**TABLE 4.11** Bond Dissociation Energies

The bond dissociation energy (enthalpy change) for a bond A—B which is broken through the reaction

$$AB \rightarrow A + B$$

is defined as the standard-state enthalpy change for the reaction at a specified temperature, here at 298 K. That is,

$$\Delta Hf_{298} = \Delta Hf_{298}(A) + \Delta Hf_{298}(B) - \Delta Hf_{298}(AB)$$

All values refer to the gaseous state and are given at 298 K. Values of 0 K are obtained by subtracting $\frac{3}{2}RT$ from the value at 298 K.

To convert the tabulated values to kcal/mol, divide by 4.184.

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Aluminum** | |
| Al—Al | 186(9) |
| Al—As | 180 |
| Al—Au | 326(6) |
| Al—Br | 439(8) |
| Al—C | 255 |
| Al—Cl | 494(13) |
| AlCl—Cl | 402(8) |
| $AlCl_2$—Cl | 372(8) |
| AlO—Cl | 515(84) |
| Al—Cu | 216(10) |
| Al—D | 291 |
| Al—F | 664(6) |
| AlF—F | 546(42) |
| $AlF_2$—F | 544(46) |
| AlO—F | 761(42) |
| Al—H | 285(6) |
| Al—I | 368(4) |
| Al—Li | 176(15) |
| Al—N | 297(96) |
| Al—O | 512(4) |
| AlCl—O | 540(41) |
| AlF—O | 582 |
| Al—P | 213(13) |
| Al—Pd | 259(12) |
| Al—S | 374(8) |
| Al—Se | 334(10) |
| Al—Si | 251(3) |
| Al—Te | 268(10) |
| Al—U | 326(29) |
| **Antimony** | |
| Sb—Sb | 299(6) |
| Sb—Br | 314(59) |
| Sb—Cl | 360(50) |
| Sb—F | 439(96) |
| Sb—N | 301(50) |
| Sb—O | 372(84) |
| Sb—P | 357 |
| Sb—S | 379 |
| Sb—Te | 277.4(38) |
| **Arsenic** | |
| As—As | 382(11) |
| As—Cl | 448 |
| As—Ga | 209.6(12) |
| As—H | 272(12) |
| As—N | 582(126) |
| As—O | 481(8) |
| As—P | 534(13) |
| As—S | (478) |
| As—Se | 96 |
| As—Tl | 198(15) |
| **Astatine** | |
| At—At | (115.9) |
| **Barium** | |
| Ba—Br | 370(8) |
| Ba—Cl | 444(13) |
| Ba—F | 487(7) |
| Ba—I | >431(4) |
| Ba—O | 563(42) |
| Ba—OH | 477(42) |
| Ba—S | 400(19) |
| **Beryllium** | |
| Be—Be | 59 |
| Be—Br | 381(84) |
| Be—Cl | 388(9) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Beryllium (*continued*)** | |
| BeCl—Cl | 540(63) |
| Be—F | 577(42) |
| Be—H | 226(21) |
| Be—O | 448(21) |
| Be—S | 372(59) |
| **Bismuth** | |
| Bi—Bi | 197(4) |
| Bi—Br | 267(4) |
| Bi—Cl | 305(8) |
| Bi—D | 284 |
| Bi—F | 259(29) |
| Bi—Ga | 159(17) |
| Bi—H | 279 |
| Bi—O | 343(6) |
| Bi—P | 280(13) |
| Bi—Pb | 142(15) |
| Bi—S | 316(5) |
| Bi—Sb | 251(4) |
| Bi—Se | 280(6) |
| Bi—Te | 232(11) |
| Bi—Tl | 121(13) |
| **Boron** | |
| B—B | 297(21) |
| $H_3B—BH_3$ | 146 |
| OB—BO | 506(84) |
| B—Br | 435(21) |
| B—C | 448(29) |
| B—Cl | 536(29) |
| BO—Cl | 460(42) |
| B—D | 341(6) |
| B—F | 766(13) |
| BF—F | 523(63) |
| $BF_2$—F | 557(84) |
| B—H | 330(4) |
| B—I | 384(21) |
| B—N | 389(21) |
| B—O | 806(5) |
| BCl—O | 715(41) |
| B—P | 347(17) |
| B—S | 581(9) |
| B—Se | 462(15) |
| B—Si | 289(29) |
| B—Te | 354(20) |

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Bromine** | |
| Br—Br | 193.870(4) |
| Br—C | 280(21) |
| $Br—CH_3$ | 284(8) |
| $Br—CH_2Br$ | 255(13) |
| $Br—CHBr_2$ | 259(17) |
