Practical Exam - Solution

Part I : Making a colorimeter - a simple spectrophotometer

P1. In the light-source circuit, measure

(0.2 pt) potential difference across a battery :

$V =$ _____9.56 V_____________

[0.1 pt] for value between 9.00 and 10.50 V
[0.1 pt] for 3 significant figures below 10 V and 4 significant figures above 10 V. (In other words, two decimal points will be good.)
[-0.05 pt] for number with no unit

(0.3 pt) potential difference across a resistor R_{LED} :

$\Delta V_{R_{\text{LED}}}$ = ____6.93 V___________

[0.2 pt] for value between 6.50 and 7.50 V
This is 0.1 pt higher than for the battery because the student has to have a correct wiring to get this value.
[0.1 pt] for 3 significant figures
[-0.05 pt] for number with no unit

(0.3 pt) and potential difference across the LED :

ΔV_{LED} = ___2.630 V_______________.

[0.2 pt] for value within 0.50 V from $V - \Delta V_{R_{\text{LED}}}$
[0.1 pt] for 4 or 3 significant figures (two decimal points, for example 2.63 V, are also OK)
[-0.05 pt] for number with no unit

(0.2 pt) Given $R_{\text{LED}} = 2.20\ \text{k}\Omega$, calculate electric current in this circuit :

$i =$ ______ 3.15 mA ____________ .

[0.1 pt] for correct result
[0.1 pt] for 3 sig. fig.
[-0.05 pt] for number with no unit

P2. In the light-intensity sensor circuit, measure

(0.2 points) potential difference across a battery :

$V =$ ____9.56 V_______________

[0.1 pt] for value between 9.00 and 10.50 V
[0.1 pt] for 3 significant figures below 10 V and 4 significant figures above 10 V (In other words, two decimal points will be good.)
[-0.05 pt] for number with no unit

(0.3 points) potential difference across a resistor R_{PD} :

$\Delta V_{R_{\mathrm{PD}}}$ = ____5.300 V____________

[0.2 pt] for value between 5.000 and 6.000 V
This is 0.1 pt higher than for the battery because the student has to have a correct wiring to get this value.
[0.1 pt] for 3 or 4 significant figures (two decimal points, for example 5.29 V, are also OK)
[-0.05 pt] for number with no unit

(0.3 points) and potential difference across the photodiode :

ΔV_{PD} = ____3.970 V____________.

[0.2 pt] for value within 0.50 V from $V - \Delta V_{R_{\mathrm{PD}}}$
[0.1 pt] for 3 or 4 significant figures (two decimal points, for example 5.29 V, are also OK)
[-0.05 pt] for number with no unit

(0.2 points) Given $R_{\mathrm{PD}} = 300\ \mathrm{k\Omega}$, calculate electric current in this circuit :

$i =$ ____17.7 uA______________.

[0.1 pt] for correct result
[0.1 pt] for 3 sig. fig.
[-0.05 pt] for number with no unit

Part II - Dependence on the path length of the absorbance

P3. **(1.8 points)** Fill out the Table II.3

Given that the thickness of each acrylic plate is 1.00 mm.

Use formula $A_n = \log_{10}\left(\frac{\Delta V_{R_{\text{PD}},n=0}}{\Delta V_{R_{\text{PD}},n}}\right)$ for the values of A_n in the forth column.

Table II.3 - Measurement results of $\Delta V_{R_{\text{PD}}}$ when blocking the light path with n pieces of blue acrylic plates

Number of acrylic plates (n)	Total thickness of the plates l (____mm_____)	$\Delta V_{R_{\text{PD}}}$ (____V_______)	A_n
0	0	5.284	X
1	1.00	4.726	0.04847
2	2.00	4.255	0.09406
3	3.00	3.836	0.1391
4	4.00	3.481	0.1813
5	5.00	3.142	0.2258

