
Appendices

1 APPENDIX 1

Tables of Unknowns and Derivatives

More extensive tables of unknowns may be found in Z. Rappoport, ed. *Handbook of Tables for Organic Compound Identification*, 3rd ed. CRC Press: Boca Raton FL, 1967.

ALDEHYDES

Compound	BP	MP	Semi-carbazone*	2,4-Dinitrophenyl-hydrazone*
Ethanal (acetaldehyde)	21	—	162	168
Propanal (propionaldehyde)	48	—	89	148
Propenal (acrolein)	52	—	171	165
2-Methylpropanal (isobutyraldehyde)	64	—	125	187
Butanal (butyraldehyde)	75	—	95	123
3-Methylbutanal (isovaleraldehyde)	92	—	107	123
Pentanal (valeraldehyde)	102	—	—	106
2-Butenal (crotonaldehyde)	104	—	199	190
2-Ethylbutanal (diethylacetaldehyde)	117	—	99	95
Hexanal (caproaldehyde)	130	—	106	104
Heptanal (heptaldehyde)	153	—	109	108
2-Furaldehyde (furfural)	162	—	202	212
2-Ethylhexanal	163	—	254	114
Octanal (caprylaldehyde)	171	—	101	106
Benzaldehyde	179	—	222	237
Nonanal (nonyl aldehyde)	185	—	100	100
Phenylethanal (phenylacetaldehyde)	195	33	153	121
2-Hydroxybenzaldehyde (salicylaldehyde)	197	—	231	248
4-Methylbenzaldehyde (<i>p</i> -tolualdehyde)	204	—	234	234
3,7-Dimethyl-6-octenal (citronellal)	207	—	82	77
Decanal (decyl aldehyde)	207	—	102	104
2-Chlorobenzaldehyde	213	11	229	213
3-Chlorobenzaldehyde	214	18	228	248
3-Methoxybenzaldehyde (<i>m</i> -anisaldehyde)	230	—	233 d.	—
3-Bromobenzaldehyde	235	—	205	—
4-Methoxybenzaldehyde (<i>p</i> -anisaldehyde)	248	2.5	210	253
<i>trans</i> -Cinnamaldehyde	250 d.	—	215	255
3,4-Methylenedioxybenzaldehyde (piperonal)	263	37	230	266 d.
2-Methoxybenzaldehyde (<i>o</i> -anisaldehyde)	245	38	215 d.	254
3,4-Dimethoxybenzaldehyde	—	44	177	261
2-Nitrobenzaldehyde	—	44	256	265
4-Chlorobenzaldehyde	—	48	230	254
4-Bromobenzaldehyde	—	57	228	257
3-Nitrobenzaldehyde	—	58	246	293

ALDEHYDES (Cont.)

Compound	BP	MP	Semi-carbazone*	2,4-Dinitro-phenyl-hydrazone*
2,4-Dimethoxybenzaldehyde	—	71	—	—
2,4-Dichlorobenzaldehyde	—	72	—	—
4-Dimethylaminobenzaldehyde	—	74	222	325
4-Hydroxy-3-methoxybenzaldehyde (vanillin)	—	82	230	271
3-Hydroxybenzaldehyde	—	104	198	259
5-Bromo-2-hydroxybenzaldehyde (5-bromosalicylaldehyde)	—	106	297 d.	—
4-Nitrobenzaldehyde	—	106	221	320 d.
4-Hydroxybenzaldehyde	—	116	224	280 d.
(±)-Glyceraldehyde	—	142	160 d.	167

Note: "d" indicates "decomposition."

*See Appendix 2, "Procedures for Preparing Derivatives."

KETONES

Compound	BP	MP	Semi-carbazone*	2,4-Dinitro-phenyl-hydrazone*
2-Propanone (acetone)	56	—	187	126
2-Butanone (methyl ethyl ketone)	80	—	146	117
3-Buten-2-one (methyl vinyl ketone)	81	—	140	—
3-Methyl-2-butanone (isopropyl methyl ketone)	94	—	112	120
2-Pentanone (methyl propyl ketone)	102	—	112	143
3-Pentanone (diethyl ketone)	102	—	138	156
3,3-Dimethyl-2-butanone (pinacolone)	106	—	157	125
4-Methyl-2-pentanone (isobutyl methyl ketone)	117	—	132	95
2,4-Dimethyl-3-pentanone (diisopropyl ketone)	124	—	160	86
3-Hexanone	125	—	113	130
2-Hexanone (methyl butyl ketone)	128	—	121	106
4-Methyl-3-penten-2-one (mesityl oxide)	130	—	164	200
Cyclopentanone	131	—	210	146
5-Hexen-2-one	131	—	102	108
2,3-Pentanedione	134	—	122 (mono) 209 (di)	209
5-Methyl-3-hexanone	136	—	—	—
2,4-Pentanedione (acetylacetone)	139	—	122 (mono)	209

KETONES (Cont.)

Compound	BP	MP	Semi-carbazone*	2,4-Dinitro-phenyl-hydrazone*
			209 (di)	
4-Heptanone (dipropyl ketone)	144	—	132	75
5-Methyl-2-hexanone	145	—	—	—
1-Hydroxy-2-propanone (hydroxyacetone, acetol)	146	—	196	129
3-Heptanone	148	—	101	—
2-Heptanone (methyl amyl ketone)	151	—	123	89
Cyclohexanone	156	—	166	162
2-Methylcyclohexanone	165	—	191	136
3-Octanone	167	—	—	—
2,6-Dimethyl-4-heptanone (diisobutyl ketone)	168	—	122	66
2-Octanone	173	—	122	92
Cycloheptanone	181	—	163	148
Ethyl acetoacetate	181	—	129 d.	93
5-Nonanone	186	—	90	—
3-Nonanone	187	—	112	—
2,5-Hexanedione (acetylacetone)	191	-9	185 (mono) 224 (di)	257 (di)
2-Nonanone	195	-8	118	—
Acetophenone (methyl phenyl ketone)	202	20	198	238
2-Hydroxyacetophenone	215	28	210	212
1-Phenyl-2-propanone (phenylacetone)	216	27	198	156
Propiophenone (1-phenyl-1-propanone)	218	21	173	191
Isobutyrophenone (2-methyl-1-phenyl-1-propanone)	222	—	181	163
1-Phenyl-2-butanone	226	—	135	—
4-Methylacetophenone	226	28	205	258
3-Chloroacetophenone	228	—	232	—
2-Chloroacetophenone	229	—	160	—
Butyrophenone (1-phenyl-1-butanone)	230	12	187	190
2-Undecanone	231	12	122	63
4-Chloroacetophenone	232	12	204	231
4-Phenyl-2-butanone (benzylacetone)	235	—	142	127
2-Methoxyacetophenone	239	—	183	—
3-Methoxyacetophenone	240	—	196	—
Valerophenone (1-phenyl-1-pentanone)	248	—	160	166
4-Chloropropiophenone	—	36	176	—
4-Phenyl-3-buten-2-one (benzalacetone)	—	37	187	227
4-Methoxyacetophenone	—	38	198	220
3-Bromopropiophenone	—	40	183	—
1-Indanone	—	41	233	258

KETONES (Cont.)

