UNIVERSITY OF SWAZILAND
Faculty of Health Sciences
Department of Environmental Health Science
BACHELOR OF SCIENCE IN ENVIRONMENTAL HEALTH

## MAIN EXAMINATION PAPER 2019

| | | |
|---|---|---|
| TITLE OF PAPER | : | CHEMISTRY FOR HEALTH SCIENCES |
| COURSE CODE | : | EHS 111 |
| DURATION | : | 2 HOURS |
| MARKS | : | 100 |
| INSTRUCTIONS | : | READ THE QUESTIONS & INSTRUCTIONS CAREFULLY |
| | : | ANSWER **ANY FOUR** QUESTIONS |
| | : | EACH QUESTION **CARRIES 25** MARKS. |
| | : | WRITE NEATLY & CLEARLY |
| | : | NO PAPER SHOULD BE BROUGHT INTO OR OUT OF THE EXAMINATION ROOM. |
| | : | BEGIN EACH QUESTION ON A SEPARATE SHEET OF PAPER. |

DO NOT OPEN THIS QUESTION PAPER UNTIL PERMISSION IS GRANTED BY THE INVIGILATOR.

## Section A (50 Marks)

This section is compulsory and it consists of multiple choice questions. A 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.

## QUESTION ONE

1. If matter is uniform throughout and cannot be separated into other substances by physical means, it is _____.

   A) a compound    B) either an element or a compound   C) a homogeneous mixture

   D) a heterogeneous mixture    E) an element

2. Which of the following are chemical processes?

   1. rusting of a nail

   2. freezing of water

   3. decomposition of water into hydrogen and oxygen gases

   4. compression of oxygen gas

   A) 2, 3, 4   B) 1, 3, 4    C) 1, 3     D) 1, 2     E) 1, 4

3. Which one of the following is the highest temperature?

   A) 38 °C   B) 96 °F    C) 302 K    D) none of the above

   E) the freezing point of water

4. The length of the side of a cube having a density of 12.6 g/ml and a mass of 7.65 g is _____ cm.

   A) 3.20   B) 0.847    C) 1.02    D) 0.584    E) 1.32

5. The output of a plant is 4335 pounds of ball bearings per week (five days). If each ball bearing weighs 0.0113 g, how many ball bearings does the plant make in a single day? (Indicate the number in proper scientific notation with the appropriate number of

significant figures.)

 A) $3.84 \times 10^5$     B) $7.67 \times 10^4$    C) 867    D) $3.49 \times 10^7$

 E) $2.91 \times 10^6$

6. All atoms of a given element have the same _____ .

 A) mass    B) number of protons     C) number of neutrons

 D) number of electrons and neutrons     E) density

7. Which pair of atoms constitutes a pair of isotopes of the same element?

 A) $^{14}_{6}X$   $^{14}_{7}X$     B) $^{14}_{6}X$   $^{12}_{6}X$     C) $^{17}_{9}X$   $^{17}_{8}X$

 D) $^{19}_{10}X$   $^{19}_{9}X$     E) $^{20}_{10}X$   $^{21}_{11}X$

8. What volume (mL) of a concentrated solution of sodium hydroxide (6.00 M) must be diluted to 200. mL to make a 1.50 M solution of sodium hydroxide?

 A) 0.0500     B) 50.0     C) 45.0     D) 800.     E) 0.800

9. Which one of the following statements is true?

 A) Enthalpy is an intensive property.

 B) The enthalpy change for a reaction is independent of the state of the reactants and products.

 C) Enthalpy is a state function.

 D) H is the value of q measured under conditions of constant volume.

 E) The enthalpy change of a reaction is the reciprocal of the $\Delta H$ of the reverse reaction.

10. An 8.29 g sample of calcium carbonate [$CaCO_3$ (s)] absorbs 50.3 J of heat, upon which the temperature of the sample increases from 21.1 °C to 28.5 °C. What is the specific heat of calcium carbonate?

