NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF HEALTH, NATURAL RESOURCES AND APPLIED SCIENCES

SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF BIOLOGY, CHEMISTRY AND PHYSICS

QUALIFICATION: BACHELOR OF SCIENCE	
QUALIFICATION CODE: 07BOSC	**LEVEL:** 7
COURSE CODE: OCH701S	**COURSE NAME:** ORGANIC CHEMISTRY 2
SESSION: JUNE 2023	**PAPER:** THEORY
DURATION: 3 HOURS	**MARKS:** 100

FIRST OPPORTUNITY EXAMINATION QUESTION PAPER	
EXAMINER(S)	DR. MARIUS MUTORWA
MODERATOR:	DR. RENATE HANS

INSTRUCTIONS

1. Answer ALL the questions.
2. Write clearly and neatly.
3. Number the answers clearly
4. All written work must be done in blue or black in and sketches must be done in pencil
5. No book, notes and other additional aids are allowed

- **PERMISSIBLE MATERIALS**

Non-programmable Calculators

- **ATTACHMENTS**

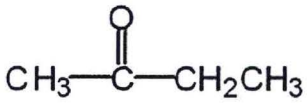
NMR and IR Spectral Data, pKa Chart and Periodic Table

THIS QUESTION PAPER CONSISTS OF 12 PAGES (Including this front page)

SECTION A [50]

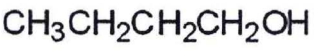
- **QUESTION 1: Multiple Choice Questions** **[50]**
- *There are 25 multiple choice questions and each question carries 2 marks.*
- *Answer ALL questions by selecting the letter of the correct answer.*

1.1 Consider the three organic compounds drawn below. Which of the following statements is (are) true about the IR spectra of A, B, and C?



A

B



C

A. A shows strong absorptions at 3000 cm–1 and 1700 cm^{-1}.

B. B shows strong absorptions at 3000 cm–1 and 2250 cm^{-1}.

C. C shows strong absorptions at 3000 cm–1 and 3200–3600 cm^{-1}.

D. Statements (A shows strong absorptions at 3000 cm^{-1} and 1700 cm^{-1}) and (C shows strong absorptions at 300 cm^{-1} and 3200–3600 cm^{-1}) are true.

E. Statements (A shows strong absorptions at 3000 cm^{-1} and 1700 cm^{-1}), (B shows strong absorptions at 3000 cm^{-1} and 2250 cm^{-1}), and (C shows strong absorptions at 3000 cm^{-1} and 3200–3600 cm^{-1}) are all true.

1.2 Which molecular formula is consistent with the following mass spectrum data?

$M^{+\cdot}$ at m/z= 84, relative height=10.0%

$(M+1)^{+\cdot}$ at m/z= 85, relative height=0.56%

A. $C_5H_{10}O$

B. C_5H_8O

C. C_5H_{24}

D. C_6H_{12}

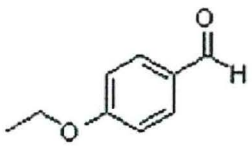
E. $C_4H_6O_2$

1.3 Identify the structure that is consistent with the following data.

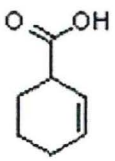
a. The IR includes peaks at 1603 and 1495 cm^{-1}.

b. The ^{13}C NMR has a total of 7 signals.

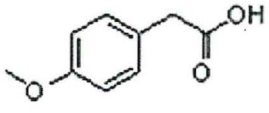
c. The compound has one acidic proton.