(0.1 pt) correct unit of thickness
(0.1 pt) correct unit of potential difference

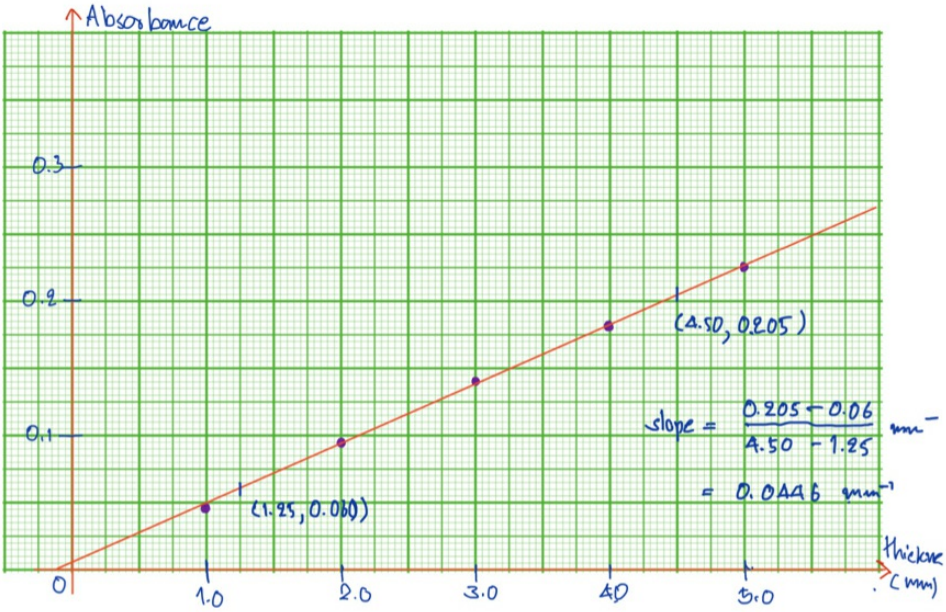
(0.2 pt) correct sig. fig. for thickness (three sig. fig.)
(0.2 pt) correct sig. fig. for potential difference (four or three sig. fig., or two decimal points)

(0.3 pt) correct sig. fig. for the absorbance (four or three sig.fig. depending on the potential difference values)
(0.5 pt, 0.1 pt for each value) correct calculation of A_n

(0.4 pt) values of potential differences are between 2.0 to 6.0 V.

P4. **(2.2 points)** Plot the values of A_n versus l. Make sure to represent data points with clear marks. Draw a linear best fit line through the data points.

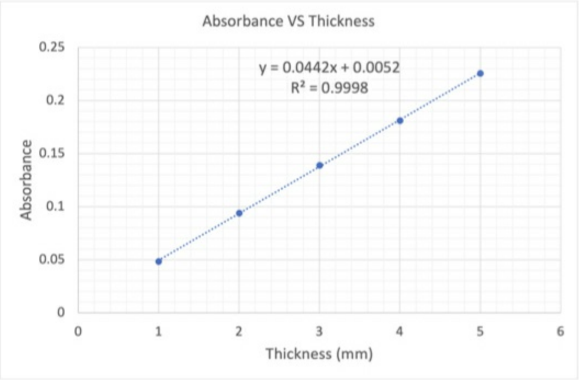
Figure II.4 Graph of the absorbance A_n versus thickness l of the acrylic plates.



(0.2 pt) Absorbance along y-axis
(0.2 pt) thickness along x-axis
(0.2 pt) with correct unit for thickness

(0.2 pt) Use about 80% of provided graph space
(0.4 pt) Data points are clearly marked.

(0.5 pt) Data points are at the correct coordinates
(0.5 pt) Best fit line is reasonable



P5. **(1.0 points)** According to Beer - Lambert law, absorbance A_n should depend linearly on thickness l. Therefore, the relationship between A_n and l can be written as $A_n = \epsilon_{\mathrm{ac}} \cdot l + c$. The parameter c is added into the equation to take into account of the systematic error of length measurement. Determine the values of ϵ_{ac} and c without uncertainties from graph in Figure II.4.

