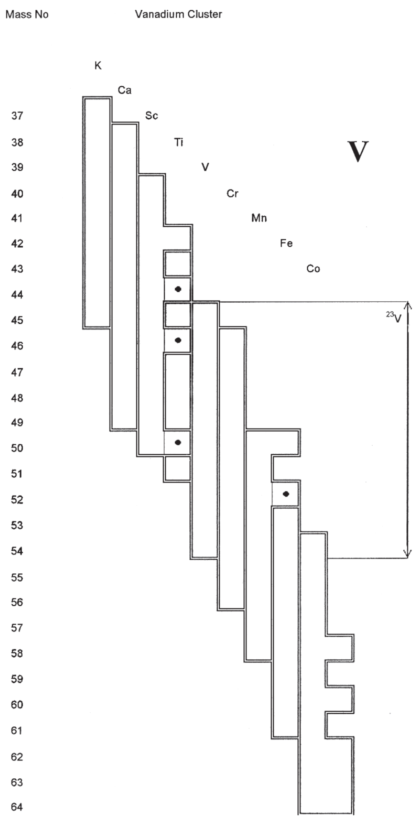
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Vanadium Cluster
K
Ca
Sc
Ti
V
Cr
Mn
Fe
Co
V
23V
37
38
39
40
41
42
43
44
45
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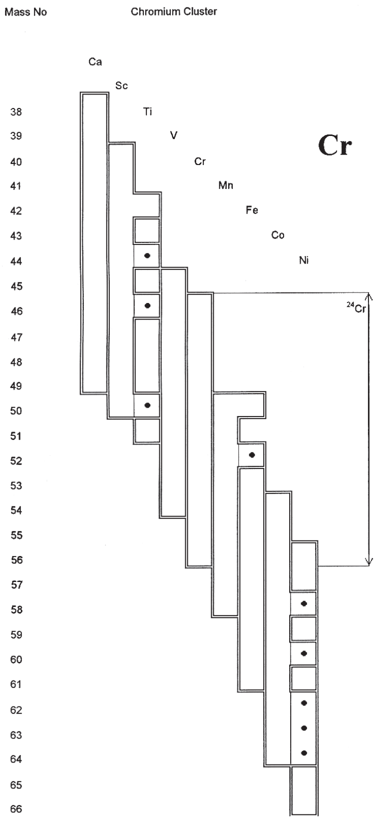
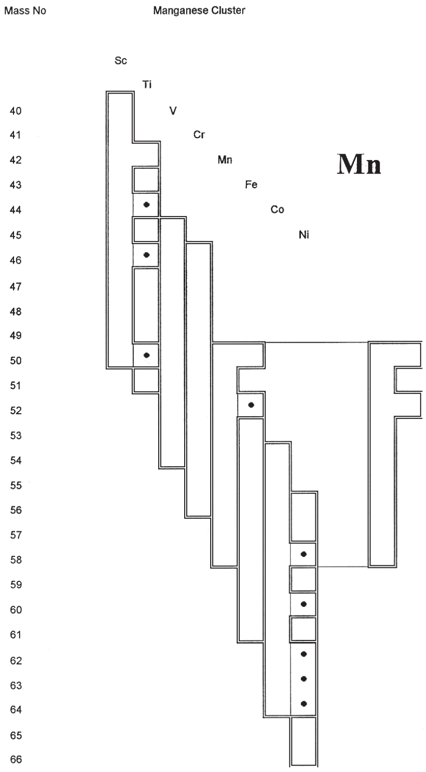
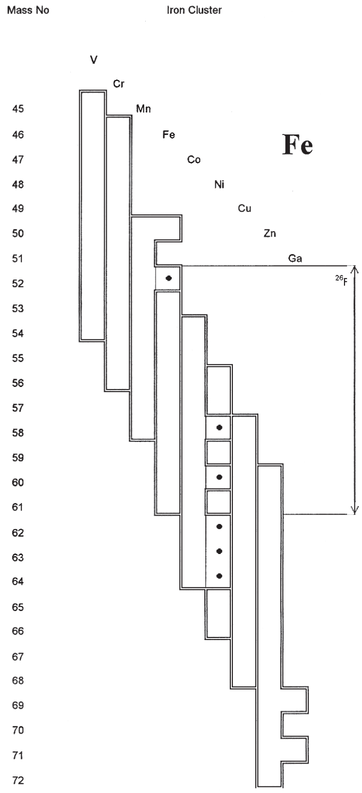
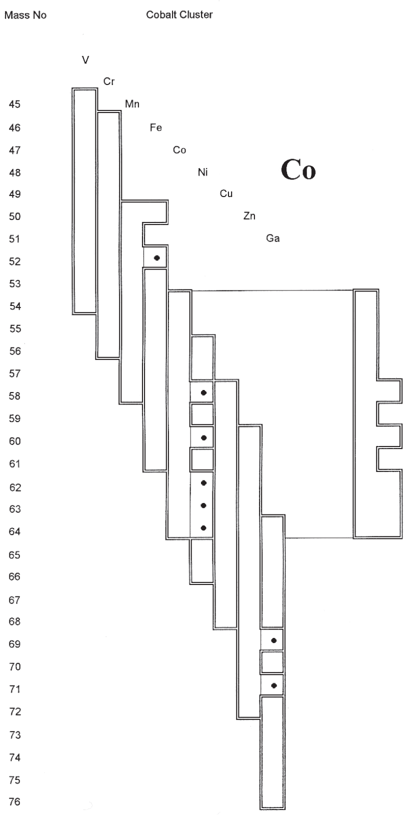

Mass No
Chromium Cluster
Cr
Ca
Sc
Ti
V
Cr
Mn
Fe
Co
Ni
^{24}Cr
38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66


Mass No
Manganese Cluster
Mn
Sc
Ti
V
Cr
Mn
Fe
Co
Ni
40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66


Mass No
Iron Cluster
Fe
V
Cr
Mn
Fe
Co
Ni
Cu
Zn
Ga
^{26}F
45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72