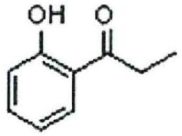
A



B



C



D

A. A

B. B

C. C

D. D

E. None of the above

1.4 Which of the following compounds will produce a prominent (M-18) peak in the mass spectrum?

A. 2-methylheptane

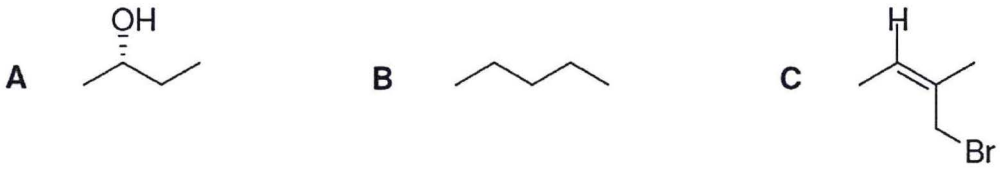
B. 1-heptanol

C. Heptanamine

D. Heptanal

E. None of the above

1.5 How many different proton environments are present in each of the following molecules?



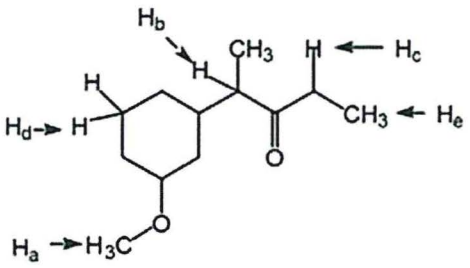
A. A = 6 ; B = 3 and C = 4

B. A = 5; B = 3 and C = 4

C. A = 6; B = 4 and C = 5

D. A = 6; B = 4 and C = 4

1.6 Which of the indicated protons absorbs furthest downfield in NMR?



A. Ha

B. Hb

C. Hc

D. Hd

E. He

1.7 Which of the following type of protons are chemically equivalent?

A. Homotopic
B. Enantiotopic
C. Diastereotopic
D. A & B
E. B & C

1.8 Which of the following compounds is the kinetic product of the reaction of HBr with 1,3-cyclohexadiene?

A B C D

A. A
B. B
C. C
D. D
E. A & D

1.9 Which of the following statements about Diels-Alder reaction is false?

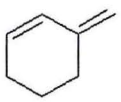
A. The reaction is stereospecific
B. The diene must be in the s-cis conformation in order to react
C. The dienophile must contain an electron withdrawing group
D. The diene and dienophile line up so that the exo product is favoured.

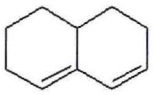
1.10 Which of the following dienophiles is most reactive in a Diels-Alder reaction?

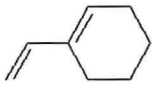
A. B. C. D.

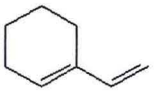
A. A
B. B
C. C
D. D

1.11 Which of the following conjugated dienes would not react with a dienophile in a Diels-Alder reaction?

I. 

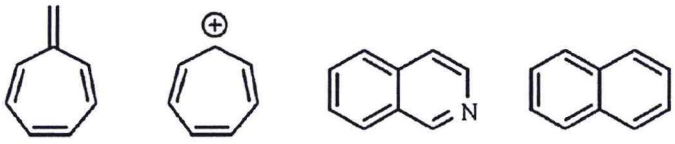
III. 

II. 

IV. 

A. I
B. II
C. III
D. IV
E. I & III

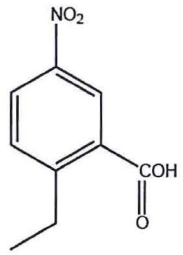
1.12 Which of the following compounds is not aromatic?



A. B. C. D.

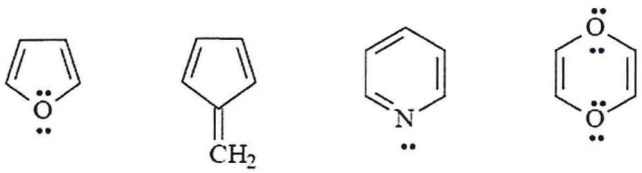
A. A
B. B
C. C
D. D

1.13 What is the IUPAC name for the following compound?



A. 6-ethyl-3-nitrobenzoic acid
B. 1-ethyl-4-nitrobenzoic acid
C. 2-ethyl-5-nitrobenzoic acid
D. 2-ethyl-5-nitrobenzaldehyde
E. 4-nitro-3-carboxyethylbenzene