Calculation:

$\epsilon_{\mathrm{ac}} =$ 0.0442 mm^{-1}

c = 0.0032

(0.1 pt) calculate ϵ_{ac} from the slope

(0.1 pt) calculate c from the y-intercept

(0.1 pt) correct unit of ϵ_{ac}

(0.4 pt) value of ϵ_{ac} is within 5% of the value obtained from the computer

(0.2 pt) value of ϵ_{ac} is within 10% of the value obtained from the computer

(-0.1 pt) use values from the data points directly in slope calculation

(0.1 pt) value of ϵ_{ac} has two or three sig. fig.

(0.2 pt) value of c is between 0.01 and -0.01

Part III - Dependence on the concentration of the absorbance

P6. **(1.8 points)** Fill out the table III.6

In this case, the absorbance of cuvette n or A_n is determined with respect to the “cuvette 0” which contains only water hence 0 ppm in concentration. Therefore, A_n can be calculated using

$$A_n = \log_{10}\left(\frac{\Delta V_{\mathrm{R_{PD}},0}}{\Delta V_{\mathrm{R_{PD}},n}}\right),$$

where $\Delta V_{\mathrm{R_{PD}},n}$ is $\Delta V_{\mathrm{R_{PD}}}$ of cuvette number n.

Table III.6 - Measurement results of $\Delta V_{R_{\mathrm{PD}}}$ when blocking the light path with different concentrations of red-dye solution.

cuvette number n	concentration (ppm) c	$\Delta V_{R_{\mathrm{PD}}}$ (________)	A_n
0	0	5.291	X
1	1.0	4.452	0.07498
2	2.0	3.769	0.1473
3	3.0	3.183	0.2207
4	4.0	2.721	0.2888
5	5.0	2.381	0.3468
X	-	2.875	0.2649

(0.1 pt) correct unit of potential difference

(0.3 pt) correct sig. fig. for potential difference (four or three sig. fig., or two decimal points)

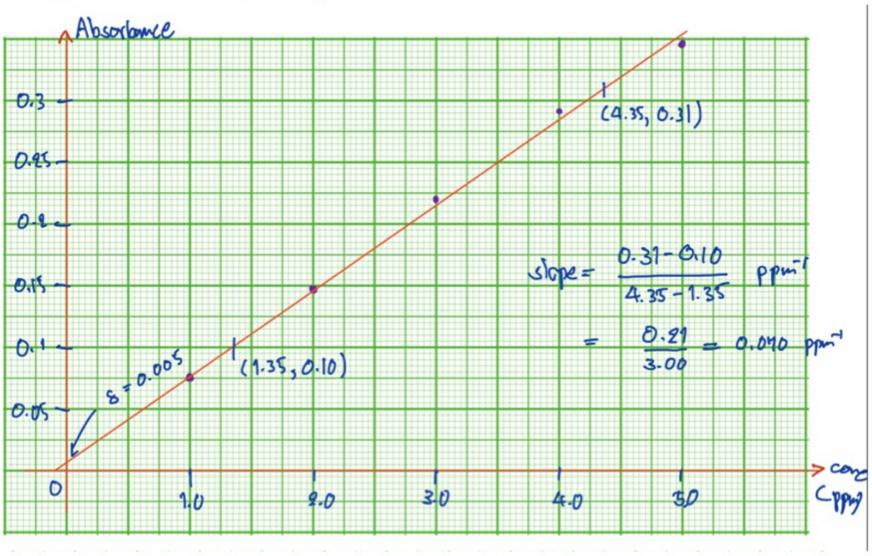
(0.4 pt) correct sig. fig. for the absorbance (four or three sig.fig. depending on the potential difference values)

(0.6 pt, 0.1 pt for each value) correct calculation of A_n

(0.4 pt) values of potential differences are between 2.0 to 6.0 V.

P7. **(2.2 points)** Plot the values of A_n versus c of data from cuvette number 1 to 5. Make sure to represent data points with clear marks. Draw a linear best fit line through the data points.

