

SOLUTIONS FOR CHAPTER 7

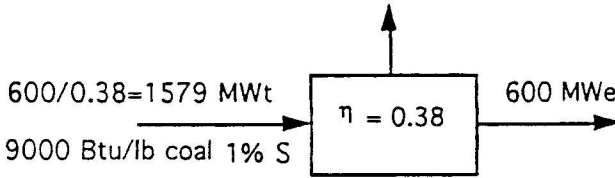
7.1 From (1.8), $\text{mg/m}^3 = \frac{\text{ppm} \times \text{mol wt}}{24.465}$ (at 1 atm and 25°C)

a. $\text{CO}_2 \text{ mg/m}^3 = \frac{5000 \text{ ppm} \times (12 + 2 \times 16)}{24.465} = 8992 \text{ mg/m}^3 \approx 9000 \text{ mg/m}^3$

b. $\text{HCHO ppm} = \frac{24.465 \times 3.6 \text{ mg/m}^3}{(2 \times 1 + 12 + 16)} = 2.94 \text{ ppm}$

c. $\text{NO mg/m}^3 = \frac{25 \text{ ppm} \times (14 + 16)}{24.465} = 30.7 \text{ mg/m}^3$

7.2 70% efficient scrubber, find S emission rate:



$$\text{Input} = \frac{600.000 \text{ kWe}}{0.38} \times \frac{3412 \text{ Btu}}{\text{kWhr}} \times \frac{\text{lb coal}}{9000 \text{ Btu}} \times \frac{0.01 \text{ lb S}}{\text{lb coal}} = 5986 \text{ lb S/hr}$$

70% efficient, says release $0.3 \times 5986 \text{ lbS/hr} = 1796 \text{ lb S/hr} \approx 1800 \text{ lbS/hr}$

7.6 Pollutant Standards Index:

Pollutant	Standard	Day 1 (index)	Day 2 (index)	Day 3 (index)
O ₃ (1hr)	0.12	0.15 (>100)	0.18 (>100)	0.12 (=100)
CO (8hr)	9	12 (>100)	9 (=100)	14 (>100)
PM 10	150	150 (=100)	350 (=200)	90 (<100)
SO ₂	0.14	0.12 (<100)	0.28 (<200)	0.14 (=100)
NO ₂	0.6 alert	0.4 none	0.3 none	0.5 none

a. Day 1, both O₃ and CO are above 100:

$$\text{O}_3 \text{ subindex} = 100 + \frac{(0.15 - 0.12) \times 100}{(0.20 - 0.12)} = 137.5$$

$$\text{CO subindex} = 100 + \frac{(12 - 9) \times 100}{(15 - 9)} = 150$$

so PSI = 150 Unhealthful

b. Day 2, highest is PM 10 at 200, so PSI = 200, Very Unhealthful

c. Day 3, CO is the highest, so

$$\text{PSI (CO)} = 100 + \frac{(14 - 9) \times 100}{(15 - 9)} = 183$$

Now turn off the burners and watch CO coast down until 10pm, 3hrs later:

$$C(3\text{hrs}, 10\text{pm}) = C(0, 7\text{pm})e^{-kt} = 16.8e^{-0.2/\text{hr} \times 3\text{hrs}} = 9.3\text{mg}/\text{m}^3$$

7.48 $I=0.39\text{ach}$, $V=27\text{m}^3$, after 1-hr $\text{NO} = 4.7\text{ppm}$; find source strength, S :
first convert NO in ppm to mg/m^3 using (1.8) and assuming $T=25^\circ\text{C}$,

$$\text{mg}/\text{m}^3 = \frac{\text{ppm} \times \text{mol wt}}{24.465} = \frac{4.7 \times (14 + 16)}{24.465} = 5.76\text{mg}/\text{m}^3$$

a. Source strength, rearrange (7.62)

$$S = \frac{IVC}{(1 - e^{-kt})} = \frac{0.39 \frac{\text{ac}}{\text{hr}} \times 27 \frac{\text{m}^3}{\text{ac}} \times 5.76 \frac{\text{mg}}{\text{m}^3}}{(1 - e^{-0.39/\text{hr} \times 1\text{hr}})} = 188\text{mgNO}/\text{hr}$$

b. 1-hr after turning off the heater,

$$C = C_0 e^{-kt} = 4.7\text{ppm} \times e^{-0.39/\text{hr} \times 1\text{hr}} = 3.2\text{ppmNO}$$

c. in a house with 0.2ach , 300m^3 ,

$$C(\infty) = \frac{S}{IV} = \frac{188\text{mg}/\text{hr}}{0.2 \frac{\text{ac}}{\text{hr}} \times 300 \frac{\text{m}^3}{\text{ac}}} = 3.1\text{mg}/\text{m}^3 \times \frac{24.465}{30} = 2.6\text{ppm}$$

