1-1 Using Equation 1-1 M_w of CO = 12+16 = 28

$$\mu g/m^3 = \frac{ppm\,(M_w)(10^3)}{24.5}$$

$$= \frac{(35)(28)(10^3)}{24.5} = 40{,}000\ \mu g/m^3$$

or $40\ mg/m^3$

1-2 Eq. 1-1

$$ppm = \frac{(\mu g/m^3)(24.5)}{M_w\,(10^3)}$$

$$= \frac{(80)(24.5)}{64 \times 10^3} = 0.0306\ ppm$$

1-3 7000 grains = 1 lb.

$$Conc = 150\frac{\mu g}{m^3} \times \frac{1\ m^3}{35.3\ ft^3} \times \frac{1\ g}{10^6\ \mu g} \times \frac{1\ lb}{453.6\ g} \times \frac{7000\ gr}{lb}$$

$$= 6.5 \times 10^{-5}\ grains/ft^3$$

1-4 Eq 1-1

$$\mu g/m^3 = \frac{0.25 \times 48 \times 10^3}{24.5} = 490$$

$$\%\ exceeded = \frac{490-240}{240} = 104\%$$

1-5 % by volume = ppm $\times 10^{-4}$ = 400×10^{-4}

= 0.04

Using Eq. 1-1 $\mu g/m^3 = \dfrac{400 \times 28 \times 10^3}{24.5}$

Conc = $457 \times 10^{3}\ \mu g/m^3 = 457\ mg/m^3$

1-6. Rewriting eq 1-1.

$$ppm = \frac{(\mu g/m^3)(24.5)}{(10)^3(\text{mol wt})}$$

$$= \frac{(100)(24.5)}{(10)^3(46)} = 0.05326$$

1-7. (a) $C = 160\ \mu g/m^3$

$$C = (160\ \mu g/m^3)\left(\frac{1\ \text{grain}/ft^3}{2.29\ g/m^3}\right) \times \frac{g}{10^6\ \mu g} = 6.99 \times 10^{-5}\ \text{grains}/ft^3$$

(b) $C = 10\ \text{grains}/ft^3$

$$C = \left(\frac{10\ \text{grains}}{1\ ft^3}\right)\left(\frac{2.29\ g/m^3}{1\ \text{grain}/ft^3}\right)\left(\frac{10^6\ \mu g}{g}\right) = 22.9 \times 10^6\ \mu g/m^3$$

1-8. (a) Eq. 1-7. $L_V = \frac{3.9}{\sigma}$ $\quad \sigma = \left(\frac{3.9}{2}\right) mi$

and $\left(I/I_o\right)_{0.2\,mi} = \exp\left[\left(-\frac{3.9}{2}\right)(0.2)\right] = 0.677$ or 67.7%

(b) When 99% is used, $\ln I/I_o = -\sigma d$

$\ln(0.01) = -\sigma L_V \quad L_V = 4.605/\sigma$

$\therefore\ \sigma = \left(\frac{4.605}{2}\right) mi^{-1}$

and $\left(I/I_o\right)_{0.2\,mi} = \exp\left[\left(\left(-\frac{4.605}{2}\right)(0.2)\right]\right.$

$= .631$ or 63.1%

1-9.

$I/I_o = \exp(-\sigma d)$

$0.02 = \exp(-\sigma L_v)$

$\sigma = \frac{\ln 0.02}{-L_V} = 3.912/L_V$

(a) $\left(I/I_0\right)_{10\%\ path} = \exp\left(\frac{-3.912}{L_v} \times 0.1 L_v\right) = 0.676$

% extinc = 32.4%

(b) $\left(I/I_0\right)_{20\%\ path} = \exp\left(\frac{-3.912}{L_v} \times 0.2 L_v\right) = 0.457$

% extinc = 54.3%

(c) $\left(I/I_0\right)_{50\%\ path} = \exp(-3.912 \times .5) = 0.141$

% extinc = 85.9%

1-10 (a)

