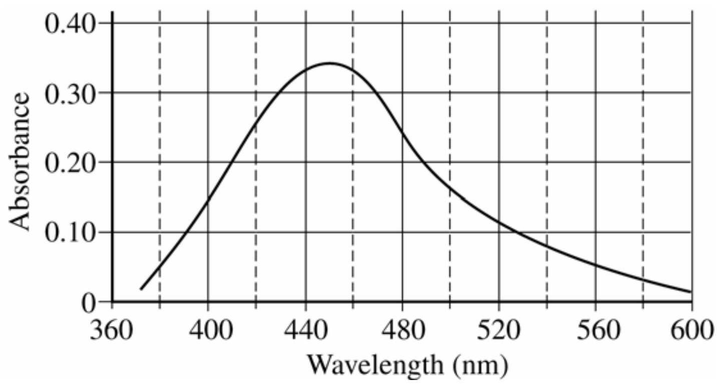
Question 5

5. A student carries out an experiment to determine the equilibrium constant for a reaction by colorimetric (spectrophotometric) analysis. The production of the red-colored species $FeSCN^{2+}(aq)$ is monitored.

(a) The optimum wavelength for the measurement of $[FeSCN^{2+}]$ must first be determined. The plot of absorbance, A, versus wavelength, λ, for $FeSCN^{2+}(aq)$ is given below. What is the optimum wavelength for this experiment? Justify your answer.



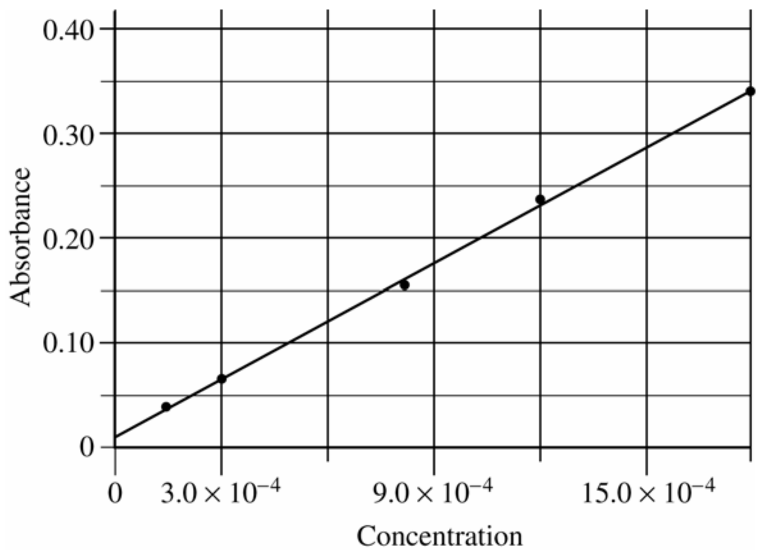
The optimum wavelength is 450 nm <u>because</u> that is the wavelength of maximum absorbance by $FeSCN^{2+}(aq)$.	One point is earned for the correct answer <u>with</u> justification.

(b) A calibration plot for the concentration of $FeSCN^{2+}(aq)$ is prepared at the optimum wavelength. The data below give the absorbances measured for a set of solutions of known concentration of $FeSCN^{2+}(aq)$.

Concentration ($mol\ L^{-1}$)	Absorbance
1.1×10^{-4}	0.030
3.0×10^{-4}	0.065
8.0×10^{-4}	0.160
12×10^{-4}	0.239
18×10^{-4}	0.340

Question 5 (continued)

(i) Draw a Beer's law calibration plot of all the data on the grid below. Indicate the scale on the horizontal axis by labeling it with appropriate values.



One point is earned for a straight-line plot. One point is earned for a correctly scaled horizontal axis.

(ii) An $FeSCN^{2+}(aq)$ solution of unknown concentration has an absorbance of 0.300. Use the plot you drew in part (i) to determine the concentration, in moles per liter, of this solution.

