

Characteristic Infrared Absorptions of Some Functional Groups

<i>Functional group class</i>	<i>Band position (cm⁻¹)</i>	<i>Intensity</i>
Alkanes, alkyl groups C-H	2850 – 2960	Medium to strong
Alkenes =C-H	3020 – 3100	Medium
C=C	1650 – 1670	Medium
Alkynes ≡C-H	3300	Strong
-C≡C-	2100 – 2260	Medium
Alkyl halides C-Cl	600 – 800	Strong
C-Br	500 – 600	Strong
C-I	500	Strong
Alcohols O-H	3400 – 3640	Strong, broad
C-O	1050 – 1150	Strong
Aromatics Ar-H	3030	Medium
C ₆ ring	1600, 1500	Strong
Amines N-H	3310 – 3500	Medium
C-N	1030, 1230	Medium
Carbonyl compounds C=O	1670 – 1780	Strong
Carboxylic acids O-H	2500 – 3100	Strong, very broad
Nitriles C≡N	2210 – 2260	Medium
Nitro compounds NO ₂	1540	Strong

Correlation of ^1H Chemical Shift with Environment

<i>Type of Proton</i>	<i>Formula</i>	<i>Chemical Shift (δ)</i>
Reference Peak	$(\text{CH}_3)_4\text{Si}$	0
Saturated primary	$-\text{CH}_3$	0.7-1.3
Saturated secondary	$-\text{CH}_2-$	1.2-1.4
Saturated tertiary	$\text{R}_3-\text{C}-\text{H}$	1.4-1.7
Allylic primary	$\text{R}_2\text{C}=\text{CR}-\text{CH}_3$	1.6-1.9
Methyl ketones	$-\text{C}(=\text{O})-\text{CH}_3$	2.1-2.4
Aromatic methyl	$\text{Ar}-\text{CH}_3$	2.5-2.7
Alkyl chloride	$\text{Cl}-\text{CR}_2-\text{H}$	3.0-4.0
Alkyl bromide	$\text{Br}-\text{CR}_2-\text{H}$	2.5-4.0
Alkyl iodide	$\text{I}-\text{CR}_2-\text{H}$	2.0-4.0
Alcohol, ether	$-\text{O}-\text{CR}_2-\text{H}$	3.3-4.0
Alkynyl	$-\text{C}\equiv\text{C}-\text{H}$	2.5-2.7
Vinylic	$\text{R}_2\text{C}=\text{CR}-\text{H}$	5.0-6.5
Aromatic	$\text{Ar}-\text{H}$	6.5-9.0
Aldehyde	$-\text{C}(=\text{O})-\text{H}$	8.0-12.0
Carboxylic acid	$-\text{C}(=\text{O})-\text{O}-\text{H}$	11.0-15.0
Alcohol	$\text{R}_3-\text{O}-\text{H}$	Extremely variable (2.5-6.0)

PHYSICAL CONSTANTS

1 atm = 760 mm Hg = 760 Torr = 101.3 kPa
R = 8.314 J·K⁻¹·mol⁻¹ or 0.08206 L·atm·K⁻¹·mol⁻¹
h = 6.626 x 10⁻³⁴ J·s
N = 6.023 x 10²³ mol⁻¹
e = 1.6021 x 10⁻¹⁹ coulomb
F = 96,485 C·mol⁻¹ or 96,485 J·V⁻¹·mol⁻¹
c = 3.00 x 10⁸ m·s⁻¹

ACID-BASE INDICATORS AT 25°C

pH Range	pK _{in}	Acid	Base	Indicator
1.2 - 2.8	1.6	red	yel	Thymol blue
2.9 - 4.0	3.3	red	yel	Methyl yellow
3.1 - 4.4	4.2	red	yel	Methyl orange
3.8 - 5.4	4.7	yel	blu	Bromocresol green
4.2 - 6.2	5.0	red	yel	Methyl red
4.8 - 6.4	6.0	yel	red	Chlorophenol red
6.0 - 7.6	7.1	yel	blu	Bromothymol blue
6.4 - 7.6	7.4	yel	red	Phenol red
7.4 - 9.0	8.3	yel	pur	Cresol purple
8.0 - 9.6	8.9	yel	blu	Thymol blue
8.0 - 9.8	9.7	-	red	Phenolphthalein
9.3 - 10.5	9.9	-	blu	Thymolphthalein

