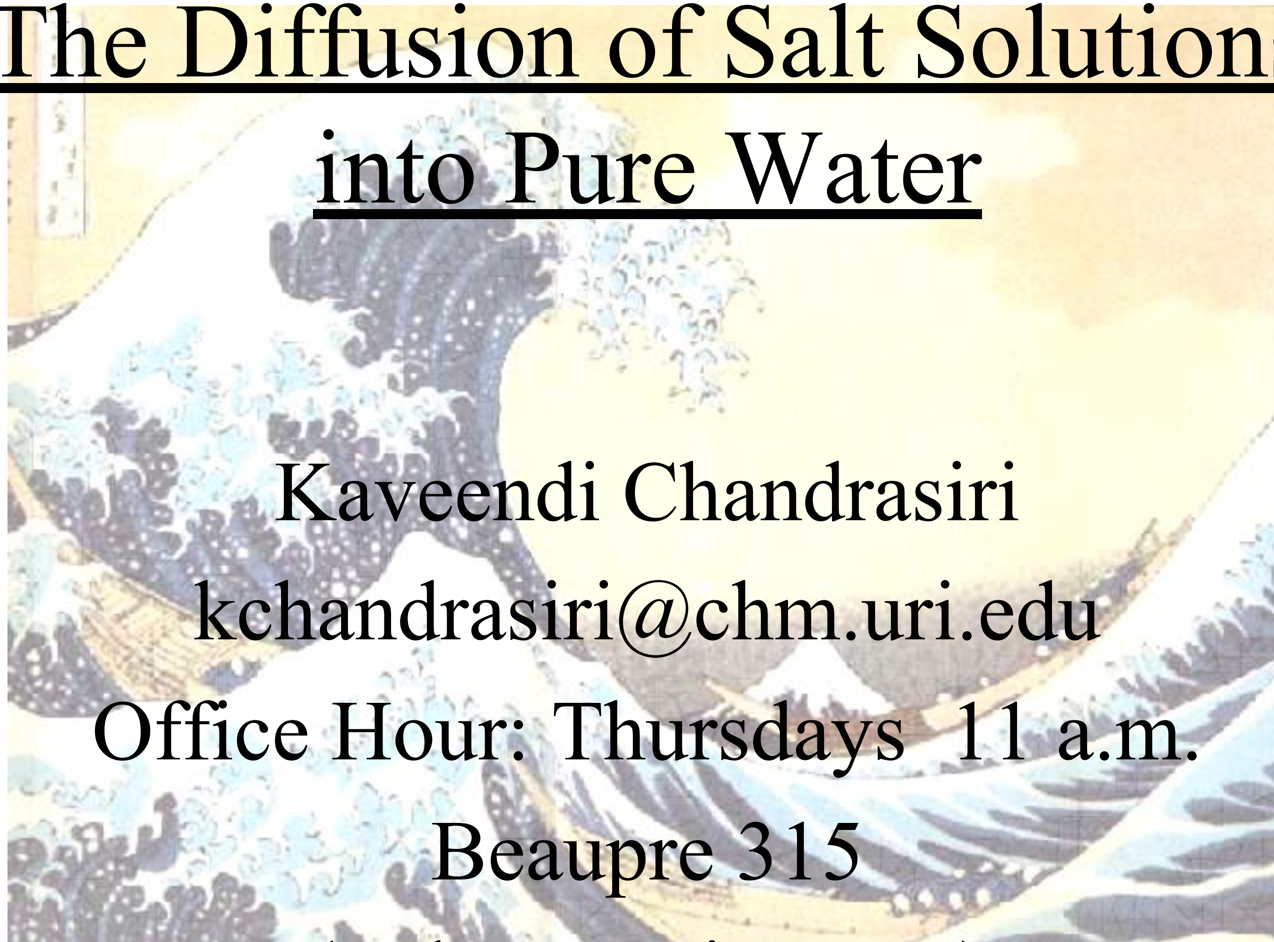
Experiment 2
The Diffusion of Salt Solutions into Pure Water

Kaveendi Chandrasiri
kchandrasiri@chm.uri.edu
Office Hour: Thursdays 11 a.m.
Beaupre 315
(or by appointment)



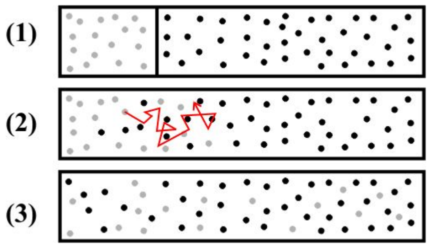
The Great Wave off Kanagawa, Katsushika Hokusai, 1830.

http://www.30minutedinnerparty.com/2010/italianiced-coffee-caffe-shakerato-recipe

Purpose

http://mathforum.org/mathimages/index.php/Snell%27s_Law

- Measure the molecular diffusion rate due to change in solution concentration.
- Use laser light refraction to measure the extent of diffusion as a function of time.
- To visually and mathematically represent this data in a meaningful manner (graphs & tables).



