

Metal-based Questionnaire

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Abstract: Metals are important in many products that we use in our daily lives and they play an important role in many different types of chemical reactions in several biomolecules. This paper presents a specially designed metal-specific question and answer format as a non-formal method of learning. This was developed as an attempt to produce supplementary material in smaller doses to regular classes on foundation courses. The use of this model for the conduct of chemical education provides an opportunity for learning activities beyond textbooks. These self-study questions focus on the metal's occurrence, extraction, properties, applications, their relationship to living species and environment, and metal-containing substances. The purpose of the questionnaire is to help students in schools and colleges acquire some background information that builds confidence by an open-learning technique. It is so easy for students, particularly those with a minimal chemistry background, to get a feeling for metals in everyday life. This list contains 160-selected short-answer metal-centered questions and includes answers to all questions at the end.

Introduction: Metal forms nearly eighty percent of the known elements in the periodic table. The functional values of individual metals are common and important in everyday life [1-26]. One can list many applications from bucket to bridge construction associated with metals. Metals in a free state and in chemically combined form are used in aeroplanes, batteries, bicycles, coatings, coins, drugs, machinery, paints, ships, statues, tools, utensils, vehicles, watches, and weapons. Also, molten metals, alloy metals, semimetals, amalgams, organometallics, metal salts and complex compounds have several specialized applications both in the laboratory and in industry. There is a wide range of applications, because of recent exciting advances in optoelectronic and superconducting devices, in solar energy conversion and in pharmaceuticals [9,10]. In addition, they are of importance from the fundamental research viewpoint i.e. to address the key questions like ‘how many metal atoms are required to exhibit metallic properties?’, to understand the role of metal ions in biology and to prepare new tailor made materials at the molecular level design. The bottom line is that metals are indispensable and we need them often enough for them to make a real difference in our lives.

The figure 1 below depicts various types of metals and figure 2 gives common properties that make metals unique. The idea that different types of metals exhibit different properties and consequently a wide variety of everyday applications possible, is fundamental to the ‘general knowledge’ about metals. It is important to know metals in their wider context as a developing subject and highlight consequences of metal applications grouped under different headings. Part of the learning activity in general chemistry is to involve students actively in learning

process and to provide informative and educative material to those who are very serious about improving their general knowledge. Reading with questions does provide an increase in comprehension and question and answer format is often easier to remember the subject longer. The illustrative material from our everyday experience is presented in a manner that will inspire the students to learn the subject with interest. Students would assimilate a specific interesting fact about several individual metals depending on their mental impact.

This questionnaire may be useful to students studying in schools and colleges to have general knowledge about metals. It is intended for those individual students wanting to learn by self-study in their own time to obtain useful information. General information about metals can be introduced informally through the handouts before the topic related to metals to be covered in class without loss of class time. The questions about metals may also be useful to an average educated individual or someone attempting to create chemistry-based Olympiad questions for a particular purpose. The idea of teaching about the role of metals online through such an auxiliary questionnaire source would be beneficial to the selected section of student viewers and should complement the overall question scheme for regular courses in satisfying the inherent curiosity of young learners of a wide capacity range. This questionnaire is limited to the selected 160 questions for reasons of space and the answers to all questions are listed at the end to facilitate the learning process. The questions in this list are grouped according to the following themes depending on the purpose: physical properties, biological relevance, metallurgy, catalysis, and miscellaneous applications. These representative questions give an approach to these

themes involving the individual metals that provides a flavor of the diverse type of applications and avoid much of the detailed uses or properties. The classification is not rigid and some questions can be placed in more than one category. Further, the questions are organized according to those based on the metals, alloys and amalgams at the beginning of each section followed by those that deal with metal-containing compounds, complexes and organometallics. The general references listed in the end can provide particularly useful additional material for some of its expansion, adding value.