7.49 100MW coal plant, 33.3% efficient, $\text{CF}=0.70$,

a. electricity generated per year,

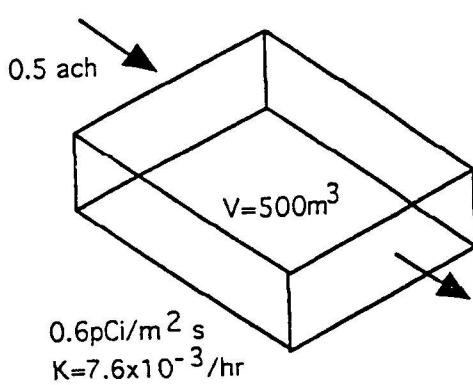
$$\text{Energy} = 100,000\text{kW} \times 24\text{hr}/\text{day} \times 365\text{day}/\text{yr} \times 0.70 = 613 \times 10^6 \text{kWh}/\text{yr}$$

b. heat input = $613 \times 10^6 \text{kWh}/\text{yr}$ out $\times \frac{3 \text{kWh}_t \text{ in}}{1 \text{kWh}_e \text{ out}} \times \frac{3412\text{Btu}}{\text{kWh}} = 6.28 \times 10^{12} \text{Btu}/\text{yr}$

c. Shut it down and sell the allowances,

$$\text{SO}_2 \text{ saved by shutting down} = 6.28 \times 10^{12} \frac{\text{Btu}}{\text{yr}} \times \frac{0.6 \text{ lb SO}_2}{10^6 \text{ Btu}} \times \frac{\text{ton}}{2000 \text{ lb}} = 1883 \text{ tons}/\text{yr}$$

$$1883 \frac{\text{tons}}{\text{yr}} \times \frac{1 \text{ allowance}}{\text{ton}} \times \frac{\$1500}{\text{allowance}} = \$2.85 \text{ million}/\text{yr}$$



7.45 Just have half as much ground-floor area to let radon in, so:

$$S = \frac{(S/V)}{I + K} = \frac{\left(0.6 \text{ pCi/m}^2 \text{ s} \times 100 \text{ m}^2 / 500 \text{ m}^3\right)}{\left(0.5 / \text{hr} + 7.6 \times 10^{-3} / \text{hr}\right) \times \frac{1 \text{ hr}}{3600 \text{ s}}} = 850 \text{ pCi/m}^3 = 0.85 \text{ pCi/L}$$

7.46 Using exposure factors from Table 4.10 and potency from Prob. 4.10 and 4.12,

$$\text{Exposure} = \frac{1.7 \text{ pCi/L} \times 360 \frac{\text{day}}{\text{yr}} \times 30 \text{ yr}}{365 \text{ day/yr} \times 70 \text{ yr}} = 0.72 \text{ pCi/L average over 70 yr}$$

$$\text{potency} = \frac{400 \text{ mrem/yr}}{1.5 \text{ pCi/L}}$$

$$\text{Risk} = 0.72 \text{ pCi/L} \times \frac{400 \text{ mrem/yr}}{1.5 \text{ pCi/L}} \times \frac{1 \text{ cancer death}}{8000 \text{ rem}} \times \frac{\text{rem}}{10^3 \text{ mrem}} \times 70 \text{ yr} = 0.0017 = 0.2\%$$

Exposure × Potency × Cancer risk due to exposure

1 cancer / 8000 person-rem exposure

7.47 300 m^3 house, 0.2 ach , oven + 2 burners 6pm to 7pm, find CO 7pm and and 10pm. For these circumstances, (7.62) is appropriate:

$$C(t) = \frac{S}{IV} (1 - e^{-Kt})$$

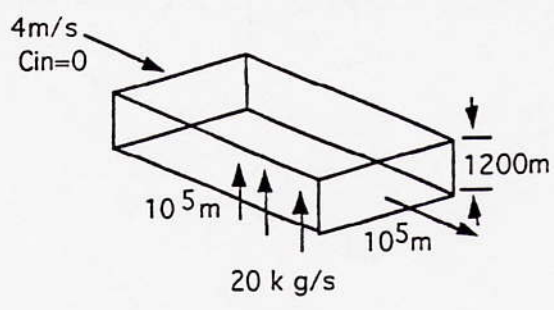
the source strength, S is

$$6 - 7 \text{ pm} : \text{oven} + 2 \text{ burners}, 1900 \text{ mg/hr} + 2 \times 1840 \text{ mg/hr} = 5580 \text{ mg/hr}$$

solving for C after 1 hr:

$$C(1 \text{ hr}, 7 \text{ pm}) = \frac{5580 \text{ mg/hr}}{0.2 \frac{\text{airchange}}{\text{hr}} \times 300 \frac{\text{m}^3}{\text{ac}}} (1 - e^{-0.2 / \text{hr} \times 1 \text{ hr}}) = 16.8 \text{ mg/m}^3$$

