Instructor's Manual

Unit Operations and Processes in Environmental Engineering

Second Edition

Reynolds/Richards

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UNIT OPERATIONS AND PROCESSES IN ENVIRONMENTAL ENGINEERING

Second Edition

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Contents

[1] No quantitative problems in Chapter 6 or Chapter 24 - hence no worked solutions

Problem 1.1

Na^{+} $\underline{AW = 23}$ Eq. wt. = 23/1 = 23 gm

Ca^{+2} $\underline{AW = 40}$ Eq. wt. = 40/2 = 20 gm

Na^{+} meq wt = 23 mg

Meqs = (102 mg/l) ÷ 23 mg/meq = $\underline{4.43 \text{ meqs/l}}$

Ca^{+} meq wt = 20 mg

Meqs = (68 mg/l) ÷ 20 mg/meq = $\underline{3.40 \text{ meqs/l}}$

Problem 1.2

$CaCl_2$ MW = 40 + 2(35) = 110

Meq wt = 110/2 = 55 mg

Meqs = (168 mg/L) ÷ 55 mg/meq = 3.05 meq/L

Problem 1.3

1 ppm = 1 mg/L if specific gravity = 1.00

134 parts per million = <u>134 mg/L</u>

Problem 1.4

$pH = 7.6$

$pH = \log \frac{1}{[H^+]}$

$[H^+] = \underline{10^{-7.6} \text{ moles}/l}$

$[H^+][OH^-] = 10^{-14}$

$[10^{-7.6}][OH^-] = 10^{-14}$

$[OH^-] = \underline{10^{-6.4} \text{ moles}/l}$

Problem 1.5

It goes to completion because an insoluble product is formed.

Problem 1.6

Carbonate CO_3^{-2}

Bicarbonate HCO_3^-

Hydroxyl OH^-

Problem 1.7

$CaCO_3$ Meq wt $= [40 + 12 + 3(16)]\,1/2 = 50$

Meqs/l $= (185\ mg/l) \div 50\ mg/meq =$ 3.70 m.