See plot in part (i). At $A = 0.300$, $[FeSCN^{2+}]$ is approximately 16×10^{-4} mol L^{-1}.	One point is earned for the correct answer.

Question 5 (continued)

(c) The purpose of the experiment is to determine the equilibrium constant for the reaction represented below.

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftarrows FeSCN^{2+}(aq)$$

(i) Write the equilibrium-constant expression for K_c .

$K_c = \dfrac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^{-}]}$	One point is earned for the correct expression.

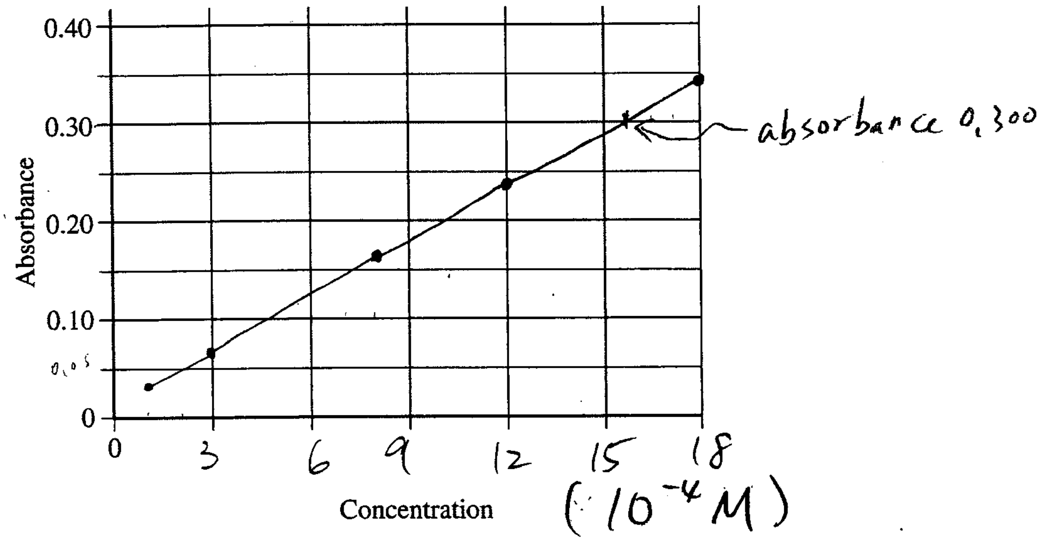
(ii) The student combines solutions of $Fe(NO_3)_3$ and KSCN to produce a solution in which the initial concentrations of $Fe^{3+}(aq)$ and $SCN^{-}(aq)$ are both 6.0×10^{-3} *M*. The absorbance of this solution is measured, and the equilibrium $FeSCN^{2+}(aq)$ concentration is found to be 1.0×10^{-3} *M*. Determine the value of K_c .

	$Fe^{3+}(aq)$ +	$SCN^{-}(aq)$	$\rightleftarrows$ $FeSCN^{2+}(aq)$	One point is earned for the correct equilibrium concentration.
I	6.0×10^{-3} *M*	6.0×10^{-3} *M*	0	
C	-1.0×10^{-3} *M*	-1.0×10^{-3} *M*	$+1.0 \times 10^{-3}$ *M*	
E	5.0×10^{-3} *M*	5.0×10^{-3} *M*	$+1.0 \times 10^{-3}$ *M*	One point is earned for the correct substitutions and the calculated value.
	$K_c = \dfrac{1.0 \times 10^{-3}}{(5.0 \times 10^{-3})(5.0 \times 10^{-3})} = 40.$			

(d) If the student's equilibrium $FeSCN^{2+}(aq)$ solution of unknown concentration fades to a lighter color before the student measures its absorbance, will the calculated value of K_c be too high, too low, or unaffected? Justify your answer.

The value of K_c will be too low; the lower absorbance reading indicates a lower $[FeSCN^{2+}]$ than actually existed before the fading occurred, so substitution of a lower $[FeSCN^{2+}]$ into the equilibrium expression will result in a lower value of K_c.	One point is earned for the correct prediction. One point is earned for the correct justification.

