

1. Assume that you will be measuring the concentration of a compound in the gas phase via its proton transfer reactions with a reagent ion. You begin with a fixed number of reagent ions in the presence of a constant concentration of analyte species. You are able to measure the abundances of the remaining reagent ion at two fixed times (which you know). Assuming you also know the rate constant for the reaction and that there are no other loss mechanisms for the reagent ion, answer the following questions:

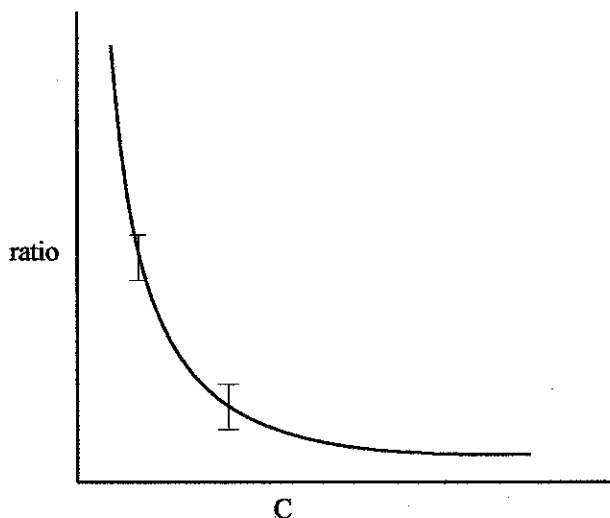
- a) Write the relationship you would use to determine the analyte concentration.
(5 pts.)

$$\frac{[R^+]_{t_2}}{[R^+]_{t_1}} = e^{-Ck(t_2-t_1)} \quad \text{therefore, } C = \frac{-\ln \frac{[R^+]_{t_2}}{[R^+]_{t_1}}}{k(t_2-t_1)}$$

Where C is concentration, k is the rate constant, and t2 and t1 are the two times (t2 > t1).

- b) Draw a plot of the measured quantity versus concentration to show the qualitative shape of the relationship.
(5 pts.)

$$\frac{[R^+]_{t_2}}{[R^+]_{t_1}} = \text{ratio}$$



c) Assuming a fixed indeterminate error in the measurement discussed in b), how will the resulting absolute error in concentration depend upon concentration? Don't worry about the sign of the error, just its magnitude. Write the appropriate relationship and draw the shape of the absolute error versus concentration curve.

(10 pts.)

Sensitivity = derivative in response with respect to concentration

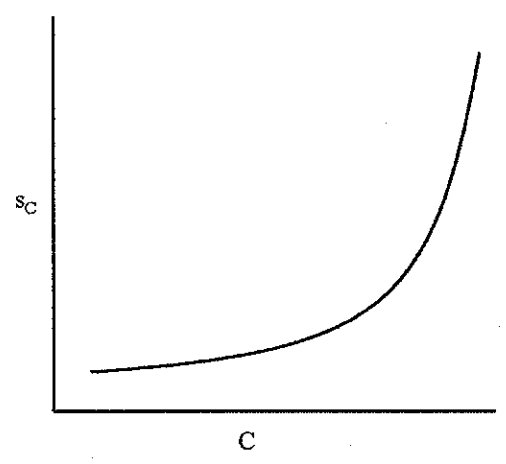
$$\frac{d(\text{ratio})}{dC} = \frac{d(e^{-Ck(t_2-t_1)})}{dC} = -kte^{-Ck(t_2-t_1)}$$

The error in measurement of the ratio, s_R , and the resulting error in concentration, s_C , are also related by the sensitivity, i.e.

Sensitivity = s_{ratio}/s_C .

Hence, $s_C = s_{\text{ratio}}/\text{sensitivity}$

$$s_C = -\frac{s_{\text{ratio}}}{k(t_2-t_1)e^{Ck(t_2-t_1)}} = -\frac{e^{Ck(t_2-t_1)}}{k(t_2-t_1)} s_{\text{ratio}} = -\frac{s_{\text{ratio}}}{k(t_2-t_1)(\text{ratio})}$$



d) If the analyte were present at concentrations that exceeded the dynamic range of your procedure (i.e., the concentration is too high), provide and discuss two approaches to modify the procedure (other than sample dilution) that would allow for a measurement in the linear range of the procedure.