Problem 1.8

$CaCO_3$ Meq wt = $[40 + 12 + 3(16)]/2 = 50$

Meq/L = (225 mg/L) ÷ 50 mg/meq = <u>4.50 meq</u>

Problem 1.9

a. Second

b. Zero

c. First

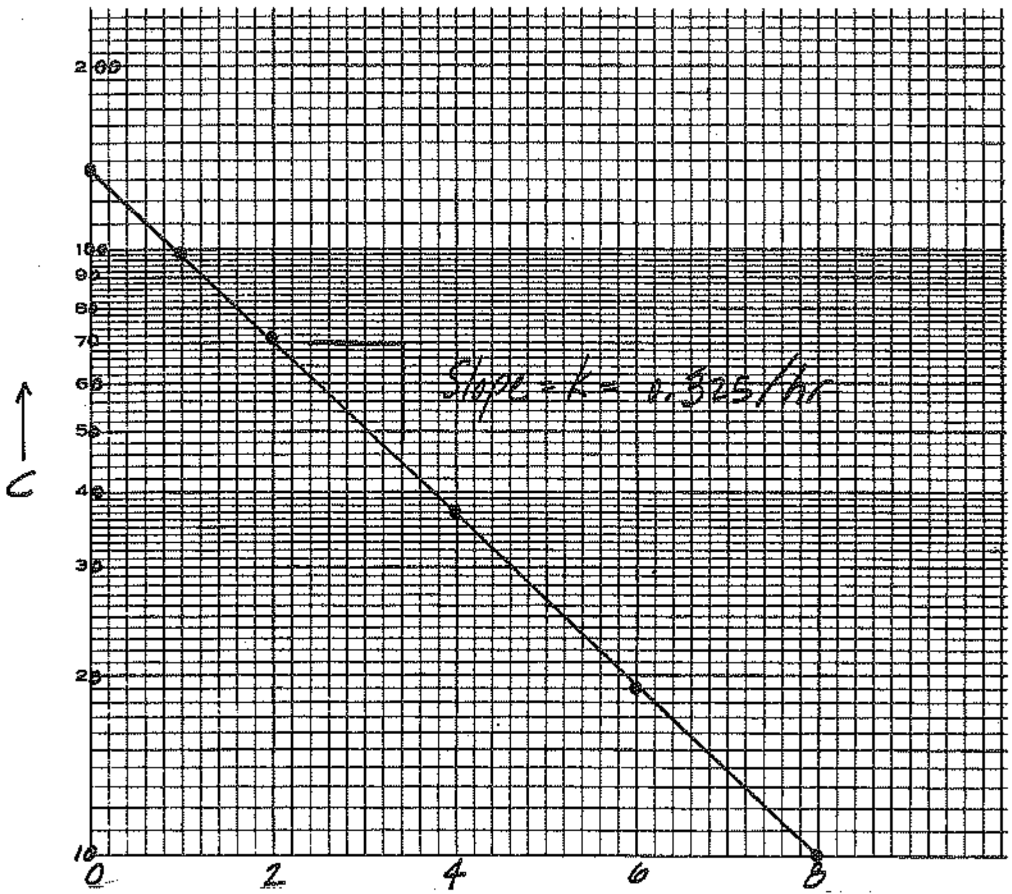
Problem 1.10

a. Assume a first-order reaction. A plot of $\ln C = \ln C_0 - kt$ is shown in Figure 1. Since it is a straight line, its first order.
<u>first-order reaction</u>

b. $K = \dfrac{\ln 135 - \ln 10}{8\,hrs}$

$= \underline{0.325/hr}$

Problem 1.10



t, hrs →

Figure 1

Problem 1.11

a. Assume a second-order reaction. Plot is

$$\frac{1}{C} = \frac{1}{C_0} + Kt$$

Reduced data is:

Time, t (hrs)	C (mg/l)	1/C (l/mg)
0	135	0.0074
1	53	0.0189
2	33	0.0303
3	24	0.0417
4	19	0.0526
5	15	0.0667
6	13	0.0769
7	11	0.0909
8	10	0.100

