# UNIVERSITY OF SWAZILAND

## FINAL EXAMINATION 2012/13

TITLE OF PAPER: INTRODUCTORY CHEMISTRY I

COURSE NUMBER: C111

TIME: THREE (3) HOURS

**INSTRUCTIONS:**

(i) Answer **all questions** in section A (total 50 marks)
(ii) Answer **any 2 questions** in section B (Each question is 25 marks)

Non-programmable electronic calculators may be used.

A data sheet, a periodic table and answer sheet for section A are attached

**DO NOT OPEN THIS PAPER UNTIL PERMISSION TO DO SO IS GRANTED BY THE CHIEF INVIGILATOR.**

## SECTION A (50 Marks)

This section consists of multiple choice questions. Correct answer must be indicated by putting a circle around the letter for that answer on the answer sheet provided. If you change your answer, please cancel the wrong answer with a cross and then put a circle around the correct one. If more than one option has a circle around it a zero will be given for that question. Attempt all 50 questions.

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1. The symbol for the element potassium is _____.
   (A) Po (B) Pt (C) K (D) P (E) none of these

2. A combination of salt and water is an example of a _____.
   (A) homogeneous mixture (B) heterogeneous mixture (C) compound
   (D) pure substance (E) solid

3. Which one of the following has the element name and symbol correctly matched?
   (A) P, potassium (B) C, copper (C) Mg, manganese
   (D) Au, gold (E) Sn, antimony

4. Which one of the following is often easily separated into its components by simple techniques such as filtering or decanting?
   (A) solutions (B) Elements (C) homogeneous mixture
   (D) compounds (E) heterogeneous mixture

5. Of the following, only _____ is a chemical reaction.
   (A) melting of copper (B) dissolving salt in water (C) burning sugar
   (D) crushing of stone (E) dropping a penny into a glass of water

6. Which of the following has the same number of significant figures as the number 1.030?
   (A) $1 \times 10^6$ (B) 199.791 (C) 8.66 (D) 5.119 (E) 100

7. Which atom has the smallest number of neutrons?
   (A) Chlorine-35 (B) chlorine-37 (C) potassium-39
   (D) Sulphur-33 (E) calcium-40

8. An atom of an isotope of bromine, $^{79}Br$, has _____ protons, _____ neutrons, and _____ electrons.
   (A) 79, 35, 35 (B) 35, 35, 79 (C) 35, 44, 35
   (D) 44, 35, 44 (E) 35, 79, 35

9. The element X has three naturally occurring isotopes. The masses (amu) and % abundances of the isotopes are given in the table below. The average atomic mass of the element is _____ amu.

| Isotope | Abundance(%) | Mass (amu) |
|---|---|---|
| $^{35}X$ | 75.53 | 34.9688 |
| $^{37}X$ | 24.4 | 36.9651 |

(A) 35.97 (B) 71.93 (C) 35.46 (D) 36.55 (E) 36.00

10. Which one of the following is a nonmetal?
(A) Pb (B) Ba (C) Ru (D) Se (E) Sc

11. An element that appears in the top right corner of the periodic table is _____.
(A) either a metal or metalloid (B) definitely a metal
(C) either a metalloid or a non-metal (D) definitely a non-metal
(E) definitely a metalloid

12. Which compounds do not have the same empirical formula?
(A) $C_2H_2$, $C_6H_6$ (B) $H_2O$, $H_2O_2$ (C) $C_2H_4$, $C_3H_6$
(D) $C_2H_4O_2$, $C_6H_{12}O_6$ (E) $C_2H_5COOCH_3$, $CH_3CHO$

13. Which species has 16 electrons?
(A) $^{31}P$ (B) $^{34}S$ (C) $^{36}Cl^-$ (D) $^{80}Br^-$ (E) $^{16}O$

14. Which of the following compounds would you expect to be ionic?
(A) $H_2O$ (B) $CO_2$ (C) $K_2O$ (D) $SO_2$ (E) $Cl_2O$