(i) Draw a Beer's law calibration plot of all the data on the grid below. Indicate the scale on the horizontal axis by labeling it with appropriate values.



(ii) An $FeSCN^{2+}(aq)$ solution of unknown concentration has an absorbance of 0.300. Use the plot you drew in part (i) to determine the concentration, in moles per liter, of this solution.

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(d) If the student's equilibrium $FeSCN^{2+}(aq)$ solution of unknown concentration fades to a lighter color before the student measures its absorbance, will the calculated value of K_c be too high, too low, or unaffected? Justify your answer.

a) optimum wavelength = 450 nm because the graph of absorbance against wavelength has its peak at 450 nm.

b) ii) 15.75×10^{-4} M

c) $K_c = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^{-}]}$

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ii) $Fe^{3+} + SCN^- \rightleftharpoons FeSCN^{2+}$

I 6.0×10^{-3} 6.0×10^{-3} 0

Δ $-x$ $-x$ $+x$

E $6.0\times10^{-3}-x$ $6.0\times10^{-3}-x$ $+x$

$x = 1.0\times10^{-3}$

$$K_c = \frac{1.0\times10^{-3}}{(6.0\times10^{-3}-1.0\times10^{-3})^2}$$

$$= \frac{10^{-3}}{(5\times10^{-3})^2} = \frac{10^{-3}}{25\times10^{-6}}$$

$$= 0.04\times10^{3} = 40$$

d) if the color fades, the absorbance would be too small, ∵ the absorbance is directly related to the concentration ∴ the concentration would be too low. then ∵ $[FeSCN^{2+}]$ would be too small ∴ $[Fe^{3+}][SCN^-]$ would be too large ∴ Kc would be too small.

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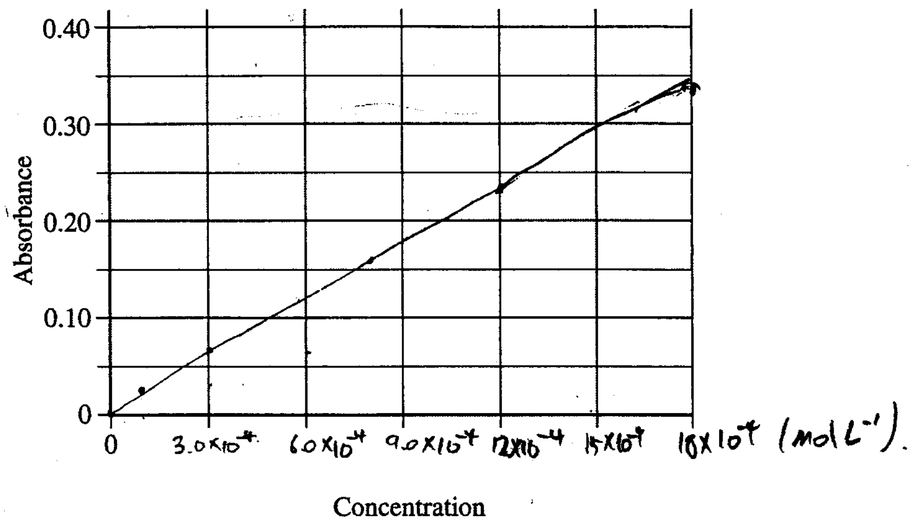
(i) Draw a Beer's law calibration plot of all the data on the grid below. Indicate the scale on the horizontal axis by labeling it with appropriate values.



(ii) An $FeSCN^{2+}(aq)$ solution of unknown concentration has an absorbance of 0.300. Use the plot you drew in part (i) to determine the concentration, in moles per liter, of this solution.

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(d) If the student's equilibrium $FeSCN^{2+}(aq)$ solution of unknown concentration fades to a lighter color before the student measures its absorbance, will the calculated value of K_c be too high, too low, or unaffected? Justify your answer.

