



**PAMIBIA UNIVERSITY**  
OF SCIENCE AND TECHNOLOGY

**FACULTY OF HEALTH AND APPLIED SCIENCES**

**DEPARTMENT OF NATURAL AND APPLIED SCIENCES**

|   |   |
|---|---|
| <b>QUALIFICATION:</b> BACHELOR OF SCIENCE |   |
| <b>QUALIFICATION CODE:</b> 07BOSC         | <b>LEVEL:</b> 7                         |
| <b>COURSE CODE:</b> OCH701S               | <b>COURSE NAME:</b> ORGANIC CHEMISTRY 2 |
| <b>SESSION:</b> JUNE 2019                 | <b>PAPER:</b> THEORY                    |
| <b>DURATION:</b> 3 HOURS                  | <b>MARKS:</b> 100                       |

|   |                    |
|---|--------------------|
| <b>FIRST OPPORTUNITY EXAMINATION QUESTION PAPER</b> |                    |
| <b>EXAMINER(S)</b>                                  | DR. MARIUS MUTORWA |
| <b>MODERATOR:</b>                                   | DR. RENATE HANS    |

|  |
|--|
| <p style="text-align: center;"><b>INSTRUCTIONS</b></p> <ol style="list-style-type: none"><li>1. Answer ALL the questions.</li><li>2. Write clearly and neatly.</li><li>3. Number the answers clearly</li><li>4. All written work must be done in blue or black ink and sketches must be done in pencil</li><li>5. No book, notes and other additional aids are allowed</li></ol> |
|--|

**PERMISSIBLE MATERIALS**

Non-programmable Calculators

**ATTACHMENTS**

Solvent Chart, pKa Chart and Periodic Table

**THIS QUESTION PAPER CONSISTS OF 14 PAGES**

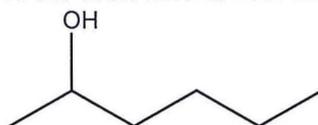
(Including this front page and attachments)

## QUESTION 1: Multiple Choice Questions

[50]

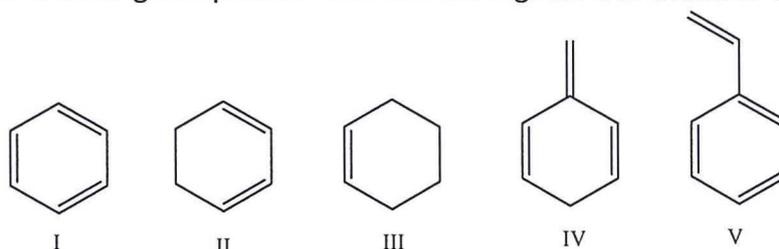
- There are 25 multiple choice questions and each question carries 2 marks.
- Answer ALL questions by selecting the letter of the correct answer.
- Choose the best possible answer for each question, even if you think there is another possible answer that is not given.

1.1 Which of the  $m/z$  values correspond to the molecular ion for the following compound?



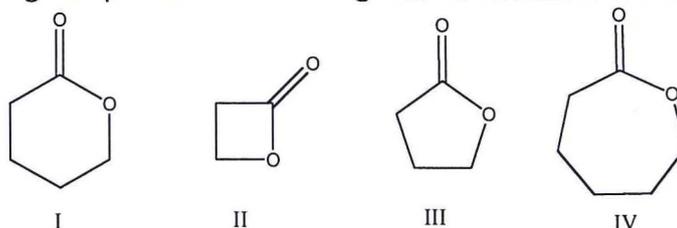
- A. 18
- B. 82
- C. 100
- D. 102
- E. 103

1.2 Which one of the following compounds will have the highest wavenumber for C=C absorption?



- A. I
- B. II
- C. III
- D. IV
- E. V

1.3 Which of the following compounds will have highest wavenumber for carbonyl absorption?



- A. I
- B. II
- C. III
- D. IV
- E. II and III

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

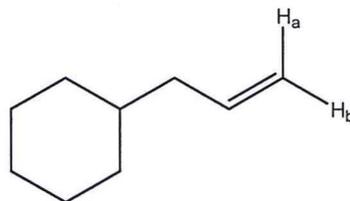
$M^{+\bullet}$  at  $m/z = 84$ , relative height=10.0%  
 $(M+1)^{+\bullet}$  at  $m/z = 85$ , relative height=0.56%