15. Which species below is the sulphate ion?
(A) $SO_2^{-2}$ (B) $SO_3^{-2}$ (C) $S^{2-}$ (D) $SO_4^{-2}$ (E) $HS^-$

16. Which formula/name pair is **incorrect**?
(A) $MnCl_2$ manganese(II) Chloride (B) $KMnO_4$ potassium permanganate
(C) $Mn(ClO_3)_2$ manganese(IV) chlorate (D) $MgCl_2$ magnesium chloride
(E) $Mg(ClO_4)_2$ magnesium perchlorate

17. When the following equation is balanced, the coefficients are _____.
$Al(NO_3)_3 + Na_2S \rightarrow Al_2S_3 + NaNO_3$
(A) 4, 6, 3, 2 (B) 2, 1, 3, 2 (C) 2, 3, 1, 6 (D) 1, 1, 1, 1 (E) 2, 3, 2, 3

18. There are _____ carbon atoms in 25 molecules of $C_4H_4S_2$.
(A) 100 (B) $9.6 \times 10^{25}$ (C) $3.0 \times 10^{25}$ (D) 50 (E) $6.02 \times 10^{23}$

19. The formula weight of potassium permanganate, $KMnO_4$, is _____ u.
(A) 155.06 (B) 158.04 (C) 108.00 (D) 185.04 (E) 142.04

20. The mass % of C in methane $C_2H_8$ is _____.
(A) 25.13 (B) 133.6 (C) 74.87 (D) 92.26 (E) 7.743

21. There are _____ atoms of hydrogen are in 300 molecules of $CH_3CO_2H$.
(A) 1200 (B) 600 (C) $6.02 \times 10^{24}$ (D) $3.61 \times 10^{26}$ (E) $7.2 \times 10^{26}$

22. How many moles of sodium carbonate contain $3.01 \times 10^{19}$ carbon atoms?
(A) $2.83 \times 10^{17}$ (B) $4.71 \times 10^{-7}$ (C) $1.473 \times 10^{-7}$ (D) $5.00 \times 10^{-5}$
(E) $9.817 \times 10^{-8}$

23. Lithium and nitrogen react to produce lithium nitride:

$6Li\,(s) + N_2\,(g) \rightarrow 2Li_3N\,(s)$

How many moles of Li are needed to react with 0.500 mol of $N_2$?

(A) 3.00 (B) 0.500 (C) 0.167 (D) 1.50 (E) 0.0833

24. Which of the following are weak electrolytes?

HCl, $BaCl_2$, $NH_3$ , KCl

(A) HCl , KCl (B) HCl , $BaCl_2$, $NH_3$ , KCl (C) $BaCl_2$, KCl

(D) $NH_3$ (E) HCl , $BaCl_2$ , KCl

25. The balanced molecular equation for complete neutralization of $H_2SO_4$ by KOH in aqueous solution is _____.

(A) $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$

(B) $2H^+(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + 2K^+(aq)$

(C) $H_2SO_4(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + SO_4^{2-}(aq)$

(D) $H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(s)$

(E) $H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$

26. When aqueous solutions of _____ are mixed, a precipitate forms.

(A) $KNO_3$ and $BaCl_2$ (B) $AgNO_3$ and KBr (C) $K_2SO_4$ and $CrCl_3$

(D) KOH and $Ba(NO_3)_2$ (E) $Li_2CO_3$ and CsI

27. The molarity of a solution prepared by diluting 43.72 mL of 5.005 M aqueous NaOH to 500. mL is _____M.

(A) 57.2 (B) 0.0044 (C) 0.438 (D) 0.0879 (E) 0.870

28. The wavelength of light emitted from a traffic light having a frequency of $5.75\times10^{14}$ Hz is _____.

(A) 702 nm (B) 641 nm (C) 674 nm (D) 521 nm (E) 583 nm

29. The de Broglie wavelength of a 6.0 gram bullet traveling at 330 m/sec is_____

(A) $2.7\times10^{-34}$ m (B) $3.3\times10^{-34}$ m (C) $3.35\times10^{-33}$ m (D) $2.7\times10^{-37}$ m