1.14 Which structures are aromatic?



I II III IV

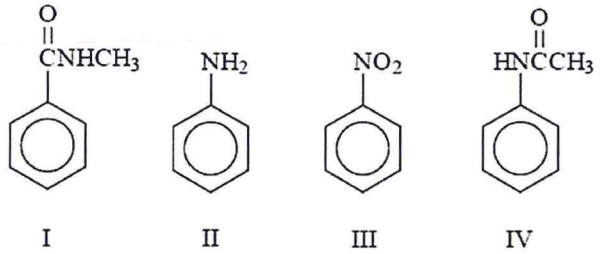
A. II and III

B. III and IV

C. I and III

D. II and IV

1.15 Arrange the compounds in order of increasing reactivity towards electrophilic substitution?



I II III IV

A. II, I, IV, III

B. I, III, IV, II

C. III, I, IV, II

D. IV, III, II, I

1.16 Which of the following statements is (are) true about electrophilic aromatic substitution?

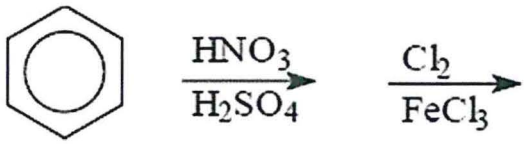
A. The methoxy group is an ortho, para activator because of a strong electron donating effect

B. The methoxy group is an ortho, para director because of a strong electron withdrawing inductive effect

C. The methoxy group is an ortho, para activator because the O atom is an electronegative atom strong electron donating effect

D. Statement A (The methoxy group is an ortho, para activator because of a strong electron donating effect) and Statement C (the methoxy group is an ortho, para activator because the O atom is an electronegative atom strong electron donating effect) are the only true statements.

1.17 What is the structure of the final product resulting from the sequence of reactions shown below?



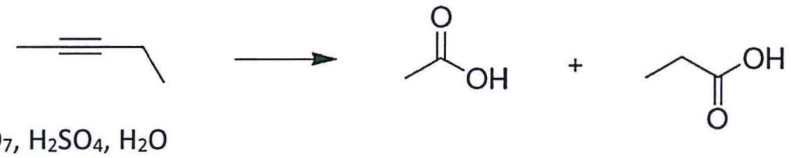
A. 1-chloro-4-nitrobenzene

B. 1-chloro-3-nitrobenzene

C. 1-chloro-2nitrobenzene

D. a mixture of 1-chloro-4-nitrobenzene and 1-chloro-2-nitrobenzene

1.18 Choose the best reagent to carry out the reaction below?



A. $K_2Cr_2O_7$, H_2SO_4, H_2O

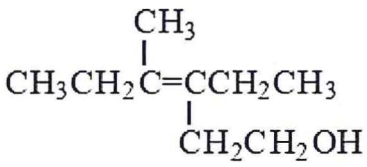
B. (1) O_3, (2) H_2O

C. NaOH, H_2O

D. NaH

E. None of the above

1.19 What is the correct name for the following compound?



A. 3-methyl-4-ethyl-3-hexen-6-ol

B. 4-ethyl-3-methyl-3,6-hexenol

C. 3-ethyl-4-methyl-3-hexen-1-ol

D. 3-methyl-4-(2-hydroxyethyl)-3-hexene

E. 3-(2-hydroxyethyl)-3-methyl-3-hexene

1.20 Select the correct reagent(s) for the following reaction.

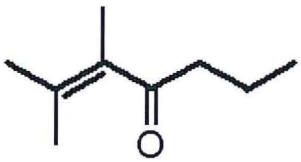
A. $LiAlH_4$/ether; then H_3O^+

B. $NaBH_4$; then H_3O^+

C. H_2 and Pt/C

D. B and C above are correct

1.21 What is the correct name for the following compound?



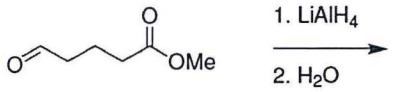
A. 1,1,2-trimethyl-1,3-hexenone

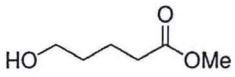
B. 1,2-dimethyl-1,3-hexenone

C. 2,3-dimethyl-1,3-heptenone

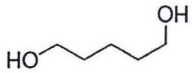
D. 2,3-dimethyl-2-hepten-4-one

1.22 Select the product of the following reaction.

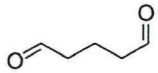




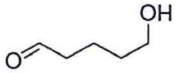
A.