- A.  $C_5H_{10}O$
- B.  $C_5H_8O$
- C.  $C_5H_{24}$
- D.  $C_6H_{12}$
- E.  $C_4H_6O_2$

1.5 Which of the following is true about the relationship between the energy gap ( $\Delta E$ ) between the spin states for a  $^1H$  nucleus and the strength of the external magnetic field?

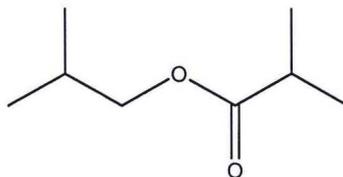
- A. They are inversely proportional
- B. They are directly proportional
- C. There is no relationship
- D. The magnetic field is slightly less
- E. None of the above

1.6 Protons  $H_a$  and  $H_b$  in the following compound are:



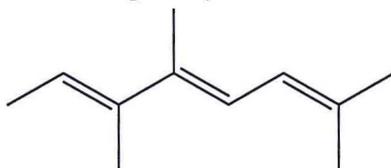
- A. homotopic
- B. Enantiotopic
- C. Diastereotopic
- D. mesotopic
- D. None of the above

1.7 How many signals would you expect to find in the  $^1H$  NMR spectrum of the compound below?



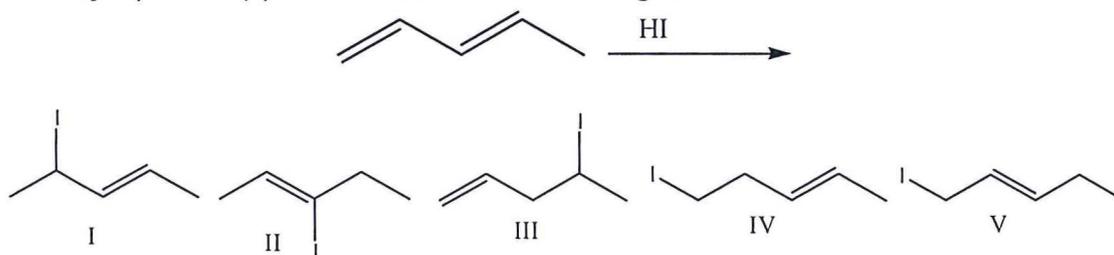
- A. 4
- B. 5
- C. 6
- D. 7
- E. 8

1.8 What is the IUPAC name for the following compound?



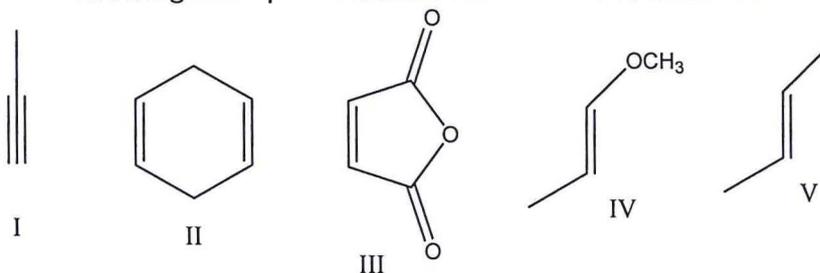
- A. (2E,4Z,6E)-3,4,7,8-tetramethyl-2,4,6-heptatriene
- B. (2Z,4E,)-3,4,7-trimethyl-2,4,6-octatriene
- C. (2E,4Z,6E)-2,5,6,7-tetramethyl-3,5,7-heptatriene
- D. (2E,4Z)-2,5,6-trimethyl-3,5,7-octatriene
- E. (2E,4E,6E)-2,5,6-trimethyl-2,4,6-octatriene