 A) .63     B) .82     C) 1.1     D) 2.2     E) 4.2

11. The value of $\Delta H°$ for the reaction below is -790 kJ. The enthalpy change accompanying the reaction of 0.95 g of S is _____ kJ.

$$2S\ (s)\ +\ 3O_2\ (g)\ \rightarrow\ 2SO_3\ (g)$$
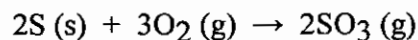
A) 23        B) -23        C) -12        D) 12        E) -790

12. The ground state electron configuration of Ga is _____.

    A) $1s^2 2s^2 3s^2 3p^6 4s^2 3d^{10} 4p^1$          B) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4d^{10} 4p^1$

    C) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^1$          D) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4d^1$

    E) $[Ar]4s^2 3d^{11}$

13. Osmium has a density of 22.6 $g/cm^3$. What volume (in $cm^3$) would be occupied by a 21.8 g sample of osmium?

A) 0.965        B) 1.04        C) 493        D) $2.03 \times 10^{-3}$

E) $2.03 \times 10^3$

14. Chlorine is much more apt to exist as an anion than is sodium. This is because _____.

    A) chlorine is bigger than sodium

    B) chlorine has a greater ionization energy than sodium does

    C) chlorine has a greater electron affinity than sodium does

    D) chlorine is a gas and sodium is a solid

    E) chlorine is more metallic than sodium

15. Transition metals within a period differ mainly in the number of _____ electrons.

    A) s        B) p        C) d        D) f        E) all of the above

16. Which of the following traits characterizes the alkali metals?

    A) very high melting point        B) existence as diatomic molecules

    C) formation of dianions        D) the lowest first ionization energies in a period

E) the smallest atomic radius in a period

17. Ca reacts with element X to form an ionic compound with the formula CaX. Al will react with X to form _____.

    A) $AlX_2$    B) AlX        C) $Al_2X_3$    D) $Al_3X_2$        E) $Al_3X$

18. The type of compound that is most likely to contain a covalent bond is _____.

    A) one that is composed of a metal from the far left of the periodic table and a nonmetal from the far right of the periodic table

    B) a solid metal

    C) one that is composed of only nonmetals

    D) held together by the electrostatic forces between oppositely charged ions

    E) There is no general rule to predict covalency in bonds.

19. Based on the octet rule, phosphorus most likely forms a _____ ion.

    A) $P^{3+}$        B) $P^{3-}$        C) $P^{5+}$    D) $P^{5-}$    E) $P^{+}$

20. Of the atoms below, _____ is the least electronegative.

    A) Ba        B) Be        C) Mg        D) Sr        E) Ca

21. In counting the electron domains around the central atom in VSEPR theory, a _____ is not included.

    A) nonbonding pair of electrons        B) single covalent bond

    C) core level electron pair        D) double covalent bond

    E) triple covalent bond

22. The phrase "like dissolves like" refers to the fact that _____.

    A) gases can only dissolve other gases

    B) polar solvents dissolve polar solutes and nonpolar solvents dissolve nonpolar solutes

    C) solvents can only dissolve solutes of similar molar mass

    D) condensed phases can only dissolve other condensed phases

E) polar solvents dissolve nonpolar solutes and vice versa

23. Calculate the molarity of a 17.5% (by mass) aqueous solution of nitric acid.

A) 0.274 m        B) 2.74 m              C) 3.04 m              D) 4.33 m

E) The density of the solution is needed to solve the problem.

24. A solution is prepared by dissolving 23.7 g of $CaCl_2$ in 375 g of water. The density of the resulting solution is 1.05 g/mL. The concentration of $Cl^-$ in this solution is _____ M.

A) 0.214    B) 0.562      C) 1.12      D) 1.20      E) $6.64 \times 10^{-2}$

25. What is the conjugate base of $OH^-$?

A) $O_2$              B) $O^-$        C) $H_2O$              D) $O^{2-}$        E) $H_3O^+$

26. The $K_a$ of hypochlorous acid (HClO) is $3.00 \times 10^{-8}$. What is the pH at 25.0°C of an aqueous solution that is 0.0200 M in HClO?