B.



C.



D.

A. A
B. B
C. C
D. D

1.23 Why do aldehydes undergo nucleophilic addition reactions while esters undergo nucleophilic acyl substitution reactions?

A. The carbonyl carbon of an ester is more electrophilic than that of an aldehyde.
B. Aldehydes are more sterically hindered than esters.
C. Once the nucleophile adds to an aldehyde, the tetrahedral intermediate is too sterically hindered to eliminate one of the attached groups.
D. The ester carbonyl carbon is sp^3 hybridized while the aldehyde carbonyl carbon is sp^2 hybridized.
E. Once the nucleophile adds to an aldehyde, neither H- nor R- can be eliminated since they are strongly basic.

1.24 Which one of the following is the strongest acid?

A. benzoic acid
B. 4-nitrobenzoic acid
C. 4-ethylbenzoic acid
D. 4-chlorobenzoic acid

1.25 Why would the alcohol in the following compound need to be protected before the reaction?

A. If it is not protected, the product will be a carboxylic acid
B. The Grignard reagent will react with the alcohol before the ketone
C. Magnesium is Lewis acidic and will coordinate with the alcohol
D. There is no need to protect the alcohol

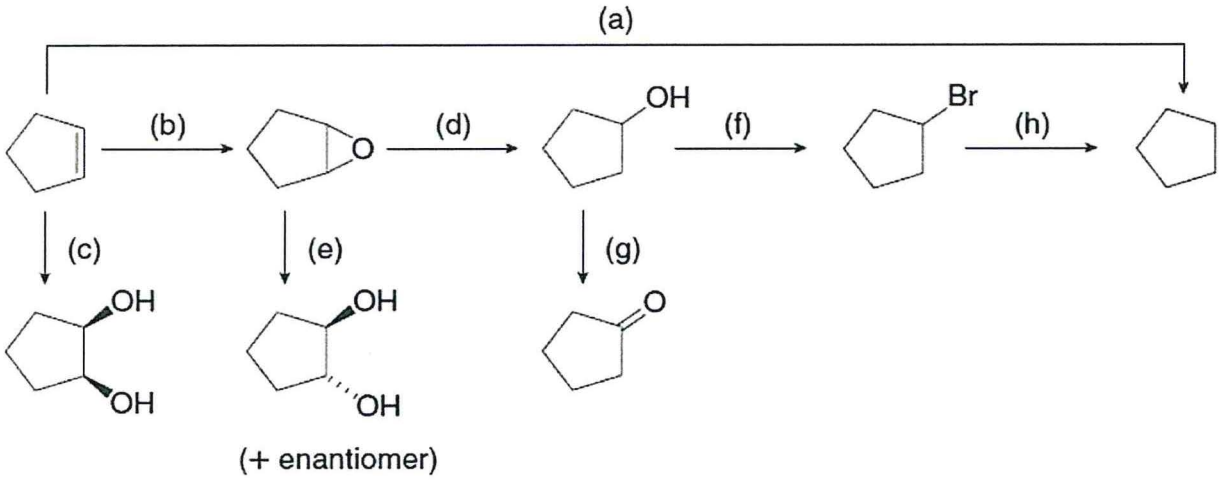
END OF SECTION A

SECTION B [50]

QUESTION 2 [16]

Identify the lettered reagents **(A-H)** in the following reaction sequence.

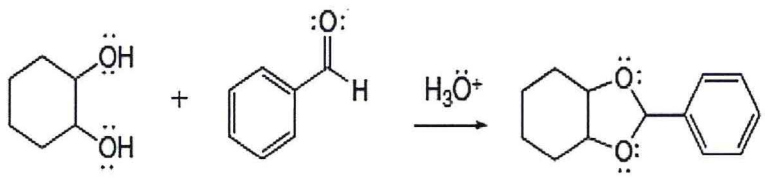
Note: 2 marks for each intermediate



QUESTION 3 [14]

Draw a full detailed mechanism for the reaction below. In order to receive full marks, show all intermediates and flow of electrons using the appropriate arrows.