The plot is a straight line in Figure 1, so it is a <u>second order reaction</u>

b. Slope $= K = \dfrac{(0.10 - 0.0074)\ l/mg}{8\ hrs}$

$= \underline{0.011575\ l/mg\text{-}hr}$

Problem 1.11

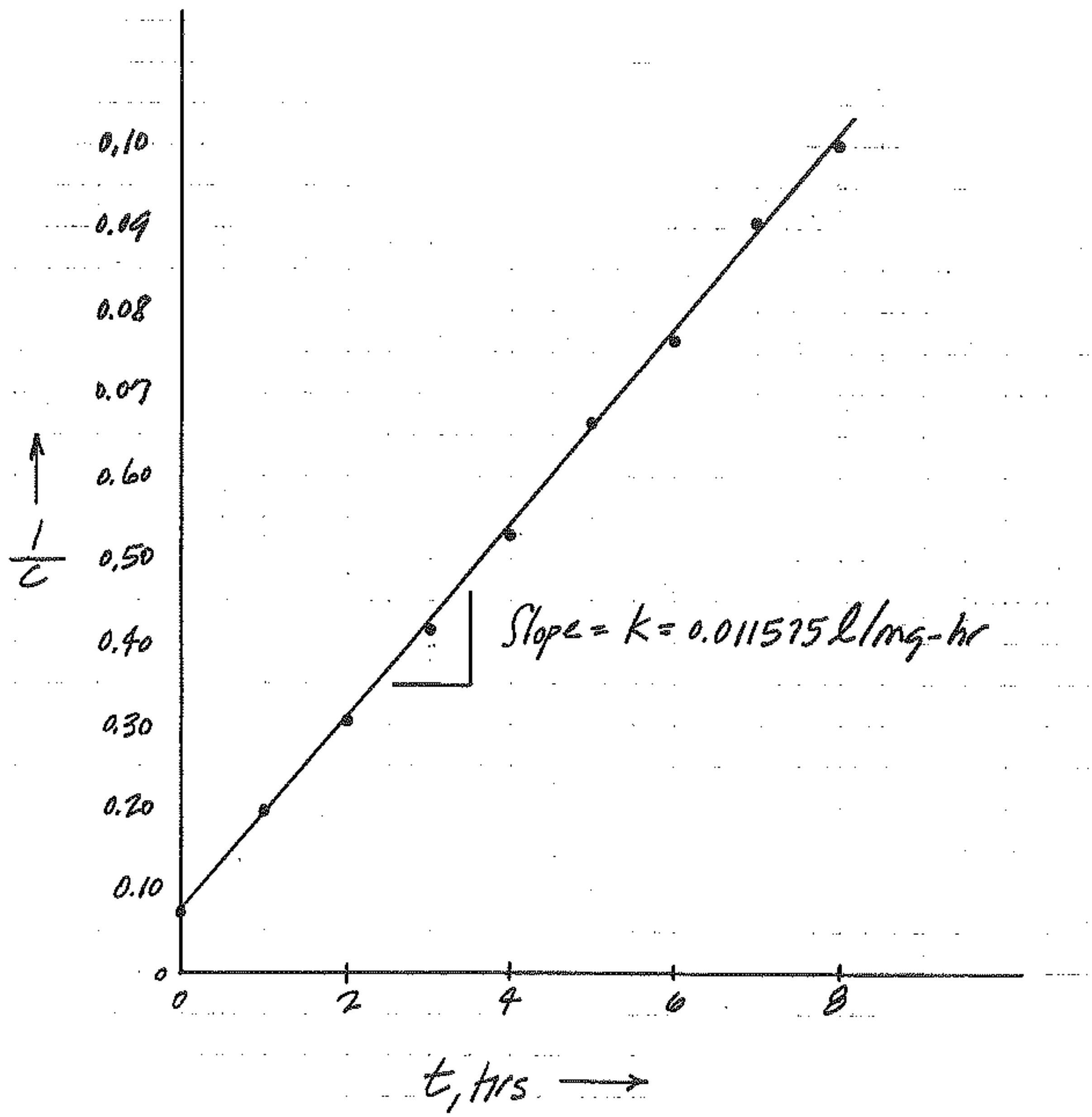


Figure 1

Problem 1.12

a. Assume a zero-order reaction. Plot is

$C = C_0 - kt$

Plot is shown in appropriate figure. Since it is straight line it is zero-order

b. Slope $= k = \dfrac{(135-10)\ mg/l}{8\ hr} = \underline{15.625\ mg/l\text{-}hr}$