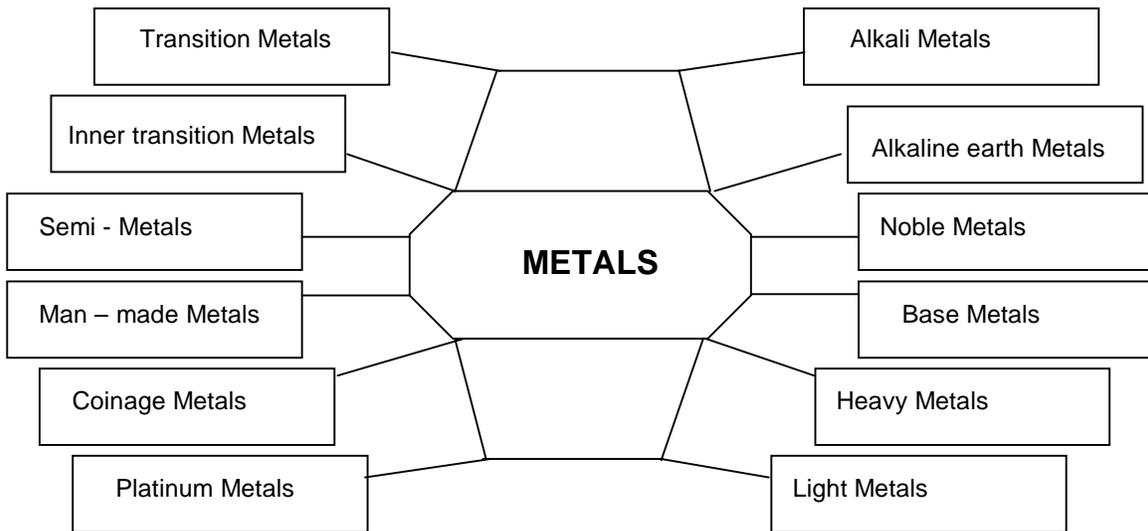


Figure 1. Word picture indicating the diverse range of metal types

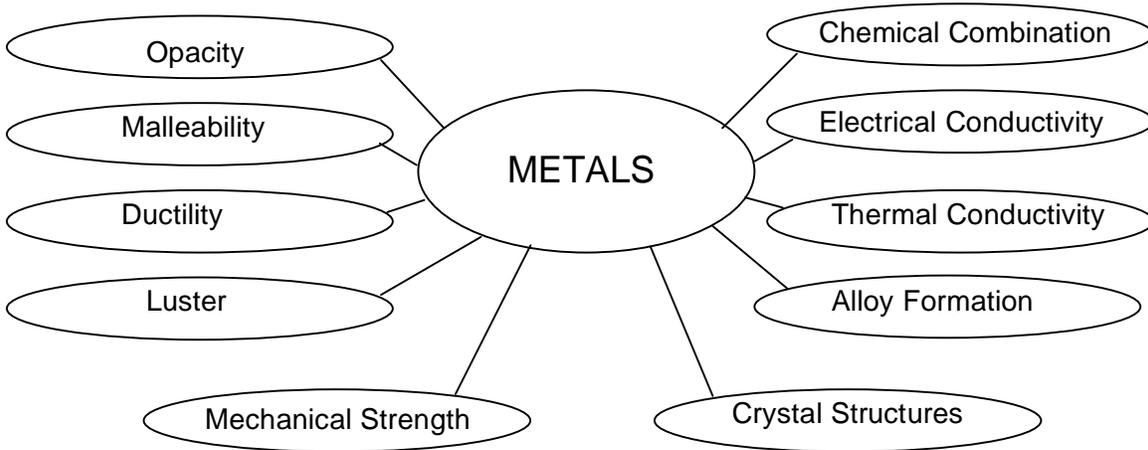


Figure 2. Schematic diagram showing general properties of metals

Physical Properties

1. Which metal has the highest electrical and thermal conductivities?
2. Name the lightest and the densest metal in the periodic table.
3. Which metal has the highest enthalpy of atomization?
4. Which is the most malleable and ductile of the metals?
5. Mention the metal having longest liquid range of all the metals.
6. Which metal is in liquid state at room temperature (298 K)?
7. Name the naturally occurring metal with highest atomic number.
8. Which transition metal has highest melting point of any metal because of high bond strength and is used to make the filaments of electric light bulbs?
9. Which alkali metal is used extensively in photocells, in television cameras and in atomic clocks because of its lowest ionization energy?
10. Suggest a light metal with significant strength and excellent corrosion resistance that would be suitable as structural metal in aircraft, ships, and cars?
11. Name the two transition metals which exhibit the maximum oxidation state of + 8 in their compounds.
12. Mention the metal having such a low melting point that it can melt in your hand and the solid is less dense than the liquid.
13. Name the inner-transition metal whose electronic configuration is $[\text{Rn}]5f^7 7s^2$
14. Which is the most abundant metal to be found in the Earth's crust?

15. What are the three main allotropic forms that the metal tin exists in?
16. Which is the most commonly used metal as an electrical conductor, to make calorimeters, and to produce pipes?
17. What are the two important metals used in coinage alloy because of their relatively low cost and unreactive nature in alloy form?
18. Mention the soft metal used in toothpaste tubes, bottle tops, window frames, and in preparing paints.
19. Which is the most commonly used metalloid in the manufacture of transistors, integrated circuits, and computer chips because of its semimetallic properties?
20. Which metal is used in ordinary thermometers, manometers, barometers, and diffusion pumps?
21. Which metal coating on windows reflects infrared light in summer and minimizes heat losses in winter?
22. Name the group 15 metal whose solid is less dense than the liquid and hence used to produce type molds in the printing industry.
23. Which metal is commonly used in overhead power transmission lines because of high electrical conductivity, corrosion resistance and ready workability?