(10 pts.)

a) modify the procedure by using a reagent ion with a smaller rate constant, k . This reduces the change in ratio for a given reaction time

b) make the difference between t_1 and t_2 smaller

2. A method was used to determine H_2O_2 by reacting it quantitatively with excess iodide ion to produce I_3^- , followed by the determination of the concentration of this species potentiometrically. The relationship between electrochemical response and $[\text{I}_3^-]$ was:

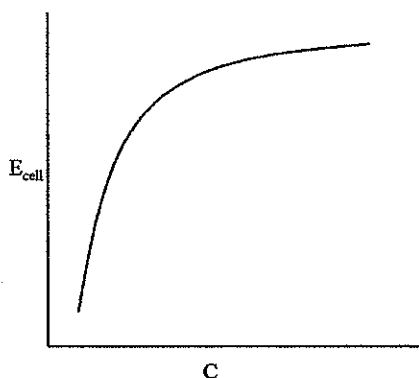
$$E_{\text{cell}} = \alpha + \beta \ln[\text{I}_3^-]$$

Answer the following questions:

a) Draw the qualitative shape of the response as a function of concentration.

(5 pts.)

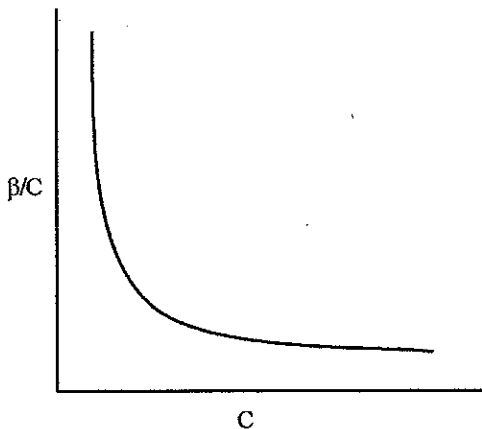
$$[\text{I}_3^-] = C = e^{(E_{\text{cell}} - \alpha)/\beta}$$



b) What is the relationship between concentration and sensitivity for this method? Write the appropriate relationship and draw the shape of the sensitivity versus concentration curve.

(5 pts.)

$$\text{Sensitivity} = dE_{\text{cell}}/dC = 0 + \beta(d\ln C/dC) = \beta/C$$

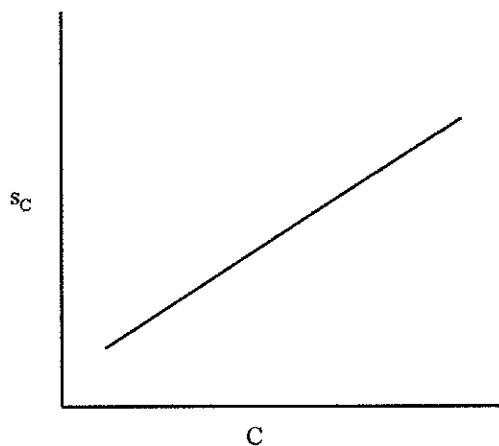


c) Provide the relationship between indeterminate error and the resulting concentration error (i.e., indicate how the measurement error propagates to concentration error). Draw the shape of the curve expected for concentration error versus concentration when the measurement error is constant with concentration.

(10 pts.)

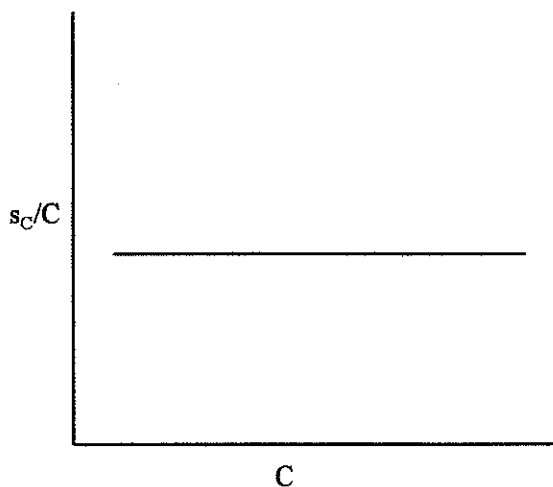
$$\text{Absolute concentration error} = s_{E_{\text{cell}}}/\text{sensitivity} = s_C$$

$$s_C = \frac{C}{\beta} s_{E_{\text{cell}}}$$



d) How does the relative concentration error depend upon concentration for this method? Draw the shape of the curve expected for relative concentration error versus concentration when the measurement error is constant with concentration. (10 pts.)