Compound	BP	MP	Semi-carbazone*	2,4-Dinitro-phenyl-hydrazone*
Benzophenone	—	48	164	238
4-Bromoacetophenone	—	51	208	230
3,4-Dimethoxyacetophenone	—	51	218	207
2-Acetonaphthone (methyl 2-naphthyl ketone)	—	53	234	262 d.
Desoxybenzoin (benzyl phenyl ketone)	—	60	148	204
1,1-Diphenylacetone	—	61	170	—
4-Chlorobenzophenone	—	76	—	185
3-Nitroacetophenone	—	80	257	228
4-Nitroacetophenone	—	80	—	—
4-Bromobenzophenone	—	82	350	230
Fluorenone	—	83	—	283
4-Hydroxyacetophenone	—	109	199	210
Benzoin	—	136	206	245
4-Hydroxypropiophenone	—	148	—	229
(±)-Camphor	—	179	237	164

Note: "d" indicates "decomposition."

*See Appendix 2, "Procedures for Preparing Derivatives."

CARBOXYLIC ACIDS

Compound	BP	MP	<i>p</i> -Toluidide*	Anilide*	Amide*
Methanoic acid (formic acid)	101	8	53	47	43
Ethanoic acid (acetic acid)	118	17	148	114	82
Propenoic acid (acrylic acid)	139	13	141	104	85
Propanoic acid (propionic acid)	141	—	124	103	81
2-Methylpropanoic acid (isobutyric acid)	154	—	104	105	128
Butanoic acid (butyric acid)	162	—	72	95	115
3-Butenoic acid (vinylacetic acid)	163	—	—	58	73
2-Methylpropenoic acid (methacrylic acid)	163	16	—	87	102
Pyruvic acid	165 d.	14	109	104	124
3-Methylbutanoic acid (isovaleric acid)	176	—	106	109	135
3,3-Dimethylbutanoic acid	185	—	134	132	132
Pentanoic acid (valeric acid)	186	—	74	63	106
2-Chloropropanoic acid	186	—	124	92	80

CARBOXYLIC ACIDS (Cont.)

Compound	BP	MP	<i>p</i> -Toluidide*	Anilide*	Amide*
Dichloroacetic acid	194	6	153	118	98
2-Methylpentanoic acid	195	—	80	95	79
Hexanoic acid (caproic acid)	205	—	75	95	101
2-Bromopropanoic acid	205 d.	24	125	99	123
Heptanoic acid	223	—	81	70	96
2-Ethylhexanoic acid	228	—	—	—	102
Cyclohexanecarboxylic acid	233	31	—	146	186
Octanoic acid (caprylic acid)	237	16	70	57	107
Nonanoic acid	254	12	84	57	99
Decanoic acid (capric acid)	—	32	78	70	108
4-Oxopentanoic acid (levulinic acid)	—	33	108	102	108 d.
Trimethylacetic acid (pivalic acid)	—	35	120	130	155
3-Chloropropanoic acid	—	40	—	—	101
Dodecanoic acid (lauric acid)	—	43	87	78	100
3-Phenylpropanoic acid (hydrocinnamic acid)	—	48	135	98	105
Bromoacetic acid	—	50	—	131	91
4-Phenylbutanoic acid	—	52	—	—	84
Tetradecanoic acid (myristic acid)	—	54	93	84	103
Trichloroacetic acid	—	57	113	97	141
3-Bromopropanoic acid	—	61	—	—	111
Hexadecanoic acid (palmitic acid)	—	62	98	90	106
Chloroacetic acid	—	63	162	137	121
Cyanoacetic acid	—	66	—	198	120
Octadecanoic acid (stearic acid)	—	69	102	95	109
<i>trans</i> -2-Butenoic acid (crotonic acid)	—	72	132	118	158
Phenylacetic acid	—	77	136	118	156
α -Methyl- <i>trans</i> -cinnamic acid	—	81	—	—	128
4-Methoxyphenylacetic acid	—	87	—	—	189
3,4-Dimethoxyphenyl acetic acid	—	97	—	—	147
Pentanedioic acid (glutaric acid)	—	98	218 (di)	224 (di)	176 (di)
Phenoxyacetic acid	—	99	—	99	102
2-Methoxybenzoic acid (<i>o</i> -anisic acid)	—	100	—	131	129
2-Methylbenzoic acid (<i>o</i> -toluic acid)	—	104	144	125	142
Nonanedioic acid (azelaic acid)	—	106	201 (di)	107 (mono) 186 (di)	93 (mono) 175 (di)
3-Methoxybenzoic acid (<i>m</i> -anisic acid)	—	107	—	—	136
3-Methylbenzoic acid (<i>m</i> -toluic acid)	—	111	118	126	94
4-Bromophenylacetic acid	—	117	—	—	194
(\pm)-Phenylhydroxyacetic acid (mandelic acid)	—	118	172	151	133
Benzoic acid	—	122	158	163	130
2,4-Dimethylbenzoic acid	—	126	—	141	180
2-Benzoylbenzoic acid	—	127	—	195	165

CARBOXYLIC ACIDS (Cont.)

