2411/302
INORGANIC CHEMISTRY
Oct./Nov. 2022
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

# DIPLOMA IN ANALYTICAL CHEMISTRY

INORGANIC CHEMISTRY

**3 hours**

## INSTRUCTIONS TO CANDIDATES

*You should have the following for this examination:*
*Answer booklet;*
*Non-programmable scientific calculator.*
*This paper consists of TWO sections; A and B.*
*Answer ALL the questions in section A and any THREE questions from section B in the answer booklet provided.*
*Each question in section A carries 4 marks while each question in section B carries 20 marks.*
*Maximum marks for each part of a question are as shown.*
***Candidates should answer the questions in English.***



**This paper consists of 11 printed pages.**

**Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.**

## SECTION A (40 marks)

*Answer ALL the questions in this section.*

1. The discharge tube experiment was conducted to study the electric nature of atoms.

   (a) List **three** observations from the discharge tube experiment. (3 marks)

   (b) State the main conclusion from the discharge tube experiment. (1 mark)

2. The seven ionization energies of an element **A**, in kJ/mol. are: 1012, 1903, 2912, 4957, 6274, 21269 and 25398.

   (a) State, with an explanation, the group of the periodic table to which element **A** is most likely to belong. (3 mark)

   (c) If element **A** is in period 2, write its electronic configuration. (1 mark)

3. Strontium nitrate, $Sr(NO_3)_2$ undergoes decomposition when heated.

   (a) State the observation that would be made during this reaction. (2 marks)

   (b) Write a balanced equation for this equation. (2 marks)

4. Aluminium reacts with chlorine.

   (a) Starting with aluminium powder, outline how the reaction would be carried out in a laboratory to produce a small sample of aluminium chloride. (2 marks)

   (b) Describe the observation made for this reaction. (2 marks)

5. Copper and titanium both react with chlorine. Copper forms two chlorides, $CuCl$ and $CuCl_2$.

   (a) Write electronic configuration for:

   (i) $Cu$; (1 mark)

   (ii) $Ti$. (1 mark)

   (b) Explain why when copper is reacted directly with chlorine, only $CuCl_2$ is formed. (1 mark)

   (c) Write a balanced equation for the reaction between titanium and chlorine. (1 mark)

6. (a) Complete the following nuclear equations:

(i) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{60}_{38}Sr + {}^{143}_{54}Xe + \square$ (1 mark)

(ii) $^{232}_{90}Th \longrightarrow \square + {}^{4}_{2}He$ (1 mark)

(b) Radioactivity may be detected and measured using a Geiger counter. State how the device detects radiation. (2 marks)

7. The energy levels of the orbitals present in the atoms of the second period (*Li* to *Ne*) are represented in figure 1.

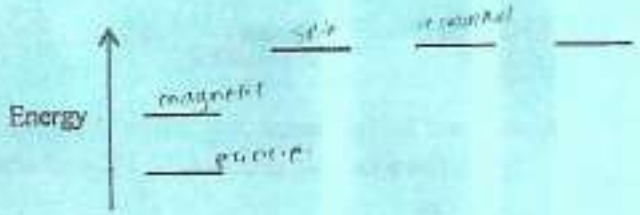


Fig. 1

(a) Label the energy levels to indicate the principal quantum number and the type of orbital at each energy level. (2 marks)

(b) On the axis below, draw a sketch diagram of one of each different type of orbital that is occupied by the electrons in a second period element. (2 marks)

8. (a) Figure 2 shows the outer electron arrangements of the atom and ions indicated. Use the symbol ↿⇂ to represent a pair of electrons in an orbital. (3 marks)

(b) Explain why $Fe^{2+}_{(aq)}$ ions are coloured whereas $Zn^{2+}_{(aq)}$ ions are not. (1 mark)