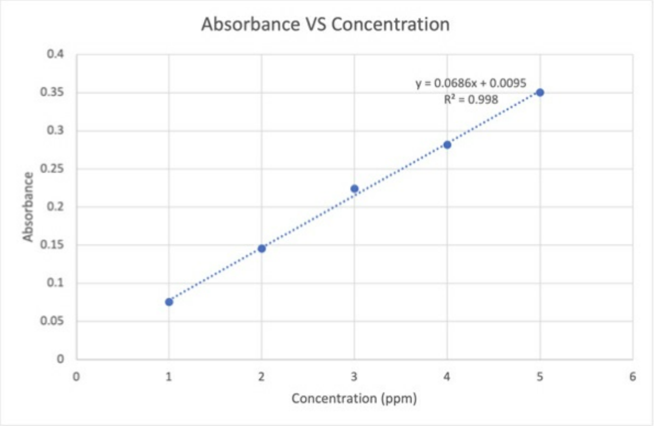
Figure III.7 Graph of the absorbance A_n versus concentration c of the solution.



(0.2 pt) Absorbance along y-axis
(0.2 pt) concentration along x-axis
(0.2 pt) with correct unit for thickness

(0.2 pt) Use about 80% of provided graph space
(0.4 pt) Data points are clearly marked.

(0.5 pt) Data points are at the correct coordinates
(0.5 pt) Best fit line is reasonable



P8. **(1.0 points)** According to Beer - Lambert law in the Equation (2), absorbance A_n should depend linearly on the concentration c. Therefore, the relationship between A_n and c can be written as

$$A_n = \epsilon l \cdot c + \delta.$$

In this case, constant δ comes from the systematic errors in the measurement of A and c.

Determine the values of ϵl and δ without uncertainties from graph in Figure III.7.

calculation:

$\epsilon l =$ 0.0685 ppm^{-1}

$\delta =$ 0.010

(0.1 pt) calculate ϵl from the slope

(0.1 pt) calculate δ from the y-intercept

(0.1 pt) correct unit of ϵl

(0.4 pt) value of ϵl is within 5% of the value obtained from the computer

(0.2 pt) value of ϵl is within 10% of the value obtained from the computer

(-0.1 pt) use values from the data points directly in slope calculation

(0.1 pt) value of ϵl has two sig. fig.

(0.2 pt) value of δ is between 0.02 and 0.0

P9. **(1.0 points)** Determine the concentration of the solution in “cuvette X” using information from question 7 and 8.

calculation:

From the experiment data: $A_n = (0.0685\ \text{ppm}^{-1}) \cdot c + 0.010$

which can be written as $c = \dfrac{A_n - 0.010}{0.0685\ \text{ppm}^{-1}}$

Therefore $c_x = \dfrac{0.2649 - 0.010}{0.0685\ \text{ppm}^{-1}} = 3.72\ \text{ppm}$

concentration of the solution in “cuvette X”: ______3.72 ppm__________________ .

Note: The fitted line in Figure III.7 is called the calibration curve. In the chemistry part of the exam, this curve was given to you.

Method 1 Project from the graph

(0.2 pt) Show the correct projection lines (horizontal and vertical lines)
(0.4 pt) Obtain correct value of *Cx* from *Ax* used
(0.2 pt) Value of *Cx* has two to three sig.fig.
(0.2 pt) Correct unit for Cx

Method 2 Calculate from linear equation

(0.2 pt) Show the correct equation
(0.4 pt) Obtain correct value of *Cx* from *Ax* used
(0.2 pt) Value of *Cx* has two to three sig.fig.
(0.2 pt) Correct unit for Cx

Part 1: Fe(III) content in rice extract

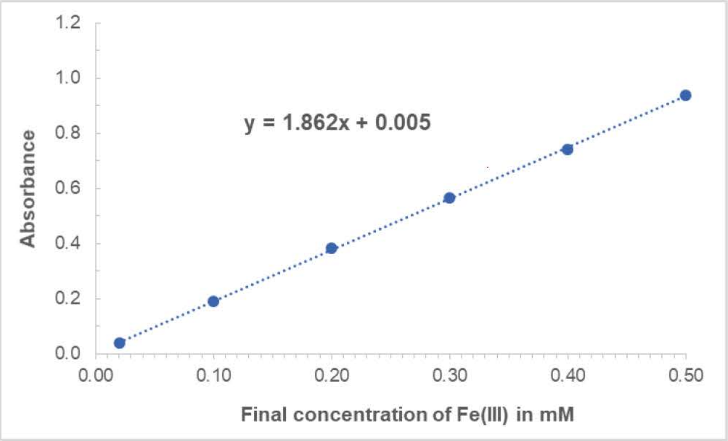


Figure C1. Calibration curve of Fe(III) using complex formation reaction with sulfosalicylic acid

C-1.1) (0.3pt) What is the molar absorptivity of the complex?

