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To Determine the Concentration Of Cobalt (II) In The Cobalt (II) Nitrate Hexahydarate Solution by UV-Visible Spectroscopy.

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Abstract: *According to Beer-Lambert Law, absorbance of the UV Visible radiations by any solution is a function of concentration of the solute i.e., concentration of a chemical is directly proportional to the absorbance of a solution. This relation was used to determine the concentration of cobalt nitrate hexahydrate in differently diluted solutions using spectrophotometer. The maximum wavelength of absorbance was 510 nm which was first determined from the stock solution and the same wavelength was applied to determine the absorbance of differently diluted solutions prepared from the same stock solution. A solution of unknown concentration was prepared and its absorbance was recorded and corresponding to that point on the linear graph (Concentration vs Absorbance), concentration of the unknown solution was calculated.*

Keywords*: UV-Vis spectroscopy, Beer's Law, Lambert's Law, Cobalt nitrate hexahydrate*

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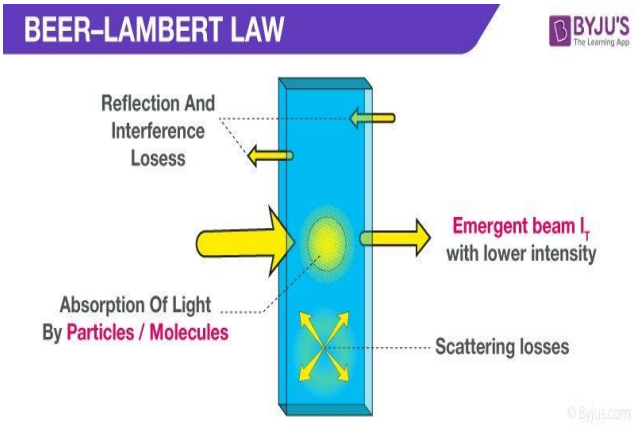
I. Introduction

The Cobalt nitrate hexahydrate $Co(NO_3)_2 \cdot 6H_2O$, which is a red-brown deliquescent salt is an Inorganic compound that is soluble in water and other polar solvents. It is absorbed on to various catalyst supports for use in Fischer-Tropsch catalysis. It is also used in preparing dyes and inks[1].Cobalt nitrate is a source of high-purity cobalt for the electronics and related industrial use[2].

Spectroscopy is defined as the study of interaction between electromagnetic radiations and the matter. The study of spectroscopy deals with the absorption and emission of spectra. If the electromagnetic rays of certain wavelength are passed through a sample under analysis, then the radiations of certain wavelengths are absorbed by the sample[3]. UV Visible absorption spectroscopy deals with the measurements of energy absorbed when electrons get excited to higher energy levels. The UV Visible spectrum of a molecule results from transitions between electronic energy levels which in turn includes both vibrational and rotational transitions[4].Beer Lambert law governs the absorption of the light by the molecules. Absorbance is dependent on the concentration of solution and also on the quantity of solution (meaning sample size); this relationship can also be written

$A = \varepsilon bc$

ε– molar absorptivity (molar extinction coefficient)
b – Path length; typically, 1 cm
c – conc. of solution in moles per litre
A – Absorbance, unitless[5]



Source image*:* "Beer-Lambert Law - Statement, Derivation, Formula, Equation." BYJUS, Byju's, 28 June

2019, https://byjus.com/physics/derivation-of-beer-lambert-law/

A stock solution of Cobalt nitrate Hexahydrate solution is prepared. Solutions of different concentrations are prepared by diluting the stock solution with different amounts of solvent (water).Use the law of conservation of mass to perform the calculation for the dilution:

$M_{dilution}*V_{dilution} = M_{stock}*V_{stock}$ (6)

II. Material and Method:

Apparatus:

An advanced UV-Visible spectrophotometer was used to analyse the absorbance of the radiations from the stock as well as from the sample solutions. Highly calibrated borosil flasks of 25mL were utilised.

Reagents:

Ultra-high-purity grade reagents were used for the dilution, preparation and analysis of samples so as to avoid contamination at trace element levels.

A stock solution of $Co(N0_3)_2.6H_2O$ was prepared with a concentration of 0.2N by dissolving the 1.455g of the cobalt nitrate in 50mL of water.