$$S_C/C = s_{E_{cell}}/\beta = \text{constant}$$



3. You are asked to determine the concentration of a particular species that you know fluoresces with a relatively high quantum efficiency. Assuming there are no significant matrix effects and that you can work under conditions in which the product of pathlength, molar absorptivity, and concentration is < 0.05 , answer the following questions:

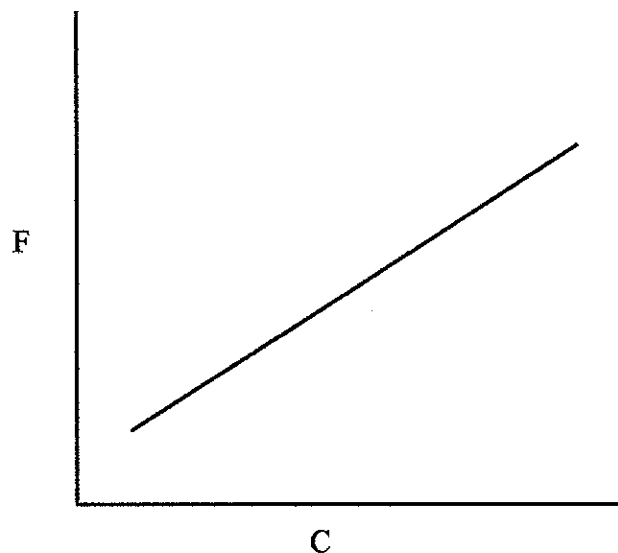
a) Assuming a constant incident radiative power, how will the fluorescence signal vary with analyte concentration?

(5 pts.)

$$F \approx 2.3\epsilon b\kappa C P_0$$

Where ϵ is molar absorptivity, b is path length, κ is a constant related to quantum efficiency and P_0 is the incident power.

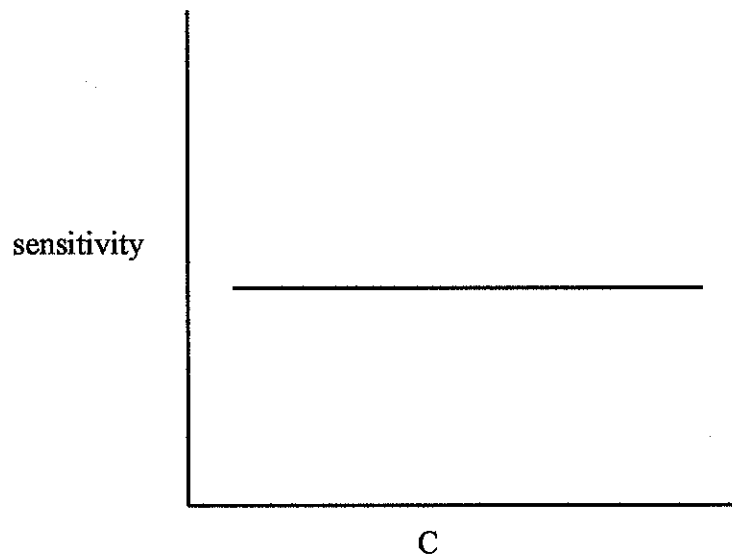
Hence, $C \approx F/(2.3 \epsilon b\kappa P_0) = F/\text{constant}$



b) How will sensitivity depend upon concentration?

(5 pts.)

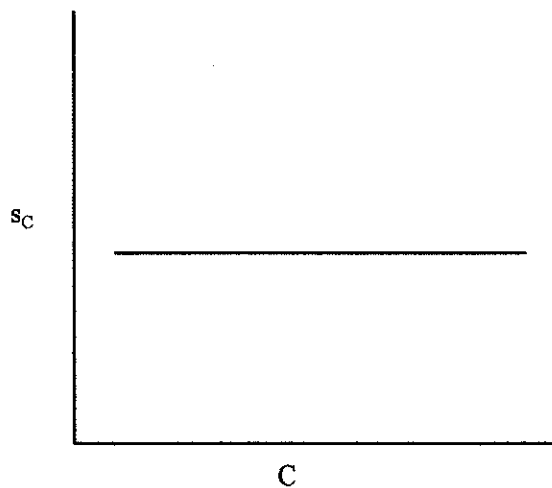
$$\text{Sensitivity} = dF/dC = d(2.3 \epsilon b\kappa P_0 C)/dC = 2.3 \epsilon b\kappa P_0$$



c) For a fixed indeterminate measurement error, how will concentration error vary with concentration?