| $Br—CBr_3$ | 209(13) |
| $Br—CCl_3$ | 218(13) |
| $Br—CF_3$ | 285(13) |
| $Br—CF_2CF_3$ | 287.4(63) |
| $Br—CF_2CF_2CF_3$ | 278.2(63) |
| $Br—CHF_2$ | 289 |
| Br—Cl | 218.84(4) |
| Br—CN | 381 |
| $Br—CO—C_6H_5$ | 268 |
| Br—F | 233.8(2) |
| Br—N | 276(21) |
| $Br—NF_2$ | 222 |
| Br—NO | 120.1(63) |
| Br—O | 235.1(4) |
| **Cadmium** | |
| Cd—Cd | 11.3(8) |
| Cd—Br | 159(96) |
| Cd—Cl | 206.7(34) |
| Cd—F | 305(21) |
| Cd—H | 69.0(4) |
| Cd—I | 138(21) |
| Cd—In | 138 |
| Cd—O | 142(42) |
| Cd—S | 196 |
| Cd—Se | 310 |
| **Calcium** | |
| Ca—Ca | 14.98(46) |
| Ca—Br | 321(23) |
| Ca—Cl | 398(13) |
| Ca—F | 527(21) |
| Ca—H | 167.8 |
| Ca—I | 285(63) |
| Ca—O | 464(84) |
| Ca—S | 314(19) |
| **Carbon** | |
| C—C | 607(21) |
| $H_3C—CH_3$ | 368 |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| Carbon (*continued*) | |
| $(CH_3)_2C—CH_3$ | 335 |
| $(CH_3)_2C—C(CH_3)_2$ | 282.4 |
| $CH_3—C_6H_5$ | 389 |
| $CH_3—CH_2C_6H_5$ | 301 |
| $(CH_3)_3C—C(C_6H_5)_3$ | 63 |
| $CH_3$—allyl | 301 |
| $CH_3$—vinyl | 121 |
| $CH_3—C\equiv CH$ | 490 |
| $CH_2=CH—CH=CH_2$ | 418 |
| $HC\equiv C—C\equiv CH$ | 628 |
| $H_2C=CH_2$ | 682 |
| $HC\equiv CH$ | 962 |
| $CH_3—CN$ | 506(21) |
| $CH_3—CH_2CN$ | 305(8) |
| $CH_3—CH(CH_3)CN$ | 331(8) |
| $CH_3—C(C_6H_5)CN(CH_3)$ | 251 |
| $CH_3CH_2—CH_2CN$ | 321.8(71) |
| $NC—CN$ | 603(21) |
| $C_6H_5—C_6H_5$ | 418 |
| $CH_3—CF_3$ | 423.4(46) |
| $CH_2F—CH_2F$ | 368(8) |
| $CF_3—CF_3$ | 406(13) |
| $CF_2=CF_2$ | 318(13) |
| $CF_3—CN$ | 501 |
| $CH_3—CHO$ | 314 |
| $CH_3—CO$ | 342.7 |
| $CH_3CO—CF_3$ | 308.8 |
| $CH_3CO—COCH_3$ | 280(8) |
| $C_6H_5CO—COC_6H_5$ | 277.8 |
| Aryl—$CH_2COCH_2$—aryl | 273.6 |
| $C_6H_5CH_2—COOH$ | 284.9 |
| $(C_6H_5CH_2)_2CH—COOH$ | 248.5 |
| $C—Cl$ | 397(29) |
| $C—F$ | 536(21) |
| $C—H$ | 337.2(8) |
| $C—I$ | 209(21) |
| $C—N$ | 770(4) |
| $CF_3—NF_2$ | 272(13) |
| $CH_3—NH_2$ | 331(13) |
| $C_6H_5CH_2—NH_2$ | 301(4) |
| $CH_3—NHC_6H_5$ | 285 |
| $CH_3—N(CH_3)C_6H_5$ | 272 |
| $C_6H_5CH_2—NHCH_3$ | 289(4) |
| $C_6H_5CH_2—N(CH_3)_2$ | 255(4) |
| $CH_3—(N=NCH_3)$ | 219.7 |
| $C_2H_5—(N=NC_2H_5)$ | 209.2 |
| $(CH_3)_3C—N=NC(CH_3)_3$ | 182.0 |
| Aryl—$CH_2N=NCH_2$—aryl | 157 |
| $CF_3—(N=NCF_3)$ | 231.0 |
| $H_2C=NH$ | 644(21) |
| $HC\equiv N$ | 937 |
| $CH_3—NO$ | 174.9(38) |
| $C_2H_5—NO$ | 175.7(54) |
| $C_3H_7—NO$ | 167.8(75) |
| $(CH_3)_2CH—NO$ | 171.5(54) |
| $n$-$C_4H_9—NO$ | 215.5(42) |
| $C_6H_5—NO$ | 215.5(42) |
| $Cl_3C—NO$ | 134 |
| $F_3C—NO$ | 130 |
| $C_6F_5—NO$ | 211.3(42) |
| $NC—NO$ | 121(13) |
| $CH_3—NO_2$ | 247(13) |
| $C_2H_5—NO_2$ | 259 |
| $C—O$ | 1076.5(4) |
| $CH_3—OCH_3$ | 335 |
| $CH_3—OC_6H_5$ | 381 |
| $CH_3—OCH_2C_6H_5$ | 280 |
| $C_2H_5—OC_6H_5$ | 213 |
| $C_6H_5CH_2—OCOCH_3$ | 285 |
| $C_6H_5CH_2—OCOC_6H_5$ | 289 |
| $CH_3CO—OCH_3$ | 406 |
| $CH_3—OSOCH_3$ | 280 |
| $CH_2=CHCH_2—OSOCH_3$ | 209 |
| $C_6H_5CH_2—OSOCH_3$ | 222 |
| $C=O$ | 749 |
| $H_2C=O$ | 732 |
| $OC=O$ | 532.2(4) |