		M_w
N_2 =	78% by volume	28
O_2 =	21% by volume	32
MEK =	0.05%	72

M_w MEK = $(CH_3CH_2COCH_3) = 4(12) + 8(1) + 16 = 72$

$1\% \equiv 10^4$ ppm

$\therefore\ N_2 = 78\% \times 10^4 = 780{,}000$ ppm

$O_2 = 21\% \times 10^4 = 210{,}000$ ppm

$MEK = 0.05\% \times 10^4 = 500$ ppm

(b) Eq. 1-1 $\quad \mu g/m^3 = \frac{ppm \times M_w \times 10^3}{24.5}$

$$N_2 = \frac{780{,}000(28)10^3}{24.5} = 8.91 \times 10^8\ \mu g/m^3$$

$$O_2 = \frac{210{,}000(32)(10^3)}{24.5} = 2.7 \times 10^8\ \mu g/m^3$$

$$MEK = \frac{500(72)10^3}{24.5} = 1.47 \times 10^6\ \mu g/m^3$$

1.11 Can use the ideal gas law or start with the equation at 25°C & 1 atm:

(a) use $\frac{\mu g}{m^3} = \frac{ppm(Mw)(10^3)}{24.5}$ and adjust 24.5.

NO: $M_w = 30$

$$\frac{\mu g}{m^3} = \frac{ppm(Mw)10^3}{24.5\left(\frac{300+460}{77+460}\right)\left(\frac{29.92}{30.20}\right)} = \frac{(450)(30)10^3}{24.5\left(\frac{760}{537}\right)(.991)}$$

$$= 392,870\ \mu g/m^3 = \boxed{0.393\ g/m^3}$$

NO_2 $M_w = 46$

$$\frac{\mu g}{m^3} = \frac{(30)(46)10^3}{24.5\left(\frac{760}{537}\right)(.991)} = 40,160\ \mu g/m^3 = \boxed{0.04\ g/m^3}$$

(b) Concentration in ppm remains unchanged unless condensation occurs.

$\therefore$ $NO_2 = \boxed{450\ ppm}$ $NO_2 = \boxed{30\ ppm}$

(c) As in part a, except correct to 20°C & 29.92" Hg

$$\therefore NO = \frac{(450)(30)10^3}{24.5\left(\frac{293}{298}\right)\left(\frac{29.92}{29.92}\right)} = 560,423\ \mu g/m^3 \text{ or } \boxed{0.56\ g/m^3}$$

$$NO_2 = \frac{(30)(46)10^3}{24.5\left(\frac{293}{298}\right)} = 57288\ \mu g/m^3 \text{ or } \boxed{0.057\ g/m^3}$$

1-12 (a) $I = I_0 e^{-\sigma_{scat} d}$

$$-\sigma_{scat} d = \ln(0.08) = -2.526$$

$$\therefore \sigma_{scat} = \frac{2.526}{1{,}000} = 2.53 \times 10^{-3}\ m^{-1}$$

(b) $\sigma_{scat} = NK\pi r^2$ $\quad N m_p = C$ and $\left(\frac{4\pi r^3}{3}\right)\rho_p = m_p$

$$\therefore N = \frac{C}{\frac{4}{3}\pi r^3 \rho_p} = 745\ \frac{\mu g}{m^3} \times \frac{3}{4\pi(0.4\times10^{-6})^3}\ \frac{1}{m^3}$$

$$\times \frac{cm^3}{1.15 g} \times \frac{m^3}{10^6 cm^3} \times \frac{g}{10^6 \mu g} =$$

$$\frac{(745)(3)}{4\pi} \times \frac{1}{1.15} \times \left(\frac{1}{0.4}\right)^3 \times \frac{1}{10^{-6}} = 2.416\times10^9$$

$$= 2{,}420\ \text{parts}/cm^3$$

$$K = \frac{\sigma_{scat}}{N\pi r^2} = \frac{2.53\times10^{-3}}{m} \times \frac{cm^3}{2420} \times \frac{1}{\pi} \times$$

$$\frac{1}{(0.4\times10^{-6})^2 m^2} \times \frac{m^3}{10^6 cm^3} = 2.08$$

(c) $L_v = \frac{5.2\ \rho_p\ r}{KC} = \frac{3.9}{\sigma_{scat}}$

$$= \frac{3.9\ m}{2.53\times10^{-3}} \times \frac{km}{10^3 m} = 1.54\ km$$

or

$$L_v = \frac{5.2 \times 1.15 \times 0.4 \times 10^{-6}}{(2.08)(745)} \frac{g}{cm^3} \times m \times \frac{m^3}{\mu g} \times \frac{10^6 cm^3}{m^3}$$