Compound	BP	MP	<i>p</i> -Toluidide*	Anilide*	Amide*
Maleic acid	—	130	142 (di)	198 (mono) 187 (di)	172 (mono) 260 (di)
Decanedioic acid (sebacic acid)	—	133	201 (di)	122 (mono) 200 (di)	170 (mono) 210 (di)
3-Chlorocinnamic acid	—	133	142	135	76
2-Furoic acid	—	133	170	124	143
<i>trans</i> -Cinnamic acid	—	133	168	153	147
2-Acetylsalicylic acid (aspirin)	—	138	—	136	138
5-Chloro-2-nitrobenzoic acid	—	139	—	164	154
2-Chlorobenzoic acid	—	140	131	118	139
3-Nitrobenzoic acid	—	140	162	155	143
4-Chloro-2-nitrobenzoic acid	—	142	—	—	172
2-Nitrobenzoic acid	—	146	—	155	176
2-Aminobenzoic acid (anthranilic acid)	—	146	151	131	109
Diphenylacetic acid	—	148	172	180	167
2-Bromobenzoic acid	—	150	—	141	155
Benzilic acid	—	150	190	175	154
Hexanedioic acid (adipic acid)	—	152	239	151 (mono) 241 (di)	125 (mono) 220 (di)
Citric acid	—	153	189 (tri)	198 (tri)	210 (tri)
4-Nitrophenylacetic acid	—	153	—	198	198
2,5-Dichlorobenzoic acid	—	153	—	—	155
3-Chlorobenzoic acid	—	156	—	123	134
2,4-Dichlorobenzoic acid	—	158	—	—	194
4-Chlorophenoxyacetic acid	—	158	—	125	133
2-Hydroxybenzoic acid (salicylic acid)	—	158	156	136	142
5-Bromo-2-hydroxybenzoic acid (5-bromosalicylic acid)	—	165	—	222	232
3,4-Dimethylbenzoic acid	—	165	—	104	130
2-Chloro-5-nitrobenzoic acid	—	166	—	—	178
Methylenesuccinic acid (itaconic acid)	—	166 d.	—	152 (mono)	191 (di)
(+)-Tartaric acid	—	169	—	180 (mono) 264 (di)	171 (mono) 196 (di)
5-Chlorosalicylic acid	—	172	—	—	227
4-Methylbenzoic acid (<i>p</i> -toluic acid)	—	180	160	145	160
4-Chloro-3-nitrobenzoic acid	—	182	—	131	156
4-Methoxybenzoic acid (<i>p</i> -anisic acid)	—	184	186	169	167
Butanedioic acid (succinic acid)	—	188	180 (mono) 255 (di)	143 (mono) 230 (di)	157 (mono) 260 (di)
4-Ethoxybenzoic acid	—	198	—	170	202
Fumaric acid	—	200 s.	—	233 (mono) 314 (di)	270 (mono) 266 (di)

CARBOXYLIC ACIDS (Cont.)

Compound	BP	MP	<i>p</i> -Toluidide*	Anilide*	Amide*
3-Hydroxybenzoic acid	—	201 s.	163	157	170
3,5-Dinitrobenzoic acid	—	202	—	234	183
3,4-Dichlorobenzoic acid	—	209	—	—	133
Phthalic acid	—	210 d.	150 (mono) 201 (di)	169 (mono) 253 (di)	144 (mono) 220 (di)
4-Hydroxybenzoic acid	—	214	204	197	162
3-Nitrophthalic acid	—	215	226 (di)	234 (di)	201 (di)
Pyridine-3-carboxylic acid (nicotinic acid)	—	236	150	132	128
4-Nitrobenzoic acid	—	240	204	211	201
4-Chlorobenzoic acid	—	242	—	194	179
4-Bromobenzoic acid	—	251	—	197	190

Note: "d" indicates "decomposition"; "s" indicates "sublimation."

*See Appendix 2, "Procedures for Preparing Derivatives."

PHENOLS[†]

Compound	BP	MP	α -Naphthyl- urethane*	Bromo Derivative*			
				Mono	Di	Tri	Tetra
2-Chlorophenol	176	7	120	48	76	—	—
3-Methylphenol (<i>m</i> -cresol)	203	12	128	—	—	84	—
2-Ethylphenol	207	—	—	—	—	—	—
2,4-Dimethylphenol	212	23	135	—	—	—	—
2-Methylphenol (<i>o</i> -cresol)	191	32	142	—	56	—	—
2-Methoxyphenol (guaiacol)	204	32	118	—	—	116	—
4-Methylphenol (<i>p</i> -cresol)	202	35	146	—	49	—	198
3-Chlorophenol	214	35	158	—	—	—	—
4-Methyl-2-nitrophenol	—	35	—	—	—	—	—
2,4-Dibromophenol	238	40	—	95	—	—	—
Phenol	181	42	133	—	—	95	—
4-Chlorophenol	217	43	166	33	90	—	—
4-Ethylphenol	219	45	128	—	—	—	—
2-Nitrophenol	216	45	113	—	117	—	—
2-Isopropyl-5-methylphenol (thymol)	234	51	160	55	—	—	—
4-Methoxyphenol	243	56	—	—	—	—	—
3,4-Dimethylphenol	225	64	141	—	—	171	—
4-Bromophenol	238	64	169	—	—	—	—
4-Chloro-3-methylphenol	235	66	153	—	—	—	—
3,5-Dimethylphenol	220	68	—	—	—	166	—
2,6-Di- <i>tert</i> -butyl-4-methylphenol	—	70	—	—	—	—	—

PHENOLS[†] (Cont.)

Compound	BP	MP	α -Naphthyl- urethane*	Bromo Derivative*			
				Mono	Di	Tri	Tetra
2,4,6-Trimethylphenol	232	72	—	—	—	—	—
2,5-Dimethylphenol	212	75	173	—	—	178	—
1-Naphthol (α -naphthol)	278	94	152	—	105	—	—
2-Methyl-4-nitrophenol	186	96	—	—	—	—	—
2-Hydroxyphenol (catechol)	245	104	175	—	—	—	192
2-Chloro-4-nitrophenol	—	106	—	—	—	—	—
3-Hydroxyphenol (resorcinol)	—	109	—	—	—	112	—
4-Nitrophenol	—	112	150	—	142	—	—
2-Naphthol (β -naphthol)	—	123	157	84	—	—	—
3-Methyl-4-nitrophenol	—	129	—	—	—	—	—
1,2,3-Trihydroxybenzene (pyrogallol)	—	133	—	—	158	—	—
4-Phenylphenol	—	164	—	—	—	—	—

*See Appendix 2, "Procedures for Preparing Derivatives."

[†]Also check:

- Salicylic acid (2-hydroxybenzoic acid)
- Esters of salicylic acid (salicylates)
- Salicylaldehyde (2-hydroxybenzaldehyde)
- 4-Hydroxybenzaldehyde
- 4-Hydroxypropiophenone
- 3-Hydroxybenzoic acid
- 4-Hydroxybenzoic acid
- 4-Hydroxybenzophenone

PRIMARY AMINES[†]

Compound	BP	MP	Benzamide*	Picrate*	Acetamide*
<i>t</i> -Butylamine	46	—	134	198	101
Propylamine	48	—	84	135	—
Allylamine	56	—	—	140	—
<i>sec</i> -Butylamine	63	—	76	139	—
Isobutylamine	69	—	57	150	—
Butylamine	78	—	42	151	—
Isopentylamine (ioamylamine)	96	—	—	138	—
Pentylamine (amylamine)	104	—	—	139	—
Ethylenediamine	118	—	244 (di)	233 (di)	172 (di)
Hexylamine	132	—	40	126	—
Cyclohexylamine	135	—	149	—	101
1,3-Diaminopropane	140	—	148 (di)	250	126 (di)
Furfurylamine	145	—	—	150	—
Heptylamine	156	—	—	121	—

PRIMARY AMINES[†] (Cont.)

