NUMERICAL SOLUTIONS TO PROBLEMS

Chapter 1

1.1 282 K. **1.2** 4.8 g m^{-3}. **1.3** (1) 4.2 ppmv; (2) 42 ppbv; (3) $7.5x10^{22}$ molecules m^{-2}; (4) 2.7 mm.

Chapter 2

2.1 11.2 km. **2.2** (2.1) 1.22 kg m^{-3}; (2.2) $4.5x10^{18}$ kg; (3) $1.8x10^{9}$ kg.

Chapter 3

3.1 (1) $m = (E/k)(1\text{-}e^{-kt})$ and $m(\infty) = E/k$; (2) $m(\tau)/m(\infty) = 0.63$, $m(3\tau)/m(\infty) = 0.95$; (3) $t = 3\tau$. **3.2** (1) 5.8 days; (2) $f = 1/(1 + \tau_{out}/\tau_{chem})$. **3.3** (4) 16% of HCFC-123 and 44% of HCFC-124. **3.4** (1) $\tau = 1.0$ years. **3.5** 1300 km. **3.6** Box model: $[X] = EL/Uh$; column model: $[X] = EL/2Uh$. **3.7** (2) $7.0x10^{9}$ kg in 2050, $4.2x10^{9}$ kg in 2100; (3) $10x10^{9}$ kg in 2050, $6.1x10^{9}$ kg in 2100.

Chapter 4

4.1 1-C; 2-D; 3-A; 4-B. **4.3** 26%. **4.5** (3) 10:30 a.m. **4.6** (1) A-B unstable, B-C stable, C-D very stable (isothermal); (2) 4.5 km. **4.7** 90%. **4.8** (1) yes; (3.2) L_{strat} = $2.7x10^{12}$ moles yr^{-1}. **4.9** (1) 6.9 h (sea level), 1.7 h (10 km); (2) 93 km.

Chapter 5

5.1 (3) 0.9 atoms cm^{-2} s^{-1}; (4) 5.0 km.

Chapter 6

6.1 (4) $1.9x10^{18}$ kg O. (5) summer, 3 ppmv. **6.3** (1) escape to outer space; (4) 1.1 million years. **6.4** (1.1) 0.022; (1.3) no; (1.5) 14%; (2.2) 58%; (2.3) no. **6.5** (2) 320 years; (3) ~20% land biota, ~0.1% ocean biota. **6.6** pH 8.1. **6.7** (1) 12 years; (2) 6%. **6.8** (1.2) one; (1.3) no; (2.1) +8.9 ppmv CO_2 and -12.4 ppmv O_2; (2.2) 40% biosphere, 24% oceans, 36% accumulation. **6.9** (5) 7%.

Chapter 7

7.3 (1.1) 89 K; (1.3) 15 W m^{-2}, four times the source from solar radiation; (2.1) 218 K. **7.4** (1) 270 K; (2) 284 K; (3) 314 K. **7.5** 216 K. **7.6** Optical depth 0.0084.

Chapter 10

10.2 (1) 0.0015 s (20 km), 2.8 s (45 km), yes; $1.5x10^{-5}$ (20 km), 0.028 (45 km), yes; (4) 2.0 years (20 km), 6 hours (45 km). **10.3** (1.1) $6.6x10^{-7}$ s, $5.4x10^{2}$ molecules cm^{-3}; (1.2) 2.3 s, $2.4x10^{9}$ molecules cm^{-3}; (1.3) 18 hours; (2) 24%. **10.4** (1) 3+6, 3+7, 1+5, 1+4+7, 1+4+6; (2) 2, 8. **10.5** (1) $3.5x10^{-2}$ s (reaction 1), 30 s (reaction 5); (3) no;

(4) 1+6+8+9, six times slower; (5) 35 minutes. **10.6** (1) Cl 0.025 s, ClO 36 s, $ClNO_3$ 4 hours, HCl 12 days; (2) 9 days. **10.7** (2) 1+3, 1+11+5, 1+15+4+7. **10.8** (2) Cl 0.06 s, NO 2 s. **10.9** (2) no, it would make it worse; (3) 3 ppbv ethane. **10.10** (1) yes, B,D,Q; (2) yes, up to 235 K; (3.1) 195 K, NAT; (3.2) water ice PSCs will eventually form.

Chapter 11.

11.1 35% (north), 56% (south). **11.2** (1) $3x10^{13}$ moles yr^{-1}; (2.1) 1 for CO, 4 for CH_4; (2.2) $1.6x10^{14}$ moles yr^{-1}. **11.3** (1.2) 2.25; (1.3) 2.11; (1.4) 0.14; (2.1) 50%; (2.2) 1.06 (CH_4), 0.5 (CO). **11.4** (2.1) $1.9x10^5$ (present), $2.3x10^5$ (preindustrial), $1.1x10^5$ (glacial). **11.5** (1) 11 O_3, 6 HO_x; (2) $9x10^3$ molecules cm^{-3} s^{-1} (acetone), $3.3x10^3$ molecules $cm^{-3}s^{-1}$ (ozone); (4.1) 1 O_3, zero HO_x; (4.2) $1.1x10^5$ molecules cm^{-3} s^{-1} (CO), $1.6x10^4$ molecules cm^{-3} s^{-1} (acetone). **11.6** (3) f_{H2O2} = 4.2, f_{CH3OOH} = 0.06; (4) $5x10^3$ molecules cm^{-3} s^{-1}; (5) HO_x yield 1.7, HO_x source $8.5x10^3$ molecules cm^{-3} s^{-1}. **11.7** (2) Reaction 3; (3) 39 ppbv day^{-1}; (4.2) 0.15 pptv Br, 11 pptv BrO, 16 pptv HOBr, 23 pptv HBr. **11.8** (3) 2.0 hours; (4) 15 hours. **11.9** (1) 19 ppbv NO, 81 ppbv NO_2; (3.1) 4.5 pptv NO_x; (3.2.1) 35 minutes for NO_x, 47 minutes for PAN (298 K), 25 days for PAN (260 K); (3.2.2) 0.56 ppbv NO_x; (3.2.3) 0.10 ppbv NO_x. **4.10** (1) $[NO]/[NO_2]$ = 0.5, achieved in a few minutes; (3) underestimate.

Chapter 12.

12.1 (1) 0.92. **12.2** (3) 30 km downwind.

Chapter 13.

13.2 pH 4.4. **13.4** (1) 15 ppbv SO_2; (2) pH 2.18; (3) yes, barely. **13.5** (1) pH 5.7; (2) HCOOH; (3.1) $[NO_3^-] = [SO_4^{2-}] = 2.7x10^{-6}$ *M*; (3.2) pH 4.85, H_2SO_4 followed by HCOOH.