Mass No
Cobalt Cluster
Co
V
Cr
Mn
Fe
Co
Ni
Cu
Zn
Ga
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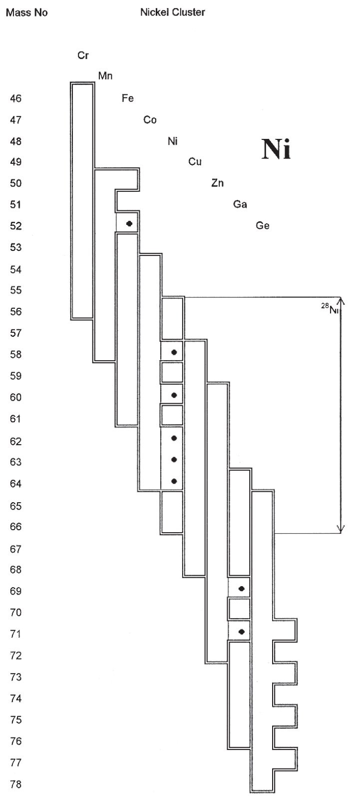
Mass No
Nickel Cluster
Ni
Cr
Mn
Fe
Co
Ni
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Ga
Ge
^{28}Ni
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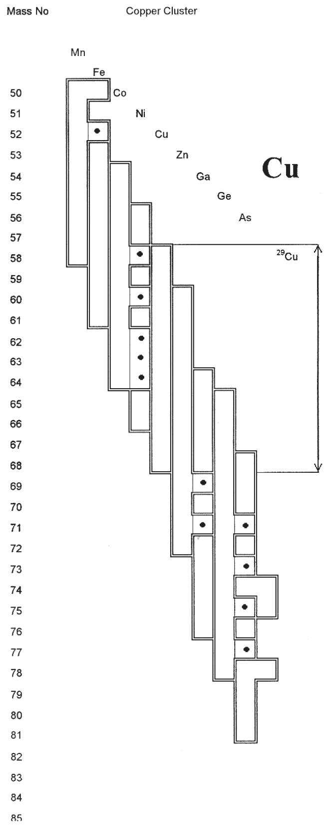
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Copper Cluster
Cu
Mn
Fe
Co
Ni
Cu
Zn
Ga
Ge
As
^{29}Cu
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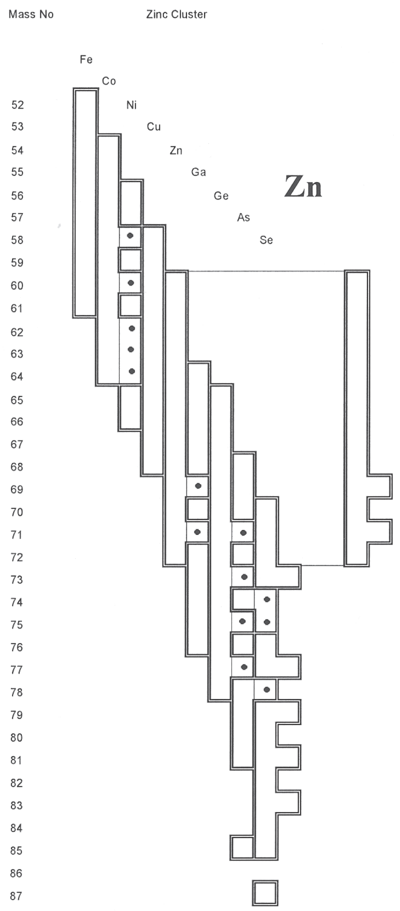
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Zinc Cluster
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Co
Ni
Cu
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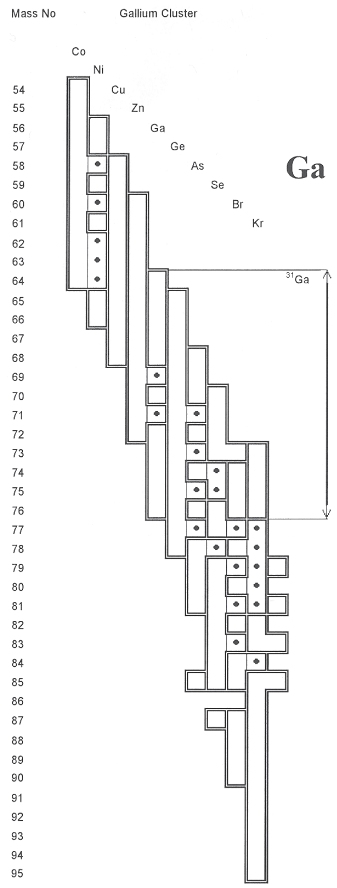
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Ge
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Se
Br
Kr
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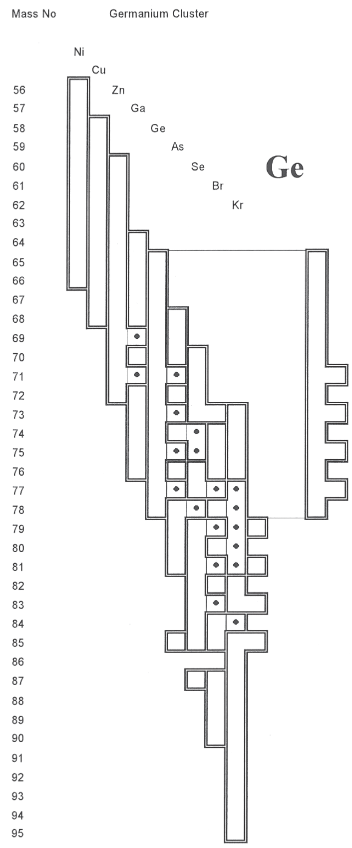
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Cu