(E) $6.6\times10^{-31}$ m

30. All of the orbitals in a given electron shell have the same value of the _____ quantum number.

(A) principal (B) azimuthal (C) magnetic (D) spin (E) psi

31. Which of the subshells below do <u>not</u> exist due to the constraints upon the azimuthal quantum number?

(A) 3d (B) 3f (C) 3p (D) all of the above (E) none of the above

32. An electron cannot have the quantum numbers n = ____, l = _____, $m_l$ = ____.

(A) 2, 0, 0 (B) 2, 1, -1 (C) 3, 1, -2 (D) 3, 2, -1 (E) 3, 2, 2

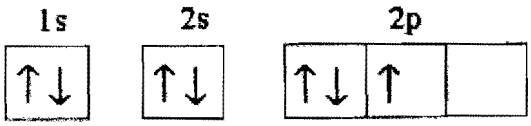
33. The _____ orbital is degenerate with $4p_x$ in a many-electron atom.

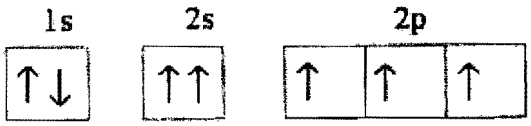
(A) 5s (B) $5p_x$ (C) $4p_y$ (D) $5d_{xy}$ (E) 4s

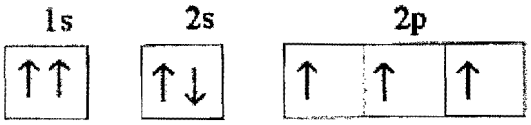
34. Which of the following is **not** a valid set of four quantum numbers? (n, l, $m_l$, $m_s$)

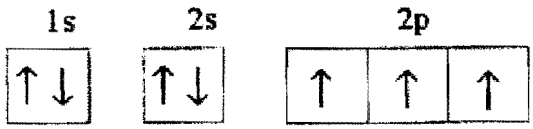
(A) 3, 0, 0, +1/2 (B) 3, 1, 0, +1/2 (C) 3, 1, -1, -1/2 (D) 3, 2, 1, +1/2
(E) 3, 3, 2, +1/2

35. Which one of the following is the correct electron configuration for a ground-state nitrogen atom?

(A) 


(B) 


(C) 


(D) 


(E) None of the above is correct.

36. The ground state electron configuration of Co is _____.

(A) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$ (B) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ (C) $1s^2 2s^2 3s^2 3p^{10}$
(D) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$ (E) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4d^7$

37. The ground state configuration of tungsten is _____.

(A) $[Xe]6s^2 5d^4$ (B) $[Xe]6s^2 4f^{14} 5d^4$ (C) $[Kr]5s^2 4d^5$ (D) $[Xe]6s^2 4f^7$
(E) $[Kr]5s^2 4d^{10} 5p^5$

38. The element that has a valence configuration of $4s^1$ is _____.

(A) Cl (B) Na (C) K (D) Rb (E) Sr

39. In which set of elements would all members be expected to have very similar chemical properties?

(A) O, P, Se (B) N, O, F (C) Na, K, Rb (D) S, Se, Si (E) Ne, Na, Mg

40. Atomic radius generally increases as we move _____.

(A) down a group and from right to left across a period
(B) up a group and from left to right across a period
(C) down a group and from left to right across a period
(D) up a group and from right to left across a period
(E) down a group; the period position has no effect

41. Which isoelectronic series is correctly arranged in order of increasing radius?
(A) $Ca^{2+} < K^+ < Ar < Cl^-$ (B) $Cl^- < Ar < K^+ < Ca^{2+}$ (C) $Ca^{2+} < Ar < K^+ < Cl^-$
(D) $K^+ < Ca^{2+} < Ar < Cl^-$ (E) $Ca^{2+} < K^+ < Cl^- < Ar$

42. Of the choices below, which gives the order for first ionization energies?
(A) Cl > S > Al > Ar > Si (B) S > Si > Cl > Al > Ar
(C) Ar > Cl > S > Si > Al (D) Cl > S > Al > Si > Ar
(E) Al > Si > S > Cl > Ar

43. Which ion below has the largest radius?
(A) $Cl^-$ (B) $K^+$ (C) $Br^-$ (D) $Ca^{2+}$ (E) $Na^+$

44. Which one of the following compounds would produce an acidic solution when dissolved in water?
(A) $Na_2O$ (B) CaO (C) MgO (D) $SO_3$ (E) SrO