| $SC=O$ | 628 |
| $C\equiv O$ | 1075 |
| $C—P$ | 513(8) |
| $C—S$ | 699(8) |
| $CH_3—SH$ | 305(13) |
| $CH_3—SC_6H_5$ | 285(8) |
| $CH_3—SCH_2C_6H_5$ | 247(8) |
| $OC—S$ | 310.4 |
| $C—Se$ | 582(96) |
| Cerium | |
| $Ce—Ce$ | 243(21) |
| $Ce—F$ | 582(42) |
| $Ce—N$ | 519(21) |
| $Ce—O$ | 795(13) |
| $Ce—S$ | 573(13) |
| $Ce—Se$ | 495(15) |
| $Ce—Te$ | 389(42) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Cesium** | |
| Cs—Cs | 41.75(93) |
| Cs—Br | 397.5(42) |
| Cs—Cl | 439(21) |
| Cs—F | 514(8) |
| Cs—H | 178.1(38) |
| Cs—I | 339(4) |
| Cs—O | 297(25) |
| Cs—OH | 385(13) |
| **Chlorine** | |
| Cl—Cl | 242.580(16) |
| Cl—C | 338(42) |
| Cl—$CH_3$ | 339(21) |
| Cl—$CH_3^+$ | 213 |
| Cl—$C(CH_3)_3$ | 328.4 |
| Cl—$CH_2Cl$ | 310(13) |
| Cl—$CCl_3$ | 293(21) |
| Cl—$CF_3$ | 360(33) |
| Cl—$CCl_2F$ | 305(8) |
| Cl—$CClF_2$ | 318(8) |
| Cl—$CF_2CF_2$ | 346.0(71) |
| Cl—$CH{=}CH_2$ | 351 |
| Cl—CN | 439 |
| Cl—COCl | 328 |
| Cl—$COCH_3$ | 349.4 |
| Cl—$COC_6H_5$ | 310(13) |
| Cl—$Cl^+$ | 393 |
| Cl—ClO | 143.3(42) |
| $O_3Cl$—$ClO_4$ | 243 |
| Cl—F | 250.54(8) |
| $O_3Cl$—F | 255 |
| Cl—N | 389(50) |
| Cl—NCl | 280 |
| Cl—$NCl_2$ | 381 |
| Cl—$NF_2$ | *ca.* 134 |
| Cl—$NH_2$ | 251(25) |
| Cl—NO | 159(6) |
| Cl—$NO_2$ | 142(4) |
| Cl—O | 272(4) |
| OCl—O | 243(13) |
| $O_2Cl$—O | 201(4) |
| Cl—P | 289(42) |
| Cl—$SiCl_3$ | 464 |
| **Chromium** | |
| Cr—Cr | 155(21) |
| Cr—Br | 328(24) |
| Cr—Cl | 366(24) |
| Cr—Cu | 155(21) |
| Cr—F | 437(20) |
| Cr—Ge | 170(29) |
| Cr—H | 280(50) |
| Cr—I | 287(24) |
| Cr—N | 378(19) |
| Cr—O | 427(29) |
| OCr—O | 531(63) |
| $O_2Cr$—O | 477(84) |
| Cr—S | 339(21) |
| **Cobalt** | |
| Co—Co | 167(25) |
| Co—Br | 331(42) |
| Co—Cl | 398(8) |
| Co—Cu | 162(17) |
| Co—F | 435(63) |
| Co—Ge | 239(25) |
| Co—I | 235(81) |
| Co—O | 368(21) |
| Co—S | 343(21) |
| **Copper** | |
| Cu—Cu | 202(4) |
| Cu—Br | 331(25) |
| Cu—Cl | 383(21) |
| Cu—F | 431(13) |
| Cu—Ga | 216(15) |
| Cu—Ge | 209(21) |
| Cu—H | 280(8) |
| Cu—I | 197(21) |
| Cu—Ni | 206(17) |
| Cu—O | 343(63) |
| Cu—S | 285(17) |
| Cu—Se | 293(38) |
| Cu—Sn | 177(17) |
| Cu—Te | 176(38) |
| **Curium** | |
| Cm—O | 736 |
| **Dysprosium** | |
| Dy—F | 527(21) |
| Dy—O | 611(42) |
| Dy—Se | 322(42) |
| Dy—Te | 234(42) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Erbium** | |
| Er—F | 565(17) |
| Er—O | 611(13) |
| Er—S | 418(42) |
| Er—Se | 326(42) |
| Er—Te | 239(42) |
| **Europium** | |
| Eu—Eu | 33.5(165) |
| Eu—Cl | *ca.* 326 |
| Eu—F | 528(18) |
| Eu—O | 557(13) |
| Eu—S | 364(15) |
| Eu—Se | 301(15) |
| Eu—Te | 243(15) |
| **Fluorine** | |
| F—F | 156.9(96) |
| F—$F^+$ | >251 |
| F—$CH_3$ | 452(21) |
| F—$C(CH_3)_3$ | 439 |
| F—$C_6H_5$ | 485 |
| F—$CCl_3$ | 444(21) |
| F—$CCl_2F$ | 460(25) |
| F—$CClF_2$ | 490(25) |
| F—$CF_3$ | 523(17) |
| F—$COCH_3$ | 498 |
| F—FO | 272(13) |
| F—$FO_2$ | 81.0 |
| F—N | 301(42) |
| F—NF | 318(25) |
| F—$NF_2$ | 243(8) |
| F—NO | 235.6(42) |