Answer: 1,862 L/mol·cm (molar absorptivity can be determined from slope of linear equation of the calibration curve in Figure C1)

C-1.2) (0.3pt) What is the absorbance (*Abs*) of the iron complex compound formed from the original **Extract Sample**?

Answer: approximately 1.500 - 1.700 (Data recorded from the Spectrophotometer) Out of this range, student will not get any point.

C-1.3) (0.3pt) What volume of rice **Extract Sample** did you use for preparing the **Solution** A?

Answer: 0.50 - 12.50 mL (From the concentration of Fe(III) standard solution for calibration curve construction ranging between 0.1 mM and 2.5 mM)

#assume that the volume of the sample for dilution is X mL

Assume X = 5.00 mL

C-1.4) (0.3pt) What is the absorbance of the complex in **Solution B**?

Answer: Read Absorbance from instrument.

Concentration of the diluted extract = (5.00 mM)(5.00 mL)/25.0 mL = 1.00 mM

For complex formation, 5.00 mL of the diluted sample is mixed with 5.00 mL of SA and the volume is adjusted to the final volume of 25.0 mL.

So, the concentration of Fe(III) equals to (1.00 mM)(5.00 mL)/25.0 mL = 0.200 mM

Abs = y = 1.862(0.200 mM) + 0.005

Abs = 0.377

C-1.5) (1.5pts) Calculate the concentration of Fe(III) in the original rice Extract Sample in molar. Report your answer in correct significant figure.

Answer: Place Absorbance from C-1.4 in linear equation to obtain the final concentration of Fe(III) in the diluted rice extract sample, C_{dil} in mM;

$0.377 = 1.862(C_{dil}) + 0.005$

$C_{dil} = 0.200$ mM (+0.4)

(Therefore, the concentration of Fe(III) in the diluted rice extract sample is ($C_{dil}\times 5$) mM = 1.00 mM) (+0.4)

Thus, concentration of Fe(III) in original rice extract, C_{origi} in mM, can be calculated from $C_1V_1 = C_2V_2$, So, $C_2 = C_1V_1/V_2$

(1.00 × 25.0 mL)/(X mL) (+0.4 for correct method)

C_{origi} = [1.00 × 25.0 mL)]/(5.00 mL) = 5.00 mM = 5.00×10^{-3} M (+0.2 for correct answer with unit, +0.1 for correct significant figure)

C-1.6) (0.6pt) Calculate the concentration of Fe(III) in the original rice **Extract Sample** in mg/L. Report your answer in correct significant figure.

Answer: (5.00×10^{-3} mol/L)(55.85 g/mol) = 0.279 g/L = 279 mg/L

(+0.3 for correct calculation method, +0.2 for correct answer with unit, +0.1 for correct significant figure)

C-1.7) (1.6pt) Calculate the mass of Fe(III) in mg per kg of rice, if the 100.0 cm3 of original rice **Extract Sample** containing only Fe(III) ions was extracted from 200.0 g of Jasmine rice. Report your answer in correct significant figure.