45. Based on the octet rule, magnesium most likely forms a _____ ion.
(A) $Mg^{2+}$ (B) $Mg^{2-}$ (C) $Mg^{6-}$ (D) $Mg^{6+}$ (E) $Mg^-$

46. Which of the following would have to lose two electrons in order to achieve a noble gas electron configuration?
S Ca Na Se Br
(A) S, Se (B) Ca (C) Na (D) Br (E) Ca, S, Se

47. What is the electron configuration for the $Ti^{2+}$ ion?
(A) [Ar] $3d^4$ (B) [Ar]$4s^2 3d^2$ (C) [Ar]$3d^2$ (D) [Ar]$4s^2 3d^8$
(E) [Ar]$4s^2$

48. The Lewis structure of $PH_3$ shows _____ nonbonding electron pair(s) on P.
(A) 0 (B) 1 (C) 2 (D) 3 (E) This cannot be determined from the data given.

49. For a molecule with the formula $AB_2$ the molecular shape is _____.
(A) linear or bent (B) linear or trigonal planar (C) linear or T-shaped
(D) T-shaped (E) trigonal planar

50. Of the molecules below, only _____ is nonpolar.
(A) $CO_2$ (B) $H_2O$ (C) $NH_3$ (D) HCl (E) $TeCl_2$

**Please insert your answer sheet inside the answer book used for section B.**

## SECTION B (50 Marks)

**There are three questions in this section. Each question is worth 25 marks. Answer any two questions. In all calculations answers must have the correct number of significant figures and correct units.**

### Question 1 (25 marks)

(a) Name the following compounds

(i) $Co(NO_3)_2 \cdot 6H_2O$ (ii) $Ca_3(PO4)_2$ (iii) $N_2O_4$ (iv) $Cl_2O_7$ (8)

(b) Give the chemical formulas of the following species:
(i)sodium carbonate monohydrate (ii) Bromic acid (4)

(c) The mass composition of cryolite, a compound used in electrolytic production is aluminum is: 32.79% Na, 13.02% Al and 54.19% F. Determine its empirical formula. (4)

(d) Calculate
(i) the mass (in grams) of one $H_2O$ molecule.
(ii) determine the number of $H_2O$ molecules in 1.00 g of water. (6).

(e) Determine the molar mass of $Co(NO_3)_2 \cdot 6H_2O$ (3)

### Question 2 (25 marks)

(a) When the solution in Beaker 1 (below) is mixed with the solution in Beaker 2, a precipitate forms. Write two equations describing the formation of the precipitate in terms of the overall and the net ionic reaction and identify the spectator ions.
(i) Beaker 1: $FeCl_3(aq)$ Beaker 2: $NaOH(aq)$
(ii) Beaker 1: $Pb(NO_3)_2(aq)$ Beaker 2: $K_2SO_4(aq)$ (6)

(b) Select an acid and a base that for a neutralization reaction that results in the formation of (i) $K_3PO_4$ and (ii) $CaBr_2$. Write the overall equation for each reaction. (6)

(c) Identify the oxidizing agent and reducing agent in each of the following reactions:

(i) $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

(ii) $2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(l)$

(iii) $Cl_2(g) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$

(6)

(d) Phosphorus trichloride, $PCl_3$, reacts with water to form phosphorous acid, $H_3PO_3(aq)$ and hydrochloric acid.:

$PCl_3(l) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq)$

(i) Which is the limiting reactant when 12.4 g of $PCl_3$ is mixed with 10.0 g of $H_2O$?