1.9 Which major product(s) are formed for the following reaction?



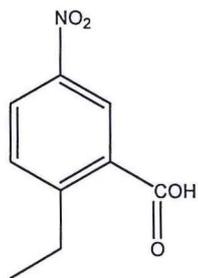
- A. I
- B. II
- C. III
- D. IV
- E. V

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



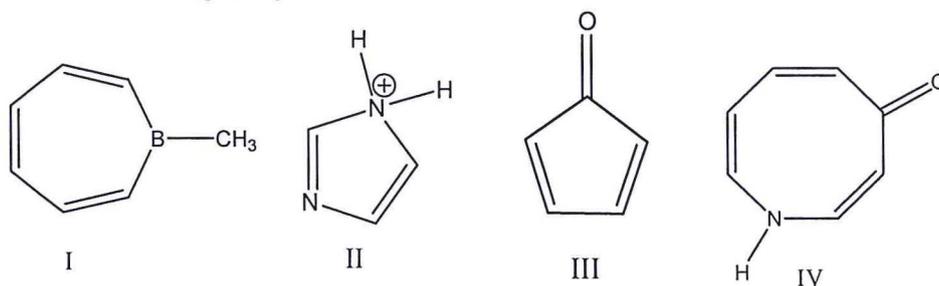
- A. I
- B. II
- C. III
- D. IV
- E. V

1.11 What is the IUPAC name for the following compound?



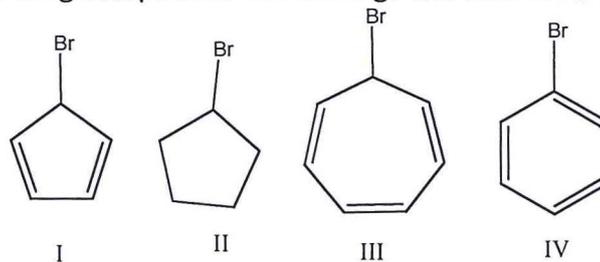
- A. 6-ethyl-3-nitrobenzoic acid
- B. 1-ethyl-4-nitrobenzoic acid
- C. 2-ethyl-5-nitrobenzoic acid
- D. 2-ethyl-5-nitrobenzaldehyde
- E. 4-nitro-3-carboxyethylbenzene

1.12 Which one of the following compounds is aromatic?



- A. I
- B. II
- C. III
- D. IV
- E. I and III

1.13 Which one of the following compounds will undergo the fastest  $S_N1$  reaction?



- A. I
- B. II
- C. III
- D. IV
- E. III and IV

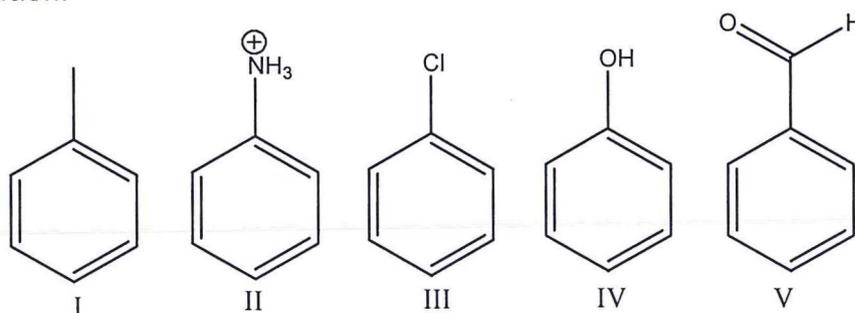
1.14 Which of these is the rate-determining step in the electrophilic aromatic substitution of benzene?

- A. Formation of an electrophile
- B. Formation of sigma complex.
- C. Loss of proton from sigma complex.
- D. Addition of electrophile & loss of proton
- E. None of the above

1.15 Predict the major product for the reaction between benzene and 2-chlorobutane in the presence of  $\text{AlCl}_3$ .

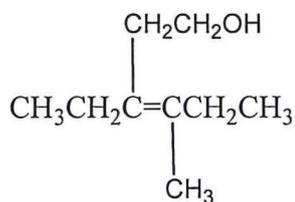
- A. Chlorobenzene
- B. sec-butylbenzene
- C. ethylbenzene
- D. isopropylbenzene
- E. tert-butylbenzene