Zn
Ga
Ge
As
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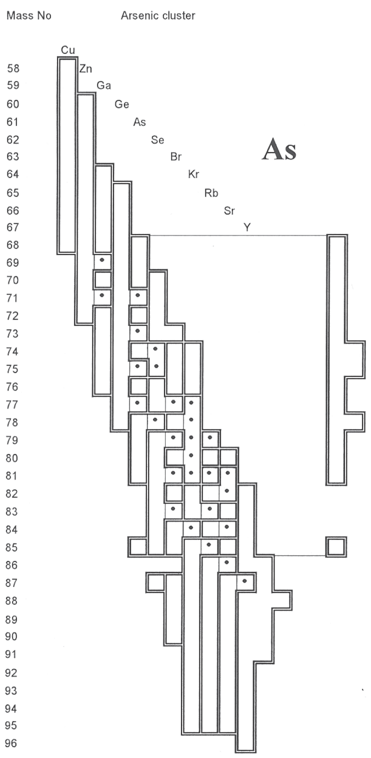
Br
Kr
Ge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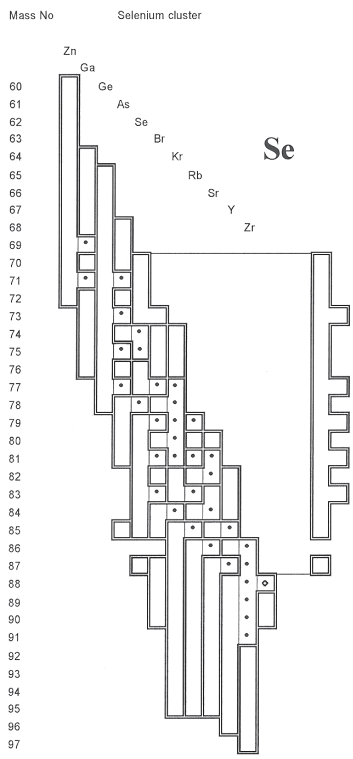
Zn
Ga
Ge
As
Se
Br
Kr
Rb
Sr
Y
As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Selenium cluster
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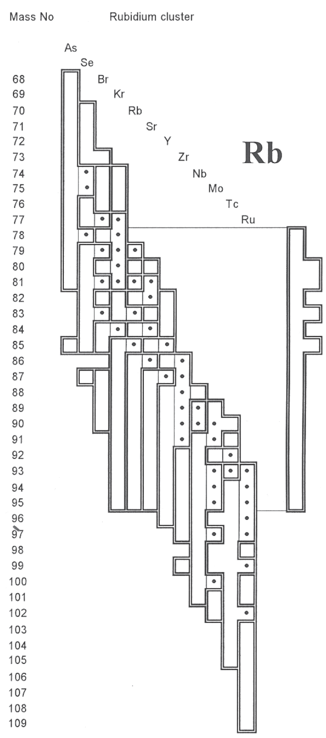
Ga
Ge
As
Se
Br
Kr
Rb
Sr
Y
Zr
Se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Rubidium cluster
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Se
Br
Kr
Rb
Sr
Y
Zr
Nb
Mo
Tc
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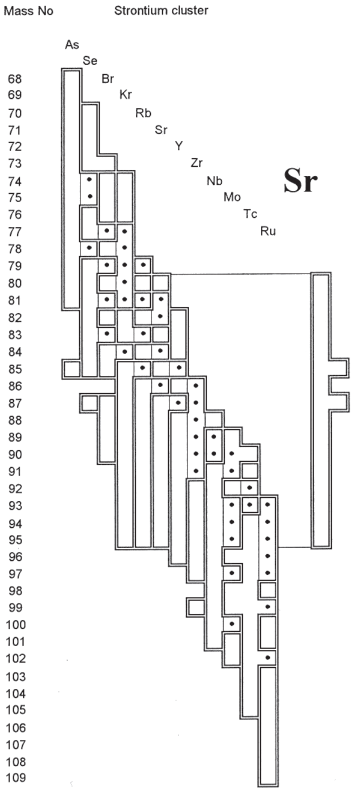
Rb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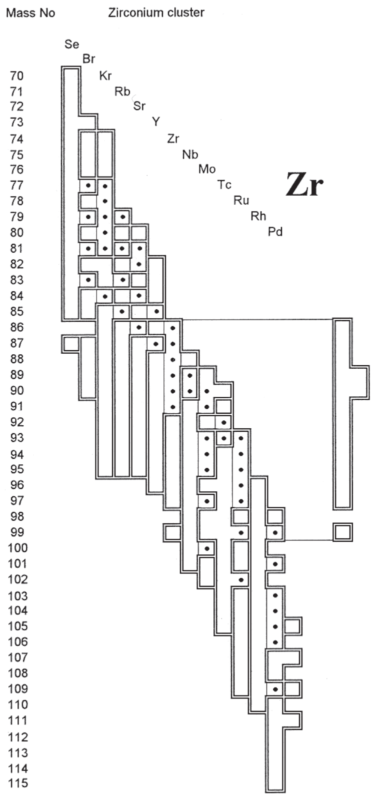
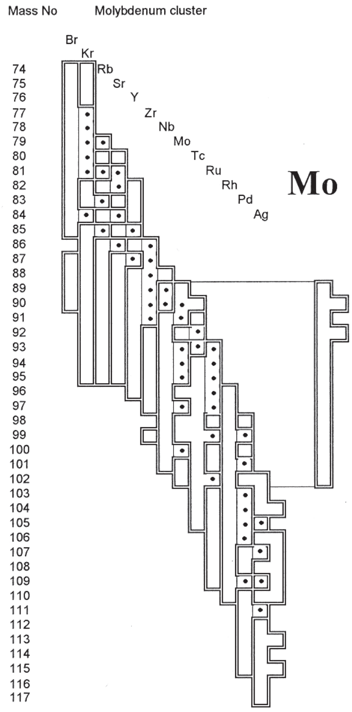
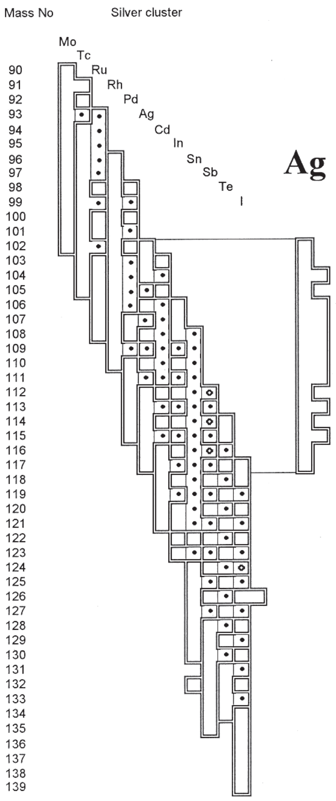
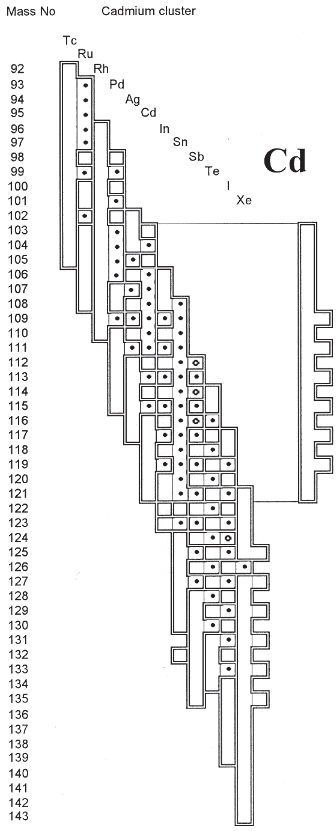
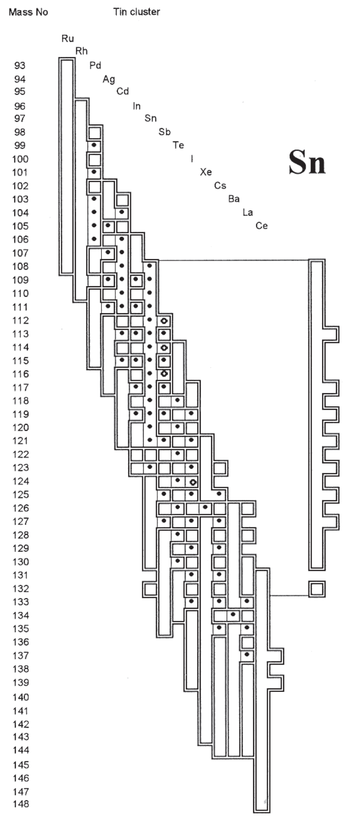
Strontium cluster
As Se Br Kr Rb Sr Y Zr Nb Mo Tc Ru
Sr