Note: 1 mark for each appropriate arrow



QUESTION 4 [20]

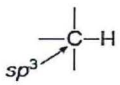
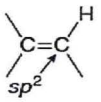
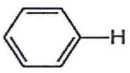
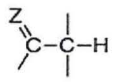
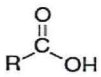
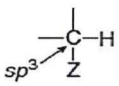
Use the ^1H NMR spectral table provided to identify the structure of compound X with the following ^1H NMR spectral data:

- Molecular formula: $C_7H_{14}O_2$
- ^1H NMR (ppm)
  - : 0.94 (doublet, 6 H)
  - : 1.15 (triplet, 3 H)
  - : 1.91 (multiplet, 1 H)
  - : 2.33 (quartet, 2 H)
  - : 3.86 (doublet, 2 H)
- IR absorption at ~1720 cm^{-1}

THE END
GOODLUCK

^{1}H NMR SPECTRAL DATA

Characteristic Chemical Shifts of Common Types of Protons

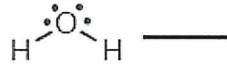
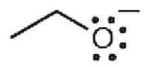
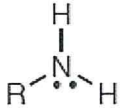
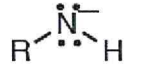
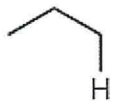
Type of proton	Chemical shift (ppm)	Type of proton	Chemical shift (ppm)
	0.9–2		4.5–6
• RCH_3 • R_2CH_2 • R_3CH	~0.9 ~1.3 ~1.7		6.5–8
 Z = C, O, N	1.5–2.5		9–10
—C≡C—H	~2.5		10–12
 Z = N, O, X	2.5–4	RO—H or 	1–5