$$\times 10^6 \frac{\mu g}{g} = 1{,}544\ m = 1.54\ km$$

1-13 Droplets are 0.5 μm in diameter

$r = 0.25\ \mu m$, refraction index = 1.5

$\rho_p = 1.1\ g/cm^3$, $\lambda = 0.48\ \mu m$

Visibility = 2 miles = 3220 m

Use Eq. 1-8 $C = \dfrac{5.2\,\rho_p r}{K L_v}$

Use Fig 1-6 to determine K

$$\frac{4\pi r\,|m-1|}{\lambda} = \frac{4(3.14)(0.25)\,|1.5-1|}{0.48}$$

$$= 3.27$$

From Fig 1-6, $K \sim 3.7$

$$\therefore\ C = \frac{(5.2)\left(1.1\frac{g}{cm^3}\right)\left(10^6\frac{cm^3}{m^3}\right)\left(0.25\times10^{-6}\,m\right)}{3.7\,(3220\,m)}$$

$$= 120\times10^{-6}\,g/m^3 = 1.2\times10^{-4}\,g/m^3$$

or $120\ \mu g/m^3$

1-14 Eq 1-7

$$\sigma = \frac{3.9}{L_v} = \frac{3.9}{3} = 1.3\ mi^{-1}$$

Using Eq 1-3 for a length of 0.5 mi

$$\frac{I}{I_o} = \exp\left(-1.3\,mi^{-1}\times 0.5\,mi\right) = 0.522$$

$\therefore$ 52.2% will pass through 0.5 mi

1-15 From Eq. 1-5, $L_v = \frac{3.9}{\sigma_{ext}}$

From Eq. 1-6, $\sigma = NK\pi r^2$

$$\therefore \quad L_v = \frac{3.9}{NK\pi r^2}$$

$$C = N\left(\frac{4\pi r^3}{3}\right)(\rho_p) \quad \text{or} \quad N = \frac{3C}{4\pi r^3 \rho_p}$$

$$\therefore \quad L_v = \frac{3.9}{\left(\frac{3C}{4\pi r^3 \rho_p}\right) K\pi r^2} = \frac{5.2\, r \rho_p}{KC}$$

1-16

(a) From Fig. 1-5,

$\sigma_{abs} \cong 0.14\ km^{-1}$ for 0.1 ppm NO_2 at 0.45 μm

at 30 ppm, $\sigma_{abs} = \frac{30}{0.1} \times 0.14\ km^{-1} = 42\ km^{-1}$

$$\therefore \quad I/I_0 = \exp\left(-42\ km^{-1} \times 6\,m \times \frac{km}{1000\,m}\right)$$

$$= 0.78$$

$$\text{Opacity} = (1 - I/I_0) \times 100\%$$

$$= (1 - .78) \times 100 = 22\%$$

(b) From Fig. 1-5, $\sigma_{abs} \simeq 0.025\ km^{-1}$ at 0.1 ppm

$$\frac{I}{I_0} = \exp\left(-.025\left(\frac{30}{.1}\right)(6\,m)\left(\frac{1}{1000}\right)\right) = 0.956$$

$$\text{Opacity} = (1 - I/I_0) \times 100\% = 4.4\%$$

1-17 $$d_{aero} = d_p \left(\frac{K_c \rho_p}{K_{c_{aero}} \rho_{aero}} \right)^{0.5}$$

For $d_p > 1\,\mu m$, $K_c \simeq 1.0$

$$\therefore d_{aero} \simeq d_p \left(\frac{\rho_p}{1} \right)^{0.5}$$

(a) $d_{aero} = 5\,\mu m\,(1)^{0.5} = 5\,\mu m$

yes, it will be collected in a PM_{10} sampler

(b) $d_{aero} = 5\,\mu m\,(7.9)^{0.5} = 14\,\mu m$; no

(c) $d_{aero} = 10\,\mu m\,(2)^{0.5} = 14\,\mu m$; no

(d) $d_{aero} = 2.5\,\mu m\,(4)^{0.5} = 5\,\mu m$, yes

1-18 From Figure 1-5 for 0.1 ppm of NO_2:

$\sigma_{abs_{0.45\mu m}} = 0.14$, $\sigma_{0.5ppm} = \frac{0.5}{0.1}(0.14) = 0.7\ km^{-1}$

$\sigma_{abs_{0.55\mu m}} = 0.027$, $\sigma_{0.5ppm} = \frac{0.5}{0.1}(0.027) = 0.135\ km^{-1}$

$\sigma_{abs_{0.65\mu m}} = 0.0046$, $\sigma_{0.5ppm} = \frac{0.5}{0.1}(0.0046) = 0.023\ km^{-1}$

$$\sigma_{ext} = \sigma_{Rayleigh} + \sigma_{abs}$$

$\sigma_{Rayleigh} =$ 0.026 km^{-1} at 0.45 μm
0.011 km^{-1} at 0.55 μm
0.006 km^{-1} at 0.65 μm