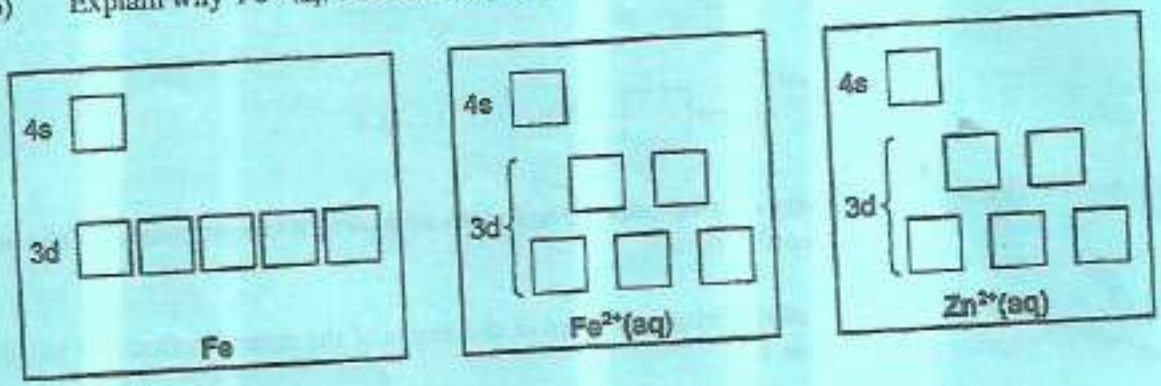


FIGURE 2-

9. Neon and argon can be obtained by fractional distillation of liquid air as they have different boiling points. Neon has a boiling point of 27.3 K and argon has a boiling point of 87.4 K.

(a) Name the forces to be overcomed in order to boil neon and argon. (1 mark)

(b) Explain what causes the force in (a). (1 mark)

(c) Explain why argon has a higher boiling point than neon. (2 marks)

10. Bromine exists naturally as a mixture of two stable isotopes, $^{79}Br$ and $^{81}Br$, with relative isotopic masses of 78.92 and 80.92 respectively. Using the relative atomic mass of bromine which is 79.90, calculate the abundances of $^{79}Br$ and $^{81}Br$. (4 marks)

## SECTION B (60 marks)

*Answer any THREE questions from this section.*

11. (a) The relative atomic mass of an element can be determined using data from its mass spectrum. The mass spectrum of element **X** is shown in figure 3, with the percentage abundance of each isotope indicated.

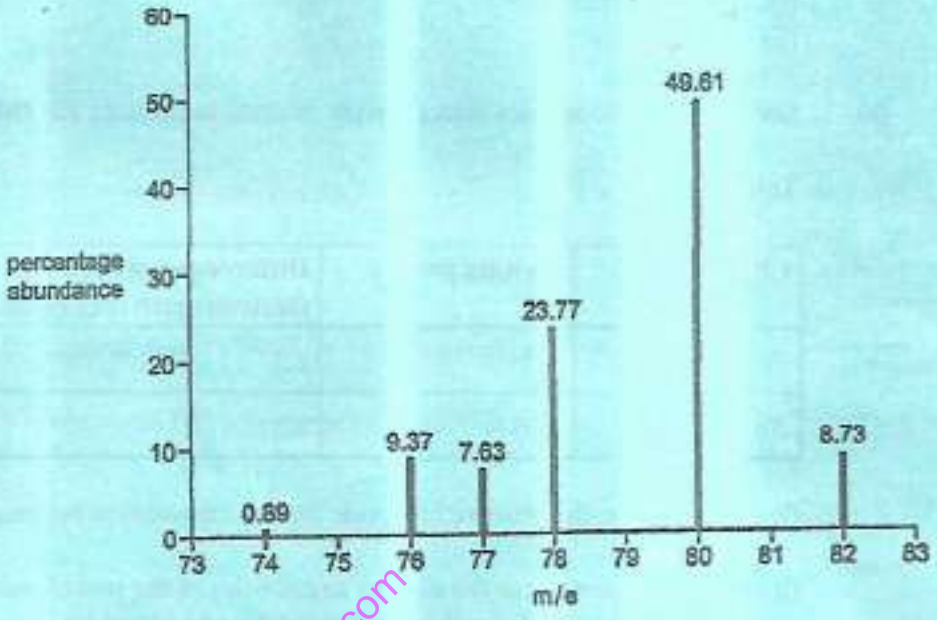




FIGURE 3-

(i) Define the following terms:

(I) relative atomic mass; (2 marks)

(II) isotope. (1 mark)

(ii) Use the information in figure 3 to calculate the relative atomic mass of **X**. (2 marks)

(iii) Identify element **X**. (1 mark)

(iv) In order to obtain the mass spectrum of **X**, a gaseous sample is first ionized.