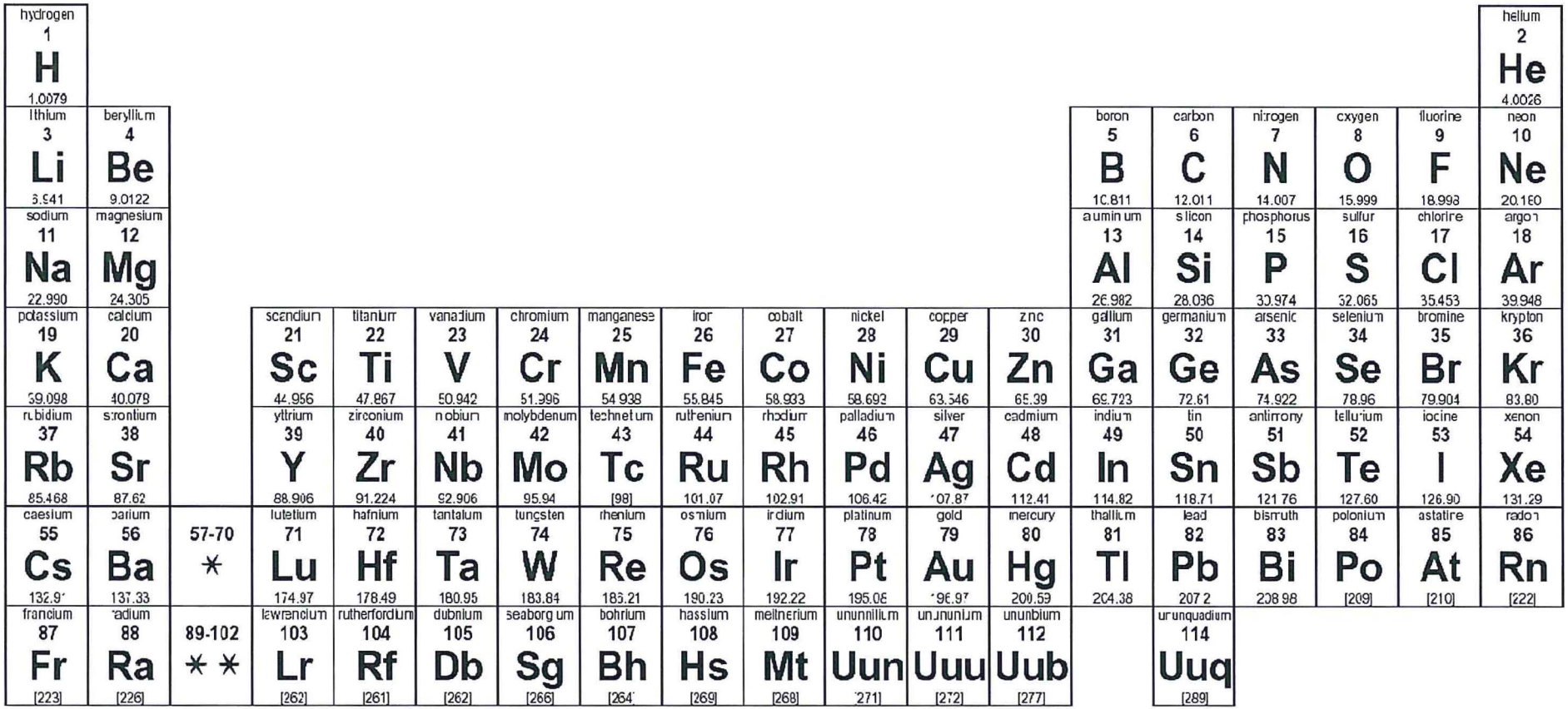
Important IR Absorptions

Bond type	Approximate $\tilde{\nu}$ (cm^{-1})	Intensity
O–H	3600–3200	strong, broad
N–H	3500–3200	medium
C–H	~3000	
• C_{sp^3}–H	3000–2850	strong
• C_{sp^2}–H	3150–3000	medium
• C_{sp}–H	3300	medium
C≡C	2250	medium
C≡N	2250	medium
C=O	1800–1650 (often ~1700)	strong
C=C	1650	medium
	1600, 1500	medium

pKa Chart

conjugate acid		conjugate base	
sulfuric acid	H_2SO_4	HSO_4^-	**-10**
hydroiodic acid	HI	I^-	**-9**
hydrobromic acid	HBr	Br^-	**-8**
hydrochloric acid	HCl:	:Cl:$^-$	**-7**
carbocations			**-3**
protonated alcohol			**-2.4**
hydronium ion			**-1.7**
nitric acid	HNO_3	NO_3^-	**-1.3**
hydrofluoric acid	HF	F^-	**3.2**
carboxylic acids			**4.8**

conjugate acid		conjugate base	
hydrogen cyanide	H—C≡N:	:C≡N:$^-$ (cyanide)	**9.1**
phenols			**10**
water		:O—H$^-$ (hydroxide)	**15.7**
primary alcohols		 (alkoxides)	**16**
alkynes	C≡C—H	C≡C:$^-$ (acetylide anions)	**26**
hydrogen	H—H	:H$^-$ (hydride)	**35**
ammonia/amines		 (amide bases)	**36**
alkanes			**~60**