A) +2.45    B) -2.45        C) -9.22        D) +9.22        E) +4.61

27. In which of the following aqueous solutions does the weak acid exhibit the lowest percentage ionization?

A) 0.01 M $HC_2H_3O_2$ ($K_a = 1.8 \times 10^{-5}$)  B) 0.01 M $HNO_2$ ($K_a = 4.5 \times 10^{-4}$)

C) 0.01 M HF ($K_a = 6.8 \times 10^{-4}$)          D) 0.01 M HClO ($K_a = 3.0 \times 10^{-8}$)

E) These will all exhibit the same percentage ionization.

28. Which one of the following is a BrØnsted -Lowry base?

A) $(CH_3)^3N$        B) $CH_3COOH$          C) HF        D) $HNO_2$      E) none of the above

29. A BrØnsted-Lowry acid is defined as a substance that _____.

A) increases $K_a$ when placed in $H_2O$     B) decreases $[H^+]$ when placed in $H_2O$

C) increases $[OH^-]$ when placed in $H_2O$   D) acts as a proton acceptor

E) acts as a proton donor

30. A substance that is capable of acting as both an acid and as a base is _____.
   A) autosomal          B) conjugated        C) amphoteric         D) saturated
   E) miscible

31. Which one of the following reactions is a redox reaction?
   A) $NaOH + HCl \rightarrow NaCl + H_2O$          B) $Pb^{2+} + 2Cl^- \rightarrow PbCl_2$
   C) $AgNO_3 + HCl \rightarrow HNO_3 + AgCl$   D) None of the above is a redox reaction.

32. What is the oxidation number of nitrogen in the $HNO_3$?
   A) -1            B) +1          C) +3          D) +5          E) +7

33. Of the following species, _____ will have bond angles of 120°.
   A) $PH_3$            B) $ClF_3$              C) $NCl_3$              D) $BCl_3$
   E) All of these will have bond angles of 120°.

34. What is the conjugate acid of $CO_3^{-2}$?
   A) $CO_2^{-2}$         B) $HCO_2^{-2}$            C) $H_2CO_3$            D) $HCO_3^-$
   E) none of the above

35. What is the pH of an aqueous solution at 25.0 °C that contains $3.98 \times 10^{-9}$ M hydroxide ion?
   A) 8.40     B) 5.60        C) 9.00        D) 3.98        E) 7.00

36. Which one of the following is a metalloid?
   A) Ge            B) S            C) Br            D) Pb            E) C

37. Non metals within a period differ mainly in the number of _____ electrons.

    A) s        B) p        C) d        D) f        E) all of the above

38. For a given process at constant pressure, $\Delta H$ is negative. This means that the process is _____.

    A) endothermic        B) equithermic        C) exothermic

    D) a state function        E) energy

39. Each p-subshell can accommodate a maximum of _____ electrons.

    (A) 6        (B) 2        (C) 10        (D) 3        (E) 5

40. Which one of the following is a diprotic acid?

    A) nitric acid        B) chloric acid        C) phosphoric acid        D) hydrofluoric acid

    E) sulfuric acid

41. The thermodynamic quantity that expresses the degree of disorder in a system is _____.

    A) enthalpy        B) internal energy        C) bond energy        D) entropy
    E) heat flow

42. The correct ground-state electron configuration for molybdenum is _____

    (A) $[Kr]\ 5s^1 4d^{10}$    (B) $[Kr]\ 5s^2 4d^4$        (C) $[Kr]\ 5s^1 4d^5$    (d) $[Kr]\ 5s^2 4d^5$

    (E) $[Kr]\ 5s^2 4d^9$

43. Which group in the periodic table contains elements with the valence electron 2 configuration of $ns^2 np^1$?

    (A) 1        (B) 2        (C) 13        (D) 14        (E) 18

44. Of the units below, _____ are appropriate for a first-order reaction rate constant.

    A) $M\ s^{-1}$        B) $s^{-1}$        C) mol/L        D) $M^{-1}\ s^{-1}$
    E) $L\ mol^{-1}\ s^{-1}$