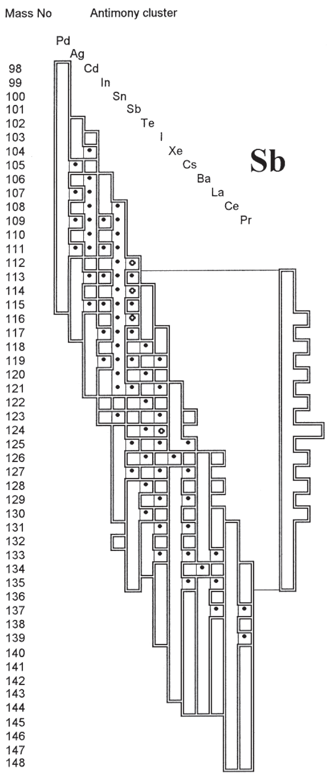

Mass No
Zirconium cluster
Se Br Kr Rb Sr Y Zr Nb Mo Tc Ru Rh Pd
Zr

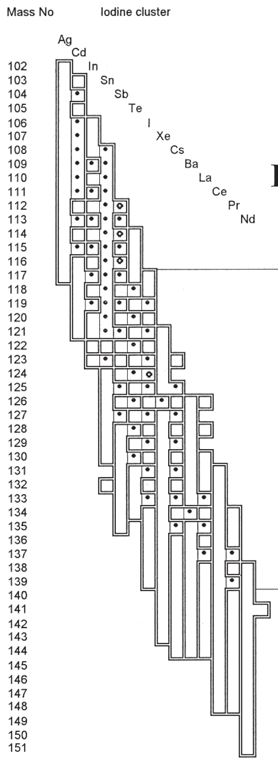

Mass No
Molybdenum cluster
Br Kr Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag
Mo