Answer: (from C-1.6) original rice extract sample solution 100 mL from 200.0 g of Jasmine rice has Fe(III) = (279 mg/L)(100.0 mL)/(1000 mL) = 27.9 mg

(+0.3 for correct calculation method, +0.1 for correct answer)

200.0 g of rice contains Fe(III) = 27.9 mg

Therefore, 1000.0 g (1kg) of rice has Fe(III) = [(1000.0 g)(27.9 mg)/(200.0 g)] = 139.6 mg ≈ 140 mg

(+0.3 for correct calculation method, +0.2 for correct answer with unit, +0.1 for correct significant figure)

*Remark; - Correct calculation gets 1.0 pt

- Accuracy (0.6 pt)

The score for the [Fe(III)] (mg/kg) is calculated as follows:

Criteria			Score
	$\lvert X - \bar{X} \rvert \le$	0.5S.D.	0.6
0.5S.D.	$< \lvert X - \bar{X} \rvert \le$	1S.D.	0.4
1S.D.	$< \lvert X - \bar{X} \rvert \le$	1.5S.D.	0.2
	$\lvert X - \bar{X} \rvert >$	1.5S.D.	0

C-1.8) (0.5pt) Sulfosalicylic acid selectively reacts with Fe(III) to form a red complex. However, the rice **Extract Sample** contains both Fe(III) and Fe(II). To obtain a total amount of iron ions in rice, Fe(II) in rice **Extract Sample** is oxidized to Fe(III) before performing a complex formation reaction with sulfosalicylic acid. Assume that the absorbance of your **Solution** B after oxidation process increases by 25.0 % of the absorbance from C-1.4, calculate the mass of Fe(II) in mg per kg of rice, when the 100.0 cm3 of original rice Extract Sample was extracted from 200.0 g of Jasmine rice. (Round your answer to one decimal place)

Answer: 0.25(140 mg) = 35.0 mg

(+0.3 for correct calculation method, +0.2 for correct answer with unit)

Part 2: Stoichiometry of the reaction

C-2.1) (1.0pt) Calculate mole fraction of Fe(III) ion and record absorbance of the complex in the answer sheet.

Answer:

Flask Number	Mole fraction of Fe(III)	Absorbance (*Abs*)
1	0.1	Read from instrument
2	0.2	Read from instrument
3	0.3	Read from instrument
4	0.4	Read from instrument
5	0.5	Read from instrument
6	0.6	Read from instrument
7	0.7	Read from instrument
8	0.8	Read from instrument
9	0.9	Read from instrument

(+0.1 for each correct mole fraction = 0.9, and +0.1 for correct significant figure of *Abs*)

C-2.2) (0.5pt) Show your working for the calculation of the mole fraction of Fe(III) ion in Flask number 2.

Answer: mol of Fe(III)/[mol of Fe(III) + mol of SA] or

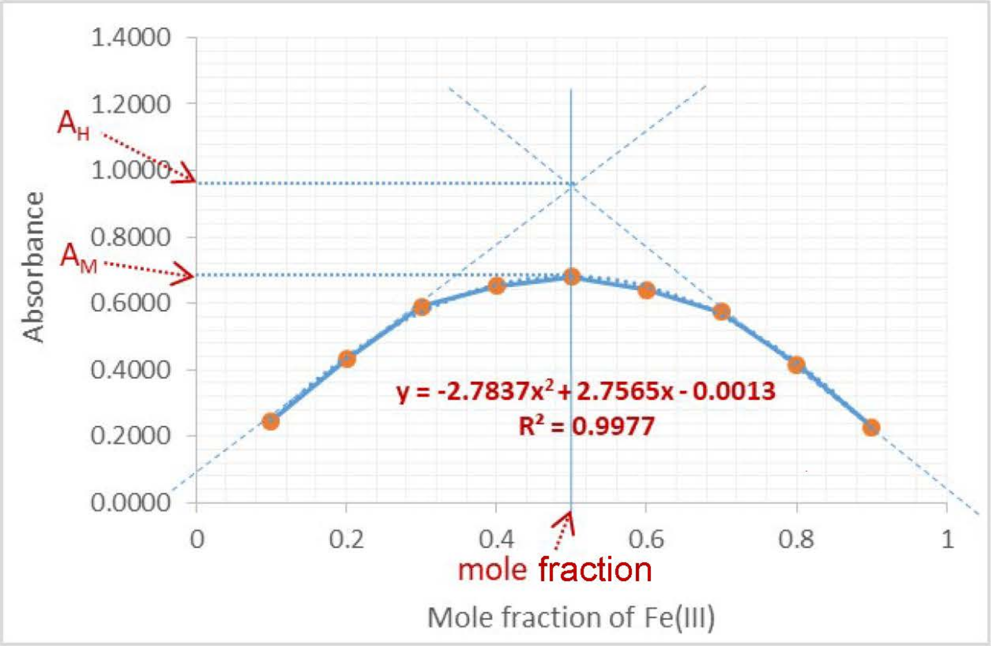
Volume of Fe(III)/[Volume of Fe(III) + Volume of SA]