(a) As A is the biggest in the wavelength of 450nm, it is 450nm (optimum wavelength)

(b) (i) I drew it above

(ii) About 15×10^{-4} mol L^{-1}.

(c) (i) $K_c = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^{-}]}$

(ii) $K_c = \frac{1.0 \times 10^{-3}}{(6.0 \times 10^{-3})^2} = \frac{1}{36.0 \times 10^{-3}} = 27.8$

36) 1000
27.8

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(d) As it fades to light color, its absorbance decreases
When the absorbance decreases, as you can know from (b) the concentration of $FeSCN^{2+}(aq)$ decreases
thus, Kc would be too low.

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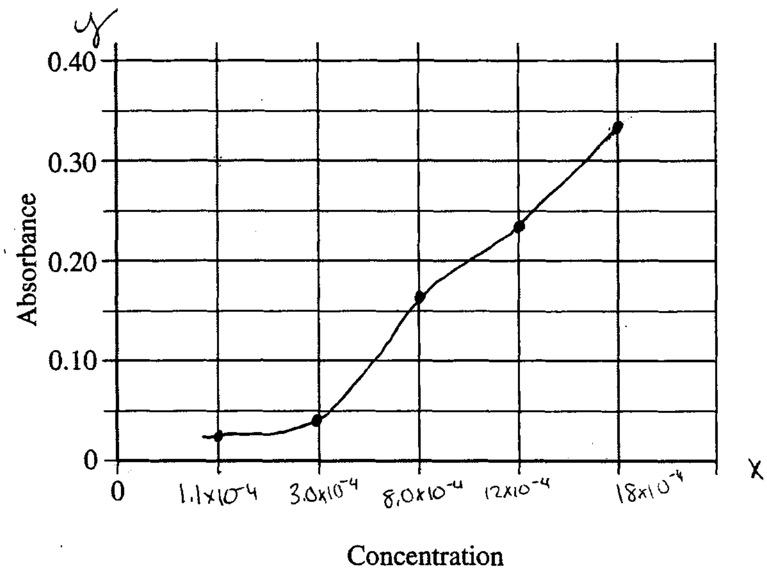
(i) Draw a Beer's law calibration plot of all the data on the grid below. Indicate the scale on the horizontal axis by labeling it with appropriate values.



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(d) If the student's equilibrium $FeSCN^{2+}(aq)$ solution of unknown concentration fades to a lighter color before the student measures its absorbance, will the calculated value of K_c be too high, too low, or unaffected? Justify your answer.

(5) a) the optimum wavelength is about 450 nm because that is where it has the highest absorbancy.

i) on graph

ii) 16x10⁻⁴ m/L (read from graph)

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c) i) $K_c = \frac{[FeSCN^{2+}]}{[Fe^{3+}][SCN^-]}$

ii) $K_c = \frac{[1.0\times10^{-3}]}{[6.0\times10^{-3}]^2}$ $\frac{1.0\times10^{-3}}{360.0\times10^{-9}}$ $= 360\times10^{-3} = K_c$

d) The calculated K_c will be unaffected because the color does not affect the concentration.

Question 5

Sample: 5A
Score: 8

This was an excellent response that earned 8 out of 9 points: 1 point for part (a), 2 points for part (b)(i), 1 point for part (c)(i), 2 points for part (c)(ii), and 2 points for part (d). The point was not earned in part (b)(ii) because the answer given has four significant figures, which is more than one different from the appropriate number of two significant figures (the original concentrations used to construct the graph have only two significant figures).

Sample: 5B
Score: 7

The 2 available points in part (c)(ii) were not earned because the equilibrium concentration of Fe^{3+} and SCN^{-} are not used.

Sample: 5C
Score: 3

No points were earned for part (b)(i) because the scale labeled on the horizontal axis is not uniform and the absorbance values are not plotted accurately. The points were not earned in part (c)(ii) because the equilibrium concentrations of Fe^{3+} and SCN^{-} are not used. The points were not earned in part (d) because the response incorrectly indicates that color does not affect the calculated value of K_c.