Compound	BP	MP	Benzamide*	Picrate*	Acetamide*
Octylamine	180	—	—	112	—
Benzylamine	184	—	105	194	65
Aniline	184	—	163	180	114
2-Methylaniline (<i>o</i> -toluidine)	200	—	144	213	110
3-Methylaniline (<i>m</i> -toluidine)	203	—	125	200	65
2-Chloroaniline	208	—	99	134	87
2,6-Dimethylaniline	216	11	168	180	177
2,5-Dimethylaniline	216	14	140	171	139
3,5-Dimethylaniline	220	—	144	225	—
4-Isopropylaniline	225	—	162	—	102
2-Methoxyaniline (<i>o</i> -anisidine)	225	6	60	200	85
3-Chloroaniline	230	—	120	177	74
2-Ethoxyaniline (<i>o</i> -phenetidine)	231	—	104	—	79
4-Chloro-2-methylaniline	241	29	142	—	140
4-Ethoxyaniline (<i>p</i> -phenetidine)	250	2	173	69	137
3-Bromoaniline	251	18	120	180	87
2-Bromoaniline	250	31	116	129	99
2,6-Dichloroaniline	—	39	—	—	—
4-Methylaniline (<i>p</i> -toluidine)	200	43	158	182	147
2-Ethylaniline	210	47	147	194	111
2,5-Dichloroaniline	251	50	120	86	132
4-Methoxyaniline (<i>p</i> -anisidine)	—	58	154	170	130
2,4-Dichloroaniline	245	62	117	106	145
4-Bromoaniline	245	64	204	180	168
4-Chloroaniline	—	72	192	178	179
2-Nitroaniline	—	72	110	73	92
2,4,6-Trichloroaniline	262	75	174	83	204
Ethyl <i>p</i> -aminobenzoate	—	89	148	—	110
<i>o</i> -Phenylenediamine	258	102	301 (di)	208	185 (di)
2-Methyl-5-nitroaniline	—	106	186	—	151
4-Aminoacetophenone	—	106	205	—	167
2-Chloro-4-nitroaniline	—	108	161	—	139
3-Nitroaniline	—	114	157	143	155
4-Methyl-2-nitroaniline	—	116	148	—	99
4-Chloro-2-nitroaniline	—	118	133	—	104
2,4,6-Tribromoaniline	—	120	200	—	232
2-Methyl-4-nitroaniline	—	130	—	—	202
2-Methoxy-4-nitroaniline	—	138	149	—	153
<i>p</i> -Phenylenediamine	—	140	128 (mono) 300 (di)	—	162 (mono) 304 (di)
4-Nitroaniline	—	148	199	100	215
4-Aminoacetanilide	—	162	—	—	304
2,4-Dinitroaniline	—	180	202	—	120

*See Appendix 2, "Procedures for Preparing Derivatives."

[†]Also check 4-aminobenzoic acid and its esters.

SECONDARY AMINES

Compound	BP	MP	Benzamide*	Picrate*	Acetamide*
Diethylamine	56	—	42	155	—
Diisopropylamine	84	—	—	140	—
Pyrrolidine	88	—	Oil	112	—
Piperidine	106	—	48	152	—
Dipropylamine	110	—	—	75	—
Morpholine	129	—	75	146	—
Diisobutylamine	139	—	—	121	86
<i>N</i> -Methylcyclohexylamine	148	—	85	170	—
Dibutylamine	159	—	—	59	—
Benzylmethylamine	184	—	—	117	—
<i>N</i> -Methylaniline	196	—	63	145	102
<i>N</i> -Ethylaniline	205	—	60	132	54
<i>N</i> -Ethyl- <i>m</i> -toluidine	221	—	72	—	—
Dicyclohexylamine	256	—	153	173	103
<i>N</i> -Benzylaniline	298	37	107	48	58
Indole	254	52	68	—	157
Diphenylamine	302	52	180	182	101
<i>N</i> -Phenyl-1-naphthylamine	335	62	152	—	115

*See Appendix 2, "Procedures for Preparing Derivatives."

TERTIARY AMINES†

Compound	BP	MP	Picrate*	Methiodide*
Triethylamine	89	—	173	280
Pyridine	115	—	167	117
2-Methylpyridine (α -picoline)	129	—	169	230
2,6-Dimethylpyridine (2,6-lutidine)	143	—	168	233
4-Methylpyridine (4-picoline)	143	—	167	—
3-Methylpyridine (β -picoline)	144	—	150	92
Tripropylamine	157	—	116	207
<i>N,N</i> -Dimethylbenzylamine	183	—	93	179
<i>N,N</i> -Dimethylaniline	193	—	163	228 d.
Tributylamine	216	—	105	186
<i>N,N</i> -Diethylaniline	217	—	142	102
Quinoline	237	—	203	72/133

Note: "d" indicates "decomposition."

*See Appendix 2, "Procedures for Preparing Derivatives."

†Also check nicotinic acid and its esters.

ALCOHOLS

Compound	BP	MP	3,5-Di-nitrobenzoate*	Phenyl-urethane*
Methanol	65	—	108	47
Ethanol	78	—	93	52
2-Propanol (isopropyl alcohol)	82	—	123	88
2-Methyl-2-propanol (<i>t</i> -butyl alcohol)	83	26	142	136
3-Buten-2-ol	96	—	54	—
2-Propen-1-ol (allyl alcohol)	97	—	49	70
1-Propanol	97	—	74	57
2-Butanol (<i>sec</i> -butyl alcohol)	99	—	76	65
2-Methyl-2-butanol (<i>t</i> -pentyl alcohol)	102	-8.5	116	42
2-Methyl-3-butyn-2-ol	104	—	112	—
2-Methyl-1-propanol (isobutyl alcohol)	108	—	87	86
3-Buten-1-ol	113	—	59	25
3-Methyl-2-butanol	114	—	76	68
2-Propyn-1-ol (propargyl alcohol)	114	—	—	—
3-Pentanol	115	—	101	48
1-Butanol	118	—	64	61
2-Pentanol	119	—	62	—
3,3-Dimethyl-2-butanol	120	—	107	77
2,3-Dimethyl-2-butanol	121	—	111	65
2-Methyl-2-pentanol	123	—	72	—
3-Methyl-3-pentanol	123	—	96	43
2-Methoxyethanol	124	—	—	(113) [†]
2-Methyl-3-pentanol	128	—	85	50
2-Chloroethanol	129	—	95	51
3-Methyl-1-butanol (isoamyl alcohol)	132	—	61	56
4-Methyl-2-pentanol	132	—	65	143
2-Ethoxyethanol	135	—	75	(67) [†]
3-Hexanol	136	—	97	—
1-Pentanol	138	—	46	46
2-Hexanol	139	—	39	(61) [†]
2,4-Dimethyl-3-pentanol	140	—	—	95
Cyclopentanol	140	—	115	132
2-Ethyl-1-butanol	146	—	51	—
2,2,2-Trichloroethanol	151	—	142	87
1-Hexanol	157	—	58	42
2-Heptanol	159	—	49	(54) [†]
Cyclohexanol	160	—	113	82
3-Chloro-1-propanol	161	—	77	38
(2-Furyl)-methanol (furfuryl alcohol)	170	—	80	45
1-Heptanol	176	—	47	60
2-Octanol	179	—	32	114
2-Ethyl-1-hexanol	185	—	—	(61) [†]
1-Octanol	195	—	61	74

ALCOHOLS (Cont.)