(I) Describe how ionization is achieved in a mass spectrometer. (3 marks)

(II) State **three** reasons why ionization is necessary. (3 marks)

(b) (i) With explanation, arrange each of the following compounds in order of increasing covalent character.

(I) $LiCl$, $LiBr$ and $LiI$. (3 marks)
(II) $NaCl$, $MgCl_2$ and $AlCl_3$. (3 marks)

(c) Draw a Lewis structure for:

(i) $PCl_5$ molecule; (1 mark)
(ii) $CO_3^{2-}$ ion. (1 mark)

12. (a) Sodium and silicon react directly with chlorine to produce the chlorides in table I.

**Table I**

| Chloride | Melting point / °C | Difference between the electronegativities of the elements |
|---|---|---|
| $NaCl$ | 801 | 2.2 |
| $SiCl_4$ | −69 | 1.3 |

(i) Describe the observation made during the reaction between sodium and chlorine. (3 marks)
(ii) With reference to the electro negativities of the two elements, explain the differences in the melting points of the two chlorides in terms of structure and bonding. (6 marks)



(b) Successive ionization energies (IE) for the elements from magnesium to barium are shown in table II.

**Table II**

| Element | $IE_1$(kJ/mol) | $IE_2$(kJ/mol) | $IE_3$(kJ/mol) |
|---|---|---|---|
| Mg | 736 | 1450 | 7740 |
| Ca | 590 | 1150 | 4940 |
| Sr | 548 | 1060 | 4120 |
| Ba | 502 | 966 | 3390 |

(i) Write the full electronic configuration for strontium. (1 mark)

(ii) Explain why the first ionization energies ($IE_1$) decrease down the group. (3 marks)

(iii) Explain why there is a large increase between second ($IE_2$) and third ($IE_3$) ionization energies. (3 marks)

Na + Cl$_2$ → NaCl



metallic
metta

(c) Explain each of the following: $P + H_2O \rightarrow POH$

(i) during production of elemental phosphorous, the phosphorous vapour is cooled under water. (1 mark)

(ii) Nitrogen gas does not easily react with other elements or compounds. (2 marks)

(iii) Water ($H_2O$) is a liquid while hydrogen sulphide ($H_2S$) is a gas at standard conditions. (1 mark)

13. (a) (i) The nuclide $^{203}_{83}Bi$ can decay by electron capture as shown as per the equation

$$^{203}_{83}Bi + ^{0}_{-1}e \longrightarrow ^{203}_{82}Pb + \upsilon$$

(I) Define 'electron capture'. — is a proces by which electrons av (2 marks)

(II) State one reason why electromagnetic radiation is emitted during this process. (2 marks) absorbe by t neucl

(b) Write equations for the following nuclear reactions:

(i) emission of an $\alpha$-particle by an $^{238}_{92}U$ isotope; (2 marks)

(ii) $^{236}_{92}U \longrightarrow ^{145}_{56}Ba + ^{87}_{30}Kr + \square$ (1 mark)

(c) Plot a graph on figure 4 to show how the number of neutrons, N, varies with the number of protons, Z, for stable nuclei over the range $Z = 0$ to $Z = 80$. (3 marks)