7.38 Box model, 10^5 m on a side, $H=1200$ m, $u=4$ m/s, $SO_2=20$ kg/s, steady state:



input rate = output rate

$$20 \frac{\text{kg}}{\text{s}} \times \frac{10^9 \mu\text{g}}{\text{kg}} = 4 \frac{\text{m}}{\text{s}} \times 10^5 \text{m} \times 1200 \text{m} \times C \left(\frac{\mu\text{g}}{\text{m}^3} \right)$$

$$C = \frac{20 \times 10^9}{4 \times 10^5 \times 1200} = 41.7 \mu\text{g} / \text{m}^3$$

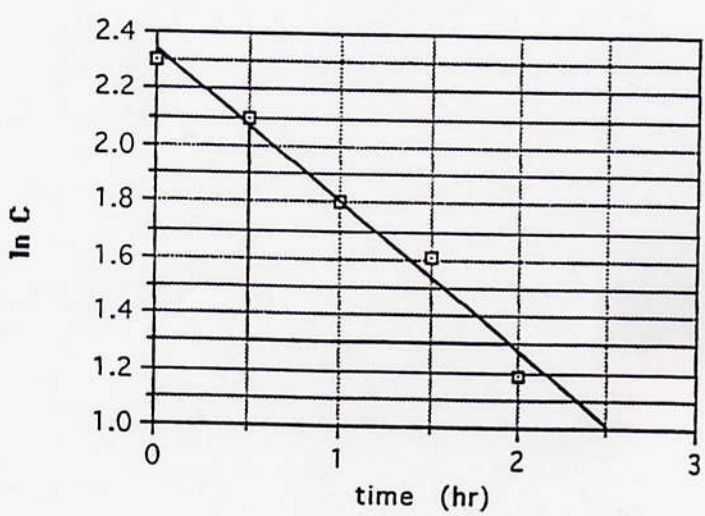
7.43 Starting with (7.61) and using the special conditions of this tracer-gas study; that is, a conservative tracer ($K=0$), no tracer in the air leaking into the room ($C_a=0$), and the tracer source turned off at $t=0$ ($S=0$) gives the exponential decay of tracer as:

$$C(t) = C_0 e^{-It}$$

$$\ln[C(t)] = \ln(C_0) - It \text{ which is of the form}$$

$$y = mx + b, \text{ where } y = \ln C, m = I, \text{ and } b = \ln C_0$$

time (hr)	C (ppm)	ln C
0	10.0	2.303
0.5	8.0	2.079
1.0	6.0	1.792
1.5	5.0	1.609
2.0	3.3	1.194



From the graph, the slope is about: $\text{slope} \approx \frac{(2.1 - 1.3)}{2.0 - 0.5} = 0.53$

Thus, the infiltration rate is about 0.53 air changes per hour.

7.7 8 hrs of CO at 50 ppm, from (7.6): $\% \text{COHb} = \beta (1 - e^{-\gamma t}) [\text{CO}]$

$$\% \text{COHb} = 0.15\% (1 - e^{-0.402 \text{ hr} \times 8 \text{ hr}}) \times 50 = 7.2\%$$

$$\beta = 0.15\% \text{ ppm CO}$$

$$\gamma = 0.402 \text{ hr}^{-1} \quad t = \text{exposure time}$$

7.8 $\% \text{COHb} = 0.15\% (1 - e^{-0.402}) (\text{ppm}) = 0.15\% (1 - e^{-0.402 \times 1}) \times 436 = 21.6\%$

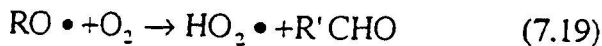
To reach 10% COHb,

$$10 = 0.15 (1 - e^{-0.402t}) \times 436 = 65.4 - 65.4e^{-0.402t}$$

$$e^{-0.402t} = \frac{55.4}{65.4} = 0.871$$

$$\text{so } t = -\frac{1}{0.402} \ln(0.871) = 0.41 \text{ hr}$$

7.9



for R'CHO to be HCHO, R' must be H so that

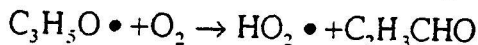
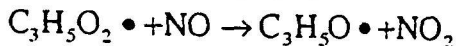
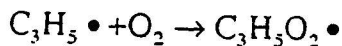
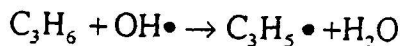


for the reaction to balance, R = CH₃

which says RH in (7.16) must be CH₄ (methane)

7.10 RH = propene = CH₂=CH-CH₃ = C₃H₆ so, R = C₃H₅

so the sequence of reactions (7.16) to (7.19) are:



The end product is acrolein, CH₂CHCHO.