Compound	BP	MP	3,5-Di-nitrobenzoate*	Phenyl-urethane*
3,7-Dimethyl-1,6-octadien-3-ol (linalool)	196	—	—	66
2-Nonanol	198	—	43	(56) [†]
Benzyl alcohol	204	—	113	77
1-Phenylethanol	204	20	92	95
1-Nonanol	214	—	52	62
1,3-Propanediol	215	—	178 (di)	137 (di)
2-Phenylethanol	219	—	108	78
1-Decanol	231	7	57	59
3-Phenylpropanol	236	—	45	92
1-Dodecanol (lauryl alcohol)	—	24	60	74
3-Phenyl-2-propen-1-ol (cinnamyl alcohol)	250	34	121	90
α -Terpineol	221	36	78	112
1-Tetradecanol (myristyl alcohol)	—	39	67	74
(-)-Menthol	212	41	158	111
1-Hexadecanol (cetyl alcohol)	—	49	66	73
2,2-Dimethyl-1-propanol (neopentyl alcohol)	113	56	—	144
4-Methylbenzyl alcohol	217	59	117	79
1-Octadecanol (stearyl alcohol)	—	59	77	79
Diphenylmethanol (benzhydrol)	—	68	141	139
4-Nitrobenzyl alcohol	—	93	157	—
Benzoin	—	136	—	165
Cholesterol	—	147	—	168
Triphenylmethanol	—	161	—	—
(+)-Borneol	—	208	154	138

*See Appendix 2, "Procedures for Preparing Derivatives."

[†] α -Naphthylurethane.**ESTERS**

Compound	BP	MP	Compound	BP	MP
Methyl formate	32	—	Ethyl chloroformate	93	—
Ethyl formate	54	—	Methyl isobutyrate	93	—
Methyl acetate	57	—	(methyl 2-methylpropanoate)		
Isopropyl formate	71	—	2-Propenyl acetate (isopropenyl acetate)	94	—
Vinyl acetate	72	—	<i>tert</i> -Butyl acetate		
Ethyl acetate	77	—	(1,1-dimethylethyl acetate)	98	—
Methyl propionate (methyl propanoate)	80	—	Ethyl propionate (ethyl propanoate)	99	—
Methyl acrylate	80	—	Methyl methacrylate		
Propyl formate	81	—	(methyl 2-methylpropenoate)	100	—
Isopropyl acetate	89	—	Methyl pivalate		
			(methyl trimethyl acetate)	101	—

ESTERS (Cont.)

Compound	BP	MP	Compound	BP	MP
Ethyl acrylate (ethyl propenoate)	101	—	Ethyl heptanoate	187	—
Propyl acetate	102	—	Heptyl acetate	192	—
Methyl butyrate (methyl butanoate)	102	—	Dimethyl succinate	196	—
Ethyl isobutyrate			Phenyl acetate	197	—
(ethyl 2-methylpropanoate)	110	—	Diethyl malonate	199	—
Isopropyl propionate			Methyl benzoate	199	—
(isopropyl propanoate)	110	—	Dimethyl maleate	204	—
2-Butyl acetate (<i>sec</i> -butyl acetate)	111	—	Ethyl levulinate	206	—
Methyl isovalerate	117	—	Ethyl octanoate	208	—
(methyl 3-methylbutanoate)			Ethyl cyanoacetate	208	—
Isobutyl acetate			Ethyl benzoate	212	—
(2-methylpropyl acetate)	117	—	Benzyl acetate	217	—
Ethyl pivalate			Diethyl succinate	217	—
(ethyl 2,2-dimethylpropanoate)	118	—	Diethyl fumarate	219	—
Methyl crotonate (methyl 2-butenate)	119	—	Methyl phenylacetate	220	—
Ethyl butyrate (ethyl butanoate)	121	—	Methyl salicylate	224	—
Propyl propionate (propyl propanoate)	123	—	Diethyl maleate	224	—
Butyl acetate	126	—	Ethyl phenylacetate	228	—
Methyl valerate (methyl pentanoate)	128	—	Propyl benzoate	231	—
Methyl methoxyacetate	130	—	Ethyl salicylate	234	—
Methyl chloroacetate	130	—	Dimethyl suberate	268	—
Ethyl isovalerate			Ethyl cinnamate	271	—
(ethyl 3-methylbutanoate)	134	—	Dimethyl phthalate	284	—
Ethyl crotonate (ethyl 2-butenate)	138	—	Diethyl phthalate	298	—
Isopentyl acetate			Methyl cinnamate	—	36
(3-methylbutyl acetate)	142	—	Ethyl 2-furoate	—	36
2-Methoxyethyl acetate	145	—	Methyl stearate	—	39
Ethyl chloroacetate	145	—	Dimethyl itaconate	—	39
Ethyl valerate (ethyl pentanoate)	146	—	Phenyl salicylate	—	42
Ethyl α -chloropropanoate	146	—	Diethyl terephthalate	—	44
Pentyl acetate	147	—	Methyl 4-chlorobenzoate	—	44
Methyl hexanoate	151	—	Ethyl 3-nitrobenzoate	—	47
Ethyl lactate	154	—	Methyl mandelate	—	53
Butyl butyrate	167	—	Ethyl 4-nitrobenzoate	—	56
Ethyl hexanoate	168	—	Dimethyl isophthalate	—	68
Hexyl acetate	169	—	Phenyl benzoate	—	69
Methyl acetoacetate	170	—	Methyl 3-nitrobenzoate	—	78
Methyl heptanoate (methyl enanthlate)	172	—	Methyl 4-bromobenzoate	—	81
Furfuryl acetate	176	—	Ethyl 4-aminobenzoate	—	89
Methyl 2-furoate	181	—	Methyl 4-nitrobenzoate	—	96
Dimethyl malonate	181	—	Dimethyl fumarate	—	102
Ethyl acetoacetate	181	—	Cholesterol acetate	—	114
Diethyl oxalate	185	—	Ethyl 4-hydroxybenzoate	—	116

Procedures for Preparing Derivatives

CAUTION

Some of the chemicals used in preparing derivatives are suspected carcinogens. Before beginning any of these procedures, consult the list of suspected carcinogens on pp. 561–562. Exercise care in handling these substances.