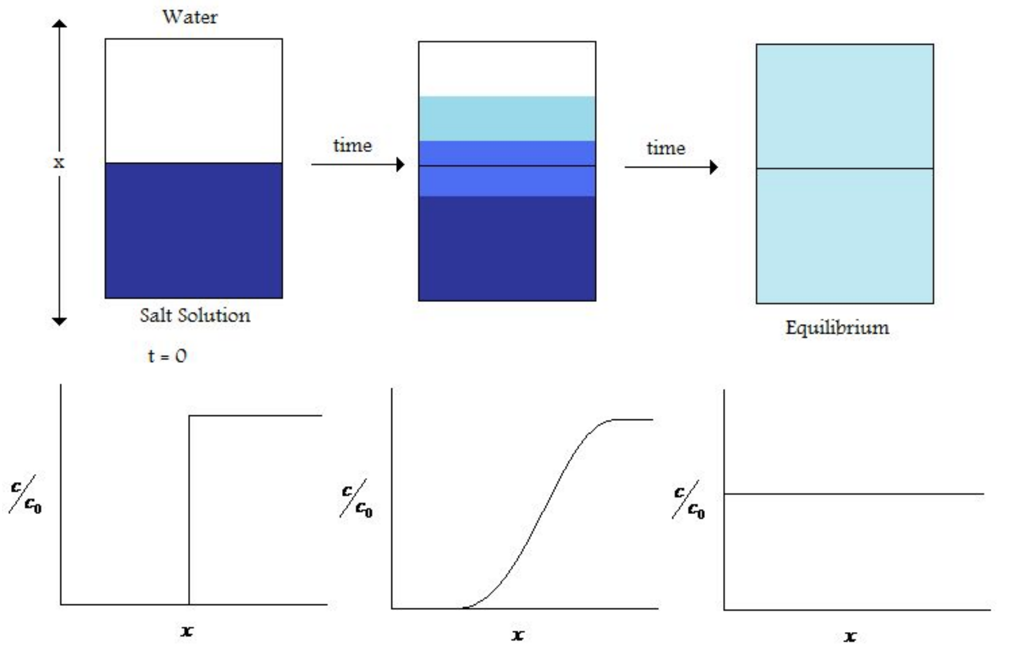
Theory

- Diffusion- the net movement of solutes (e.g., salt) from a region of high concentration to a region of low concentration.
- Brownian motion (random walk) of solute molecules causes diffusion.
- An initially sharp boundary of concentration difference of salt in water will blur over time.
- The sharpness of the concentration difference (c gradient) is measured by the extent of bending of laser light in this lab.

wikipedia

Concentration Dependence on Depth and Time

1. Left: Prepare salt solution at bottom, water on top. Sharp concentration gradient
2. Middle: Diffusion leads blurring of boundary.
3. Right: Equilibrium state: uniform concentration.



Measuring Concentration via Laser

- Refractive Index "n" is proportional to the salt concentration c.

$$\frac{\partial c}{\partial x} = K'\frac{\partial n}{\partial x}$$

- Light ray bends towards high n region of the interface if there is a gradient of the refractive index. .
- The amount of downward bending of laser light is proportional to the concentration gradient at the spot where the light ray passes through.