(5 pts.)

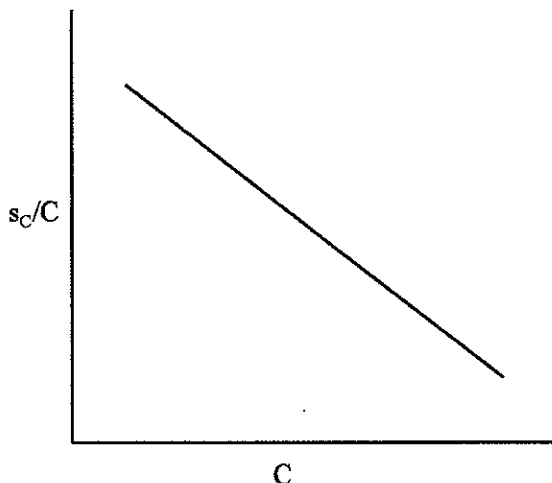
$$\text{Absolute concentration error} = s_C = s_F / \text{sensitivity} = s_F / (2.3 \epsilon b \kappa P_0)$$



d) For a fixed indeterminate measurement error, how will relative concentration error vary with concentration?

(5 pts.)

Relative concentration error = s_c/C



4. You are determining the concentration of the substrate of a particular enzyme via an approach based on Michaelis-Menten kinetics. That is, you are measuring a reaction rate or velocity, v , between the enzyme and substrate that obeys the relation:

$$v = \frac{v_{\max} [S]}{K_M + [S]}$$

where K_M is the Michaelis constant.

a) Of the three approaches discussed in questions 1-3, which will show qualitatively the most similar dependence of relative concentration error on concentration as the kinetic approach in this question? Again, assume a constant indeterminate error in the measurement of v .

(5 pts.)

Answer: question #1

b) Provide justification for your answer.

(10 pts.)

Answer:

$$s_c = \Delta v / \text{sensitivity}$$

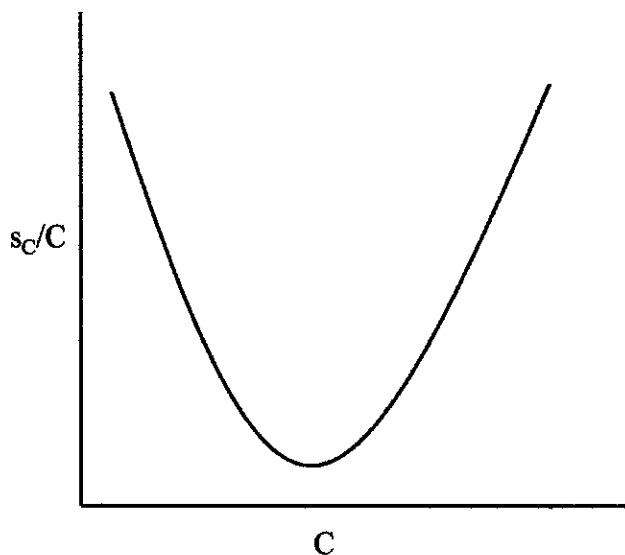
$$\text{sensitivity} = dv/d[S]$$

$$\frac{dv}{d[S]} = \frac{v_{\max} (K_M + [S]) - v_{\max} [S]}{(K_M + [S])^2} = \frac{v_{\max} K_M}{(K_M + [S])^2}$$

$$s_c = \frac{(K_M + [S])^2}{v_{\max} K_M} \times \Delta v = \text{absolute concentration error for fixed } \Delta v$$

$$\frac{s_c}{C} = \frac{(K_M + [S])^2}{v_{\max} K_M C} \times \Delta v = \text{relative concentration error for fixed } \Delta v$$

Plot of s_c/C looks qualitatively similar to that for the method of #1.



5. Estimate the absolute standard deviation for y, as determined from three values according to the following relationship:

$$y = \frac{251(\pm 1) \times 860(\pm 2)}{1.673(\pm 0.006)}$$

where the number in parentheses are the absolute standard deviations associated with each value.