24. Mention the metals used in thermocouples because of their high temperature resistance.
25. Write the class of metals whose densities are less than 0.004 kg/m^3 .

26. Mention the metal whose ion has the most negative value of reduction potential and hence acts as strongest reducing agent?
27. Which heavier transition metal is used in the form of its disulfide, with the layer structure, as an excellent solid lubricant in reduced pressure or at high-pressure conditions?
28. Why do you think pure yellow gold metal is not used in jewelry?
29. Which are the two most abundant metals that occur in the combined state in seawater?
30. Which transition metal in its dioxide form is generally used in audiotape because of its magnetic properties?
31. Which metal is present as the metal carbide used in cutting tools, drill bits, and abrasives because of its hardness?

Biological Relevance

32. Which metal artificial isotope, find use as source of high-energy radiation for treatment of cancer by radiotherapy?
33. Which synthetic metal isotope is the most widely used in the detection of brain tumors, hemorrhages or blood clots?
34. Which alkaline earth metal is the major chemical constituent of structural biomaterials, bones and teeth and is found in the form of carbonate and phosphate?
35. Which radioactive metal isotope is used in detecting circulatory problems of blood in the human body?
36. Which metal accumulation in the human body causes Wilson's disease?

37. Which is the only second-row transition metal believed to be essential to the life of plants or animals?
38. Which metal exposure is an occupational hazard in the chloralkali industry that leads to health problems?
39. Which metal is ideal for windows of X-ray tubes because of high transparency to X-rays?
40. Which metal is used in making surgical appliances because of its immunity to body liquids and non-irritating nature to tissues?
41. Which heavy metal was the first man-made element and used in diagnostic radio imaging?
42. What is the chemical symbol of the group 1 alkali metal whose salts are mainly used as chemical fertilizers that provide the metal macromineral to a plant?
43. Which alkaline earth metal is an essential constituent of chlorophyll that converts carbon dioxide and water into glucose and oxygen?
44. What metal is involved in maintaining the correct level of glucose in the blood?
45. Indicate the deficiency of which metal causes *anemia* in man because of low intake/poor absorption or due to heavy loss of blood.
46. Which metal is found in metal-containing enzymes carboxypeptidase and carbonic anhydrase, essential to catalytic peptide hydrolysis and respiration respectively?