| F—$NO_2$ | 197(25) |
| **Gadolinium** | |
| Gd—F | 590(27) |
| Gd—O | 716(17) |
| Gd—S | 525(15) |
| Gd—Se | 431(15) |
| **Gallium** | |
| Ga—Ga | 138(21) |
| Ga—Br | 444(17) |
| $(CH_3)_3Ga—CH_3$ | 253 |
| Ga—Cl | 481(13) |
| Ga—F | 577(15) |
| Ga—H | <274 |
| Ga—I | 339(10) |
| **Gallium (*continued*)** | |
| Ga—O | 285(63) |
| Ga—P | 230(13) |
| Ga—Sb | 209(13) |
| Ga—Te | 251(25) |
| **Germanium** | |
| Ge—Ge | 274(21) |
| Ge—Br | 255(29) |
| Ge—Cl | 431.8(4) |
| Ge—F | 485(21) |
| Ge—H | 321.3(8) |
| Ge—O | 662(13) |
| Ge—S | 551.0(25) |
| Ge—Se | 490(21) |
| Ge—Si | 301(21) |
| Ge—Te | 402(8) |
| **Gold** | |
| Au—Au | 221.3(21) |
| Au—B | 368(11) |
| Au—Be | 285(8) |
| Au—Bi | 293(84) |
| Au—Cl | 343(10) |
| Au—Co | 215(13) |
| Au—Cr | 215(6) |
| Au—Cu | 232(9) |
| Au—Fe | 187(17) |
| Au—Ga | 294(15) |
| Au—Ge | 277(15) |
| Au—H | 314(10) |
| Au—La | 80(5) |
| Au—Li | 68.0(16) |
| Au—Mg | 243(42) |
| Au—Mn | 185(13) |
| Au—Ni | 274(21) |
| Au—Pb | 130(42) |
| Au—Pd | 143(21) |
| Au—Rh | 231(29) |
| Au—S | 418(25) |
| Au—Si | 312(12) |
| Au—Sn | 244(17) |
| Au—Te | 247(67) |
| Au—U | 318(29) |
| **Hafnium** | |
| Hf—C | 548(63) |
| Hf—N | 534(29) |
| Hf—O | 791(8) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

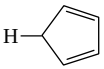
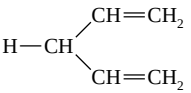
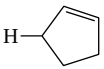
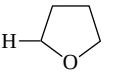
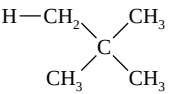
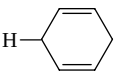
| Bond | $\Delta Hf_{298}$, kJ/mol | Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|---|---|
| Hydrogen | | Hydrogen (*continued*) | |
| H—H | 436.002(4) | H—$CHCl_2$ | 414.2 |
| H—$^2$H or H—D | 439.446(4) | H—$CCl_3$ | 377(8) |
| $^2$H—$^2$H or D—D | 443.546(4) | H—$CBr_3$ | 377(8) |
| H—Br | 365.7(21) | H—$CCl_2CHCl_2$ | 393(8) |
| H—C | 337.2(8) | H—$CH_2F$ | 423(8) |
| H—CH | 452(33) | H—$CHF_2$ | 423(8) |
| H—$CH_2$ | 473(4) | H—$CF_3$ | 444(13) |
| H—$CH_3$ | 431(8) | H—$CF_2Cl$ | 435(4) |
| $^2$H—$C^2H_3$ or D—$CD_3$ | 442.75(25) | H—$CH_2CF_3$ | 446(45) |
| H—C≡CH | 523(4) | H—$CF_2CH_3$ | 416(4) |
| H—CH═$CH_2$ | 427 | H—$CF_2CF_3$ | 431(63) |
| H—$CH_2CH_3$ | 410(4) | H—$CH_2I$ | 431(8) |
| H—$CH_2C$≡CH | 392.9(50) | H—$CHI_2$ | 431(8) |
| H—$CH_2CH$═$CH_2$ | 356 | H—CN | 540(25) |
| H—cyclopropyl | 423(13) | H—$CH_2CN$ | *ca.* 389 |
| H—$CH_2CH_2CH_3$ | 410(8) | H—$CH(CH_3)CN$ | 377(8) |
| H—$CH(CH_3)_2$ | 395.4 | H—$C(CH_3)_2CN$ | 364(8) |
| H—cyclobutyl | 397(13) | H—$CH_2NH_2$ | 397(8) |
| H—$CH_2CH(CH_3)_2$ | 360 | H—$CH_2Si(CH_3)_3$ | 414(4) |
| H—$CH(CH_3)CH_2CH_3$ | 397(4) | H—$CH_2COCH_3$ | 393(75) |
| H—$C(CH_3)_3$ | 381 | H—Cl | 431.8(4) |
|  | 339(4) | H—CO | 126(8) |
| | | H—CHO | 364(4) |
| | | H—COOH | 377 |
| | | H—$COCH_3$ | 364(4) |
|  | 335(4) | H—$COCH_2CH_3$ | 364(4) |
|  | 343(4) |  | 385 |
| | | H—$COC_6H_5$ | 364(4) |
| | | H—$COCF_3$ | 381(8) |
|  | 414(4) | H—F | 568.6(13) |