(ii) What masses of phosphorous acid and hydrochloric acid are produced? (7)

**Question 3 (25 marks)**

(a) The frequency of a particular FM radio station is 95.5 MHz. Calculate the energy produced in transmission of 1.00 mol of photons at this frequency. (3)

(b) Calculate the wavelength of a neutron with velocity $1.5 \times 10^8$ m/s. (3)

(c) Explain why the lattice enthalpy of magnesium oxide (3850 kJ/mol) is greater than that of barium oxide (3114 kJ/mol). (3)

(d) Write the Lewis structure of the following species and state the number of lone pairs on the central atom

(i) $ONO^+$ (ii) $XeO_4$ (4)

(e) Write the Lewis structures and predict the shapes of

(i) $OCCl_2$ (ii) $ClO_3^-$ (6)

(f) Write the Lewis structure of each reactant, identify the Lewis acid and the Lewis base and then write the Lewis formula of the product (complex):

(i) $I_2 + I^- \rightarrow$

(ii) $SnCl_4 + 2\ Cl^- \rightarrow$ (6)

# General data and fundamental constants

| Quantity | Symbol | Value |
|---|---|---|
| Speed of light | $c$ | $2.997\,924\,58 \times 10^{8}$ m s$^{-1}$ |
| Elementary charge | $e$ | $1.602\,177 \times 10^{-19}$ C |
| Faraday constant | $F = N_A e$ | $9.6485 \times 10^{4}$ C mol$^{-1}$ |
| Boltzmann constant | $k$ | $1.380\,66 \times 10^{-23}$ J K$^{-1}$ |
| Gas constant | $R = N_A k$ | 8.314 51 J K$^{-1}$ mol$^{-1}$ |
| | | $8.205\,78 \times 10^{-2}$ dm$^3$ atm K$^{-1}$ mol$^{-1}$ |
| | | $6.2364 \times 10$ L Torr K$^{-1}$ mol$^{-1}$ |
| Planck constant | $h$ | $6.626\,08 \times 10^{-34}$ J s |
| | $\hbar = h/2\pi$ | $1.054\,57$ X-$10^{-34}$ J s |
| Avogadro constant | $N_A$ | $6.022\,14 \times 10^{23}$ mol$^{-1}$ |
| Atomic mass unit | $u$ | $1.660\,54 \times 10^{-27}$ Kg |
| Mass | | |
| electron | $m_e$ | $9.109\,39 \times 10^{-31}$ Kg |
| proton | $m_p$ | $1.672\,62 \times 10^{-27}$ Kg |
| neutron | $m_n$ | $1.674\,93 \times 10^{-27}$ Kg |
| Vacuum permittivity | $\varepsilon_o = 1/c^2\mu_o$ | $8.854\,19 \times 10^{-12}$ J$^{-1}$ C$^2$ m$^{-1}$ |
| | $4\pi\varepsilon_o$ | $1.112\,65 \times 10^{-10}$ J$^{-1}$ C$^2$ m$^{-1}$ |
| Vacuum permeability | $\mu_o$ | $4\pi \times 10^{-7}$ J s$^2$ C$^{-2}$ m$^{-1}$ |
| | | $4\pi \times 10^{-7}$ T$^2$ J$^{-1}$ m$^3$ |
| Magneton | | |
| Bohr | $\mu_B = e\hbar/2m_e$ | $9.274\,02 \times 10^{-24}$ J T$^{-1}$ |
| nuclear | $\mu_N = e\hbar/2m_p$ | $5.050\,79 \times 10^{-27}$ J T$^{-1}$ |
| *g* value | $g_e$ | 2.002 32 |
| Bohr radius | $a_o = 4\pi\varepsilon_o\hbar/m_e e^2$ | $5.291\,77 \times 10^{-11}$ m |
| Fine-structure constant | $\alpha = \mu_o e^2 c/2h$ | $7.297\,35 \times 10^{-3}$ |
| Rydberg constant | $R_\infty = m_e e^4/8h^3 c\varepsilon_o^2$ | $1.097\,37 \times 10^{7}$ m$^{-1}$ |
| Standard acceleration of free fall | $g$ | 9.806 65 m s$^{-2}$ |
| Gravitational constant | $G$ | $6.672\,59 \times 10^{-11}$ N m$^2$ Kg$^{-2}$ |

# Conversion factors

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 cal | = | 4.184 joules (J) | 1 erg | = | $1 \times 10^{-7}$ J |
| 1 eV | = | $1.602\,2 \times 10^{-19}$ J | 1 eV/molecule | = | 96 485 kJ mol$^{-1}$ |