47. Which metal is present as part of a porphyrin structure in oxygen carriers-hemoglobin in red blood cells and myoglobin in muscle tissue?
48. Which transition metal is found in the metalloprotein-Vitamin B₁₂ coenzyme, the first organometallic compound to be recognized in biological systems?
49. Name the three metals that the microorganism incorporates into its nitrogenase enzyme system to fix atmospheric dinitrogen.
50. Which metal consumption by the human body has been linked to Alzheimer's disease?
51. Which alkali metal in the form of carbonate is administered orally in the treatment of manic-depressive psychoses?
52. Which metal in the metal complex form, though not essential to humans, is used as an effective anticancer drug and only the cis-isomer is clinically active?
53. What are the metals present in *Calamine*, which is used for relief of skin irritations?
54. Indicate the metal, not essential to biological species, whose thiolate complexes are used as injectable drugs in the treatment of rheumatoid arthritis.
55. List the four metals, the ions of which are required in major quantities in living organisms that are known to be essential for life.
56. Which metal is an essential part common to enzymes tyrosinase and superoxide dismutase?

57. Name the metal whose insoluble sulfate is used as a contrast agent to image the gastrointestinal tract because of its opaque character to X-rays.
58. Which ferromagnetic metal in the chelated complex form is used as a contrast agent for NMR imaging of the body?
59. Which transition metal is involved in the first dinitrogen complex isolated in the laboratory?
- 60.** List the two active metals involved in the preparation of metal-containing antimicrobial agents.
- 61.** Which alkaline earth metal in the form of oxalate is involved in urinary stones in the human body?
62. Which post-transition metal is present in the compound used as an antiknock additive to gasoline that leads to atmospheric pollution and is being phased out in many countries?
63. Which alkaline earth metal as carbonate salt causes hardness to water and its anhydrous chloride acts as common drying agent?
64. Name the three heavy metals used in batteries that cause environmental pollution hazard, arising from careless disposal by consumers.
65. Which transition metal corrodes readily in moist air at ordinary temperatures and is in fact the most used commercially of all metals?
66. Which alkaline earth metal in the form of hydroxide, as an aqueous suspension, is used as a digestive antacid?
67. Which transition metal is used in the preparation of *Bordeaux* mixture, an agricultural poison spray, to prevent fungus attack on areca nut crop?

68. Which metal and all the metal-containing species are considered to be very toxic for general use?
69. Which metal in hypochlorite form is commonly available as chlorine bleach solution in the market place?
70. Which metal in its iodide form is used to seed clouds to produce artificial rain?
71. Which metal in the ionic form is the principal cation of the extracellular fluid and is administered to a patient by intravenous drip?
72. Which alkaline earth metal ion is the only cation that has lower concentration in the blood serum than in the cerebrospinal fluid?
73. Which 5d-transition metal whose tetraoxide is employed as a biological fixative for fingerprint detection because of the formation of a black oxide stain if brought into contact with organic matter?
74. Name the metal in the polyatomic ion involved in the *Breathalyzer* device used to test alcohol consumption.

Metallurgy

75. Which state of metal is used in casting a statue, and metal model?
76. Which metal is used in large amounts mainly for galvanizing iron to prevent it from corrosion?
77. What are the heaviest metals in the periodic table whose alloys are used for making tips of fountain pen nibs, bearings and pivots?
78. Write the names of three metals present in *Alnico* alloy, special steel used to make more powerful permanent magnets.

79. What is the appropriate term used for metal casting factory or workshop?
80. Which metal is present in the amalgam commonly used as strong reducing agent in organic syntheses?
81. Which combination of metals gives the right indication of the composition of a typical brass alloy used to make hardware items because of good working properties?
82. Which transition metal is the main constituent of stainless steel used in making kitchenware?
83. What is the name given to an element with properties intermediate between those of typical metals and typical nonmetals?
84. List three metals found in gunmetal used for guns, gears, and castings.
85. What is the unit used to express the amount of gold present in the gold-copper / silver / other metals alloys?
86. What is the other heavy metal in the most important alloy of tin, *solder*, used for soldering joints?
87. Which metals are used in making a typical alloy *type metal*?
88. Which metal combination gives *manganin*, used in electrical instruments because of its electrical resistance unaffected by temperature?
89. Which transition metal dissolves many metals, such as silver, gold, lead, and tin, forming alloys known as *amalgams*?
90. What is the term associated with amorphous-metal magnetic materials that contain a transition metal (75-85%) and metalloid (15-25%)?

