Problem 2 4% of total	Question	2.1	2.2	2.3	Bonus	Total
	Points	1	1	1	1	4

Problem 2: Bad Signals

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Understanding signal-to-noise and error propagation is important in labs where you need quantifiable data. In this lab, your team will be creating a calibration curve (line of best fit) to determine the concentration of an unknown. According to Beer's law, the higher the concentration, the higher the absorbance. After doing a trial round you have started analyzing data so you can see if you can improve its quality.

Table 1. Data collected

Sample	$[Caffeine]\ (Mol \pm 0.0005$	Abs at $\lambda\ =\ 270\ nm$	$\sigma_{Noise}\ (std\ dev)$
BLANK	0.0000	0.0000	0.024
1	0.0025	0.275	0.021
2	0.0050	0.599	0.015
3	0.0075	0.855	0.017
UNKNOWN	??????	0.977	0.025

Even after taking a background, spectra will still have some level of noise. This is called random error. One way to remove the noise is by taking multiple data points (also known as trials).

$$(S/N) = \frac{Signal}{Noise}$$

$$(S/N)_n = \sqrt{n} \times (S/N)$$

Where

$$Signal\ =\ signal\ strength\ (Absorbance\ in\ this\ case)$$

$$Noise\ =\ std\ dev\ of\ the\ noise$$

$$(S/N) = signal\ -\ to\ -\ noise\ ratio$$

$$(S/N) = signal\ -\ to\ -\ noise\ ratio\ after\ n\ trials$$

$$n\ =\ number\ of\ trials$$

2.1) Calculate the number of trials needed to get a signal-to-noise ratio of 10 for the most and least concentrated samples. Multiply them together and submit the result.

No matter how many trials are done to improve S/N, there will still be error. In the lab report, you must include the error of your findings. We can calculate the error of absorbance from the beer's law formula:

$$Abs = \varepsilon \times l \times C$$

Where

$$\varepsilon = molar\ \ absorptivity$$

$$l = path\ length\ (width\ of\ the\ cuvette)$$

$$C = concentration\ of\ analyte$$

For all samples, $\varepsilon = 115\ cm\ mol^{-1}$, $l = 1\ cm \pm 0.01\ cm$, and table 1 can be used for the concentration of each sample. To calculate error, you use the propagation-of-error formulae, which can be neatly summarized by the following table:

Table 2. Error propagation formulae

Operation	Value	Error
Adding/Subtracting	$N_{tot} = N_1 + N_2 + \dots + N_n$	$Err_{tot} = \sqrt{\left(Err_1\right)^2 + \left(Err_2\right)^2 + \dots + \left(Err_n\right)^2}$
Multiplying/Dividing	$N_{tot} = N_1 \times N_2 \times \dots \times N_n$	$Err_{tot} = \lvert N_{tot} \rvert \times \sqrt{\left(\frac{Err_1}{N_1}\right)^2 + \left(\frac{Err_2}{N_2}\right)^2 + \dots + \left(\frac{Err_n}{N_n}\right)^2}$

2.2) You want to quickly test how good your error will be. Calculate the error for absorbance after taking 10 trials of sample 1. (Hint: you're averaging the absorbance)

Things go well until the group reaches the conclusion section of the lab report. Would you be able to successfully determine the concentration of the unknown?

2.3) Choose which of the following should be in the conclusion. Type the answer in alphabetical order with no space.

a. No problems were encountered (perfect lab!)
b. Sample 1's data had to be thrown out (Sample 1's error was 20-30% of the signal)
c. The unknown was under the limit of detection (the unknown's absorbance was less than 3 times the noise of the blank)
d. The unknown could not be accurately predicted by the calibration curve (the absorbance was outside the range of the samples).