1.16 Arrange the following compounds in order of decreasing reactivity towards electrophilic aromatic substitution.



- A.  $\text{V} > \text{II} > \text{I} > \text{III} > \text{IV}$
- B.  $\text{II} > \text{V} > \text{III} > \text{I} > \text{IV}$
- C.  $\text{IV} > \text{I} > \text{III} > \text{V} > \text{II}$
- D.  $\text{III} > \text{II} > \text{I} > \text{IV} > \text{V}$
- E.  $\text{IV} > \text{V} > \text{II} > \text{I} > \text{III}$

1.17 What is the IUPAC name for the following compound?



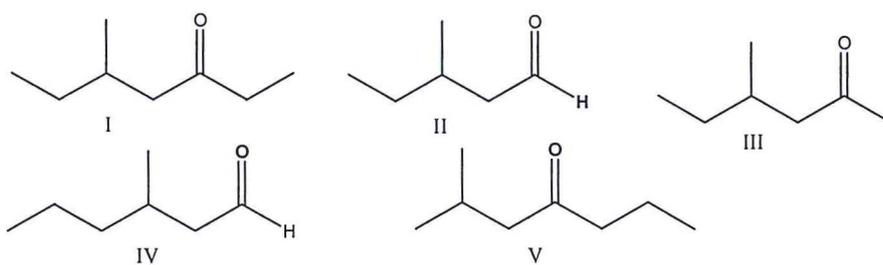
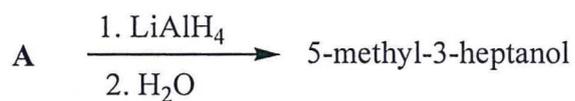
- A. 3-methyl-4-ethyl-3-hexen-6-ol
- B. 4-ethyl-3-methyl-3,6-hexenol
- C. 3-ethyl-4-methyl-3-hexen-1-ol
- D. 3-methyl-4-(2-hydroxyethyl)-3-hexene
- E. 3-(2-hydroxyethyl)-3-methyl-3-hexene

1.18 Provide the reagents necessary to carry out the following conversion.



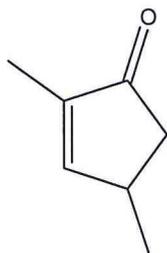
- A. NaOH/H<sub>2</sub>O
- B. 1. NaOCH<sub>3</sub>, 2. H<sub>3</sub>O<sup>+</sup>
- C. 1. (CH<sub>3</sub>)<sub>3</sub>COK, 2. BH<sub>3</sub>, 3. H<sub>2</sub>O<sub>2</sub>/NaOH/H<sub>2</sub>O
- D. 1. (CH<sub>3</sub>)<sub>3</sub>COK, 2. H<sub>3</sub>O<sup>+</sup>
- E. B and D are correct

1.19 Provide the reactant (A) for the following reaction.



- A. I
- B. II
- C. III
- D. IV
- E. V

1.20 What is the IUPAC name for the following compound?



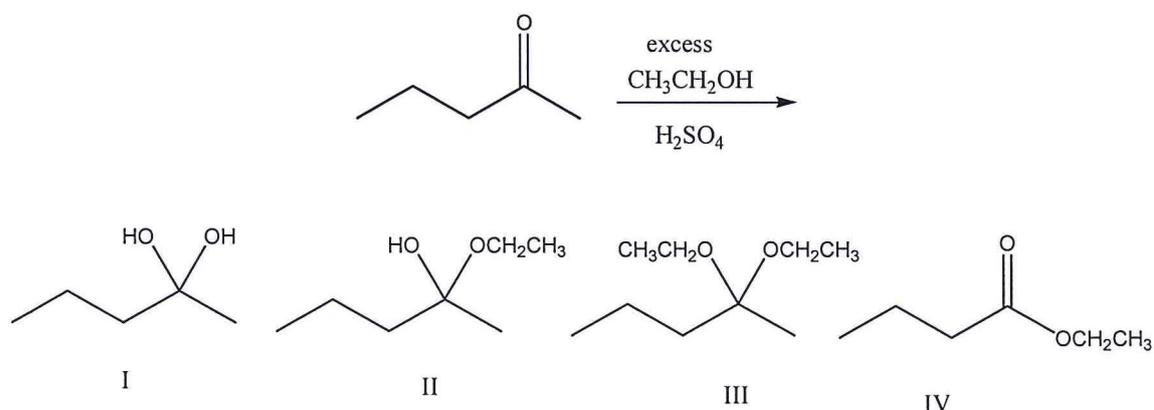
- A. 2,4-dimethyl-2-pentenone
- B. 2,5-dimethylcyclopent-3-one
- C. 2,4-dimethylcyclopent-2-enone
- D. 3,5-dimethylcyclopent-2-enone
- E. 2-methyl-5-methylcyclopent-2-enone