(5 pts.)

$$\frac{s_y}{y} = \sqrt{\left(\frac{1}{251}\right)^2 + \left(\frac{2}{860}\right)^2 + \left(\frac{0.006}{1.673}\right)^2} = 0.0058$$

$$s_y = (0.0058) \times (129,026) = \underline{750}$$

$$y = 1.290(\pm 0.008) \times 10^5$$

Useful relationships:

$$\frac{de^u}{dx} = e^u \frac{du}{dx} \quad \frac{d \ln u}{dx} = \frac{1}{u} \frac{du}{dx}$$

Biochemistry Cumulative Examination
February 5, 2005

OUTLINE OF ANSWERS

1. See for example Garrett & Grisham, *Biochemistry*, 3rd ed., p. 213. Note also that only trace amounts of open chain forms are present for any of the common pentoses and hexoses.
2. See for example *J. Chromatog. A* **1053**, 79-88 (2004).
3. See *Carbohydrate Res.* **339**, 2875-81 (2004).
4. See for example the discussion of eukaryotic N-glycosylation in Voet & Voet, including the necessary but not sufficient protein signal and the structure of the core carbohydrate and its attachment to the protein. For part C, see Hirsch et al., *EMBO Reports* **5**, 201-6 (2004).

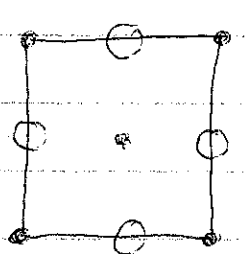
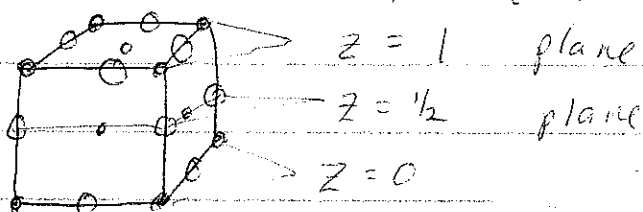
Part I

A. NaCl structure

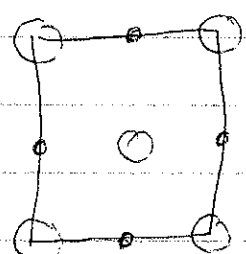
Cubic unit cell edges are equal
 $a = b = c$

• = cation located on corners and center of face of the unit cell
 ○ = anion located on middle of edges and in the center of the unit cell

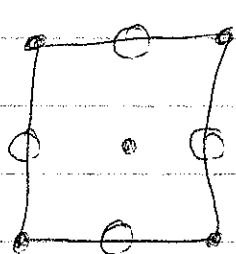
Cation + anion could be switched



plane with $z = 0$

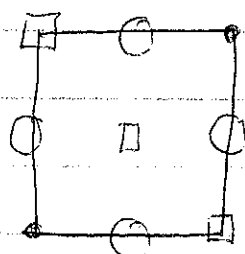


plane with $z = 1/2$

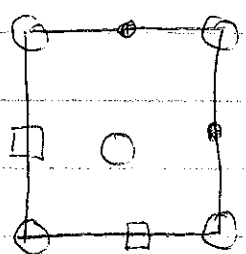


plane with $z = 1$

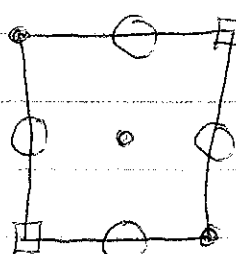
B. • = Li □ = Co^{2+} ○ = O



$z = 0$

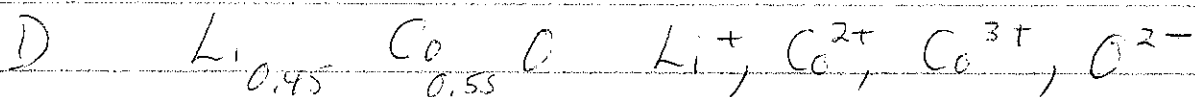
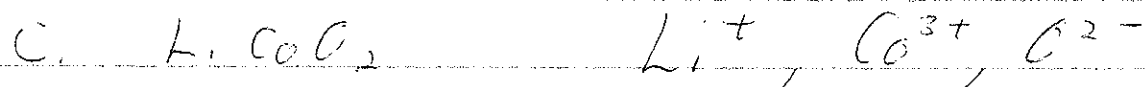