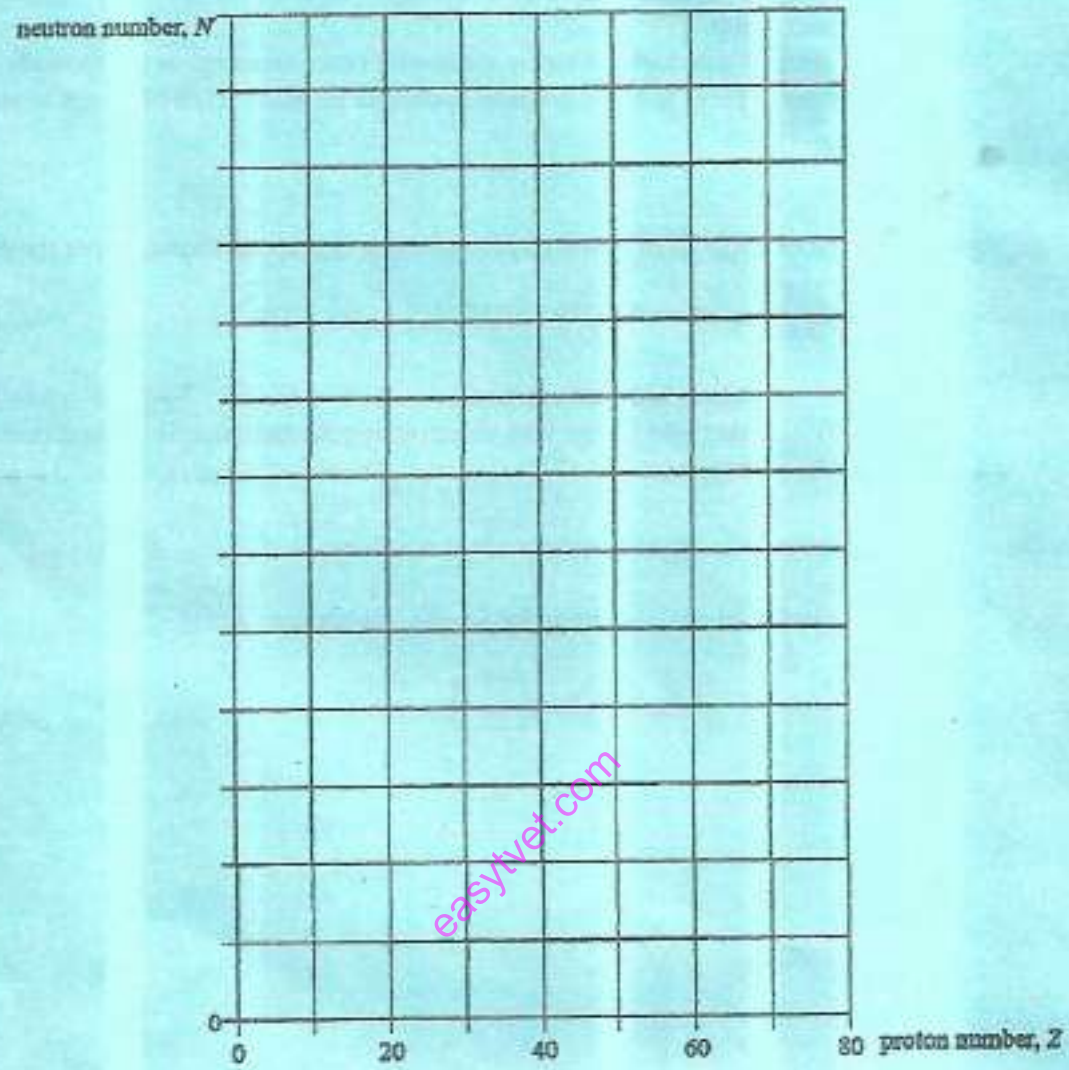


FIGURE 4

(d) A 1 g sample of bone from an ancient site has an average rate of decay of 5.2 Bq due to $^{14}C$. A 1 g sample of bone from a modern skeleton has a rate of decay of 6.5 Bq. The count are corrected for background radiation. Calculate the age in years of the ancient sample of bone. The half life of $^{14}C = 5730$ years. (4 marks)

(e) A radioactive nuclide decays by emitting $\alpha$-particles. Figure 5 shows how the rate of decay, $A_t$ of the source changes with time. Determine the:

(i) half life of the nuclide; (2 marks)
(ii) decay constant; (2 marks)
(iii) initial number of undecayed nuclei present at time $t = 0$. (0.1 MBq = 100,000 Bq). (2 marks)