Dilute solutions of $Co(NO_3)_2.6H_2O$ of concentrations 0.01N, 0.02N,0.03N,0.04N,0.05N each of 25mL and a solution with unknown concentration.

Operation:

Instrument should be warmed up for 15min before used.

Fill cuvette with deionised water to middle of white mark on tube and wipe the cuvette with kimwipe. Place the cuvette with the mark facing towards the source of light. Close the door and take readings till the absorbance shows 0.

Now in another cuvette fill the stock solution up to the mark and then close the door.

Take readings of the absorbance at different wavelengths in our experiment we started with 400nm as before this wavelength the absorbance showing was in negative.

Take readings up to 600nm, record the readings in observation table 1 and determine the λ_{max} (maximum wavelength) of the absorbance. In this experiment the maximum wavelength was 510nm.

Now, set the instrument at 510nm and take the readings of absorbance of the dilute solutions and record the data in observation table 2.

The data obtained by the experiment is tabulated in the observation tables 1 and 2 below

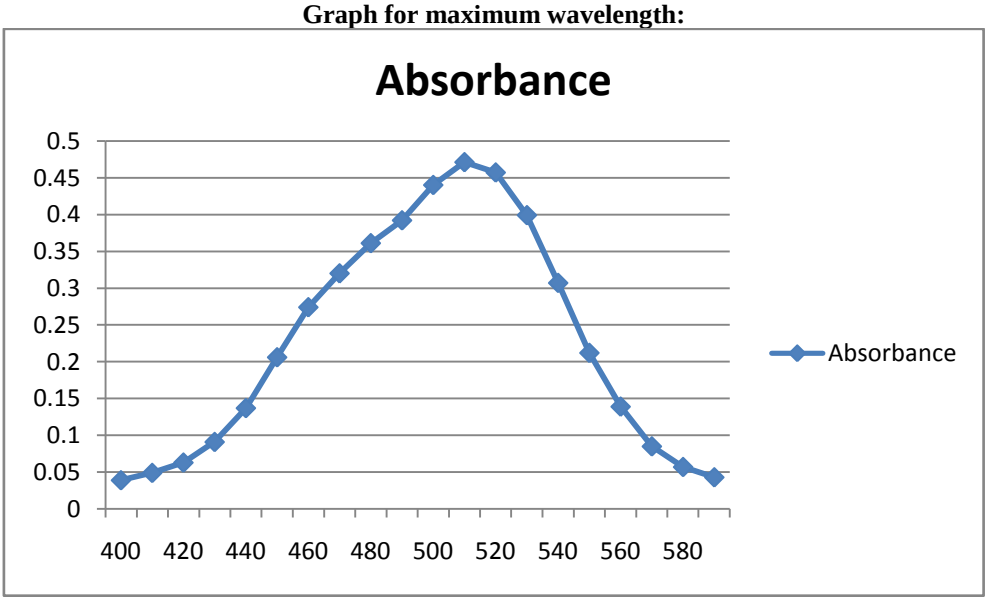
Observation table 1:

S.No.	Wavelength (nm)	Absorbance
1	400	0.039
2	410	0.049
3	420	0.063
4	430	0.091
5	440	0.131
6	450	0.206
7	460	0.274
8	470	0.320
9	480	0.361
10	490	0.392
11	500	0.440
12	510	0.471
13	520	0.457
14	530	0.399
15	540	0.307
16	550	0.212
17	560	0.139
18	570	0.085
19	580	0.057
20	590	0.043
21	600	0.037

Observation Table 2:

S.No.	Concentration	Absorbance
1	0.01N	0.016
2	0.02N	0.039
3	0.03N	0.057
4	0.04N	0.076
5	0.05N	0.099
6	Xn	0.062

Graph for maximum wavelength:



From the graph we get the value of maximum wavelength= 510nm

Calculations:-

x	y	xy	X^2	Y^2
0.01	0.016	0.00016	0.0001	0.000256
0.02	0.039	0.00078	0.0004	0.001521
0.03	0.057	0.00171	0.0009	0.003249
0.04	0.076	0.00304	0.0016	0.005776
0.05	0.099	0.00495	0.0025	0.009801
$\sum x$=0.15	**$\sum y$=0.287**	**$\sum xy$=0.01064**	**$\sum x^2$=0.0055**	**$\sum y^2$=0.020603**

An unknown dilute solution was made by mixing two different dilute solutions i.e., 0.03N and 0.04N solutions and its absorbance was determined by the same method.