SOLUBILITY PRODUCT CONSTANTS (K_{sp})

AgBr	8 x 10 ⁻¹³	Cu(OH) ₂	2 x 10 ⁻²⁰
Ag ₂ CO ₃	6 x 10 ⁻¹²	CuS	1 x 10 ⁻³⁶
AgCl	1 x 10 ⁻¹⁰	Fe(OH) ₃	1 x 10 ⁻³⁶
Ag ₂ CrO ₄	2 x 10 ⁻¹²	Hg ₂ Br ₂	3 x 10 ⁻²³
Ag[Ag(CN) ₂]	4 x 10 ⁻¹²	Hg ₂ Cl ₂	6 x 10 ⁻¹⁹
AgI	1 x 10 ⁻¹⁶	HgS	1 x 10 ⁻⁵²
Ag ₃ PO ₄	1 x 10 ⁻¹⁹	KClO ₄	2 x 10 ⁻²
Ag ₂ S	1 x 10 ⁻⁵⁰	MgCO ₃	1 x 10 ⁻⁵
AgCNS	1 x 10 ⁻¹²	MgC ₂ O ₄	9 x 10 ⁻⁵
Al(OH) ₃	2 x 10 ⁻³²	MgNH ₄ PO ₄	2 x 10 ⁻¹³
BaCO ₃	5 x 10 ⁻⁹	Mg(OH) ₂	1 x 10 ⁻¹¹
BaCrO ₄	1 x 10 ⁻¹⁰	MnS	1 x 10 ⁻¹⁵
BaC ₂ O ₄	2 x 10 ⁻⁸	PbCrO ₄	2 x 10 ⁻¹⁴
BaSO ₄	1 x 10 ⁻¹⁰	PbS	1 x 10 ⁻²⁸
CaS	1 x 10 ⁻²⁸	PbSO ₄	2 x 10 ⁻⁸
CaCO ₃	5 x 10 ⁻⁹	SrCrO ₄	4 x 10 ⁻⁵
CaF ₂	4 x 10 ⁻¹¹	Zn(OH) ₂	5 x 10 ⁻¹⁸
CaC ₂ O ₄	2 x 10 ⁻⁹	ZnS	1 x 10 ⁻²⁴

ELECTRODE POTENTIALS (E°)

Al ³⁺ + 3e → Al	-1.66	Cu ⁺ + e → Cu	0.52
Zn ²⁺ + 2e → Zn	-0.76	2HgCl ₂ + 2e → Hg ₂ Cl ₂ + 2Cl ⁻	0.63
Fe ²⁺ + 2e → Fe	-0.44	O ₂ + 2H ⁺ + 2e → H ₂ O ₂	0.68
Cd ²⁺ + 2e → Cd	-0.40	Fe ³⁺ + e → Fe ²⁺	0.77
Sn ²⁺ + 2e → Sn	-0.14	Hg ₂ ²⁺ + 2e → 2Hg	0.79
Pb ²⁺ + 2e → Pb	-0.13	Ag ⁺ + e → Ag	0.80
2H ⁺ + 2e → H ₂	0.00	Hg ⁺ + e → Hg	0.86
Sn ⁴⁺ + e → Sn ²⁺	0.15	2Hg ²⁺ + 2e → Hg ₂ ²⁺	0.91
Cu ²⁺ + e → Cu ⁺	0.15	O ₂ + 4H ⁺ + 4e → 2H ₂ O	1.23
AgCl + e → Cl ⁻ + Ag	0.22	Cl ₂ + 2e → 2Cl ⁻	1.36
Cu ²⁺ + 2e → Cu	0.34	MnO ₄ ⁻ + 8H ⁺ + 5e → 4H ₂ O + Mn ²⁺	1.50

WATER VAPOUR PRESSURE (mm)

0°C	4.6	25°	23.8
15°	12.8	30°	31.8
20°	17.5	50°	92.5

AVERAGE BOND ENERGIES (kJ/mol)

C-H	413	C-C	348	C-N	293	C-O	358
C-F	485	C-Cl	328	C-Br	276	C=C	614
C=O	799	C=N	615	C≡C	839	C≡N	891
H-H	436	H-F	567	H-Cl	431	H-O	463
N-H	391	N-N	163	N=N	418	N≡N	941