Problem 1.12

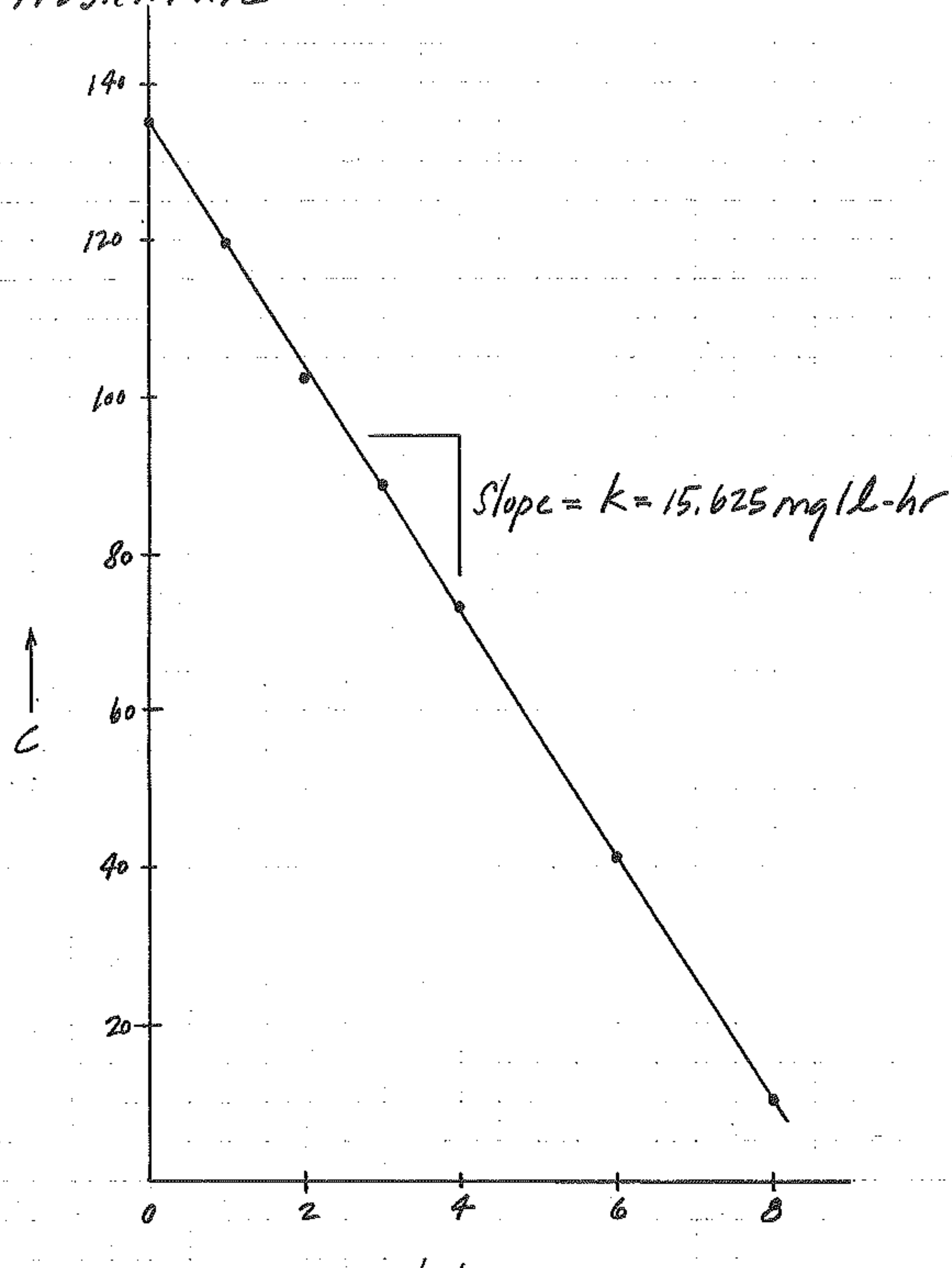


Figure 1

Problem 1.13

C_s = Constant · p_g

C_s = 43.8 mg/l-atmospheres

El. 1000	733 mm Hg
1500	x
2000	706 mm Hg

$x = (733 + 706)\frac{1}{2} = 719.5$ mm

atmospheres = 719.5/760 = 0.9467

C_s = (43.8 mg/l-atm)(0.9467 atm.)(0.209

= <u>8.67 mg/l</u>

Problem 1.14

$C_s = 43.8 \text{ mg/L-atm} \times p_g$

$p_g = 0.80$ atmospheres

$C_s = (43.8 \text{ mg/L-atm})(0.80 \text{ atm})$

$= \underline{35.0 \text{ mg/L}}$

Problem 1.16

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$T_1 = T_2$$

$$P_1 V_1 = P_2 V_2$$

For USCS Units:

$P_1 = 14.7 \text{ psi} + (10/12 \text{ ft})(\text{psi}/2.31 \text{ ft}) = 15.06 \text{ ps}$

$P_2 = 14.7 + 35 = 49.7 \text{ psia}$

$$V_2 = \frac{P_1}{P_2} V_1 = \left(\frac{15.06}{49.7}\right)(162{,}000 \text{ ft}^3/\text{day})$$

$$= 49{,}089 = \underline{49{,}100 \text{ ft}^3/\text{day}}$$

For SI Units:

$P_1 = 101.37 \text{ kPa} + (10/12 \text{ ft})(\text{psi}/2.31 \text{ ft})(6.8957 \text{ k}$

$= 101.37 + 2.49 = 103.84 \text{ kPa}$

$P_2 = 101.37 + 241 = 342.37 \text{ kPa}$

$$V_2 = \left(\frac{103.84}{342.37}\right)(4590 \text{ m}^3/\text{d})$$

$$= 1392 = \underline{1390 \text{ m}^3/\text{d}}$$

Problem 1.15

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$T_1 = T_2$, so

$P_1V_1 = P_2V_2$

For USCS Units:

$V_1 = 110{,}000\ ft^3$

$P_1 = 14.7\ psi + (10/12\ ft) \div 2.31\ ft/psi = 15.06\ psi$

$P_2 = 14.7\ psi + 30\ psi = 44.7\ psia$

$$V_2 = \frac{P_1}{P_2}V_1$$

$$= \left(\frac{15.06}{44.7}\right)(110{,}000\ ft^3) = 37{,}060 = \underline{37{,}100\ ft}$$

For SI Units

$P_1 = 101.37\ kPa + (10/12\ ft)(psi/2.31\ ft)(6.8957$

$= 101.37 + 2.49 = 103.84\ kPa$

$P_2 = 101.37 + 207 = 308.37\ kPa$

$$V_2 = \left(\frac{103.84}{308.37}\right)(3{,}114\ m^3) = 1049 = \underline{1050\ m^3}$$

Problem 1.17

Driving force = $C_s - C_a$

Ratio = $\frac{9.0 - 6.0}{9.0 - 4.0} = \frac{3}{5} = \underline{0.60}$