$z = 1/2$



$z = 1$

(2)



$$\text{Li}^+ = 0.45 \text{ positive charge}$$

$$\text{O}^{2-} = 2.00 \text{ negative charge}$$

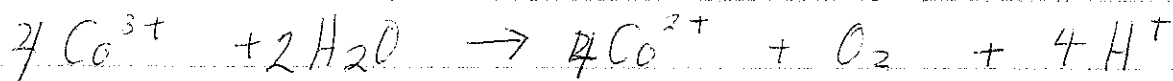
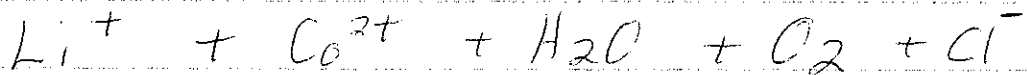
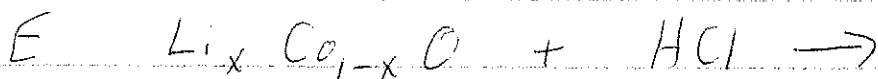
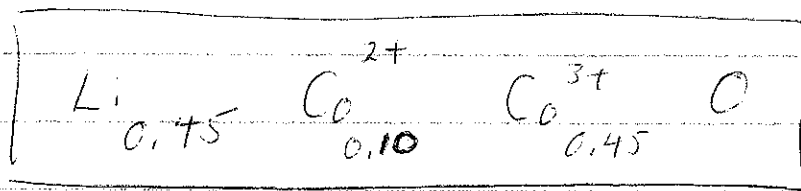
$$\text{Co}_{0.55}^{n+} \equiv 1.55 \text{ positive charge}$$

$$(0.55 - x) \text{Co}^{2+} + x \text{Co}^{3+} = 1.55$$

$$(0.55 - x)^2 + 3x = 1.55$$

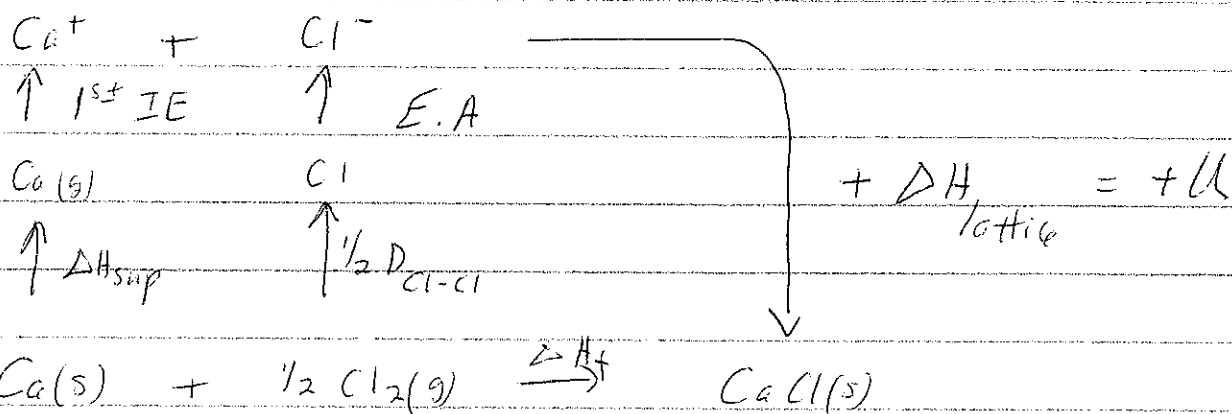
$$1.10 - 2x + 3x = 1.55$$

$$x = 0.45$$



Part II

A.



$$\Delta H_f = \Delta H_{\text{sub}} + 1^{\text{st}} \text{ IE} + \frac{1}{2} D_{\text{Cl-Cl}} + \text{E.A} + U$$

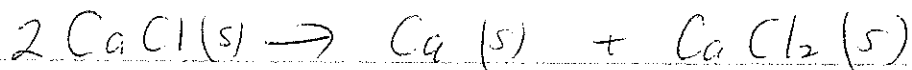
$$U = \frac{2 \times +1 \times -1}{1.20 + 1.81} \times 1.21 \times 10^6 \times \left(1 - \frac{0.345}{1.20 + 1.81}\right)$$

$$= -712 \text{ kJ/mole}$$

$$\Delta H_f = 201 + 589 + \frac{121}{2} + (-349) + (-712)$$

$$\Delta H_f = -210 \text{ kJ/mole for CaCl}$$

B.