hydrogen 1 H 1.0079
helium 2 He 4.0026
lithium 3 Li 6.941
beryllium 4 Be 9.0122
boron 5 B 10.811
carbon 6 C 12.011
nitrogen 7 N 14.007
oxygen 8 O 15.999
fluorine 9 F 18.998
neon 10 Ne 20.180
sodium 11 Na 22.990
magnesium 12 Mg 24.305
aluminum 13 Al 26.982
silicon 14 Si 28.086
phosphorus 15 P 30.974
sulfur 16 S 32.065
chlorine 17 Cl 35.453
argon 18 Ar 39.948
potassium 19 K 39.098
calcium 20 Ca 40.078
scandium 21 Sc 44.956
titanium 22 Ti 47.867
vanadium 23 V 50.942
chromium 24 Cr 51.996
manganese 25 Mn 54.938
iron 26 Fe 55.845
cobalt 27 Co 58.933
nickel 28 Ni 58.693
copper 29 Cu 63.546
zinc 30 Zn 65.39
gallium 31 Ga 69.723
germanium 32 Ge 72.61
arsenic 33 As 74.922
selenium 34 Se 78.96
bromine 35 Br 79.904
krypton 36 Kr 83.80
rubidium 37 Rb 85.468
strontium 38 Sr 87.62
yttrium 39 Y 88.906
zirconium 40 Zr 91.224
niobium 41 Nb 92.906
molybdenum 42 Mo 95.94
technetium 43 Tc [98]
ruthenium 44 Ru 101.07
rhodium 45 Rh 102.91
palladium 46 Pd 106.42
silver 47 Ag 107.87
cadmium 48 Cd 112.41
indium 49 In 114.82
tin 50 Sn 118.71
antimony 51 Sb 121.76
tellurium 52 Te 127.60
iodine 53 I 126.90
xenon 54 Xe 131.29
caesium 55 Cs 132.91
barium 56 Ba 137.33
57-70 *
lutetium 71 Lu 174.97
hafnium 72 Hf 178.49
tantalum 73 Ta 180.95
tungsten 74 W 183.84
rhenium 75 Re 186.21
osmium 76 Os 190.23
iridium 77 Ir 192.22
platinum 78 Pt 195.08
gold 79 Au 196.97
mercury 80 Hg 200.59
thallium 81 Tl 204.38
lead 82 Pb 207.2
bismuth 83 Bi 208.98
polonium 84 Po [209]
astatine 85 At [210]
radon 86 Rn [222]
francium 87 Fr [223]
radium 88 Ra [226]
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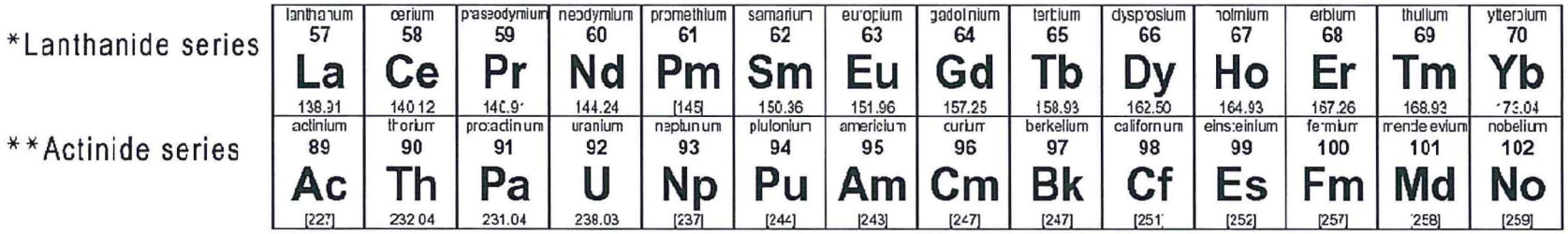
lawrencium 103 Lr [262]
rutherfordium 104 Rf [261]
dubnium 105 Db [262]
seaborgium 106 Sg [266]
bohrium 107 Bh [264]
hassium 108 Hs [269]
meitnerium 109 Mt [268]
ununnilium 110 Uun [271]
unununium 111 Uuu [272]
ununbium 112 Uub [277]
ununquadium 114 Uuq [289]


*Lanthanide series
**Actinide series
lanthanum 57 La 138.91
cerium 58 Ce 140.12
praseodymium 59 Pr 140.91
neodymium 60 Nd 144.24
promethium 61 Pm [145]
samarium 62 Sm 150.36
europium 63 Eu 151.96
gadolinium 64 Gd 157.25
terbium 65 Tb 158.93
dysprosium 66 Dy 162.50
holmium 67 Ho 164.93
erbium 68 Er 167.26
thulium 69 Tm 168.93
ytterbium 70 Yb 173.04
actinium 89 Ac [227]
thorium 90 Th 232.04
protactinium 91 Pa 231.04
uranium 92 U 238.03
neptunium 93 Np [237]
plutonium 94 Pu [244]
americium 95 Am [243]
curium 96 Cm [247]
berkelium 97 Bk [247]
californium 98 Cf [251]
einsteinium 99 Es [252]
fermium 100 Fm [257]
mendelevium 101 Md [258]
nobelium 102 No [259]