1.21 Compound A on ozonolysis yields acetophenone and propanal. What is the structure of compound A?



- A. 2-phenyl-2-pentene
- B. 1-phenyl-1-hexene
- C. 1-phenyl-2-pentene
- D. 2-phenyl-2-hexene
- E. None of the above

1.22 Predict the product for the following reaction.

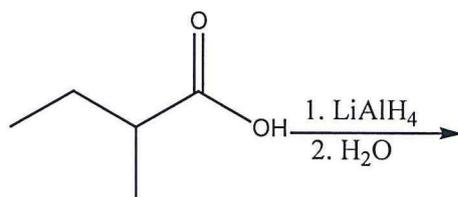


- A. I
- B. II
- C. III
- D. IV
- E. None of the above

1.23 Which one of the following is the strongest acid?

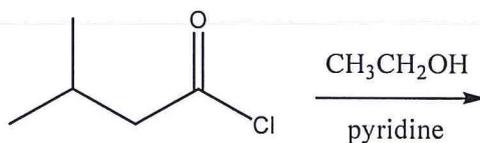
- A. benzoic acid
- B. 4-nitrobenzoic acid
- C. 4-ethylbenzoic acid
- D. 4-chlorobenzoic acid
- E. 4-hydroxybenzoic acid

1.24 Predict the product for the following reaction.



- A. 3-methyl-2-pentanone
- B. 3-methyl-1-propanol
- C. 2-methyl-1-butanol
- D. 3-methyl-2-pentanol
- E. None of the above

1.25 Predict the product for the following reaction.

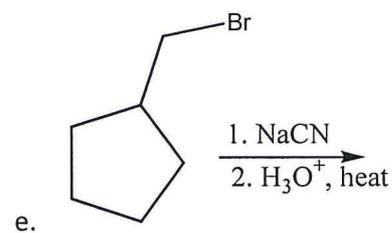
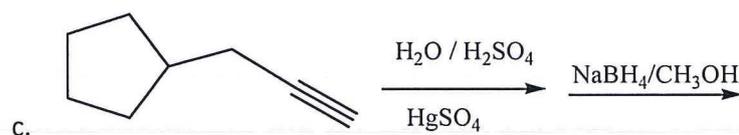
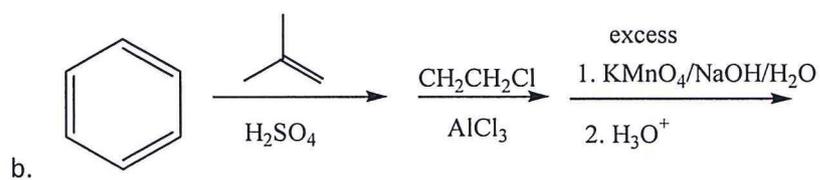
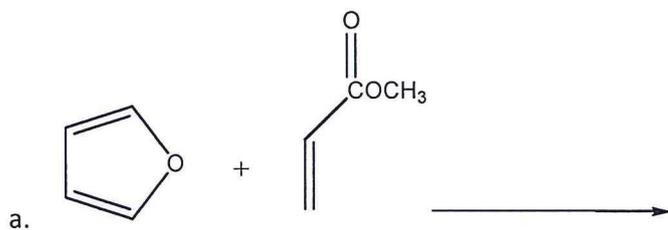