(a) $\frac{I}{I_o} = \exp(-\sigma d) = \exp\left(-(0.7 + 0.026)(3)\right) = 0.11$

attenuation = 0.89 or 89%

(b) $\frac{I}{I_o} = \exp(-(.135 + .011)(3)) = 0.65$, attenuation = 35%

(c) $\frac{I}{I_o} = \exp(-(.023 + .006)(3)) = 0.917$, attenuation = 8.3%

1-19 $I/I_o = \exp(-kCd)$ for NO_2

$k = ppm^{-1}(km^{-1})$

(a) Using Figure 1-5, determine k at $\lambda = 0.5\,\mu m$

Based on the above equation, $\sigma = kC = km^{-1}$

$$k_{0.5\,\mu m} = \frac{\sigma}{C} = \frac{0.06\ km^{-1}}{0.1\ ppm\ NO_2} = 0.6\ ppm^{-1}km^{-1}$$

(b) neglecting Rayleigh scattering & particles,

For $I/I_o = 0.40 = \exp(-kCd)$

$$C = -\frac{\ln(0.40)}{kd} = -\frac{\ln(0.40)}{0.6(2)} = 0.76\ ppm$$

For $I/I_o = 0.75$ $C = -\frac{\ln(0.75)}{0.6(2)} = 0.23\ ppm$

For $I/I_o = 0.90$ $C = -\frac{\ln(0.90)}{0.6(2)} = 0.087\ ppm$

with Rayleigh scattering of $0.016\ km^{-1}$ at $0.5\,\mu m$,

$I/I_o = 0.40 = \exp(-kCd - .016d)$

$\therefore C = 0.74\ ppm$

$I/I_o = 0.75 \therefore C = 0.21\ ppm$

$I/I_o = 0.90 \therefore C = 0.06\ ppm$

1-20 Note $K = K_{scatt.}$; Using Eq 1-8,

$$L_v = 5.2\left(\frac{1.4g}{cm^3}\right)\left(\frac{0.7\times10^{-4}\,cm}{(2.2)\left(\frac{200\times10^{-6}\,g\times10^{-4}\,cm}{m^3\times cm^2}\right)}\right)$$

$= 0.01158\times10^{-6}\ m = 11.58\ km$

1-21

$$Conc. = \frac{0.53\,g/day}{1.7\frac{m^3}{min}\times\frac{60\,min}{hr}\times\frac{24\,hr}{day}} = 2.17\times10^{-4}\,g/m^3$$

or $217\ \mu g/m^3$

1-22

$$\frac{COHb}{O_2Hb} = \frac{(240)(450)}{190{,}000} = 0.568$$

$$\frac{0.568}{1+0.568} \times 100\% = 36.2\%$$

1-23 (a). O_2 capacity $= (4800\text{ ml blood})\left(\frac{20\text{ ml }O_2}{100\text{ ml blood}}\right)$

$= 960\text{ ml }O_2$

CO breathed $= \left(\frac{4.2\times10^3\text{ ml air}}{\text{min}}\right)\left(\frac{100\times10^{-6}\text{ CO}}{\text{air}}\right)$

$= 0.42\text{ ml CO/min}$

$$t = \frac{0.7\times960}{0.42} = 160\text{ min}.$$

(b) $t = 160 \times \frac{0.05}{0.07} = 114\text{ min}.$

1-24 $\frac{COHb}{O_2Hb} = \frac{m\,P_{CO}}{P_{O_2}}$ where $m = 200-250$

$P_{O_2} = 17.5\%\ O_2 \times \frac{1\text{ ppm}}{10^{-4}\%} = 17.5\times10^4\text{ ppm}$

If $m = 200$

$$\frac{COHb}{O_2Hb} = 200\left(\frac{220}{17.5\times10^4}\right) = 0.251$$

$$\%\ COHb = \frac{0.251}{1.251}(100) = 20.1\%$$

If $m = 250$

$$\frac{COHb}{O_2Hb} = 250\left(\frac{220}{17.5\times10^4}\right) = 0.314$$

$$\%\ COHb = \frac{0.314}{1.314}\times100 = 23.9\%$$

1-25

(a) Based on Figure 1-8, the value of 1.5% COHb is created by a 1 hr exposure at a concentration of about 40 ppm.

(b) The value of 1.5% is off of the graph slightly, but is estimated to be about 8-9 ppm for an 8-hr exposure.