ALDEHYDES AND KETONES

Semicarbazones

Place 0.5 mL of a 2M stock solution of semicarbazide hydrochloride (or 0.5 mL of a solution prepared by dissolving 1.11 g of semicarbazide hydrochloride [$MW = 111.5$] in 5 mL of water) in a small test tube. Add 0.15 g of the unknown compound to the test tube. If the unknown does not dissolve in the solution or if the solution becomes cloudy, add enough methanol (maximum of 2 mL) to dissolve the solid and produce a clear solution. If a solid or cloudiness remains after adding 2 mL of methanol, do not add any more methanol and continue this procedure with the solid present. Using a Pasteur pipet, add 10 drops of pyridine and heat the mixture in a hotwater bath (about 60°C) for about 10–15 minutes. By that time, the product should have begun to crystallize. Collect the product by vacuum filtration. The product can be recrystallized from ethanol if necessary.

**Semicarbazones
(Alternative Method)**

Dissolve 0.25 g of semicarbazide hydrochloride and 0.38 g of sodium acetate in 1.3 mL of water. Then dissolve 0.25 g of the unknown in 2.5 mL of ethanol. Mix the two solutions together in a 25-mL Erlenmeyer flask and heat the mixture to boiling for about 5 minutes. After heating the mixture, place the reaction flask in a beaker of ice and scratch the sides of the flask with a glass rod to induce crystallization of the derivative. Collect the derivative by vacuum filtration and recrystallize it from ethanol.

2, 4-Dinitrophenylhydrazones

Place 10 mL of a solution of 2, 4-dinitrophenylhydrazine (prepared as described for the classification test in Experiment 54D) in a test tube and add 0.15 g of the unknown compound. If the unknown is a solid, it should be dissolved in the minimum amount of 95% ethanol or 1,2-dimethoxyethane before it is added. If crystallization is not immediate, gently warm the solution for a minute in a hotwater bath (90°C) and then set it aside to crystallize. Collect the product by vacuum filtration.

CARBOXYLIC ACIDS

Working in a hood, place 0.50 g of the acid and 2 mL of thionyl chloride into a small round-bottom flask. Add a magnetic stir bar, and attach a water-jacketed condenser and a drying tube packed with calcium chloride to the flask. While stirring, heat the reaction mixture to boiling for 30 minutes on a hot plate. Allow the mixture to cool

to room temperature. Use this mixture to prepare the amide, anilide, or *p*-toluidide derivatives by one of the following three procedures.

Amides

Working in a hood, add the thionyl chloride/carboxylic acid mixture dropwise from a Pasteur pipet into a beaker containing 5 mL of ice-cold concentrated ammonium hydroxide. The reaction is very exothermic. Stir the mixture vigorously after the addition for about 5 minutes. When the reaction is complete, collect the product by vacuum filtration and recrystallize it from water or from water-ethanol, using the mixed-solvents method (See Technique 11, Section 11.10).

Anilides

Dissolve 0.5 g of aniline in 13 mL of methylene chloride in a 50-mL Erlenmeyer flask. Using a Pasteur pipet, carefully add the mixture of thionyl chloride/carboxylic acid to this solution. Warm the mixture for an additional 5 minutes on a hot plate, unless a significant color change occurs. *If a color change occurs*, discontinue heating, add a magnetic stir bar, and stir the mixture for 20 minutes at room temperature. Then transfer the methylene chloride solution to a small separatory funnel and wash it sequentially with 2.5 mL of water, 2.5 mL of 5% hydrochloric acid, 2.5 mL of 5% sodium hydroxide, and a second 2.5-mL portion of water (the methylene chloride solution should be the bottom layer). Dry the methylene chloride layer over a small amount of anhydrous sodium sulfate. Decant the methylene chloride layer away from the drying agent into a small flask and evaporate the methylene chloride on a warm hot plate in the hood. Use a stream of air or nitrogen to speed up the evaporation. Recrystallize the product from water or from ethanol-water, using the mixed-solvents method (See Technique 11, Section 11.10).

p-Toluidides

Use the same procedure as that described in preparing anilides, but substitute *p*-toluidine for aniline.

PHENOLS

α -Naphthylurethanes

Follow the procedure given later for preparing phenylurethanes from alcohols, but substitute α -naphthylisocyanate for phenylisocyanate.

Bromo Derivatives

First, if a stock brominating solution is not available, prepare one by dissolving 0.75 g of potassium bromide in 5 mL of water and adding 0.5 g of bromine. Dissolve 0.1 g of the phenol in 1 mL of methanol or 1,2-dimethoxyethane; then add 1 mL of water. Add 1 mL of the brominating mixture to the phenol solution and swirl the mixture vigorously. Then continue adding the brominating solution dropwise while swirling, until the color of the bromine reagent persists. Finally, add 3–5 mL of water and shake the mixture vigorously. Collect the precipitated product by vacuum filtration and wash it well with water. Recrystallize the derivative from methanol-water, using the mixed-solvents method (See Technique 11, Section 11.10).

AMINES

Acetamides

Place 0.15 g of the amine and 0.5 mL of acetic anhydride in a small Erlenmeyer flask. Heat the mixture for about 5 minutes; then add 5 mL of water and stir the solution vigorously to precipitate the product and hydrolyze the excess acetic anhydride. If the product does not crystallize, it may be necessary to scratch the

walls of the flask with a glass rod. Collect the crystals by vacuum filtration and wash them with several portions of cold 5% hydrochloric acid. Recrystallize the derivative from methanol–water, using the mixed-solvents method (See Technique 11, Section 11.10).

Aromatic amines, or those amines that are not very basic, may require pyridine (2 mL) as a solvent and a catalyst for the reaction. If pyridine is used, a longer period of heating is required (up to 1 hour), and the reaction should be carried out in an apparatus equipped with a reflux condenser. After reflux, the reaction mixture must be extracted with 5–10 mL of 5% sulfuric acid to remove the pyridine.

Benzamides

Using a centrifuge tube, suspend 0.15 g of the amine in 1 mL of 10% sodium hydroxide solution and add 0.5 g of benzoyl chloride. Cap the tube and shake the mixture vigorously for about 10 minutes. After shaking the mixture, add enough dilute hydrochloric acid to bring the pH of the solution to pH 7 or 8. Collect the precipitate by vacuum filtration, wash it thoroughly with cold water, and recrystallize it from ethanol–water, using the mixed-solvents method (See Technique 11, Section 11.10).