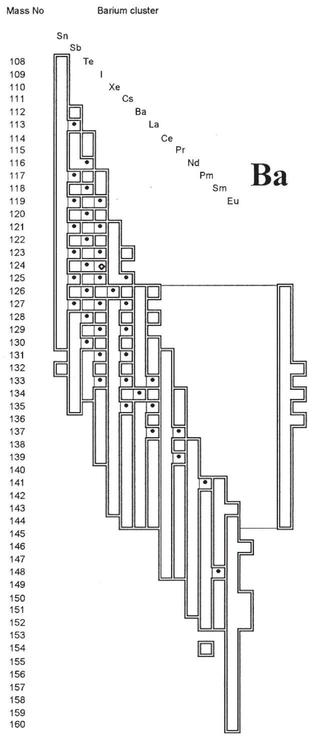

Mass No
Silver cluster
Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I
Ag

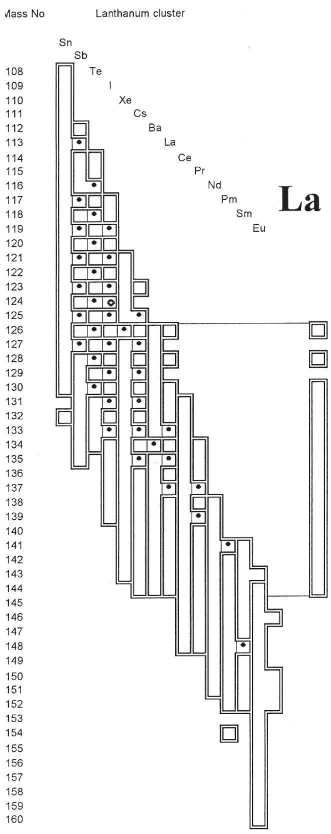

Mass No
Cadmium cluster
Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cd

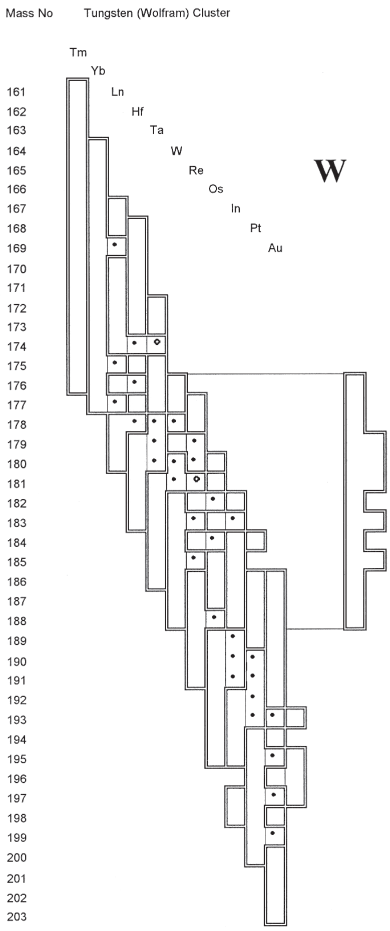

Mass No
Tin cluster
Ru Rh Pd Ag Cd In Sn Sb Te I Xe Cs Ba La Ce
Sn

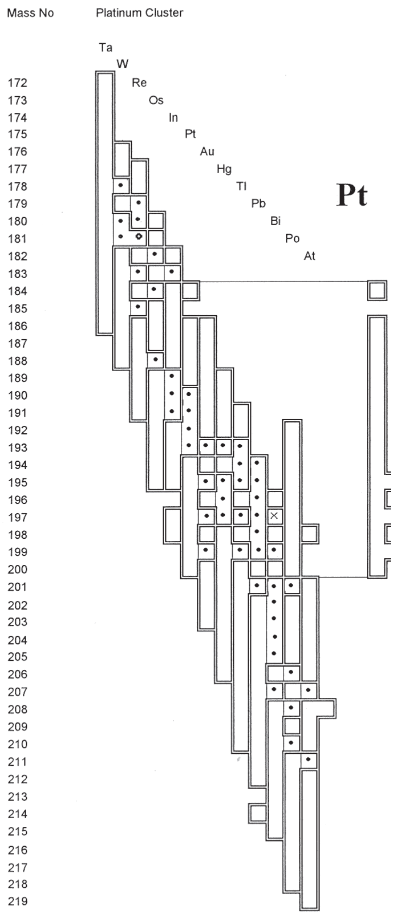

Mass No
Antimony cluster
Pd Ag Cd In Sn Sb Te I Xe Cs Ba La Ce Pr
Sb
98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148

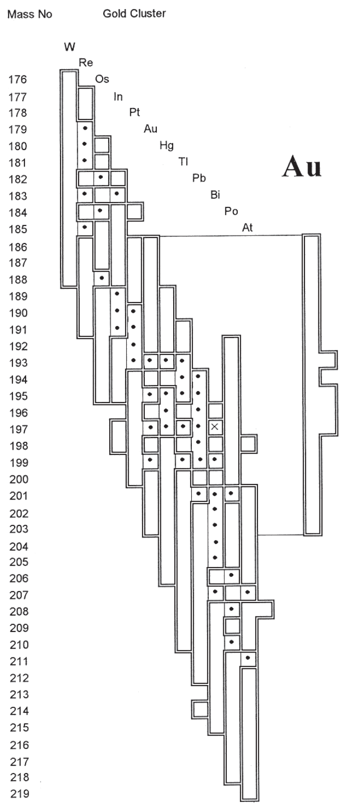

Mass No
Iodine cluster
Ag Cd In Sn Sb Te I Xe Cs Ba La Ce Pr Nd
I
102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151

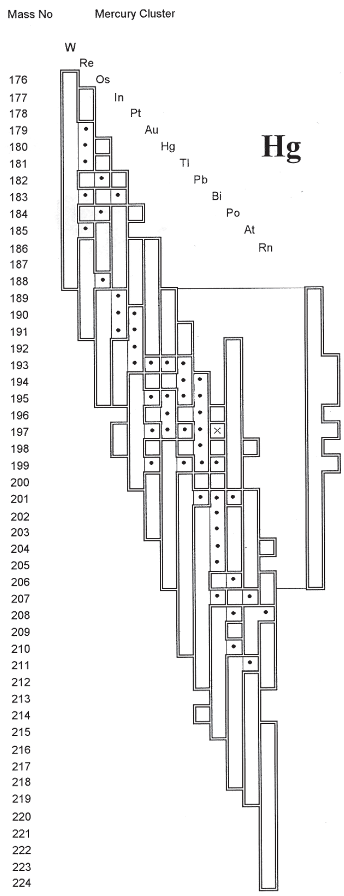

Mass No
Barium cluster
Sn Sb Te I Xe Cs Ba La Ce Pr Nd Pm Sm Eu
Ba
108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160

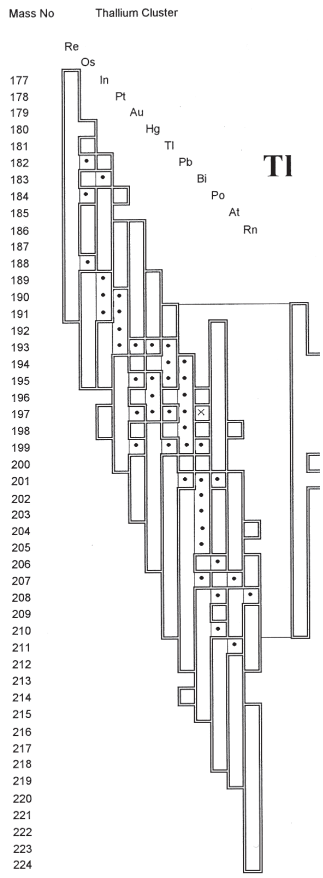

Mass No
Lanthanum cluster
Sn Sb Te I Xe Cs Ba La Ce Pr Nd Pm Sm Eu
La
108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160

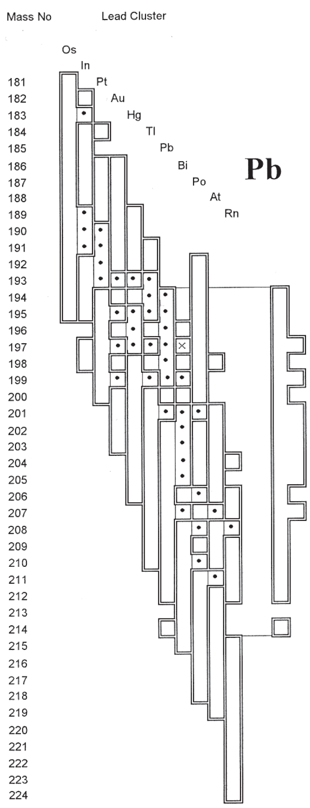

Mass No
Tungsten (Wolfram) Cluster
Tm Yb Ln Hf Ta W Re Os In Pt Au
W
161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203


Mass No
Platinum Cluster
Ta W Re Os In Pt Au Hg Tl Pb Bi Po At
Pt
172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219


Mass No
Gold Cluster
W
Re
Os
In
Pt
Au
Hg
Tl
Pb
Bi
Po
At
Au
176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219


Mass No
Mercury Cluster
W
Re
Os
In
Pt
Au
Hg
Tl
Pb
Bi
Po
At
Rn
Hg
176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224


Mass No
Thallium Cluster
Re
Os
In
Pt
Au
Hg
Tl
Pb
Bi
Po
At
Rn
Tl
177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224


Mass No
Lead Cluster
Os
In
Pt
Au
Hg
Tl
Pb
Bi
Po
At
Rn
Pb
181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224