45. As the temperature of a reaction is increased, the rate of the reaction increases because the _____.
    A) reactant molecules collide less frequently
    B) reactant molecules collide more frequently and with greater energy per collision

C) activation energy is lowered

D) reactant molecules collide less frequently <u>and</u> with greater energy per collision

E) reactant molecules collide more frequently with less energy per collision

46. The molar concentration of hydronium ion in pure water at 25°C is _____.

A) 0.00     B) $1.0 \times 10^{-7}$     C) $1.0 \times 10^{-14}$     D) 1.00     E) 7.00

47. The formula weight of potassium phosphate ($K_3PO_4$) is _____ amu.

A) 173.17     B) 251.37     C) 212.27     D) 196.27     E) 86.07

48. There are _____ atoms of oxygen are in 300 molecules of $CH_3CO_2H$.

A) 300     B) 600     C) $3.01 \times 10^{24}$     D) $3.61 \times 10^{26}$

E) $1.80 \times 10^{26}$

49. A 30.5 gram sample of glucose ($C_6H_{12}O_6$) contains _____ mol of glucose.

A) 0.424     B) 0.169     C) 5.90     D) 2.36     E) 0.136

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

A) 2d     B) 2s     C) 2p     D) all of the above

E) none of the above

## 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.
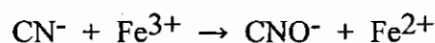
## Question 1

a. The element X has three naturally occurring isotopes. The isotopic 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 |
|---------|-----------|--------|
| $^{159}X$ | 30.60 | 159.37 |
| $^{163}X$ | 15.79 | 162.79 |
| $^{164}X$ | 53.61 | 163.92 |

**[6 marks]**

b. Balance the following redox reaction in basic medium

$$CN^- + Fe^{3+} \rightarrow CNO^- + Fe^{2+}$$

**[14 marks]**

c. Use the electronegativity table to determine whether the following compounds are ionic or covalent (pure or polar) compounds. Provide a reason for each answer.

   (i)   $SO_2$

   (ii)  CsBr

   (iii) $PbNO_2$

   (iv)  ZnO

   (v)   $C_2H_6$

**[5 Marks]**

## Question 2

a. *Use the table below to answer the questions that follow.*

Thermodynamic Quantities for Selected Substances at 298.15 K (25°C)

| Substance | $\Delta H°_f$ (kJ/mol) | $\Delta G°_f$ (kJ/mol) | S (J/K-mol) |
|-----------|----------|----------|----------|
| Carbon | | | |
| C $_{(s, diamond)}$ | 1.88 | 2.84 | 2.43 |
| C $_{(s, graphite)}$ | 0 | 0 | 5.69 |

| | | | |
|---|---|---|---|
| $C_2H_2$ (g) | 226.7 | 209.2 | 200.8 |
| $C_2H_4$ (g) | 52.30 | 68.11 | 219.4 |
| $C_2H_6$ (g) | -84.68 | -32.89 | 229.5 |
| CO (g) | -110.5 | -137.2 | 197.9 |
| $CO_2$ (g) | -393.5 | -394.4 | 213.6 |
| Hydrogen $H_{2(g)}$ | 0 | 0 | 130.58 |
| Oxygen $O_2$ (g) | 0 | 0 | 205.0 |
| $H_2O$ (l) | -285.83 | -237.13 | 69.91 |

(i) The value of $\Delta S°$ for the catalytic hydrogenation of acetylene to ethene,

$C_2H_2$ (g) + $H_2$ (g) $\rightarrow$ $C_2H_4$ (g)
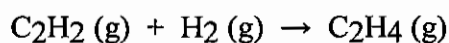
is _____ J/K· mol.                                      [3 marks]