Benzamides (Alternative Method)

In a small round-bottom flask, dissolve 0.25 g of the amine in a solution of 1.2 mL of pyridine and 2.5 mL of toluene. Add 0.25 mL of benzoyl chloride to the solution, and heat the mixture under reflux for about 30 minutes. Pour the cooled reaction mixture into 25 mL of water, and stir the mixture vigorously to hydrolyze the excess benzoyl chloride. Separate the toluene layer and wash it, first with 1.5 mL of water, and then with 1.5 mL of 5% sodium carbonate. Dry the toluene over granular anhydrous sodium sulfate, decant the toluene into a small Erlenmeyer flask, and remove the toluene by evaporation on a hot plate in the hood. Use a stream of air or nitrogen to speed up the evaporation. Recrystallize the benzamide from ethanol or ethanol–water, using the mixed-solvents method (See Technique 11, Section 11.10).

Picrates

In an Erlenmeyer flask, dissolve 0.2 g of the unknown in about 5 mL of ethanol and add 5 mL of a saturated solution of picric acid in ethanol. Heat the solution to boiling and then allow it to cool slowly. Collect the product by vacuum filtration and rinse it with a small amount of cold ethanol.

CAUTION



Great care must be taken when working with saturated solutions of picric acid. Picric acid may detonate when heated above 300°C. It is also known to explode when hearted rapidly. For this reason, it is strongly recommended that you check with your instructor before preparing this derivation.

Methiodides

Mix equal-volume quantities of the amine and methyl iodide in a small round-bottom flask (about 0.25 mL is sufficient) and allow the mixture to stand for several minutes. Then heat the mixture gently under reflux for about 5 minutes. The methiodide should crystallize on cooling. If it does not, you can induce crystallization by scratching the walls of the flask with a glass rod. Collect the product by vacuum filtration and recrystallize it from ethanol or ethyl acetate.

ALCOHOLS

3,5-Dinitrobenzoates

Liquid Alcohols

Dissolve 0.25 g of 3,5-dinitrobenzoyl chloride in 0.25 mL of the alcohol and heat the mixture for about 5 minutes¹. Allow the mixture to cool and add 1.5 mL of a 5% sodium carbonate solution and 1 mL of water. Stir the mixture vigorously and crush any solid that forms. Collect the product by vacuum filtration, and wash it with cold water. Recrystallize the derivative from ethanol–water, using the mixed-solvents method (See Technique 11, Section 11.10).

Solid Alcohols

Dissolve 0.25 g of the alcohol in 1.5 mL of dry pyridine and add 0.25 g of 3,5-dinitrobenzoyl chloride. Heat the mixture under reflux for 15 minutes. Pour the cooled reaction mixture into a cold mixture of 2.5 mL of 5% sodium carbonate and 2.5 mL of water. Keep the solution cooled in an ice bath until the product crystallizes, and stir it vigorously during the entire period. Collect the product by vacuum filtration, wash it with cold water, and recrystallize it from ethanol–water, using the mixed-solvents method (See Technique 11, Section 11.10).

Phenylurethanes

Place 0.25 g of the *anhydrous* alcohol in a dry test tube and add 0.25 mL of phenylisocyanate (α -naphthylisocyanate for a phenol). If the compound is a phenol, add 1 drop of pyridine to catalyze the reaction. If the reaction is not spontaneous, heat the mixture in a hot-water bath (90°C) for 5–10 minutes. Cool the test tube in a beaker of ice, and scratch the tube with a glass rod to induce crystallization. Decant the liquid from the solid product or, if necessary, collect the product by vacuum filtration. Dissolve the product in 2.5–3 mL of hot ligroin or hexane, and filter the mixture by gravity (preheat funnel) to remove any unwanted and insoluble diphenylurea present. Cool the filtrate to induce crystallization of the urethane. Collect the product by vacuum filtration.

ESTERS

We recommend that esters be characterized by spectroscopic methods whenever possible. A derivative of the alcohol part of an ester can be prepared with the following procedure. For other derivatives, consult a comprehensive textbook. Several are listed in Experiment 55I.

3,5-Dinitrobenzoates

Place 1.0 mL of the ester and 0.75 g of 3,5-dinitrobenzoic acid in a small round-bottom flask. Add 2 drops of concentrated sulfuric acid and a magnetic stir bar to the flask and attach a condenser. If the boiling point of the ester is above 150°C, heat at reflux while stirring for 30–45 minutes. If the boiling point of the ester is above 150°C, heat the mixture at about 150°C for 30–45 minutes. Cool the mixture, and transfer it to a small separatory funnel. Add 10 mL of ether. Extract the ether layer 2 times with 5 mL of 5% aqueous sodium carbonate (save the ether layer). Wash the organic layer with 5 mL of water, and dry the ether solution over magnesium sulfate. Evaporate the ether in a hot-water bath in the hood. Use a stream of air or

¹ 3,5-Dinitrobenzoyl chloride is an acid chloride and hydrolysis readily. The purity of this reagent should be checked before its use by determining its melting point (mp 69–71°C). When the carboxylic acid is present, the melting point will be high.

nitrogen to speed the evaporation. Dissolve the residue, usually an oil, in 2 mL of boiling ethanol and add water dropwise until the mixture becomes cloudy. Cool the solution to induce crystallization of the derivative.

**Preparation of a Solid
Carboxylic Acid from an
Ester.**

An excellent derivative of an ester can be prepared by a basic hydrolysis of an ester when it yields a solid carboxylic acid. A procedure is provided in Experiment 55I. Melting points for solid carboxylic acids are included in the Carboxylic Acids Table in Appendix 1.

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Common Organic Solvents

Solvent	Boiling Point (°C)	Density (g/mL)
Acetic acid	118	1.05
Acetic anhydride	140	1.08
Acetone	56	0.79
Benzene*	80	0.88
Carbon tetrachloride*	77	1.59
Chloroform*	61	1.48
Cyclohexane	81	0.78
Dimethylformamide (DMF)	153	0.94
Dimethyl sulfoxide (DMSO)	189	1.10
Ethanol	78	0.80
Ether (diethyl)	35	0.71
Ethyl acetate	77	0.90
Heptane	98	0.68
Hexane	69	0.66
Ligroin	60–90	0.68
Methanol	65	0.79
Methylene chloride	40	1.32
Pentane	36	0.63
Petroleum ether	30–60	0.63
1-Propanol	98	0.80
2-Propanol	82	0.79
Pyridine	115	0.98
Tetrahydrofuran (THF)	65	0.99
Toluene	111	0.87
Xylenes	137–144	0.86

Solvents indicated in boldface type are flammable.