Theoretically, the concentration of the unknown solution should be (0.03N+0.04N)/2=0.035N. But the value obtained after plotting the absorbance in the absorbance vs concentration graph came out to be 0.034N (this is the value of x stated in observation table 2) However, the concentration of the unknown solution calculated is not included in determining the regression equation , intercept and slope of the plotted graph to maximise the accuracy.

Therefore, the percent error can be calculated by the formula;

$$\%E = \frac{(T - O)}{T}$$

Where %E= Percent error

T= True value

O=Observed value

We get the value of **%E= 2.85.**

Now calculate C= Constant

$$C = \sum x^2 - \frac{(\sum x)^2}{n}$$

After calculating we get the value of C= 0.0010

From the Value of C we will calculate slope (m) with the help of equation;

$$m = \frac{\sum xy - \frac{(\sum x \sum y)}{n}}{C}$$

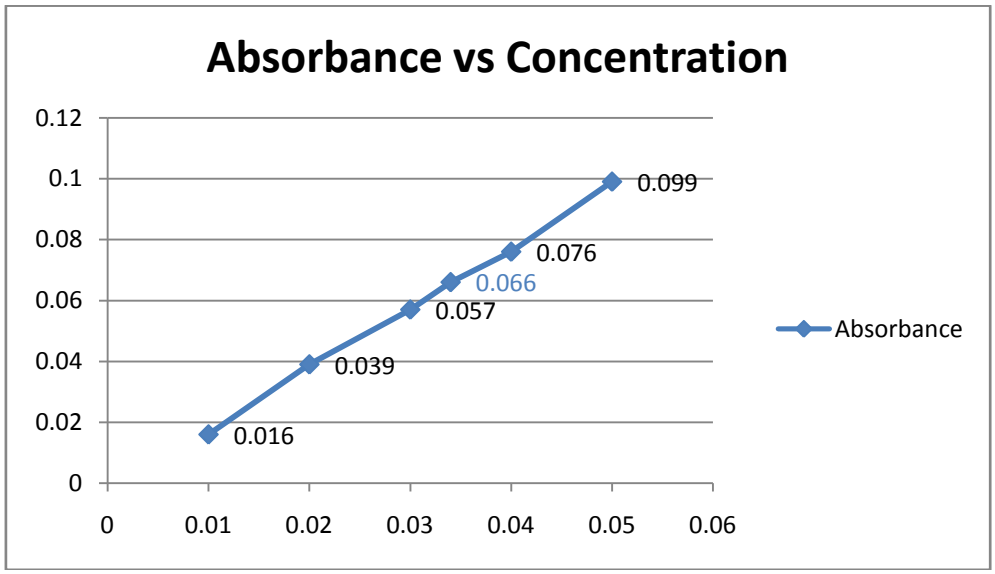
After calculating we get the value of m= 2.03
And now calculating the intercept b; with the help of equation;

$$b = \frac{\sum y - m\sum x}{n}$$

We get the value of b= -0.0035
Now finding the co-relation coefficient (r) with the help of equation;

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x^2)][n\sum y^2 - (\sum y)^2]}}$$

We get the value of r=0.99899
Therefore the regression equation;
$y = mx + b$
Becomes $y = 2.03x - 0.0035$
Drawing the graph of the above respective equation;



4d test for the values of absorbance (y)

1. Suspecting the first observation i.e., y=0.016 then;

Y	**y-∑y**	**Value (without sign)**
0.039	(0.039-0.06775)	0.02875
0.057	(0.057-0.06775)	0.01075
0.076	(0.076-0.06775)	0.00825
0.099	(0.099-0.06775)	0.03125
∑y=0.06775		**∑=0.079**

Now, calculating average deviation; by the equation

$$d_{avg} = \frac{0.028 + 0.01075 + 0.00825 + 0.03125}{4} = 0.01975$$

Now, subtracting suspected value of y from arithmetic mean ∑y we get,
0.06775-0.016= 0.05175
Now multiplying d_{avg} by 4 we get 0.079
0.05175<0.079 therefore according to 4d test the suspected value cannot be rejected.