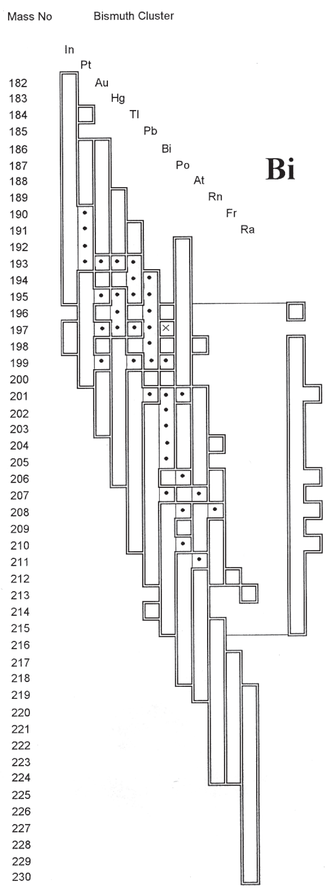

Mass No
Bismuth Cluster
In
Pt
Au
Hg
Tl
Pb
Bi
Po
At
Rn
Fr
Ra
Bi
182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

Table 1. ***Identical isotope Mass Spectra clusters of elements***

Mass	No	Elemental clusters (the principal element and the number of it's isotopes are in bold)	∑ Isotopes
H	1—3	**3 H**, 1 He	4
He	3—7	1 H, **5 He**, 3 Li, 2 Be	11
Li	5—9	3 He, **5 Li**, 4 Be, 2 B	14
Be	6—11	2 He, 4 Li, **6 Be**, 4 B, 2 C	18
B	8—13	2 Li, 4 Be, **6 B**, 4 C, 2 N	18
C	10—16	2 Be, 4 B, **7 C**, 5 N, 3 O, 1 F	22
N	12—17	2 B, 5 C, **6 N**, 4 O, 2 F	17
O	14—20	3 C, 4 N, **7 O**, 5 F, 3 Ne, 1 Na	23
F	16—21	1 C, 2 N, 5 O, **6 F**, 4 Ne, 2 Na	20
Ne	18—24	3 O, 4 F, **7 Ne**, 6 Na, 2 Mg, 2 Al	24
Na	20—26	1 O, 2 F, 5 Ne, **8 Na**, 4 Mg, 4 Al, 1 Si	25
Mg	23—27	2 Ne, 5 Na, **5 Mg**, 5 Al, 2 Si	19
Al	23—30	2 Ne, 5 Na, 5 Mg, **8 Al**, 5 Si, 3 P, 1 S	29
Si	26—32	1 Na, 2 Mg, 5 Al, **7 Si**, 5 P, 3 S, 1 Cl	24
P	28—34	3 Al, 5 Si, **7 P**, 5 S, 3 Cl	23
S	30—38	1 Al, 3 Si, 5 P, **9 S**, 7 Cl, 4 Ar, 2 K, 1 Ca	32
Cl	32—40	1 Si, 3 P, 7 S, **9 Cl**, 6 Ar, 4 K, 3 Ca, 1 Sc	34
Ar	35—42	4 S, 6 Cl, **8 Ar**, 6 K, 5 Ca, 4 Sc	33
K	37—45	2 S, 4 Cl, 6 Ar, **9 K**, 8 Ca, 8 Sc, 3 Ti	41
Ca	38—49	1 S, 3 Cl, 5 Ar, 8 K, **12 Ca**, 13 Sc, 7 T1, 5 V, 4 Cr	58
Sc	40—50	1 Cl, 3 Ar, 6 K, 10 Ca, **15 Sc**, 8 Ti, 6 V, 5 Cr, 2 Mn	56
Ti	43—51	3 K, 7 Ca, 11 Sc, **9 Ti**, 7 V, 6 Cr, 3 Mn	46

V	45—54	1 K, 5 Ca, 8 Sc, 7 Ti, **10 V**, 9 Cr, 7 Mn, 3 Fe, 1 Co	51
Cr	46—56	4 Ca, 7 Sc, 6 Ti, 9 V, **11 Cr**, 9 Mn, 5 Fe, 3 Co, 1 Ni	55
Mn	50—58	2 Sc, 2 Ti, 5 V, 7 Cr, **11 Mn**, 7 Fe, 6 Co, 3 Ni, 1, Cu	44
Fe	52—61	3 V, 5 Cr, 8 Mn, **10 Fe**, 10 Co, 6 Ni, 4 Cu, 2 Zn	48
Co	54—64	1 V, 3 Cr, 5 Mn, 8 Fe, **16 Co**, 9 Ni, 7 Cu, 5 Zn, 1 Ga	55
Ni	56—66	1 Cr, 3 Mn, 6 Fe, 14 Co, **11 Ni**, 9 Cu, 7 Zn, 3 Ga, 2 Ge	56
Cu	58—68	1 Mn, 4 Fe, 12 Co, 9 Ni, **11 Cu**, 9 Zn, 5 Ga, 4 Ge, 1 As	56
Zn	60—72	2 Fe, 9Co, 7 Ni, 9 Cu, **15 Zn**, 9 Ga, 8 Ge, 5 As, 3 Se	67
Ga	64—76	2 Co, 3 Ni, 5 Cu, 11 Zn, **13 Ga**, 12 Ge, 9 As, 7 Se, 3 Br, 3 Kr	68
Ge	65—78	1 Ni, 3 Cu, 10 Zn, 13 Ga, **18 Ge**, 14 As, 11 Se, 7 Br, 5 Kr	82
As	68—81/85	1 Cu, 7 Zn, 9 Ga, 15 Ge, **18 As**, 17 Se, 14 Br, 12 Kr, 5 Rb, 4 Sr, 1 Y	103
Se	70—85/87	4 Zn, 7 Ga, 13 Ge, 16 As, **22 Se**, 18 Br, 17 Kr, 11 Rb, 10 Sr, 6 Y, 1 Zr	125
Br	74—85/87—90	3 Ga, 7 Ge, 12 As, 17 Se, **21 Br**, 20 Kr, 14 Rb, 12 Sr, 13 Y, 6 Zr, 3 Nb, 1 Mo	129
Kr	74—90	3 Ga, 7 Ge, 12 As, 16 Se, 21 Br, **21 Kr**,16 Rb, 13 Sr, 15 Y, 7 Zr, 3 Nb, 1 Mo	98
Rb	79—95	4 As, 11 Se, 14 Br, 16 Kr, **21 Rb**, 18 Sr, 21 Y, 12 Zr, 14 Nb, 8 Mo, 7 Tc, 3 Ru	149
Sr	80—95	3 As, 9 Se, 12 Br, 14 Kr, 20 Rb, **18 Sr**, 21 Y, 12 Zr, 14 Nb, 8 Mo, 7 Tc, 5 Ru	141
Y	82—96	1 As, 6 Se, 8 Br, 11 Kr,17 Rb, 16 Sr, **22 Y**, 13 Zr, 15 Nb, 9 Mo, 9 Tc, 4 Ru, 1 Rh	132
Zr	86—97/99	1 Se, 4 Br, 5 Kr, 11 Rb, 11 Sr, 18 Y, **15 Zr**, 19 Nb, 12 Mo, 14 Tc, 7 Ru, 5 Rh, 2 Pd	124
Nb	89—101	2 Br, 2 Kr, 7 Rb, 7 Sr, 12 Zr, **14 Nb**, 16 Tc, 9 Ru, 8 Rh, Pd 4	114
Mo	90—102	1 Br, 1 Kr, 6 Rb, 6 Sr, 9 Y, 10 Zr, 20 Nb, **14 Mo**, 16 Tc, 9 Ru, 8 Rh, 4 Pd, 1 Ag	105
Tc	92—105	4 Rb, 4 Sr, 5 Y, 7 Zr, 15 Nb, 12 Mo, **21 Tc**, 13 Ru, 15 Rh, 9 Pd, 5 Ag, 3 Cd	113
Ru	93—108	3 Rb, 3 Sr, 4 Y, 6 Zr, 14 Nb,11 Mo, 20 Tc, **16 Ru**, 19 Rh, 13 Pd, 11 Ag, 6 Cd, 4 In, 1 Sn	131
Rh	96—110	1 Y, 3 Zr, 8 Nb, 7 Mo, 14 Tc, 13 Ru, **23 Rh**,16 Pd, 15 Ag, 9 Cd, 8 In, 3 Sn	120
Pd	98—115	1 Zr, 5 Nb, 5 Mo, 10 Tc, 11 Ru, 20 Rh, **22 Pd**, 23 Ag, 17 Cd, 20 In, 9 Sn, 4 Sb, Te 2	149