91. What metal combination gives *duralumin*, a ternary alloy that shows a strength approaching that of steel?
92. What is the metal combination involved in *Nichrome* used to make the wire in electric radiators?
93. Which d-block metals are combined with copper to produce special corrosion-resistant alloy *Monel*?
94. Which is an important metal to produce *Electrum*, with gold or nickel?
95. Give the names of two metalloids other than silicon, which are very important in the electronics industry?
96. What is the term used to describe homogeneous mixture of metals or of metals and nonmetals?
97. What is the technique used for the deposition of thin film of noble metal over a base metal by passing direct current through the electrolyte solution?
98. Which alkaline earth metal in alloy form with nickel is used for spark-plug wire due to its high emissivity?
99. Which metal when alloyed with tungsten is used to make high-temperature sensing thermocouples?
100. Name the two 3d-metals involved in the intermetallic alloy that acts as a shape memory alloy existing in two different bonding arrangements at different temperatures.
101. What is the term used to describe metallurgical processes based on electrolysis to reduce metal ores or purifying the metals?

102. Which 3d-transition metal can be obtained from *haematite* ore?
103. Which actinide metal is isolated from the oxide mineral *pitchblende*?
- 104.** Which metal can be extracted from the bright red colored ore *cinnabar*?
105. Which metal can be extracted from the main mineral sources *rutile* and *ilmenite*?
106. Which metal can be manufactured on a very large scale using *dolomite* mineral source deposits?
107. Which metal is extracted mainly from the ores, *Calaverite* and *Sylvinite*?
108. Which 3d-transition metal is obtained from a commercially important mineral source, *pyrolusite*?
109. Which active metal is produced commercially by the electrolysis of molten salt of the metal using the Downs cell?
110. Which metal is produced by electrolytic extraction from the mineral *bauxite*?
111. Which metals in the form of salts are commonly used as electrolyte in molten carbonate fuel cell?

Catalysis

112. Which metal is used as the catalyst in the Haber-Boşch process to manufacture ammonia that is used by crops as a source of nitrogen?
113. What role does finely divided Nickel play in commercial hydrogenation of vegetable oils?

114. Which metal center is involved in the homogenous catalyst in the commercial Monsanto process of conversion of methanol into acetic acid by carbonylation?
115. Which first row transition metal in the form of oxide is used as a catalyst in the oxidation of sulfur dioxide to the trioxide in the manufacture of sulfuric acid by Contact process?
- 116.** Which metal is in the organometallic compound form that it is used as a catalyst in the hydroformylation ('oxo') reaction?
- 117.** Which branch of chemistry deals mainly with compounds containing metal-carbon bonds?
- 118.** What is the term used to describe the compounds containing network of metal atoms connected by direct metal-metal bonds that furnish a natural bridge between homogeneous and heterogeneous catalysis?

Miscellaneous Applications

119. Which heavy metal is mainly employed as electrodes in rechargeable car batteries to start the engine in our daily life?
120. Give the English name of the precious metal whose Latin name is *Aurum*, considered as the king of metals.
121. Which metal is there as anode in rechargeable *Nicad* cell used in electrical appliances?
- 122.** Which transition metal is employed in the construction of standard hydrogen electrode?

123. Give the name of the most noble metal that does not react or corrode in atmosphere and it is in fact the most electronegative metal.
124. Name the rare-earth metal whose chemical symbol is Gd and crystallizes in the hexagonal close-packed form.
125. What is the term associated with the metal that does not conduct electricity at room temperature but does so at higher temperatures?
126. Which alkali metal is used in electric eyes because of generation of electric current when radiation falls on it?
127. Which metals are normally used to make control rods in nuclear power reactors because of their ability to absorb neutrons?
128. Give the name of the heavier noble metal that is more expensive than gold and is used widely in jewelry?
129. What is inner transition metal, *Uranium* mainly used for?
130. What are the other metals present in electroplated nickel silver?
131. Name the two electrochemically active metals present in the first rechargeable battery used in portable electronic devices.
132. Which metal is usually used for making containers for food and drink?
133. Which metals act as superconductors at temperatures near absolute zero?
134. Which active metal is used as an anode material in making cells that delivers three volts required in a photoflash unit of a camera?
135. Name the typical electronic instrument used in airports which gives off audible signals in the presence of metallic objects?