$$\Delta H = \Delta H_f(\text{Ca}) + \Delta H_f(\text{CaCl}_2) - 2\Delta H_f(\text{CaCl})$$

$$= 0 - 799 - 2(-210) = -379 \text{ kJ/mole}$$

February Organic Cumulative Examination (Crib) 2/5/05

I (70 pts)

1 (10 pts) c (100% ee)

2

2-i (10 pts) 4

2-ii (10 pts)	1R, 2R	81%
	1R, 2S	9%
	1S, 2R	9%
	1S, 2S	1%
		<hr/>
		100%

2-iii (10 pts)

$$\frac{1R, 2R + 1S, 2S}{1R, 2S + 1S, 2R} = \frac{81 + 1}{9 + 9} = \frac{82}{18} = 4.56 \approx 4.6$$

2-iv (10 pts)

$$\frac{81}{81 + 1} \times 100 = \boxed{98.8\%} \text{ enantiomerically pure}$$

$$\frac{98.8 - 1.2}{98.8 + 1.2} \times 100 = \boxed{97.6\% \text{ ee}}$$

3(20 pts)

$$\frac{90 \times 90 \times 90 \times 90}{90 \times 90 \times 90 \times 90 + 10 \times 10 \times 10 \times 10} \times 100 = \frac{6561 \times 10^4 \times 100}{6561 \times 10^4 + 1 \times 10^4}$$

$$= \frac{99.98776}{9} = \boxed{99.99\%} \text{ enantiomerically pure}$$

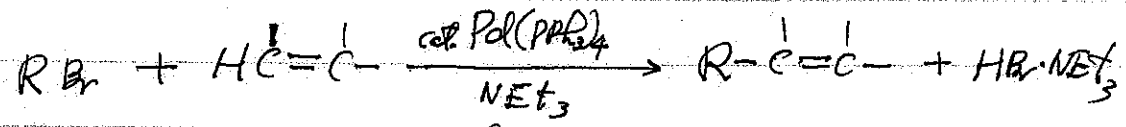
$$\text{or } \frac{99.99 - 0.01}{100} \times 100 = \boxed{99.98\% \text{ ee}}$$

Generalization

As the number of asymmetric centers in the desired product increases, the enantiomeric purity of the major isomer increases through mass action law-based statistical kinetic resolution, provided that the course of reaction is not seriously affected by internal asymmetric induction (due to substrates and/or intermediates).

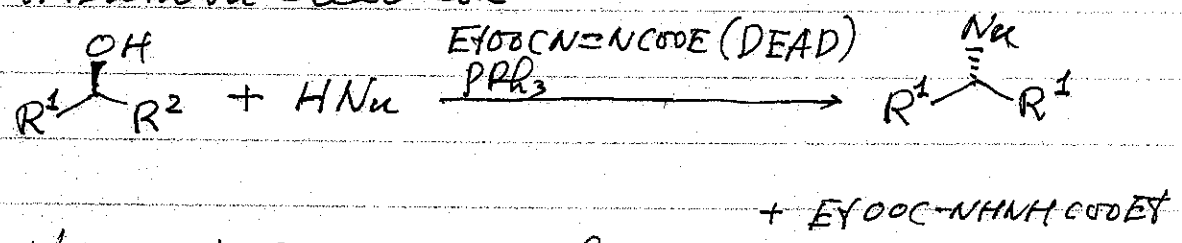
II (30 pts) No mechanism needed

1. Heck reaction



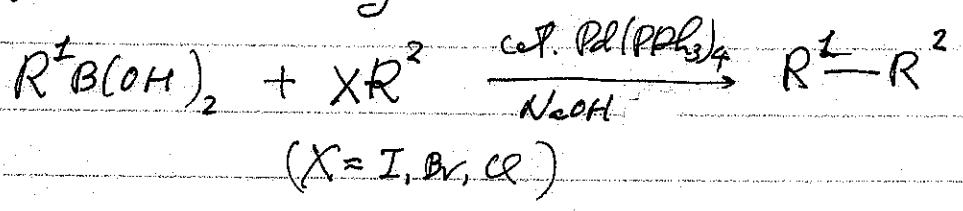
R = Ar, alkaryl, and other suitable C groups

2. Mitsunobu reaction



Nu = N, P, O, S, and other nucleophiles, such as RCOOH, ArOH, RSH, etc.
 $Ph_3P = O$

3. Suzuki coupling



R¹, R² = Various C groups

4. Swern oxidation