| | | H—I | 298.7(8) |
| | | H—N | 314(17) |
| | | H—NH | 377(8) |
| H—$C(CH_3)_2CH$═$CH_2$ | 331 | H—$NH_2$ | 435(8) |
| H—cyclopentyl | 395(42) | H—$NHCH_3$ | 431(8) |
| H—$CH_2C(CH_3)_3$ | 418(4) | H—$N(CH_3)_2$ | 397(8) |
| H—$C_6H_5$ | 431 | H—$NHC_6H_5$ | 335(13) |
| H—$CH_2C_6H_5$ | 356(4) | H—$N(CH_3)C_6H_5$ | 310(13) |
| H—$C(C_6H_5)_3$ | 314 | $HNF_2$ | 318(13) |
| | | H—$N_3$ | 356 |
|  | 310 | H—NO | <205 |
| | | H—O | 428.0(21) |
| | | H—OH | 498.7(8) |
| H—cyclohexyl | 399.6(42) | H—$OCH_3$ | 436.8(42) |
| H—cycloheptyl | 387.0(42) | H—$OCH_2CH_3$ | 436.0 |
| H—norbornyl | 406(13) | H—$OC(CH_3)_3$ | 439(4) |
| H—$CH_2Br$ | 410(25) | H—$OC_6H_5$ | 368(25) |
| H—$CHBr_2$ | 435 | H—ONO | 327.6(25) |
| H—$CH_2Cl$ | 423 | | |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Hydrogen (*continued*)** | |
| H—$ONO_2$ | 423.4(25) |
| H—OOH | 374(8) |
| H—$OOCCH_3$ | 469(17) |
| H—$OOCCH_2CH_3$ | 460(17) |
| H—$OOCC_3H_7$ | 431(17) |
| H—P | 343(29) |
| H—S | 344(12) |
| H—SH | 381(4) |
| H—$SCH_3$ | *ca.* 368 |
| H—Se | 305(2) |
| H—Si | 298.49(46) |
| H—$SiH_3$ | 393(13) |
| H—$Si(CH_3)_3$ | 377(13) |
| H—Te | 268(2) |
| **Indium** | |
| In—In | 100(8) |
| In—Br | 418(21) |
| In—Cl | 439(8) |
| In—F | 506(15) |
| In—O | 360(21) |
| In—P | 197.9(85) |
| In—S | 289(17) |
| In—Sb | 152(11) |
| In—Se | 247(17) |
| In—Te | 218(17) |
| **Iodine** | |
| I—I | 152.549(8) |
| I—Br | 179.1(4) |
| I—$CH_3$ | 232(13) |
| I—$C_2H_5$ | 223.8 |
| I—$CH(CH_3)_2$ | 222 |
| I—$C(CH_3)_3$ | 207.1 |
| I—$CH_2CF_3$ | 234(4) |
| I—$CF_2CH_3$ | 216(4) |
| I—$C_3F_7$ | 209(4) |
| I—CH═$CHCH_3$ | 172 |
| I—$C_6H_5$ | 268(4) |
| I—$C_6F_5$ | 276 |
| I—Cl | 213.3(4) |
| I—$COCH_3$ | 219.7 |
| I—CN | 305(4) |
| I—F | 280(4) |
| I—N | 159(17) |
| I—NO | 71(4) |
| I—$NO_2$ | 75(4) |
| I—O | 184(21) |
| **Iridium** | |
| Ir—O | 352(21) |
| Ir—Si | 463(21) |
| **Iron** | |
| Fe—Fe | 100(21) |
| Fe—Br | 247(96) |
| Fe—Cl | *ca.* 352 |
| Fe—O | 409(13) |
| Fe—S | 339(21) |
| Fe—Si | 297(25) |
| **Krypton** | |
| Kr—Kr | 5.4(8) |
| Kr—F | 54 |
| **Lanthanum** | |
| La—La | 247(21) |
| La—C | 506(63) |
| La—F | 598(42) |
| La—N | 519(42) |
| La—O | 799(13) |
| La—S | 577(25) |
| **Lead** | |
| Pb—Pb | 339(25) |
| Pb—Br | 247(38) |
| $Pb(CH_3)_3$—$CH_3$ | 207(42) |
| Pb—Cl | 301(29) |
| Pb—F | 356(8) |
| Pb—H | 176(21) |
| Pb—I | 197(38) |
| Pb—O | 378(4) |
| Pb—S | 346.0(17) |
| Pb—Se | 303(4) |
| Pb—Te | 251(13) |
| **Lithium** | |
| Li—Li | 106(4) |
| Li—Br | 423(21) |
| Li—Cl | 469(13) |
| Li—F | 577(21) |
| Li—H | 247 |
| Li—I | 352(13) |
| Li—Na | 88 |
| Li—O | 341(6) |
| Li—OH | 427(21) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Lutetium** | |
| Lu—Lu | 142(34) |
| Lu—F | 569(42) |
| Lu—O | 695(13) |
| Lu—S | 507(15) |
| Lu—Te | 326(17) |
| **Magnesium** | |
| Mg—Mg | 8.522(4) |
| Mg—Br | 297(63) |
| Mg—Cl | 318(13) |
| Mg—F | 462(21) |
| MgF—F | 569(42) |
| Mg—H | 197(50) |