136. Which metal in the vapor state in fused silica bulb gives out ultraviolet radiation?
137. Give the names of two rare earth metals that are used in color television picture tubes.
138. Which is the cathode active material in the electrorefining of copper based on electrolysis to make the metal suitable in electrical applications?
139. Which is the anode active metal in the inexpensive dry cell used to power torches, toys, and walkmans?
140. Which metal pair is commonly referred to as '*chemical twins*' because of their remarkably similar chemical properties?
141. Give the English name of the metal whose German name is *wolfram* that is used in making heating elements for electrical furnaces?
142. Which alkali metal is responsible for the yellow glow in streetlights and emit characteristic yellow color when placed in a flame?
143. Which f-block metal is used as a colorant for *Didymium* glass in welder's goggles?
144. What is the term used for descriptive science that deals with the internal structure of metals?
145. Name the alkaline earth metal present in *Plaster of Paris* used in making plaster casts?
146. Which metal in the halide form are used in photographic emulsions because of their sensitivity to light?

147. Which metal is present in chemically combined form in brilliant white pigment used in paints?
148. Which alkaline earth metal in the form of carbonate is used in making cement and concrete?
149. Give two examples of organic metals containing no metallic components but behave as metal conductors.
150. Write the chemical composition of high temperature oxide superconductor that exhibits highest transition temperature.
151. Which metal in the form of oxide has found application as polishing agent for lenses, mirrors, and television faceplates?
152. List the two alkaline earth metals that impart a beautiful brick red & pale green colors respectively in flame and hence their volatile compounds are often used in fireworks.
153. What is the term used to describe a chemical reaction in which a metal is displaced from a compound by another metal?
154. Which alkaline earth metal in the form of salts is responsible for the brilliant red color of a fireworks display?
155. Which metal in the form of its chromate is used as strong yellow pigment for road signs and markings?
156. Which transition metal is involved in the first recognized compound containing a metal-metal quadruple bond?

157. What metal is present in the organometallic compounds of the type *RMX*, called Grignard reagents, the most extensively used halides in organometallic and organic syntheses?
158. Which metal in the form of pentafluoride is commonly used in the production of super-acid mixture, the strongest known proton donors?
159. Which alkali metal in the form of stearate is used as automotive grease and high-temperature lubricant?
160. Which d-block metal as the dioxide is employed as a depolarizing agent in dry cells?

Concluding Remarks: The benefits the metals have conferred on society indicate various important aspects of impact of metals on our lives. We have seen selected examples of remarkable facts about metals in the fields of extraction of metals, production of new drugs, preparation of novel materials, paints and pigments, photographic chemicals, biomolecules and biomaterials, environmental pollution, mobile power sources, and chemical processes. These metal-centered questions provide an outline of the important information and illustrate certain key points. The metals have maintained their integrated identity throughout history due to the richness in the sense of diversity of applications and contributed significantly to the development of metal-based chemistry. Because of the possible outcome of future research in various fields of science and technology metals continue to play critical role soon.

It is important to create awareness in students studying at undergraduate level about metals in their wider context. Educating students about various aspects of

metals through questionnaire is one way to stimulate their interest, reinforce the subject matter, develop thinking ability, and inspire them to take up metal related academic activities. There is the possibility that some of the questions are things the general public finds curious. New metal-centered questions involving free elements or their ions from more diverse areas can be added to the list from time to time. If we decide to continue gathering chemical information about specific aspects of metals, and metal usage in various fields, this type of metal-specific questionnaire would easily make a question bankbook for conducting certain competitive examinations. Using this skeleton features of intense interest and selected reading of general books, articles and reviews listed, besides getting inputs from other valuable resource materials, can be used as a means to build awareness about answers to follow-up questions for further thinking. It is expected based on chemical education research to obtain further information about several interesting examples of properties and applications associated with each metal in the free and combined forms, which has a significant role in everyday life.