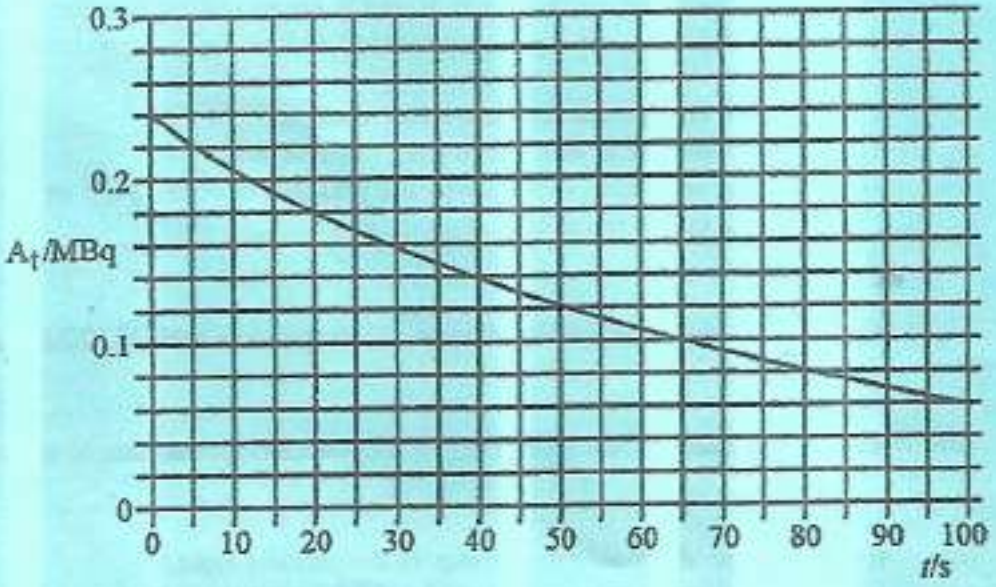


FIGURE 5

14. (a) Write electronic configurations for:

(i) $Cr^{3+}$; (1 mark)
(ii) $Mn^{2+}$. (1 mark)

(b) Identify the colour changes when each of the following oxidizing agents is completely reduced:

(i) $KMnO_4$ from _____ to _____; (2 marks)

(ii) $K_2Cr_2O_7$ from _____ to _____. (2 marks)

(c) During a reaction, concentrated hydrochloric acid is added to a solution of $Cr^{2+}_{(aq)}$ ions.

(i) Identify the colour of the resulting solution. (1 mark)
(ii) Write the formula of the species responsible for the colour in (i). (1 mark)
(iii) Name the type of reaction that has occurred. (1 mark)
(iv) Ammonia can react as a base or as a ligand.

(I) Describe the colour changes when $NH_{3(aq)}$ is gradually added with stirring to the solution in c (i). (3 marks)
(II) Identify the **three** ions responsible for the new colours. (3 marks)

(d) When aqueous solutions of KI and $K_2S_2O_8$ are mixed, no reaction occurs, but when a few drops of $Fe^{2+}_{(aq)}$ or $Fe^{3+}_{(aq)}$ are added, iodine, $I_{2(aq)}$ is produced at a steady rate.

(i) Write an equation for the overall reaction. (1 mark)
(ii) State the role of iron ions during this reaction. (1 mark)
(iii) Using equations, explain why the presence of either $Fe^{2+}$ or $Fe^{3+}$ is able to speed up the reaction. (3 marks)

15. (a) Explain why the atomic mass of carbon in the periodic table is 12.01 a.m.u and not 12.00 a.m.u. (3 marks)

(b) Compare the electrical conductivity of sodium chloride and that of sodium metal. (3 marks)

(c) (i) Define 'diagonal relationship' in the periodic table. (1 mark)
(ii) Describe the diagonal relationship between lithium and magnesium using the nitrates of the two elements. (3 marks)
(iii) Explain why $LiCl$ and $MgCl_2$ are soluble in ethanol. (3 marks)

(d) Arrange, with explanation, the following ions in terms of increasing ionic size.

$Ca^{2+}$, $Cl^-$, $V^{n+}$ and $S^{2-}$ (4 marks)

(e) Table III shows the boiling points of some hydrogen halides:

**Table III**

| Halide | $HCl$ | $HBr$ | $HI$ | $HF$ |
|---|---|---|---|---|
| Boiling point / k | 188 | 206 | 238 | 293 |

(i) Explain the trend in the boiling points from $HCl$ to $HI$. (2 marks)

(ii) State one reason why the boiling point of $HF$ is higher than that of all the other halides. (1 mark)