| Mg—I | *ca.* 285 |
| Mg—O | 394(35) |
| Mg—OH | 238(21) |
| Mg—S | 310(75) |
| **Manganese** | |
| Mn—Mn | 42(29) |
| Mn—Br | 314(10) |
| Mn—Cl | 361(10) |
| Mn—F | 423(15) |
| Mn—I | 283(10) |
| Mn—Cu | 159(17) |
| Mn—O | 402(34) |
| Mn—S | 301(17) |
| Mn—Se | 201(13) |
| **Mercury** | |
| Hg—Hg | 17.2(21) |
| Hg—Br | 72.8(42) |
| $CH_3$—$HgCH_3$ | 240.6 |
| $C_2H_5$—$HgC_2H_5$ | 182.8(42) |
| $C_3H_7$—$HgC_3H_7$ | 197.1 |
| Isopropyl—Hgisopropyl | 170.3 |
| $C_6H_5$—$HgC_6H_5$ | 285 |
| Hg—Cl | 100(8) |
| Hg—F | 130(38) |
| Hg—H | 39.8 |
| Hg—I | 38 |
| Hg—K | 8.24(21) |
| Hg—Na | >6.7 |
| Hg—S | 213 |
| Hg—Se | (167) |
| Hg—Te | (142) |

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Molybdenum** | |
| Mo—I | 372 |
| Mo—O | 607(34) |
| MoO—O | 678(84) |
| $MoO_2$—O | 565(84) |
| **Neodymium** | |
| Nd—F | 545(13) |
| Nd—O | 703(34) |
| Nd—S | 474(15) |
| Nd—Se | 385(17) |
| Nd—Te | 305(17) |
| **Neon** | |
| Ne—Ne | 3.93 |
| **Neptunium** | |
| Np—O | 720(29) |
| **Nickel** | |
| Ni—Ni | 261.9(25) |
| Ni—Br | 360(13) |
| Ni—Cl | 372(21) |
| Ni—F | 435 |
| Ni—H | 289(13) |
| Ni—I | 293(21) |
| Ni—O | 391.6(38) |
| Ni—S | 360(21) |
| Ni—Si | 318(17) |
| **Niobium** | |
| Nb—O | 753(13) |
| **Nitrogen** | |
| N—N | 945.33(59) |
| N—Br | 276(21) |
| ON—Br | 28.7(15) |
| N—Cl | 389(50) |
| ON—Cl | 159(6) |
| $O_2N$—Cl | 142(4) |
| N—F | 301(42) |
| FN—F | 318(21) |
| $F_2F$—N | 243(8) |
| ON—F | 236(4) |
| $O_2N$—F | 188(21) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Nitrogen (*continued*)** | |
| N—I | 159(17) |
| $F_2N$—$NF_2$ | 88(4) |
| $H_2N$—$NH_2$ | 297(8) |
| $H_2N$—$NHCH_3$ | 271 |
| $H_2N$—$N(CH_3)_2$ | 264 |
| $H_2N$—$NHC_6H_5$ | 213 |
| HN—$N_2$ | 38 |
| ON—N | 480.7(42) |
| ON—$NO_2$ | 39.8(8) |
| $O_2N$—$NO_2$ | 57.3(21) |
| HN═NH | 456(42) |
| N≡N | 946 |
| N—O | 630.57(13) |
| HN═O | 481 |
| NN—O | 167 |
| ON—O | 305 |
| N—P | 617(21) |
| N—S | 464(21) |
| **Osmium** | |
| $O_3Os$—O | 301(21) |
| **Oxygen** | |
| O—O | 498.34(20) |
| O—Br | 235.1(4) |
| HO—$CH_3$ | 377(13) |
| HO—CH═$CH_2$ | 364 |
| HO—$CH_2CH$═$CH_2$ | 456 |
| HO—$C_6H_5$ | 431 |
| HO—$CH_2C_6H_5$ | 322 |
| HO—CHO | 402(13) |
| HO—$COCH_3$ | 452(21) |
| HO—$COC_2H_5$ | 180 |
| O—Cl | 272(4) |
| HO—Cl | 251(13) |
| O—F | 222(17) |
| O—FO | 467 |
| FO—OF | 261(84) |
| O—I | 184(21) |
| HO—I | 234(13) |
| O—N | 630.57(13) |
| HO—$NCH_3$ | 209 |
| HO—$OC(CH_3)_3$ | 192(8) |
| HO—OH | 213.8(21) |
| O—OH | 268(4) |
| $CF_3O$—$OCF_3$ | 192 |
| $CH_3O$—$OCH_3$ | 157.3(8) |
| $C_2H_5O$—$OC_2H_5$ | 159 |
| $C_3H_7O$—$OC_3H_7$ | 155 |
| **Palladium** | |
| Pd—O | 234(29) |
| **Phosphorus** | |
| P—P | 490(11) |
| P—Br | 266.5 |
| P—C | 513(8) |
| P—Cl | 289(42) |
| P—F | 439(96) |
| P—H | 343(29) |
| P—N | 617(21) |
| P—O | 596.6 |
| $Br_3P$═O | 498(21) |
| $Cl_3P$═O | 510(21) |
| $F_3P$═O | 544(21) |
| P—S | 346.0(17) |
| P═S | 347 |
| P—Se | 363(10) |
| P—Te | 298(10) |
| **Platinum** | |