Answers: 1. Silver 2. Lithium & Iridium 3. Tungsten 4. Gold 5. Gallium 6. Mercury 7. Uranium 8. Tungsten 9. Cesium 10. Aluminum 11. Ruthenium & Osmium 12. Gallium 13. Americium 14. Aluminum 15. α , β , & γ - Tin 16. Copper 17. Copper & Nickel 18. Aluminum 19. Silicon 20. Mercury 21. Gold 22. Bismuth 23. Aluminum 24. Rhodium & Rhenium 25. Light Metals 26. Lithium 27. Molybdenum 28. Very Soft 29. Sodium & Magnesium 30. Chromium 31. Tungsten 32. Cobalt-60 33. Technetium-99 34. Calcium 35. Sodium-24 36. Copper 37. Molybdenum 38. Mercury 39. Berilium 40. Tantalum 41. Technetium 42. K 43.

Magnesium 44. Chromium 45. Iron 46. Zinc 47. Iron 48. Cobalt 49. Iron,
Molybdenum & Vanadium 50. Aluminum 51. Lithium 52. Platinum 53. Zinc & Iron
54. Gold 55. Sodium, Potassium, Calcium & Magnesium 56. Copper 57. Barium 58.
Gadolinium 59. Ruthenium 60. Silver & Mercury 61. Calcium 62. Lead 63.
Calcium 64. Mercury, Cadmium & Lead 65. Iron 66. Magnesium 67. Copper 68.
Thallium 69. Sodium 70. Silver 71. Sodium 72. Magnesium Ions 73. Osmium 74.
Chromium 75. Molten State 76. Zinc 77. Osmium & Iridium 78. Aluminum, Nickel,
Cobalt 79. Foundry 80. Sodium 81. Copper & Zinc 82. Iron 83.
Semimetal/Metalloid 84. Copper, Zinc & Tin 85. Carat 86. Lead 87. Lead, Tin &
Antimony 88. Copper, Manganese & Nickel 89. Mercury 90. Metallic Glass 91.
Barium Aluminum, Copper, & Magnesium 92. Nickel & Chromium 93. Nickel &
Traces of Iron & Manganese 94. Silver 95. Gallium & Germanium 96. Alloy 97.
Electroplating/Electrodeposition 98. Barium 99. Rhenium 100. Nickel & Titanium
101. Electrometallurgy/ Electrorefining 102. Iron 103. Uranium 104. Mercury 105
Titanium 106. Magnesium 107. Gold 108. Manganese 109. Sodium 110. Aluminum
111. Lithium & Potassium 112. Iron 113. Catalyst 114. Rhodium 115. Vanadium 116.
Cobalt 117. Organometallics 118. Metal Clusters 119. Lead 120. Gold 121.
Cadmium 122. Platinum 123. Gold 124. Gadolinium 125. Semiconductors 126.
Rubidium 127. Hafnium & Cadmium 128. Platinum 129. Nuclear Fuels 130. Copper
& Zinc 131. Nickel & Cadmium 132. Tin 133. Mercury & Lead 134. Lithium 135.
Metal Detector 136. Mercury 137. Yttrium & Europium 138. Pure Copper Sheets
139. Zinc 140. Zirconium & Hafnium 141. Tungsten 142. Sodium 143.
Praseodymium 144. Metallography 145. Calcium 146. Silver 147. Titanium 148.

Calcium **149**. 1:1 Complex of Tetrathiafulvalene (TTF) & Tetracyanoquinodimethane (TCNQ) **150**. HgBaCa₂Cu₃O_{8+δ} **151**. Cerium **152**. Calcium & Barium **153**. Transmetallation **154**. Strontium **155**. Lead **156**. Rhenium **157**. Magnesium **158**. Antimony **159**. Lithium **160**. Manganese.