- A. ethyl-3-methylbutanoate
- B. ethyl-2-methylpropanoate
- C. isobutylethanoate
- D. 5-methyl-3-hexanone
- E. None of the above

## QUESTION 2

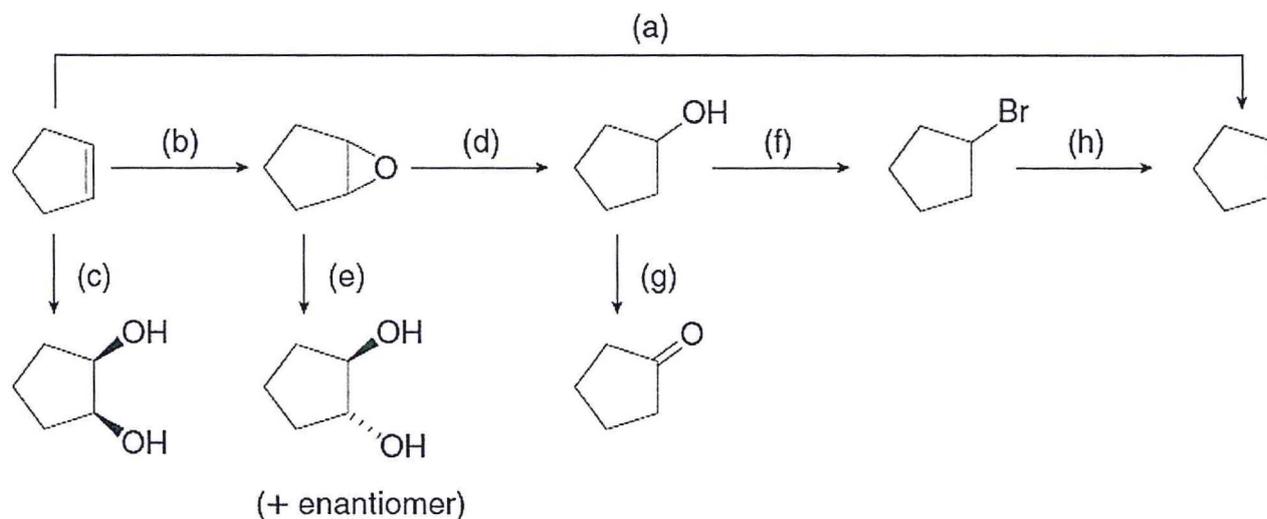
[10]

What is (are) the product(s) of the following reactions?

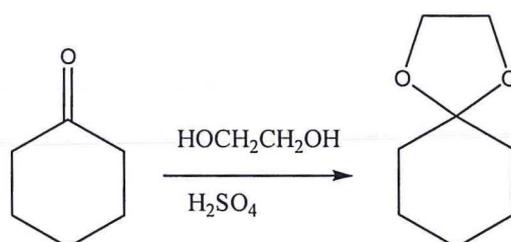
*Note: Each question carries 2 marks.*

**QUESTION 3****[16]**

Identify the reagents (a – h) needed to carry out each organic transformation.

**QUESTION 4****[14]**

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

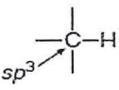
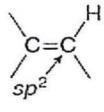
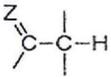
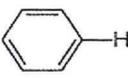
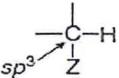
**QUESTION 5****[10]**

A compound with molecular formula  $\text{C}_9\text{H}_{10}\text{O}_2$  exhibits a triplet at  $\delta$  1.2 ( $I=3$ ), a quartet at  $\delta$  2.6 ( $I=2$ ), a doublet at  $\delta$  7.3 ( $I=2$ ), a doublet at  $\delta$  8.0 ( $I=2$ ) and a singlet at  $\delta$  11 ( $I=1$ ) in its  $^1\text{H}$ NMR spectrum. The IR spectrum shows a strong absorption band at  $3280\text{ cm}^{-1}$ . What is the structure for this compound?

