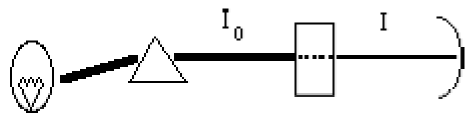
#9 Beer’s Law, Neodymium Chloride

Purpose: Using Beer’s Law you will find the concentration of neodymium chloride from the amount of light absorbed by its solution.

Background:
A spectrum is a recording of the wavelengths absorbed by a sample. Colored compounds, such as the pale violet neodymium chloride used in this experiment absorb in the visible.



The transmittance, %T, is the ratio of the intensity of the incident light (I^o) and the intensity of the emerging light (I), or %T = I / I°. Absorbance, A, is the logarithm of 100 divided by %T :

$$A = \log (100/ \%T)$$

Notice that 50% T on the meter scale corresponds to log 2 or 0.30 on the Absorbance scale. It is easier to read % T rather than A, so record the %T values and convert them to A

<u>Beer’s Law</u>
According to Beer’s Law, the absorbance (A) of a solution is proportional both to the molarity of the solute and to the path length (b) of solution:

$$A = \varepsilon \text{ x } b \text{ x molarity}$$

The constant ε is the extinction coefficient, which depends on the wavelength of light, the solvent and the solute. The path length is the diameter of the tube used to hold the sample (The diameter of the supplied cuvettes is 1 cm). In general, Beer’s Law works well for relatively dilute solutions. For neodymium chloride, deviations are observed at concentrations greater than 0.125 M.

<u>The Lanthanides</u>
The lanthanides (elements 58 -71) are also known as the “rare earths”. Compounds of the lanthanides have interesting visible spectra which consist of several sharp peaks. In this experiment you will study the spectrum of neodymium chloride solutions (Nd is element 60). Note that neodymium chloride is hydrated, $NdCl_3 \cdot 6H_2O$ and its molar mass is 358.6 g/mol.

Apparatus
You will be taking a spectrum of neodymium chloride solution using a Spectronic-20. To use the instrument refer to the operating instructions attached.

Safety and Waste Disposal
Wear safety glasses and gloves. Waste bottles are available for all used $NdCl_3$ solutions.

Procedure
Part A: Taking the Spectrum of the Stock Solution of Neodymium Chloride
1. Fill one cuvette with water (the blank) and another with the $NdCl_3$ solution. Record sample concentration from the label. It will be about 0.125 M.

2. Set the wavelength dial to 400 nm and measure the % transmittance of your sample as described before. Continue to measure the % T every 5 nm between 400 nm and 650 nm, remembering to insert the blank and adjust for 100 % transmittance at each new wavelength. When you finish taking the spectrum, pour the solution into the bottle marked "Used $NdCl_3$ solution".

3. Convert % transmittance to absorbance. Make a plot of absorbance (y axis) vs. wavelength (x axis) by drawing a smooth line through the points (drawn to reflect experimental error). This is the visible spectrum of the stock solution of neodymium chloride. Submit the plot with your lab report. Record the wavelength at which the maximum absorbance is observed.

Part B: Measuring Absorbance of Diluted Solutions of Neodymium Chloride
To verify Beer's Law you will measure absorbance at the maximum wavelength of the spectrum found in Part A. Four solutions have been prepared: 0.100 M, 0.0750 M, 0.0500 M, and 0.0250 M.

1. Measure the % T of each solution at the peak wavelength observed in Part A. Record the concentration. You can do these in any order.
When you finish taking each spectrum, pour the used solution into the bottle marked "Used $NdCl_3$ solution".

2. Convert % transmittance to absorbance. Plot the absorbance (x axis) for each solution vs. the concentration (y axis). Be sure to make the points reflect the experimental error. The plot should produce a straight line. Submit the plot with your data and results.
Note: Remember that the point 0,0 is also a data point.

3. To find ε, the extinction coefficient, use the equation $m=(y_2-y_1)/(x_2-x_1)$, where y_1 and y_2 are two different concentrations and x_1 and x_2 are the corresponding absorbance points.