References:

1. Cotton, F.A., Wilkinson, G., *Advanced Inorganic Chemistry* 5th ed. Wiley, New York, **1988**, pp 123-980.
2. Greenwood, N.N., Earnshaw, A., *Chemistry of the Elements*, Pergamon Press, Oxford, **1984**.
3. Lee, J.D., *Concise Inorganic Chemistry* 4th ed. ELBS Chapman & Hall, London, **1991**, pp 275-580, 651-901.
4. Sharpe, A.G., *Inorganic Chemistry* 3rd ed. Longman Scientific & Technical, **1992**, pp 226-339, 566-678.
5. Shriver, D.F., Atkins, P.W., Longford, C.H., *Inorganic Chemistry*, Freeman & Company, New York, **1990**, pp 434-632.
6. Kroschwitz, J.I., Ed. *Kirch-Othmer Encyclopedia of Chemical Technology*, 4th ed. Wiley & Sons, New York, **1995**.
7. Hill, G.C., Holman, J.S., *Chemistry in Context* 4th ed. Nelson International Editions, **1995**, pp 233-325.
8. Atkins, P, Jones, L., *Chemistry-Molecules, Matter & Change* 3rd ed. W.H. Freeman & Company, New York, **1997**, pp 803-881.

9. Hall, N., *The New Chemistry* Cambridge University Press, **2000**, pp 85-137, 259-440.
10. Rybolt, T.R., Waddel, T.G., *J. Chem. Ed.* **2002**, 79, pp 448-451.
11. Brown, T.L., LeMay, H.E., Burstein, B.E., Burdge, J.R., *Chemistry-The Central Science*, 9th ed. Prentice Hall, New Jersey, **2003**.
12. Spencer, J.N., Bodner, G.M., Rickard, L.H., *Chemistry: Structure and Dynamics*, 2nd ed., John Wiley & Sons, New York, **2003**.
13. Brady, J.E., Russel, J.W., Holum, J.R., *Chemistry-Matter & its Changes*, 3rd ed. John Wiley & Sons, New York, **2000**.
14. Sadler, P.J., *Adv. Inorg. Chem.* **1991**, 36, pp 1-141.
15. Farrel, N., *Transition Metal Complexes as Drugs and Chemotherapeutic Agents*, Kluwer, Dordrecht, **1989**.
16. Nicolini, M., ed., *Platinum and other Metal Coordination Complexes in Cancer Chemotherapy*, Martinus Nijhoff, Boston, Massachusetts, **1988**.
17. Frausto da Silva, J.J.R., Williams, R.J.P. *The Biological Chemistry of the Elements*, Oxford University Press, **1991**.
18. Abrams, M.J., Murrer, B.A., *Science*, **1993**, 261, 725.
19. Lippard, S.J., Berg, J.M., *Principles of Bioinorganic Chemistry*, University Science Books, Mill Valley, **1994**.
20. Cowan, J.A., *Inorganic Biochemistry*, Wiley-VCH, New York, **1997**.
21. Parshall, G.W., Ittel, S.D., *Homogeneous Catalysis*, Wiley, New York, **1992**.

22. Collman, J.P., Hegedus, L.S., Norton, J.R., Fink, R.G., *Principles and Applications of Organotransition Metal Chemistry*, University Science Books, Mill Valley, **1987**.
23. Gates, B.C. *Catalytic Chemistry*, Wiley-Interscience, New York, **1991**.
24. Ribeiro, F.H., Somorjai, G.A., in *Encyclopedia of Inorganic Chemistry*, King, R.B., ed., Wiley, New York, **1994**, 3, pp 1359-1371.
25. McMurry, J., Fay, R.C. *Chemistry*, 4th ed. Pearson Education, Inc., Singapore, **2004**, pp 915-947.
- 26.** Miessler, G.L., Tarr, D.A., *Inorganic Chemistry*, 3rd ed. Pearson Education, Inc. Singapore, **2004**, pp 594-624.
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