Flask #2, mole fraction of Fe(III) = (1.00 mL)/(1.00 mL + 4.00 mL) = 0.2

(+0.5 for correct calculation method/ no partial credit)

C-2.3) (3.0pt) Create Job's Plot from the data in C-2.1, and indicate AH, AM, and mole fraction of the Fe(III) in the graph in the same way as seen in Figure C2.

Answer:



Marking scheme

1) Axis title (+0.1 pt for each = 0.2 pt in total)

2) Plotting 9 points correctly (+0.1 pt for each = 0.9 pt in total)

3) Scale must be labelled with the quantity that is being plotted (+0.2 pt)

4) Indicate correct positions of A_H, A_M, and mole fraction of the complex in the graph (+0.2 pt for each = 0.6 pt in total)

5) Accuracy of complex solution preparations based on polynomial 2nd order regression (maximum +0.8 pt)

Curve fitting

Criteria			Score
1	$\leq R^2 \leq$	0.98	0.8
0.98	$< R^2 \leq$	0.95	0.4
0.95	$< R^2 \leq$	0.90	0.2
	$R^2 <$	0.90	0

6) The plotted points occupy at least half the graph grid (+0.3 pt)

C-2.4) (0.2pt) What are mole fraction values of Fe(III) ion and sulfosalicylic acid (SA) at the maximum absorbance of the complex in theory (A_H)?

Answer: Value of x-axis at A_H from Job's Plot (such as mole fraction of Fe(III) ion = 0.5, and mole fraction of SA = 0.5)

Remark: -0.1 for other numbers from the graph apart from 0.50±0.05

Mole fraction of Fe(III) ion = ...

Mole fraction of SA = ...

C-2.5) (0.5pt) What is the stoichiometric ratio (integer number) between Fe(III) and sulfosalicylic acid in the red complex?

Answer: (+0.2 for the ratio base on the answer of C-2.4)

(+0.3 for correct ratio of 1:1)

C-2.6) (0.2pt) Write the empirical formula of the red complex. Refer to the equation in the introduction of Part I.

Answer: $Fe(SA)^{3+}$ (Base on the answer of C-2.4)

C-2.7) (0.5pt) What is the concentration of the complex at the absorbance of A_M? (Hint: Molar absorptivity of the complex from your answer in C-1.1)

Answer: Assume that A_M = 0.900, from Beer-Lambert Law $A = \varepsilon c l$, 0.900 = 1,862(1cm)x

X = 4.83×10^{-4} M

(+0.2 for correct A_M from the graph, +0.2 for correct calculation method, +0.1 for correct answer from calculation with unit)

C-2.8) (0.7pt) What is the concentration of free Fe(III) ions at equilibrium of C-2.7? (Report your answer to three significant figures)

Answer: mol of Fe(III) = (0.01M)(2.50 mL)/1000 = 2.5×10^{-5} mol

[Fe(III)] = (2.5×10^{-5} mol)(1000)/(25.0 mL) = 0.001 M

(+0.2 for correct calculation and answer)

Concentration of complex (From C-2.7) = 4.83×10^{-4} M

Therefore, concentration of free Fe(III) = $(10.00 - 4.83)\times10^{-4}$ (+0.3)

= 5.17×10^{-4} M (+0.2 for correct calculation and answer)

C-2.9) (1.0pt) Calculate the equilibrium constant (K_f) for the formation of this complex.

Answer:

K_f = [Complex]/[Fe(III)][SA] (+0.2 for correct K_f formula)

= $(4.83 \times 10^{-4})/(5.17 \times 10^{-4})(5.17 \times 10^{-4})$

(+2 for each correct number of the concentration = +6)

= 1.81×10^{-3} (+2 for correct calculation)

C-2.10) (0.5pt) Which flasks (from number 1-9) have sulfosalicylic acid as a limiting agent for the complex formation reaction? Choose one flask from your answer to show your calculation.