# The Periodic Table of the Elements

| 1 | 2 | | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | (18) |
| | | | | | | | | | | | | | | | | | 4.0 He helium 2 |
| (1) | (2) | | | | | | | | | | | (13) | (14) | (15) | (16) | (17) | |
| 6.9 Li lithium 3 | 9.0 Be beryllium 4 | | | | | | | | | | | 10.8 B boron 5 | 12.0 C carbon 6 | 14.0 N nitrogen 7 | 16.0 O oxygen 8 | 19.0 F fluorine 9 | 20.2 Ne neon 10 |
| 23.0 Na sodium 11 | 24.3 Mg magnesium 12 | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | 27.0 Al aluminium 13 | 28.1 Si silicon 14 | 31.0 P phosphorus 15 | 32.1 S sulfur 16 | 35.5 Cl chlorine 17 | 39.9 Ar argon 18 |
| 39.1 K potassium 19 | 40.1 Ca calcium 20 | 45.0 Sc scandium 21 | 47.9 Ti titanium 22 | 50.9 V vanadium 23 | 52.0 Cr chromium 24 | 54.9 Mn manganese 25 | 55.8 Fe iron 26 | 58.9 Co cobalt 27 | 58.7 Ni nickel 28 | 63.5 Cu copper 29 | 65.4 Zn zinc 30 | 69.7 Ga gallium 31 | 72.6 Ge germanium 32 | 74.9 As arsenic 33 | 79.0 Se selenium 34 | 79.9 Br bromine 35 | 83.8 Kr krypton 36 |
| 85.5 Rb rubidium 37 | 87.6 Sr strontium 38 | 88.9 Y yttrium 39 | 91.2 Zr zirconium 40 | 92.9 Nb niobium 41 | 96.0 Mo molybdenum 42 | [97] Tc technetium 43 | 101.1 Ru ruthenium 44 | 102.9 Rh rhodium 45 | 106.4 Pd palladium 46 | 107.9 Ag silver 47 | 112.4 Cd cadmium 48 | 114.8 In indium 49 | 118.7 Sn tin 50 | 121.8 Sb antimony 51 | 127.6 Te tellurium 52 | 126.9 I iodine 53 | 131.3 Xe xenon 54 |
| 132.9 Cs caesium 55 | 137.3 Ba barium 56 | 138.9 La * lanthanum 57 | 178.5 Hf hafnium 72 | 180.9 Ta tantalum 73 | 183.8 W tungsten 74 | 186.2 Re rhenium 75 | 190.2 Os osmium 76 | 192.2 Ir iridium 77 | 195.1 Pt platinum 78 | 197.0 Au gold 79 | 200.6 Hg mercury 80 | 204.4 Tl thallium 81 | 207.2 Pb lead 82 | 209.0 Bi bismuth 83 | [209] Po polonium 84 | [210] At astatine 85 | [222] Rn radon 86 |
| [223] Fr francium 87 | [226] Ra radium 88 | [227] Ac † actinium 89 | [267] Rf rutherfordium 104 | [270] Db dubnium 105 | [269] Sg seaborgium 106 | [270] Bh bohrium 107 | [270] Hs hassium 108 | [278] Mt meitnerium 109 | [281] Ds darmstadtium 110 | [281] Rg roentgenium 111 | [285] Cn copernicium 112 | [286] Nh nihonium 113 | [289] Fl flerovium 114 | [289] Mc moscovium 115 | [293] Lv livermorium 116 | [294] Ts tennessine 117 | [294] Og oganesson 118 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 140.1 Ce cerium 58 | 140.9 Pr praseodymium 59 | 144.2 Nd neodymium 60 | [145] Pm promethium 61 | 150.4 Sm samarium 62 | 152.0 Eu europium 63 | 157.3 Gd gadolinium 64 | 158.9 Tb terbium 65 | 162.5 Dy dysprosium 66 | 164.9 Ho holmium 67 | 167.3 Er erbium 68 | 168.9 Tm thulium 69 | 173.0 Yb ytterbium 70 | 175.0 Lu lutetium 71 |
| 232.0 Th thorium 90 | 231.0 Pa protactinium 91 | 238.0 U uranium 92 | [237] Np neptunium 93 | [244] Pu plutonium 94 | [243] Am americium 95 | [247] Cm curium 96 | [247] Bk berkelium 97 | [251] Cf californium 98 | [252] Es einsteinium 99 | [257] Fm fermium 100 | [258] Md mendelevium 101 | [259] No nobelium 102 | [262] Lr lawrencium 103 |

* 58 – 71 Lanthanides

† 90 – 103 Actinides



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