**THE END****GOOD LUCK**

## $^1\text{H}$ NMR SPECTRAL DATA

### Characteristic Chemical Shifts of Common Types of Protons

| Type of proton   | Chemical shift (ppm) | Type of proton   | Chemical shift (ppm) |
|--|----------------------|--|----------------------|
|  <ul style="list-style-type: none"> <li>• <math>\text{RCH}_3</math>                      ~0.9</li> <li>• <math>\text{R}_2\text{CH}_2</math>                     ~1.3</li> <li>• <math>\text{R}_3\text{CH}</math>                        ~1.7</li> </ul> | 0.9–2                |  | 4.5–6                |
|  <p>Z = C, O, N</p>   | 1.5–2.5              |  | 6.5–8                |
| $\text{—C}\equiv\text{C—H}$  | ~2.5                 |  | 9–10                 |
|  <p>Z = N, O, X</p>   | 2.5–4                |  | 10–12                |
|  |                      | $\text{RO—H}$ or $\text{R—N—H}$  | 1–5                  |

### Important IR Absorptions

| Bond type  | Approximate $\bar{\nu}$ ( $\text{cm}^{-1}$ ) | Intensity     |
|--|--|---------------|
| O—H  | 3600–3200                                    | strong, broad |
| N—H  | 3500–3200                                    | medium        |
| C—H  | ~3000  |               |
| <ul style="list-style-type: none"> <li>• <math>\text{C}_{\text{sp}^3}\text{—H}</math>                      3000–2850                      strong</li> <li>• <math>\text{C}_{\text{sp}^2}\text{—H}</math>                      3150–3000                      medium</li> <li>• <math>\text{C}_{\text{sp}}\text{—H}</math>                        3300                              medium</li> </ul> |  |               |
| $\text{C}\equiv\text{C}$   | 2250   | medium        |
| $\text{C}\equiv\text{N}$   | 2250   | medium        |
| C=O  | 1800–1650 (often ~1700)                      | strong        |
| C=C  | 1650   | medium        |
|   | 1600, 1500                                   | medium        |

# pKa Chart

| <u>conjugate acid</u>                       | <u>conjugate base</u>                           |
|---|---|
| sulfuric acid $\text{H}_2\text{SO}_4$       | $\text{HSO}_4^-$                                |
| hydroiodic acid $\text{HI}$                 | $\text{I}^-$                                    |
| hydrobromic acid $\text{HBr}$               | $\text{Br}^-$                                   |
| hydrochloric acid $\text{HCl}$              | $\text{Cl}^-$                                   |
| carbocations                                | $\text{alkene}$                                 |
| protonated alcohol                          | $\text{alcohol}$                                |
| hydronium ion $\text{H}_3\text{O}^+$        | $\text{H}_2\text{O}$                            |
| nitric acid $\text{HNO}_3$                  | $\text{NO}_3^-$                                 |
| hydrofluoric acid $\text{HF}$               | $\text{F}^-$                                    |
| carboxylic acids                            | $\text{carboxylate anions}$                     |
| hydrogen cyanide $\text{H-C}\equiv\text{N}$ | $\text{:C}\equiv\text{N:}$<br>(cyanide)         |
| phenols                                     | $\text{phenoxide}$                              |
| water $\text{H-O-H}$                        | $\text{OH}^-$                                   |
| primary alcohols                            | $\text{alkoxide}$<br>(hydroxide)                |
| alkynes $\text{C}\equiv\text{C-H}$          | $\text{C}\equiv\text{C:}$<br>(acetylide anions) |
| hydrogen $\text{H-H}$                       | $\text{:H}^-$ (hydride)                         |
| ammonia/amines $\text{R-N(H)}_3$            | $\text{R-N}^-\text{(H)}_2$<br>(amide bases)     |
| alkanes                                     | $\text{alkyl anions}$                           |