Part C: Determining the Concentration of an Unknown Neodymium Chloride Solution
1. Record the code number/letter of your unknown. Measure the % transmittance of the sample at the peak wavelength used for the known samples, convert to A and use the extinction coefficient calculated in Part B to find the concentration of your unknown using the equation: molarity = $A/(\varepsilon \times b)$

Data and Results (Beer's Law $NdCl_3$)

Name(s) ____Date __________

Part A: Taking the Spectrum of the Stock Solution of Neodymium Chloride

Concentration of $NdCl_3$ stock solution (see label) ____________ M

λ nm	%T	A	λ nm	%T	A
400			530		
405			535		
410			540		
415			545		
420			550		
425			555		
430			560		
435			565		
440			570		
445			575		
450			580		
455			585		
460			590		
465			600		
470			605		
475			610		
480			615		
485			620		
490			625		
500			630		
505			635		
510			640		
515			645		
520			650		
525			655		

Wavelength where absorbance is maximum, λ_{max}: _________ nm

Absorbance at λ_{max}: _________

Data and Results 2 (Beer's Law $NdCl_3$)

Part B: Measuring Absorbance of Diluted Solutions of Neodymium Chloride

Molarity	%Transmittance	Absorbance
0.125		
0.100		
0.0750		
0.0500		
0.0250		

Path length: ________cm

Beer's Law constant, ε : _________$M^{-1}cm^{-1}$

(Attach absorbance vs. concentration plot)

Part C: Determining the Concentration of an Unknown

Code number/letter of the Unknown: __________

Absorbance at λ_{max}: ____________

Concentration of the Unknown: ____________ M

Questions:

1. Would you be able to use your data to find the concentration of a 1.00 M solution of neodymium chloride? Why or why not?

2. Describe two different methods that could be used to prepare 100 mL of a 50% solution starting from a stock (100%) solution of 0.100 M $NdCl_3.6H_2O$ (358.6 g/mol).

Instructor's Guide
(Beer's Law $NdCl_3$)

Part A: Taking the Spectrum of the Stock Solution of Neodymium Chloride

Concentration of $NdCl_3$ stock solution (see label) *0.125* M

λ (nm)	%T	A	λ (nm)	%T	A
400	*99.5*	*0.00*	530	*75.6*	*0.12*
405	*99.5*	*0.00*	535	*84.4*	*0.07*
410	*100*	*0.00*	540	*92*	*0.04*
415	*99*	*0.00*	545	*95.8*	*0.02*
420	*97.8*	*0.01*	550	*97*	*0.01*
425	*96.5*	*0.02*	555	*93.4*	*0.03*
430	*96.5*	*0.02*	560	*87*	*0.06*
435	*97*	*0.01*	565	*79*	*0.10*
440	*97.2*	*0.01*	570	*63*	*0.20*
445	*96.2*	*0.02*	575	*49.2*	*0.31*
450	*97*	*0.01*	580	*46*	*0.34*
455	*94.2*	*0.03*	585	*51.2*	*0.29*
460	*92*	*0.04*	590	*63.5*	*0.20*
465	*88*	*0.06*	600	*88.5*	*0.05*
470	*86.6*	*0.06*	605	*95*	*0.02*
475	*85.5*	*0.07*	610	*97*	*0.01*
480	*88.4*	*0.05*	615	*97.5*	*0.01*
485	*89.5*	*0.05*	620	*97.5*	*0.01*
490	*90*	*0.05*	625	*97*	*0.01*
500	*82.5*	*0.08*	630	*95.8*	*0.02*
505	*75.2*	*0.12*	635	*96*	*0.02*
510	*67.5*	*0.17*	640	*97*	*0.01*
515	*60*	*0.22*	645	*97.6*	*0.01*
520	*60*	*0.22*	650	*97*	*0.01*
525	*64.7*	*0.19*	655	*97*	*0.01*

Wavelength where absorbance is maximum, λ_{max}: ___580______ nm

Absorbance at λ_{max}: ___0.34______

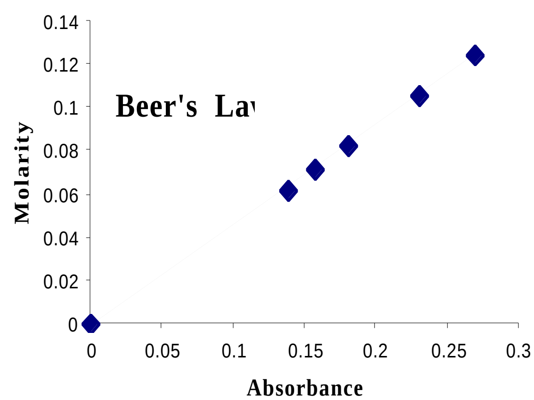
(Spectrum is on the page with **Ideas/ Information**)

Part B: Measuring Absorbance of Diluted Solutions of Neodymium Chloride

Molarity	%Transmittance	Absorbance
0.125	*46*	*0.34*
0.100	*61*	*0.22*
0.0750	*69*	*0.16*
0.0500	*78*	*0.11*
0.0250	*88*	*0.05*

Path length: __*1.00*__ cm   Beer's Law constant, ε : __*0.46*__ $M^{-1}cm^{-1}$

from: Excel and equation (y = 0.463 x) of trendline; retaining 2 significant figures.