| Pt—B | 478(17) |
| Pt—H | 352(38) |
| Pt—O | 347(34) |
| Pt—P | 417(17) |
| Pt—Si | 501(18) |
| **Potassium** | |
| K—K | 57.3(42) |
| K—Br | 383(8) |
| K—Cl | 427(8) |
| K—F | 497.5(25) |
| K—H | 183(15) |
| K—I | 331(13) |
| K—Na | 63.6(29) |
| K—O | 239(34) |
| K—OH | 343(8) |
| **Praseodymium** | |
| Pr—F | 582(46) |
| Pr—O | 753(17) |
| Pr—S | 492.5(46) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Praseodymium (*continued*)** | |
| Pr—Se | 446(23) |
| Pr—Te | 326(42) |
| **Promethium** | |
| Pm—F | 540(42) |
| Pm—O | 674(63) |
| Pm—S | 423(63) |
| Pm—Se | 339(63) |
| Pm—Te | 255(63) |
| **Radium** | |
| Ra—Cl | 343(75) |
| **Rhodium** | |
| Rh—Rh | 285(21) |
| Rh—B | 476(21) |
| Rh—C | 583.7(63) |
| Rh—O | 377(63) |
| Rh—Si | 395(18) |
| Rh—Ti | 391(15) |
| **Rubidium** | |
| Rb—Rb | 45.6(21) |
| Rb—Br | 389(13) |
| Rb—Cl | 448(21) |
| Rb—F | 494(21) |
| Rb—H | 167(21) |
| Rb—I | 335(13) |
| Rb—O | 255(84) |
| Rb—OH | 351(8) |
| **Ruthenium** | |
| Ru—O | 481(63) |
| $O_3Ru—O$ | 439 |
| Ru—Si | 397(21) |
| Ru—Th | 592(42) |
| **Samarium** | |
| Sm—Cl | 423(13) |
| Sm—F | 531(18) |
| Sm—O | 619(13) |
| Sm—S | 389 |
| Sm—Se | 331(15) |
| Sm—Te | 272(15) |
| **Scandium** | |
| Sc—Sc | 163(21) |
| Sc—Br | 444(63) |
| Sc—C | 393(63) |
| Sc—Cl | 318 |
| Sc—F | 589(13) |
| Sc—N | 469(84) |
| Sc—O | 674(13) |
| Sc—S | 478(13) |
| Sc—Se | 385(17) |
| Sc—Te | 289(17) |
| **Selenium** | |
| Se—Se | 332.6(4) |
| Se—Br | 297(84) |
| Se—C | 582(96) |
| Se—Cl | 322 |
| Se—F | 339(42) |
| Se—H | 305(2) |
| Se—N | 381(63) |
| Se—O | 423(13) |
| Se—P | 364(10) |
| Se—S | 381(21) |
| Se—Si | 531(25) |
| Se—Te | 268(8) |
| **Silicon** | |
| Si—Si | 327(10) |
| Si—Br | 343(50) |
| Si—C | 435(21) |
| Si—Cl | 456(42) |
| Si—F | 540(13) |
| Si—H | 298.49(46) |
| Si—I | 339(84) |
| Si—N | 439(38) |
| Si—O | 798(8) |
| Si—S | 619(13) |
| Si—Se | 531(25) |
| $H_3Si—SiH_3$ | 339(17) |
| $(CH_3)_3Si—Si(CH_3)_3$ | 339 |
| $(Aryl)_3Si—Si(aryl)_3$ | 368(31) |
| Si—Te | 506(38) |
| **Silver** | |
| Ag—Ag | 163(8) |
| Ag—Au | 203(9) |
| Ag—Bi | 193(42) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Silver (*continued*)** | |
| Ag—Br | 293(29) |
| Ag—Cl | 341.4 |
| Ag—Cu | 176(8) |
| Ag—F | 354(16) |
| Ag—Ga | 180(15) |
| Ag—Ge | 175(21) |
| Ag—H | 226(8) |
| Ag—I | 234(29) |
| Ag—In | 176(17) |
| Ag—O | 213(84) |
| Ag—Sn | 136(21) |
| Ag—Te | 293(96) |
| **Sodium** | |
| Na—Na | 77.0 |
| Na—Br | 370(13) |
| Na—Cl | 410(8) |
| Na—F | 481(8) |
| Na—H | 201(21) |
| Na—I | 301(8) |
| Na—K | 63.6(29) |
| Na—O | 257(17) |
| Na—OH | 381(13) |
| Na—Rb | 59(4) |
| **Strontium** | |
| Sr—Br | 332(19) |
| Sr—Cl | 406(13) |
| Sr—F | 542(7) |
| Sr—H | 163(8) |
| Sr—I | 263(42) |
| Sr—O | 454(15) |
| Sr—OH | 381(42) |
| Sr—S | 314(21) |
| **Sulfur** | |
| S—S | 429(6) |
| S—Cl | 255 |
| S—F | 343(5) |
| $O_2S$—F | 71 |
| S—N | 464(21) |
| S—O | 521.70(13) |
| OS—O | 551.4(84) |
| $O_2S$—O | 348.1(42) |