-10

-9

-8

-7

-3

-2.4

-1.7

-1.3

3.2

4.8

9.1

10

15.7

16

26

35

36

~60

|                                       |  |                                     |
|---------------------------------------|--|-------------------------------------|
| hydrogen<br>1<br><b>H</b><br>1.0079   | beryllium<br>4<br><b>Be</b><br>9.0122      | helium<br>2<br><b>He</b><br>4.0026  |
| lithium<br>3<br><b>Li</b><br>6.941    | magnesium<br>12<br><b>Mg</b><br>24.305     | neon<br>10<br><b>Ne</b><br>20.180   |
| sodium<br>11<br><b>Na</b><br>22.990   | calcium<br>20<br><b>Ca</b><br>40.078       | argon<br>18<br><b>Ar</b><br>39.948  |
| potassium<br>19<br><b>K</b><br>39.098 | scandium<br>21<br><b>Sc</b><br>44.956      | krypton<br>36<br><b>Kr</b><br>83.80 |
| rubidium<br>37<br><b>Rb</b><br>85.468 | titanium<br>22<br><b>Ti</b><br>47.867      | xenon<br>54<br><b>Xe</b><br>131.29  |
| cesium<br>55<br><b>Cs</b><br>132.91   | vanadium<br>23<br><b>V</b><br>50.942       | radon<br>86<br><b>Rn</b><br>[222]   |
| barium<br>56<br><b>Ba</b><br>137.33   | chromium<br>24<br><b>Cr</b><br>51.996      |                                     |
| radium<br>88<br><b>Ra</b><br>[226]    | manganese<br>25<br><b>Mn</b><br>54.938     |                                     |
|                                       | iron<br>26<br><b>Fe</b><br>55.845          |                                     |
|                                       | cobalt<br>27<br><b>Co</b><br>58.933        |                                     |
|                                       | nickel<br>28<br><b>Ni</b><br>58.693        |                                     |
|                                       | copper<br>29<br><b>Cu</b><br>63.546        |                                     |
|                                       | zinc<br>30<br><b>Zn</b><br>65.39           |                                     |
|                                       | gallium<br>31<br><b>Ga</b><br>69.723       |                                     |
|                                       | germanium<br>32<br><b>Ge</b><br>72.61      |                                     |
|                                       | arsenic<br>33<br><b>As</b><br>74.922       |                                     |
|                                       | selenium<br>34<br><b>Se</b><br>78.96       |                                     |
|                                       | cadmium<br>48<br><b>Cd</b><br>112.41       |                                     |
|                                       | silver<br>47<br><b>Ag</b><br>107.87        |                                     |
|                                       | mercury<br>80<br><b>Hg</b><br>200.59       |                                     |
|                                       | gold<br>79<br><b>Au</b><br>196.97          |                                     |
|                                       | platinum<br>78<br><b>Pt</b><br>195.08      |                                     |
|                                       | unnilium<br>110<br><b>Uun</b><br>[271]     |                                     |
|                                       | unnilquadium<br>112<br><b>Uun</b><br>[272] |                                     |
|                                       | unnilseptium<br>111<br><b>Uun</b><br>[273] |                                     |
|                                       | ununquadium<br>114<br><b>Uuq</b><br>[289]  |                                     |
|                                       | indium<br>49<br><b>In</b><br>114.82        |                                     |
|                                       | tin<br>50<br><b>Sn</b><br>118.71           |                                     |
|                                       | antimony<br>51<br><b>Sb</b><br>121.76      |                                     |
|                                       | tellurium<br>52<br><b>Te</b><br>127.60     |                                     |
|                                       | bismuth<br>83<br><b>Bi</b><br>208.98       |                                     |
|                                       | lead<br>82<br><b>Pb</b><br>207.2           |                                     |
|                                       | polonium<br>84<br><b>Po</b><br>[209]       |                                     |
|                                       | astatine<br>85<br><b>At</b><br>[210]       |                                     |
|                                       | iodine<br>53<br><b>I</b><br>126.90         |                                     |
|                                       | fluorine<br>9<br><b>F</b><br>18.998        |                                     |
|                                       | oxygen<br>8<br><b>O</b><br>15.999          |                                     |
|                                       | nitrogen<br>7<br><b>N</b><br>14.007        |                                     |
|                                       | phosphorus<br>15<br><b>P</b><br>30.974     |                                     |
|                                       | sulfur<br>16<br><b>S</b><br>32.065         |                                     |
|                                       | chlorine<br>17<br><b>Cl</b><br>35.453      |                                     |

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

\* Lanthanide series

\*\* Actinide series