ΔH° AND ΔG° OF FORMATION (kJ/mol)

Compound	ΔH _f ^o	ΔG _f ^o
H _(g)	217.9	203.4
F _(g)	80.0	61.9
Cl _(g)	121.7	105.7
O _(g)	247.5	230.1
HF _(g)	-269	-271
HCl _(g)	-92.3	-95.3
HBr _(g)	-36.2	-53.2
HI _(g)	25.9	1.30
H ₂ O _(g)	-241.8	-228.6
H ₂ O _(l)	-285.9	-236.8
CO _(g)	-110.5	-137.2
CO _{2(g)}	-393.5	-394.4
SO _{2(g)}	-296.9	-300.4
SO _{3(g)}	-395.2	-370.4
NO _(g)	90.4	86.7
NO _{2(g)}	33.8	51.8
N ₂ O _{4(g)}	9.66	98.28
NH _{3(g)}	-46.2	-16.7
PCl _{3(g)}	-288.1	-269.5
PCl _{5(g)}	-377.2	-306.9
CH _{4(g)}	-74.8	-50.8
CH ₃ OH _(l)	-238.6	-166.2
C ₂ H ₅ OH _(l)	-277.7	-174.8
C ₆ H _{6(l)}	49.0	124.5

IONIZATION CONSTANTS - BASES (K_b)

Acetate ion	5.3 x 10 ⁻¹⁰	Methylamine	4.4 x 10 ⁻⁴
Aminopyridine	5.0 x 10 ⁻⁸	Phosphate ion	2.5 x 10 ⁻²
Ammonia	1.8 x 10 ⁻⁵	Pyridine	1.7 x 10 ⁻⁹
Aniline	4.3 x 10 ⁻¹⁰	Triethylamine	6.4 x 10 ⁻⁵
Hydrazine	1.3 x 10 ⁻⁶	Urea	1.5 x 10 ⁻¹⁴
Hydroxylamine	1.1 x 10 ⁻⁸	Dimethylamine	6.4 x 10 ⁻⁴

IONIZATION CONSTANTS - ACIDS (K_a)

Acetic	1.8 x 10 ⁻⁵	H ₂ S	K ₁	9 x 10 ⁻⁸	
Arsenic	K ₁	5.6 x 10 ⁻³	K ₂	1 x 10 ⁻¹⁵	
Benzoic	6.5 x 10 ⁻⁵	Oxalic	K ₁	5.9 x 10 ⁻²	
Boric	K ₁	5.8 x 10 ⁻¹⁰	K ₂	6.4 x 10 ⁻⁵	
Carbonic	K ₁	4.3 x 10 ⁻⁷	Phenol	1.3 x 10 ⁻¹⁰	
	K ₂	5.6 x 10 ⁻¹¹	Phosphoric	K ₁	7.5 x 10 ⁻³
Chromic	K ₂	1 x 10 ⁻⁷	K ₂	6.2 x 10 ⁻⁸	
Citric	K ₁	3.5 x 10 ⁻⁴	K ₃	4.2 x 10 ⁻¹³	
	K ₂	1.7 x 10 ⁻⁵	Succinic	K ₁	7 x 10 ⁻⁵
	K ₃	4.0 x 10 ⁻⁶	K ₂	2.5 x 10 ⁻⁶	
Formic	1.8 x 10 ⁻⁴	Sulfuric	K ₂	1.2 x 10 ⁻²	
Hydrocyanic	4.9 x 10 ⁻¹⁰	Sulfurous	K ₁	1.7 x 10 ⁻²	
Hydrofluoric	6.8 x 10 ⁻⁴		K ₂	6.4 x 10 ⁻⁸	
CHCl ₂ COOH	5 x 10 ⁻²	CCl ₃ COOH		2 x 10 ⁻¹	

PERIODIC TABLE OF THE ELEMENTS

		1 H 1.008																2 He 4.003
1A	2A											3A	4A	5A	6A	7A		
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18	
11 Na 22.99	12 Mg 24.31	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	13 Al 26.98	14 Si 30.97	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95	
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80	
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98.9)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3	
55 Cs 132.9	56 Ba 137.3	57-71 La series	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)	
87 Fr (223)	88 Ra (226)	89-103 Ac series	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)										

57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
89 Ac (227)	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (239)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (252)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)