Answer: Flask 6-9 (+0.05 for each flask = 0.2 in total)

Example Flask #6: As the complex is 1:1 mol ratio

mol of Fe(III) = (0.01M)(3.00mL)/1000 = 3.00×10^{-5} mol (+0.15 for calculation)

Mol of SA = (0.01M)(2.00 mL)/1000 = 2.00×10^{-5} mol (+0.15 for calculation)

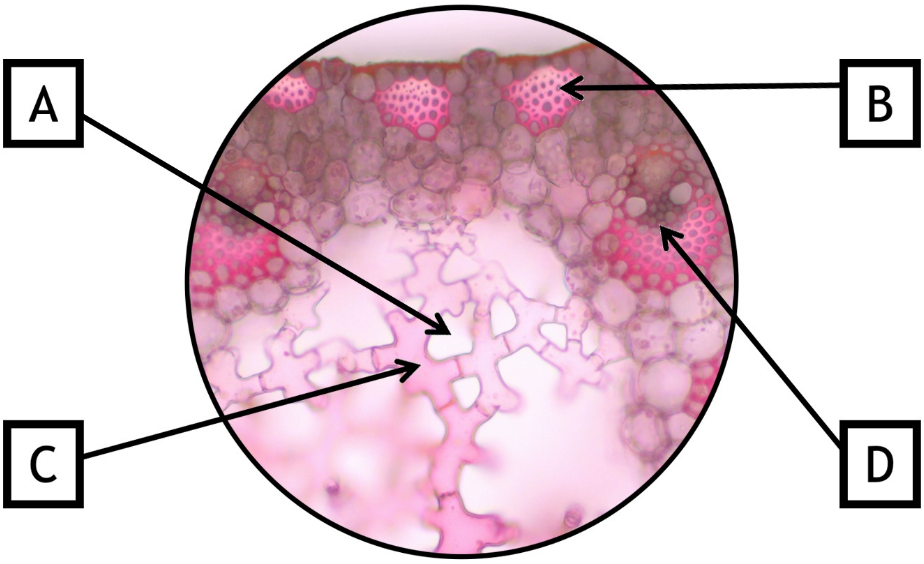
mol SA $<$ mol Fe(III) (students can also answer in terms of mole fraction, but they need to show the calculation)

Question B1: KEY (4.9pt)

	Character						
	1. Band of fibers beneath epidermis (0.7pt)	2. Group of fibers beneath epidermis (0.7pt)	3. Parenchyma in cortex (0.7pt)	4. Pericycle (0.7pt)	5. Cork (0.7pt)	6. Starch grains (0.7pt)	7. Trichome (0.7pt)
Present		X	X			X	
Absent	X			X	X		X

Marking scheme: 0.7pt for each correct answer. Students must put only one "X" in each column in order to be marked.

Question B2: KEY (2.6pt)



Marking scheme: 0.6pt for drawing will be divided into

1. Drawing skills and details of the drawing (0.2pt).
2. Proportion of the structures relative to the size of the field of view and magnification (0.2pt).
3. Accuracy (e.g. locations of the structures) (0.2pt).

and 0.5pt for each correct labeling

Remark: For each letter, only one arrow should be drawn. Otherwise, no marks will be given.

Question B3: KEY (6pt)

Steps followed to identify specimen in the image

Write every step followed, in BLOCK CAPITALS, with each step in a separate box.

Start from the left-most box. You may use all or only some of the boxes.

Steps followed:	1B	13A	14B	16A							

Place an “X” on the correct species number.	1	2	3	4	5	6	7	8
	9	10	11	12	13	14	15	16
	17	18	19	20	21	22	23	

Marking scheme: For each correct step followed, 1 pt wil be given. For the correct species number, 2 pt wil be given.

Remark: Marks for the steps followed will be given for each correct answer from left to right, up to but not including the first incorrect step. The steps must be in the correct order to receive a point.