Mass	No	Elemental clusters (the principal element and the number of it's isotopes are in bold)	∑ Isotopes
Ag	102—117	1 Mo, 5 Tc, 7 Ru, 14 Rh, 18 Pd, **25 Ag**, 20 Cd, 25 In, 12 Sn, 7 Sb, 4 Te, 1 I	139
Cd	103—121	3 Tc, 6 Ru, 13 Rh, 17 Pd, 24 Ag, **25 Cd**, 33 In, 18 Sn, 13 Sb, 10 Te, 5 I, 1 Xe	168
In	106—121/123	3 Ru, 3 Rh, 13 Pd, 20 Ag, 22 Cd, **35 In**, 20 Sn, 14 Sb, 12 Te, 6 I, 2 Xe, 1 Cs	151
Sn	108—130/132	1 Ru, 4 Rh, 10 Pd, 16 Ag, 20 Cd, 33 In, **31 Sn**, 29 Sb, 24 Te, 16 I, 14 Xe, 7 Cs, 6 Ba, 4 La, 1 Ce	216
Sb	112—135	4 Pd, 8 Ag, 14 Cd, 25 In, 27 Sn, **33 Sb**, 29 Te, 20 I, 21 Xe, 13 Cs, 10 Ba, 8 La, 5 Ce, 2 Pr	209
Te	114—134	2 Pd, 5 Ag, 11 Cd, 20 In, 24 Sn, 30 Sb, **29 Te**, 19 I, 19 Xe, 12 Cs, 10 Ba, 7 La, 4 Ce, 1 Pr	193
I	117—139	1 Ag, 7 Cd, 12 In 21Sn, 27 Sb, 26 Te, **24 I**, 25 Xe, 17 Cs, 17 Ba, 12 La, 11 Ce, 6 P, 2 Nd	208
Xe	121—143	1 Cd, 4 In, 15 Sn, 21Sb, 21 Te, 20 I, **29 Xe**, 21 Cs, 21 Ba, 16 La, 16 Ce, 10 Pr, 7 Nd, 3 Pm, 4 Sm	209
Cs	123/125—144	2 In, 12 Sn, 18, Sb, 18 Tc, 18 I, 27 Xe, **22 Cs**, 22 Ba, 17 La, 16 Ce, 11 Pr, 8 Nd, 4 Pm, 5 Sm, 1 Eu	201
Ba	126—144	7 Sn, 13 Sb, 13 Te, 15 I, 23 Xe, 20 Cs, **22 Ba**, 17 La, 16 Ce, 11 Pr, 8 Nb, 4 Pm, 5 Sm, 1 Eu	175
La	126/128/130—144	7 Sn, 13 Sb, 13 Te, 15 I, 23 Xe, 20 Cs, 22 Ba, **17 La**, 16 Ce, 11 Pr, 8 Nb, 4 Pm, 5 Sm, 1 Eu	175
Ce	131—148	1 Sn, 5 Sb, 6 Te, 9 I, 16 Xe, 15 Cs, 17 Ba, 14 La, **20 Ce**, 15 Pr, 12 Nd, 9 Pm, 9 Sm, 6 Eu, 4 Gd, 2 Tb	160
Pr	134—151	2 Sb, 1 Te, 6 I, 11 Xe, 12 Cs, 13 Ba, 11 La, 17 Ce, **15 Pr**, 12 Nd, 9 Pm, 9 Sm, 6 Eu, 4 Gd, 2 Tb	156
Nd	138—151	2 I, 6 Xe, 7 Cs, 7 Ba, 7 La, 12 Ce, 14 Pr, **15 Nd**, 12 Pm, 14 Sm, 9 Eu, 8 Gd, 5 Tb, 2 Dy	120
Pm	141—152/153	3 Cs, 4 Ba, 4 La, 4 Ce, 8 Pr, 11 Nd, **14 Pm**, 15 Sm, 17 Eu, 12 Gd, 13Tb, 9 Dy, 6 Ho	130
Sm	141—157	3 Xe, 4 Cs, 4 Ba, 4 La, 8 Ce, 8 Pr, 12 Nd, 14 Pm, **18 Sm**, 18 Eu, 13 Gd, 15 Tbg, 10 Dy, 9 Ho	140
Eu	144—160	1 Cs, 1 Ba, 1 La, 5 Ce, 5 Pr, 8 Nd, 11 Pm, 14 Sm, **21 Eu**, 16 Gd, 19Tb, 13 Dy, 13 Ho, 2 Er	140
Gd	154—162	4 Ce, 4 Pr, 7 Nd, 10 Pm, 13 Sm, 21 Eu, **18 Gd**, 21 Tb, 15Dy, 17 Ho, 4 Er, 2 Tm	135
Tb	147—164	2 Ce, 2 Pr, 5 Nd, 9 Pm, 11 Sm, 17 Eu, 16 Gd, **24 Tb**, 17 Dy, 18 Ho, 6 Er, 4 Tm, 1 Yb	132
Dy	149—167	3 Nd, 5 Pm, 9 Sm, 15 Eu, 14 Gd, 22 Tb, **21 Dy**, 23 Ho, 10 Er, 7 Tm, 4 Yb, 1 Lu	134
Ho	151—153/155—156/158—170	1 Nd, 3 Pm, 7 Sm, 12 Eu, 12 Gd, 19 Tb, 19 Dy, **26 Ho**, 13 Er, 10 Tm, 8Yb, 5 Lu, 3 Hf	138
Er	158, 160—172	3 Eu, 5 Gd, 9 Tb, 11Dy, 18 Ho, **15 Er**, 12 Tm, 10 Yb, 7 Lu, 5 Hf, 15 Ta	96
Tm	161—176	2 Gd 5 Tb, 6 Dy, 14 Ho, 13 Er, **16 Tm**, 15 Yb, 14 Lu, 9 Hf, 5 Ta, 1 W	100