**Prefixes**

| f | p | n | μ | m | c | d | k | M | G |
|---|---|---|---|---|---|---|---|---|---|
| femto | pico | nano | micro | milli | centi | deci | kilo | mega | giga |
| $10^{-15}$ | $10^{-12}$ | $10^{-9}$ | $10^{-6}$ | $10^{-3}$ | $10^{-2}$ | $10^{-1}$ | $10^{3}$ | $10^{6}$ | $10^{9}$ |

# PERIODIC TABLE OF ELEMENTS

GROUPS

| PERIODS | 1 IA | 2 IIA | 3 IIIB | 4 IVB | 5 VB | 6 VIB | 7 VIIB | 8 | 9 VIIIB | 10 | 11 IB | 12 IIB | 13 IIIA | 14 IVA | 15 VA | 16 VIA | 17 VIIA | 18 VIIIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.008 H 1 | | | | | | | | | | | | | | | | | 4.003 He 2 |
| 2 | 6.941 Li 3 | 9.012 Be 4 | | | | | | | | | | | 10.811 B 5 | 12.011 C 6 | 14.007 N 7 | 15.999 O 8 | 18.998 F 9 | 20.180 Ne 10 |
| 3 | 22.990 Na 11 | 24.305 Mg 12 | TRANSITION ELEMENTS | | | | | | | | | | 26.982 Al 13 | 28.086 Si 14 | 30.974 P 15 | 32.06 S 16 | 35.453 Cl 17 | 39.948 Ar 18 |
| 4 | 39.098 K 19 | 40.078 Ca 20 | 44.956 Sc 21 | 47.88 Ti 22 | 50.942 V 23 | 51.996 Cr 24 | 54.938 Mn 25 | 55.847 Fe 26 | 58.933 Co 27 | 58.69 Ni 28 | 63.546 Cu 29 | 65.39 Zn 30 | 69.723 Ga 31 | 72.61 Ge 32 | 74.922 As 33 | 78.96 Se 34 | 79.904 Br 35 | 83.80 Kr 36 |
| 5 | 85.468 Rb 37 | 87.62 Sr 38 | 88.906 Y 39 | 91.224 Zr 40 | 92.906 Nb 41 | 95.94 Mo 42 | 98.907 Tc 43 | 101.07 Ru 44 | 102.91 Rh 45 | 106.42 Pd 46 | 107.87 Ag 47 | 112.41 Cd 48 | 114.82 In 49 | 118.71 Sn 50 | 121.75 Sb 51 | 127.60 Te 52 | 126.90 I 53 | 131.29 Xe 54 |
| 6 | 132.91 Cs 55 | 137.33 Ba 56 | 138.91 *La 57 | 178.49 Hf 72 | 180.95 Ta 73 | 183.85 W 74 | 186.21 Re 75 | 190.2 Os 76 | 192.22 Ir 77 | 195.08 Pt 78 | 196.97 Au 79 | 200.59 Hg 80 | 204.38 Tl 81 | 207.2 Pb 82 | 208.98 Bi 83 | (209) Po 84 | (210) At 85 | (222) Rn 86 |
| 7 | 223 Fr 87 | 226.03 Ra 88 | (227) **Ac 89 | (261) Rf 104 | (262) Ha 105 | (263) Unh 106 | (262) Uns 107 | (265) Uno 108 | (266) Une 109 | (267) Uun 110 | | | | | | | | |

Atomic mass → 10.811
Symbol → B
Atomic No. → 5

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lanthanide Series | 140.12 Ce 58 | 140.91 Pr 59 | 144.24 Nd 60 | (145) Pm 61 | 150.36 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.93 Tb 65 | 162.50 Dy 66 | 164.93 Ho 67 | 167.26 Er 68 | 168.93 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 |
| **Actinide Series | 232.04 Th 90 | 231.04 Pa 91 | 238.03 U 92 | 237.05 Np 93 | (244) Pu 94 | (243) Am 95 | (247) Cm 96 | (247) Bk 97 | (251) Cf 98 | (252) Es 99 | (257) Fm 100 | (258) Md 101 | (259) No 102 | (260) Lr 103 |

*( ) indicates the mass number of the isotope with the longest half-life.*