2. Suspecting the second observation i.e., y=0.039 then;

Y	**y-∑y**	**Value (without sign)**
0.016	(0.016-0.062)	0.046
0.057	(0.057-0.062)	0.005
0.076	(0.076-0.062)	0.014
0.099	(0.099-0.062)	0.037
∑y=0.062		**∑=0.102**

Now, calculating average deviation; by the equation

$$d_{avg} = \frac{0.046+0.005+0.014+0.037}{4} = 0.0225$$

Now, subtracting suspected value of y from arithmetic mean ∑y we get,
0.062-0.039=0.023
Now multiplying d_{avg} by 4 we get 0.102
0.023<0.102 therefore according to 4d test the suspected value cannot be rejected.

3. Suspecting the third observation i.e., y=0.057 then;

Y	**y-∑y**	**Value (without sign)**
0.016	(0.016-0.0575)	0.0415
0.039	(0.039-0.0575)	0.0185
0.076	(0.076-0.0575)	0.0185
0.099	(0.099-0.0575)	0.0415
∑y=0.0575		∑=0.12

Now, calculating average deviation; by the equation

$$d_{avg} = \frac{0.0415 + 0.0185 + 0.0185 + 0.0415}{4} = 0.03$$

Now, subtracting suspected value of y from arithmetic mean ∑y we get,
0.0575-0.057=0.062
Now multiplying d_{avg} by 4 we get 0.12
0.062<0.12 therefore according to 4d test the suspected value cannot be rejected.

4. Suspecting the fourth observation i.e., y=0.076 then;

Y	**y-∑y**	**Value (without sign)**
0.016	(0.016-0.05275)	0.03675
0.039	(0.039-0.05275)	0.01375
0.057	(0.057-0.05275)	0.00425
0.099	(0.099-0.05275)	0.04625
∑y=0.05275		∑=0.101

Now, calculating average deviation; by the equation

$$d_{avg} = \frac{0.0365 + 0.01375 + 0.00425 + 0.04625}{4} = 0.02525$$

Now, subtracting suspected value of y from arithmetic mean ∑y we get,
0.05275-0.076=-0.02325
Now multiplying d_{avg} by 4 we get 0.101
0.02325<0.101 therefore according to 4d test the suspected value cannot be rejected.

5. Suspecting the fifth observation i.e., y=0.099 then;

y	**y-∑y**	**Value (without sign)**
0.016	(0.016-0.047)	0.031
0.039	(0.039-0.047)	0.008
0.057	(0.057-0.047)	0.010
0.076	(0.076-0.047)	0.052
∑y=0.047		∑=0.101

Now, calculating average deviation; by the equation

$$d_{avg} = \frac{0.031 + 0.008 + 0.010 + 0.052}{4} = 0.02525$$

Now, subtracting suspected value of y from arithmetic mean ∑y we get,
0.047-0.099=-0.052
Now multiplying d_{avg} by 4 we get 0.101
0.052<0.101 according to 4d test the suspected value cannot be rejected.

6. Suspecting the sixth (unknown) observation i.e., y=0.062 then;

y	**y-∑y**	**Value(without sign)**
0.016	(0.016-0.0574)	0.1026
0.039	(0.039-0.0574)	0.0184
0.057	(0.057-0.0574)	0.0004
0.076	(0.076-0.0574)	0.0186
0.099	(0.099-0.0574)	0.0416
∑y=0.0574		∑=0.1816

Now, calculating average deviation; by the equation

$$d_{avg} = \frac{0.1026 + 0.0184 + 0.0004 + 0.0186 + 0.0416}{5} = 0.03632$$

Now, subtracting suspected value of y from arithmetic mean ∑y we get,
0.062-0.0574= 0.0046

Now multiplying d_{avg} by 4 we get 0.0184
0.0046<0.1816 according to 4d test the suspected value cannot be rejected.

III. Result and Discussion

The concentration of the unknown compound as calculated in this experiment was 0.034N with the absorbance equal to 0.062 on the UV-Vis spectrophotometer. As per the observation we get a conclusion that as the concentration of solute decreases the absorbance of the radiation in the solution increases with almost similar trend. And also the 4d test verifies the reading mathematically for every absorbance reading.

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