| HS—SH | 272(21) |
| **Tantalum** | |
| Ta—N | 611(84) |
| Ta—O | 805(13) |
| **Tellurium** | |
| Te—B | 354(20) |
| Te—H | 268(2) |
| Te—I | 193(42) |
| Te—O | 391(8) |
| Te—P | 298(10) |
| Te—S | 339(21) |
| Te—Se | 268(8) |
| **Terbium** | |
| Tb—F | 561(42) |
| Tb—O | 707(13) |
| Tb—S | 515(42) |
| Tb—Te | 339(42) |
| **Thallium** | |
| Tl—Tl | 63 |
| Tl—Br | 333.9(17) |
| Tl—Cl | 372.8(21) |
| Tl—F | 445(19) |
| Tl—H | 188(8) |
| Tl—I | 272(8) |
| **Thorium** | |
| Th—Th | 289 |
| Th—C | 484(25) |
| Th—N | 577.4(21) |
| Th—O | 854(13) |
| Th—P | 377 |
| **Thullium** | |
| Tm—F | 569(42) |
| Tm—O | 557(13) |
| Tm—S | 368(42) |
| Tm—Se | 276(42) |
| Tm—Te | 276(42) |
| **Tin** | |
| Sn—Sn | 195(17) |
| Sn—Br | 339(4) |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|
| **Tin (*continued*)** | |
| BrSn—Br | 326 |
| $Br_3Sn$—Br | 272 |
| $(C_2H_5)_3Sn$—$C_2H_5$ | *ca.* 238 |
| Sn—Cl | 406(13) |
| Sn—F | 467(13) |
| Sn—H | 267(17) |
| Sn—I | 234(42) |
| Sn—O | 548(21) |
| Sn—S | 464(3) |
| Sn—Se | 401.3(59) |
| Sn—Te | 319.2(8) |
| **Titanium** | |
| Ti—Ti | 141(21) |
| Ti—Br | 439 |
| Ti—C | 435(25) |
| Ti—Cl | 494 |
| Ti—F | 569(34) |
| Ti—H | *ca.* 159 |
| Ti—I | 310(42) |
| Ti—N | 464 |
| Ti—O | 662(16) |
| Ti—S | 426(8) |
| Ti—Se | 381(42) |
| Ti—Te | 289(17) |
| **Tungsten** | |
| W—Cl | 423(42) |
| W—F | 548(63) |
| W—O | 653(25) |
| OW—O | 632(84) |
| $O_2W$—O | 598(42) |
| W—P | 305(4) |
| **Uranium** | |
| U—O | 761(17) |
| OU—O | 678(59) |
| $O_2U$—O | 644(88) |
| U—S | 523(10) |
| **Vanadium** | |
| V—V | 242(21) |
| V—Br | 439(42) |
| V—C | 469(63) |
| V—Cl | 477(63) |
| V—F | 590(63) |
| V—N | 477(8) |
| V—O | 644(21) |
| V—S | 490(16) |
| V—Se | 347(21) |
| **Xenon** | |
| Xe—Xe | 6.53(30) |
| Xe—F | 13.0(4) |
| Xe—O | 36.4 |
| **Ytterbium** | |
| Yb—Cl | 322 |
| Yb—F | 521(10) |
| Yb—H | 159(38) |
| Yb—O | 397.9(63) |
| Yb—S | 167 |
| **Yttrium** | |
| Y—Y | 159(21) |
| Y—Br | 485(84) |
| Y—C | 418(63) |
| Y—Cl | 527(42) |
| Y—F | 605(21) |
| Y—N | 481(63) |
| Y—O | 715.1(30) |
| Y—S | 528(11) |
| Y—Se | 435(13) |
| Y—Te | 339(13) |
| **Zinc** | |
| Zn—Zn | 29 |
| Zn—Br | 142(29) |
| $C_2H_5C$—$C_2H_5$ | *ca.* 201 |
| Zn—Cl | 229(20) |
| Zn—F | 368(63) |
| Zn—H | 85.8(21) |
| Zn—I | 138(29) |
| Zn—O | 284.1 |
| Zn—S | 205(13) |
| Zn—Se | 136(13) |
| Zn—Te | 205 |

**TABLE 4.11** Bond Dissociation Energies (*Continued*)

| Bond | $\Delta Hf_{298}$, kJ/mol | Bond | $\Delta Hf_{298}$, kJ/mol |
|---|---|---|---|
| Zirconium | | Zirconium (*continued*) | |
| Zr—C | 561(25) | Zr—O | 760(8) |
| Zr—F | 623(63) | Zr—S | 575(17) |
| Zr—N | 565(25) | | |

***Source:*** T. L. Cottrell, *The Strengths of Chemical Bonds*, 2d ed., Butterworth, London, 1958; B. deB. Darwent, *National Standard Reference Data Series*, National Bureau of Standards, no. 31, Washington, 1970; S. W. Benson, *J. Chem. Educ.* **42:**502 (1965); and J. A. Kerr, *Chem. Rev.* **66:**465 (1966).