Yb	164—177	1 Tb, 5 Dy, 9 Ho, 10 Er, 13 Tm, **17 Yb**, 15 Lu, 10 Hf, 6 Ta, 2 W, 1 Re	88
Lu	167—180	1 Dy, 4 Ho, 7 Er, 10 Tm, 14 Yb, **18 Lu**, 16 Hf, 11 Ta, 7 W, 5 Re	93
Hf	168—183	3 Ho, 5 Er, 9 Tm, 13 Yb, 18 Lu, **19 Hf**, 16 Ta, 12 W, 9 Re, 4 Os, 2 Ir	110
Ta	172—186	1 Er, 5 Tm, 8 Yb, 13 Lu, 15 Hf, **19 Ta**, 16 W, 13 Re, 7 Os, 5 Ir, 2 Pt, 1 Au	105
W	176—188	1 Tm, 3 Yb, 7 Lu, 11 Hf, 15Ta, **18 W**, 16 Re, 9 Os, 7 Ir, 5 Pt, 4 Au	96
Re	177—191	2 Yb, 5 Lu, 10Hf, 14 Ta, 17 W, **19 Re**, 15 Os, 12 Ir, 1 Pt, 10 Au, 3 Hg, 1 Tl	118
Os	181—195	3 Hf, 8 Ta, 11 W, 14 Re, **19 Os**, 18 Ir, 15 Pt, 14 Au, 10 Hg, 7 Tl, 2 Pb, 4 Po	125
Ir	182—195/197—198	2 Hf, 5 Ta, 9 W, 13 Re, 18 Os, **20 Ir**, 18 Pt, 17 Au, 14 Hg, 13 Tl, 6 Pb, 2 Bi, 7 Po, 1 At	145
Pt	184/186—200	3 Ta, 6 W, 10 Re, 15 Os, 18 Ir, **20 Pt**, 19 Au, 17 Hg, 16 Tl, 9Pb, 4 Bi, 9 Po, 1 At	147
Au	185—203	1 Ta, 3 W, 7 Re, 13 Os, 16 Ir, 19 Pt, **22 Au**, 18 Hg, 20 Tl, 15 Pb, 8 Bi, 12 Po, 4 At	158
Hg	189—206	3 Re, 10 Os, 13 Ir, 15 Pt, 18 Au, **23 Hg**, 23 Tl, 20 Pb, 12 Bi, 15 Po, 7 At, 2 Rn	161
Tl	191—210	1 Re, 6 Os, 10 Ir, 12 Pt, 14 Au, 21 Hg, **27 Tl**, 25 Pb, 18 Bi, 20 Po, 12 At, 6 Rn	172
Pb	194—212/214	2 Os, 4 Ir, 7 Pt, 10 Au, 17 Hg, 24 Tl, **28 Pb**, 22 Bi, 25 Po, 16 At, 8 Rn, 1 Fr, 1 Ra	165
Bi	196/198—215	2 Ir, 5 Pt, 8 Au, 13 Hg, 20 Tl, 26 Pb, **23 Bi**, 22 Po, 17 At, 9 Rn, 1 Fr, 1 Ra	147
Po	192—218	4 Os, 8 Ir, 10 Pt, 12 Au, 20 Hg, 26 Tl, 28 Pb, 23 Bi, **29 Po**, 20 At, 12 Rn, 3 Fr, 1 Ra	196
At	198/200—219	1 Ir, 3 Pt, 6 Au, 10 Hg,16 Tl, 23 Pb, 22 Bi, 23 Po, **21 At**, 13 Rn, 4 Fr, 2 Ra	144
Rn	204/206—212/215—224	3 Hg, 7 Tl, 3 Pb, 15 Bi, 17 Po, 17 At, **18 Rn**, 9 Fr, 7 Ra, 4 Ac, 2 Th	112
Fr	212/217—224	2 Pb, 4 Bi, 7 Po, 8 At, 11 Rn, **9 Fr**, 7 Ra, 4 Ac, 2 Th	55
Ra	213/219—230	1 Pb, 3 Bi, 6 Po, 7 At, 10 Rn, 8 Fr, **13 Ra**, 10 Ac, 8 Th, 6 Pa, 4 U	76
Ac	221—231	4 Rn, 4 Fr, 10 Ra, **11 Ac**, 9 Th, 7 Pa, 5 U	50
Th	223—235	2 Rn, 2 Fr, 8 Ra, 9 Ac, **13 Th**, 12 Pa, 10 U	56
Pa	225—235/ 237	6 Ra, 7 Ac, 11 Th, **13 Pa**, 12 U	49
U	227—240	4 Ra, 5 Ac, 9 Th, 11 Pa, **15 U**	44
Total number of isotopes			**1507**

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