Part C: Determining the Concentration of an Unknown

Code number/letter of the Unknown: ___*N-1*_____
Concentration of the Unknown: ___*0.0650*___ M

Code number/letter of the Unknown: ___*N-2*_____
Concentration of the Unknown: ___*0.0976*___ M

Code number/letter of the Unknown: ___*N-3*___
Concentration of the Unknown: ___*0.0325*___ M

Answers to Questions:

1. Would you be able to use your data to find the concentration of a 1.00 M solution of neodymium chloride? Why or why not?

No, because Beer's Law does not hold for such a high concentration. (See ***Background****)*

2. Describe two different ways that could be used to prepare 100 mL of a 0.0500 M solution starting from a stock (100%) solution of 0.100 M $NdCl_3.6H_2O$ (358.6 g/mol).

a) Mix 50.0 mL stock solution with 50.0 mL distilled water using a burette or pipet to measure the volumes.

b) Find the mass in grams needed and use a volumetric flask:
0.050 mol/L x 0.10 L x 358.6 g/mol = 1.79 g
Place 1.79 g $NdCl_3.6H_2O$ in a 100 mL volumetric flask and dilute to the mark.

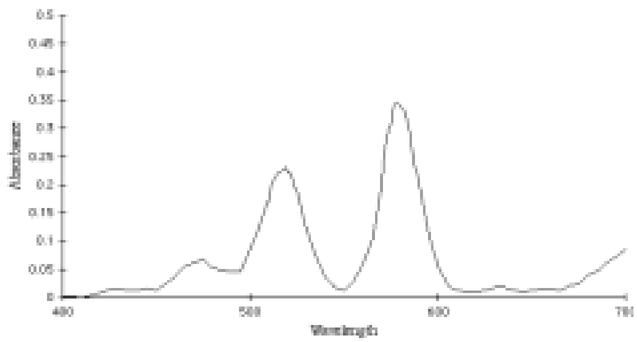
Time: 1 1/2 hours

Equipment and Materials (per group)

Items	**amount/no.**	**comment**
Wash bottles, distilled water	1	distilled water; to fill blank cuvette
Spectronic-20	1	
Stock 0.125M $NdCl_3$	5 mL	500 mL for whole class
4 other samples: 0.100, 0.0750, 0.0500, 0.0250 M	5 mL ea	500 mL for whole class
Cuvettes or 1-cm tubes	6	1 for blank; 5 for samples
Cuvette stand	1	
Waste sample bottle	1/class	
Unknown solutions	5 mL	N-1, N-2, N-3 (500 mL each for whole class)
Plastic funnel	1	
Safety glasses	1 pair per student	
Rubber gloves	1 pair per student	

Ideas/ Information

1. <u>The Lanthanides</u> The lanthanide ions have interesting visible spectra that arise from electronic transitions among f orbitals. The 4f orbitals involved are effectively shielded from their chemical environments by outer 5s and 5p electrons. As a result the spectra arising from f-f electronic transitions are extremely sharp and are unaffected by the anions. The spectra of $NdCl_3$ and $Nd(NO_3)_3$ are virtually identical.



2. Solutions could be prepared by diluting the stock solution , but it is more convenient to prepare given volumes of each solution separately. Molar mass $NdCl_3 \cdot 6H_2O$ is 358.6 g/mol

Molarity mol/L	g for 1 L solution	g for 500 mL solution	g for 100 mL solution
0.125	44.8	22.4	4.48
0.100	35.9	17.95	3.59
0.0750	26.9	13.45	2.69
0.0500	17.9	8.95	1.79
0.0250	8.96	4.48	0.896
N-2 0.0976	35.0	17.5	3.50
N-1 0.0650	23.3	11.65	2.33
N-3 0.0325	11.7	5.85	1.17