(ii) The combustion of acetylene in the presence of excess oxygen yields carbon dioxide and water:

$2C_2H_2$ (g) + $5O_2$ (g) $\rightarrow$ $4CO_2$ (g) + $2H_2O$ (l)
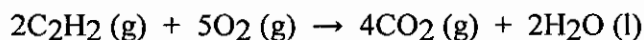
The value of $\Delta S°$ for this reaction is _____ J/K· mol.    [3 marks]

(iii) The value of $\Delta S°$ for the reaction

$2C$ (s, diamond) + $O_2$ (g) $\rightarrow$ $2CO$ (g)
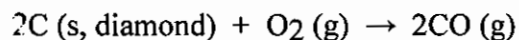
is _____ J/K· mol.                                      [3 marks]

(iv) The value of $\Delta S°$ for the catalytic hydrogenation of ethene to ethane,

$C_2H_4$ (g) + $H_2$(g) $\rightarrow$ $C_2H_6$ (g)
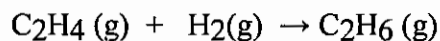
is _____ J/K· mol.                                      [3 marks]

b. A certain alcohol contains only three elements, carbon, hydrogen, and oxygen. Combustion of a 30.00 gram sample of the alcohol produced 57.30 grams of $CO_2$ and 35.22 grams of $H_2O$. What is the empirical formula of the alcohol?[7 Marks]

c. Write the full electron configuration of the following ions

(i)    $Mn^{4+}$

(ii)   $I^-$

(iii)  $S^{2-}$                                                    [ 2× 3 Marks]

                                                          i.  Total 25 marks

## Question 3

a. Qualitative analysis of an unknown acid was found to contain only carbon, hydrogen and oxygen. In a quantitative analysis, a 10.46 mg sample was found in oxygen and gave 22.17 mg carbon dioxide and 3.40 mg water. The molecular mass was determined to be 166 gmol-1. When 0.1680 g of the acid was titrated with 0.1250 M sodium hydroxide, the end point was reached after 16.18 mL of the base added.

   (i) What is the empirical formula of the acid?              [9 Marks]

   (ii) What is its molecular formula?                          [4 Marks]

   (iii) Is the acid mono-, di- or triprotic?                   [3 Marks]

b. Write out the full electron configuration of electron configuration of the following elements.

   (i) Bi

   (ii) Pm

   (iii) $Mo^{2+}$

                                                          [9 Marks]
                                                       Total 25 marks

# 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 |
| | $\hbar = h/2\pi$ | $1.054\,57 \times 10^{-34}$ 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 | $\varepsilon_0 = 1/c^2\mu_0$ | $8.854\,19 \times 10^{-12}$ J$^{-1}$ C$^2$ m$^{-1}$ |
| | $4\pi\varepsilon_0$ | $1.112\,65 \times 10^{-10}$ J$^{-1}$ C$^2$ m$^{-1}$ |
| Vacuum permeability | $\mu_0$ | $4\pi \times 10^{-7}$ 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 | $a_0 = 4\pi\varepsilon_0\hbar/m_e e^2$ | $5.291\,77 \times 10^{-11}$ m |
| Fine-structure constant | $\alpha = \mu_0 e^2 c/2h$ | $7.297\,35 \times 10^{-3}$ |
| Rydberg constant | $R_\infty = m_e e^4/8h^3 c\varepsilon_0^2$ | $1.097\,37 \times 10^7$ 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 | = | $1.6022 \times 10^{-19}$ J | 1 eV/molecule | = | 96 485 kJ mol$^{-1}$ |

## Prefixes

| f | p | n | $\mu$ | 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

TRANSITION ELEMENTS

| PERIODS | 1 IA | 2 IIA | 3 IIIB | 4 IVB | 5 VB | 6 VIB | 7 VIIB | 8 VIIIB | 9 VIIIB | 10 VIIIB | 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 | | | | | | | | | | | 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 →
Symbol →
Atomic No. →

*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 | 237.03 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.*