*Suspected carcinogen.

Atomic Mass Values for Selected Elements

Aluminum	26.98
Boron	10.81
Bromine	79.90
Carbon	12.01
Chlorine	35.45
Fluorine	18.99
Hydrogen	1.008
Iodine	126.9
Lithium	6.941
Magnesium	24.30
Nitrogen	14.01
Oxygen	15.99
Phosphorus	30.97
Potassium	39.09
Silicon	28.09
Sodium	22.99
Sulfur	32.07

Concentrated Acids and Bases

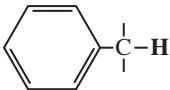
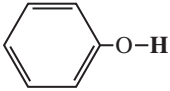
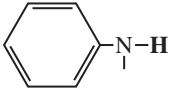
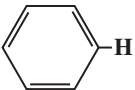
Reagent	HCl	HNO ₃	H ₂ SO ₄	HCOOH	CH ₃ COOH	NH ₃ (NH ₄ OH)
Density (g/mL)	1.18	1.41	1.84	1.20	1.06	0.90
% Acid or base (by weight)	37.3	70.0	96.5	90.0	99.7	29.0
Molecular weight	36.47	63.02	98.08	46.03	60.05	17.03
Molarity of concentrated acid or base	12	16	18	23.4	17.5	15.3
Normality of concentrated acid or base	12	16	36	23.4	17.5	15.3
Volume of concentrated reagent required to prepare 1 L of 1 M solution (ml)	83	64	56	42	58	65
Volume of concentrated reagent required to prepare 1 L of 10% solution (ml)*	227	101	56	93	95	384
Molarity of a 10% solution*	2.74	1.59	1.02	2.17	1.67	5.87

*Percent solutions by weight.

 Infrared Absorption Bands

	Type of Vibration	Frequency (cm ⁻¹)	Intensity
C—H	Alkanes (stretch)	3000–2850	s
	—CH ₃ (bend)	1450 and 1375	m
	—CH ₂ — (bend)	1465	m
	Alkenes (stretch)	3100–3000	m
	(out-of-plane bend)	1000–650	s
	Aromatics (stretch)	3150–3050	s
	(out-of-plane bend)	900–690	s
	Alkyne (stretch)	ca. 3300	s
	Aldehyde	2900–2800	w
		2800–2700	w
O—H	Alcohol, phenols		
	Free	3650–3600	m
	H-bonded	3400–3200	m
	Carboxylic acids	3400–2400	m
N—H	Primary and secondary amines and amides		
	(stretch)	3500–3100	m
	(bend)	1640–1550	m–s
C≡C	Alkyne	2250–2100	m–w
C≡N	Nitriles	2260–2240	m
C=C	Alkene	1680–1600	m–w
	Aromatic	1600 and 1475	m–w
N=O	Nitro (R—NO ₂)	1550 and 1350	s
C=O	Aldehyde	1740–1720	s
	Ketone	1725–1705	s
	Carboxylic acid	1725–1700	s
	Ester	1750–1730	s
	Amide	1680–1630	s
	Anhydride	1810 and 1760	s
	Acid chloride	1800	s
C—O	Alcohols, ethers, esters, carboxylic acids, anhydrides	1300–1000	s
C—N	Amines	1350–1000	m–s
C—X	Fluoride	1400–1000	s
	Chloride	785–540	s
	Bromide, iodide	< 667	s

NMR Chemical Shift Ranges (ppm) for Selected Protons

$R-\overset{ }{\underset{ }{\text{C}}}-\text{H}_3$		0.7–1.3	$R-\overset{ }{\underset{ }{\text{N}}}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	2.2–2.9
$R-\text{CH}_2-\text{R}$		1.2–1.4	$R-\text{S}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	2.0–3.0
R_3CH		1.4–1.7	$R-\overset{ }{\underset{ }{\text{C}}}=\overset{ }{\underset{ }{\text{C}}}-\text{H}$	2.0–4.0
$R-\overset{ }{\underset{ }{\text{C}}}=\overset{ }{\underset{ }{\text{C}}}-\text{H}$		1.6–2.6	$\text{Br}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	2.7–4.1
$R-\overset{\text{O}}{\parallel}{\text{C}}-\overset{ }{\underset{ }{\text{C}}}-\text{H}, \text{H}-\overset{\text{O}}{\parallel}{\text{C}}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$		2.1–2.4	$\text{Cl}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	3.1–4.1
$\text{RO}-\overset{\text{O}}{\parallel}{\text{C}}-\overset{ }{\underset{ }{\text{C}}}-\text{H}, \text{HO}-\overset{\text{O}}{\parallel}{\text{C}}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$		2.1–2.5	$R-\overset{\text{O}}{\parallel}{\text{S}}(\text{O})-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	ca. 3.0
$\text{N}\equiv\overset{ }{\underset{ }{\text{C}}}-\text{H}$		2.1–3.0	$\text{RO}-\overset{ }{\underset{ }{\text{C}}}-\text{H}, \text{HO}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	3.2–3.8
		2.3–2.7	$R-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	3.5–4.8
$R-\text{C}\equiv\text{C}-\text{H}$		1.7–2.7	$\text{O}_2\text{N}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	4.1–4.3
$R-\text{S}-\text{H}$	var	1.0–4.0 ^a	$\text{F}-\overset{ }{\underset{ }{\text{C}}}-\text{H}$	4.2–4.8
$R-\overset{ }{\underset{ }{\text{N}}}-\text{H}$	var	0.5–4.0 ^a		
$R-\text{O}-\text{H}$	var	0.5–5.0 ^a		
	var	4.0–7.0 ^a	$R-\overset{ }{\underset{ }{\text{C}}}=\overset{ }{\underset{ }{\text{C}}}-\text{H}$	4.5–6.5
	var	3.0–5.0 ^a		6.5–8.0
$R-\overset{\text{O}}{\parallel}{\text{C}}-\overset{ }{\underset{ }{\text{N}}}-\text{H}$	var	5.0–9.0 ^a	$R-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	9.0–10.0
			$R-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	11.0–12.0

Note: For those hydrogens shown as $\overset{|}{\underset{|}{\text{C}}}-\text{H}$, if that hydrogen is part of a methyl group (CH_3), the shift is generally at the low end of the range given; if the hydrogen is in a methylene group ($-\text{CH}_2-$), the shift is intermediate; and if the hydrogen is in a methine group ($-\text{CH}-$), the shift is typically at the high end of the range given.

^aThe chemical shift of these groups is variable, depending on the chemical environment in the molecule and on concentration, temperature, and solvent.