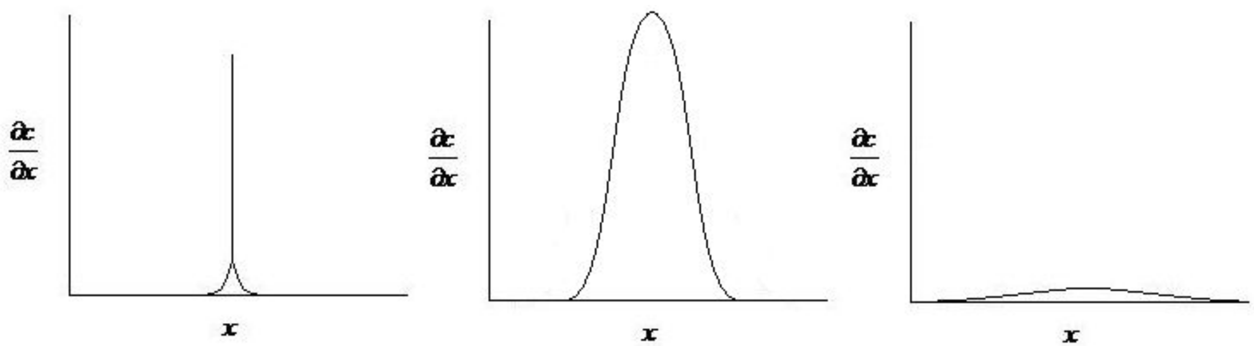
$$\text{Angle of light bending down } \propto \frac{\partial c}{\partial x} = K'\frac{\partial n}{\partial x}$$

http://www.pinterest.com/kylieamiller/marilyn-monroe/

http://www.pinterest.com/carilynwilson/wine-wine-wine/

Concentration Dependence Continued

- The derivative of this sigmoidal curve is a Gaussian distribution of the general form: $f(x) = e^{-\frac{x^2}{2\sigma^2}}$



- The width of a Gaussian distribution is proportional to "σ" in the equation. The width "σ" increases with time t.
- In this lab we experimentally determine the functional dependence of $\sigma \propto t^{\alpha}$

Part I: The "Riddle"

You have two unmarked 50 mL beakers; one contains only distilled water and the other contains a salt solution, but you do not know which beaker is which. The only tool you have to help you is a glass pipette. How can you tell which beaker contains which liquid?

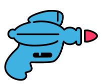
Reminder:

We *never* put unknown (or known) solutions into our bodies while in a chemistry laboratory.

Moveoninc.com online-sign.com gography.com online-sign.com http://t1.gstatic.com/images?q=tbn:ANd9GcTjlYuVPfSdfvT3_w4t2MxbG4VMydwuFZpq2v3m8BVA5Vba61Yd-Q

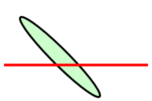
Part II: Experimental Procedure

1. Prepare 25 mL of a 2 M NaCl salt solution using distilled water. <u>Remember to **thoroughly mix** this solution.</u>

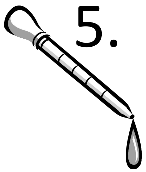


2. Place a clean, dry cuvette on a laboratory jack at the edge of the lab bench. Place a He-Ne laser on bricks pointing through (1/3 from the bottom of) the cuvette at the wall. Attach a piece of graph paper to the wall with the laser pointing near the center, 1/3 from the top of the graph paper.
3. Fill 1/3 of cuvette with your salt solution up to the laser point. Adjust the height of the laboratory jack so that the laser hits the meniscus of the salt solution, making a vertical line of laser light appear on the graph paper. **Trace this line.**

4. Using a ring stand & clamp, place a glass rod angled at ~45° in the path of the laser light between the laser & cuvette. A ~45° angle line of laser light should appear on the graph paper. **Trace this line.**

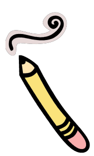


Part II: Experimental Procedure



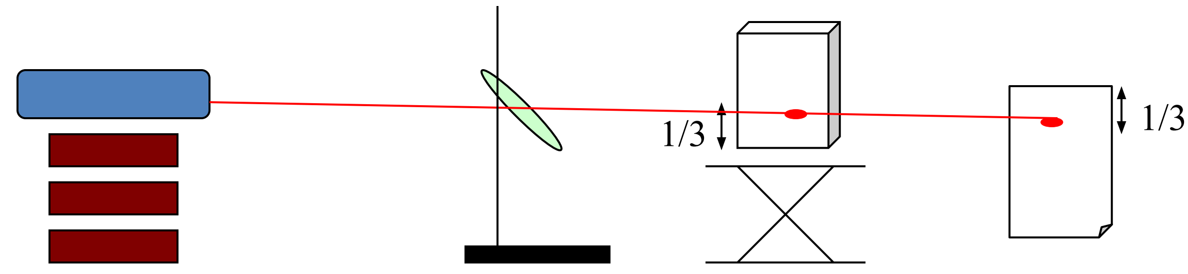
5. Gently add distilled water to the cuvette by slowly pipetting the water over a floating cork, being careful to not disturb the interface. Start the stopwatch when you begin to add the distilled water (t=0). This process will take several minutes.

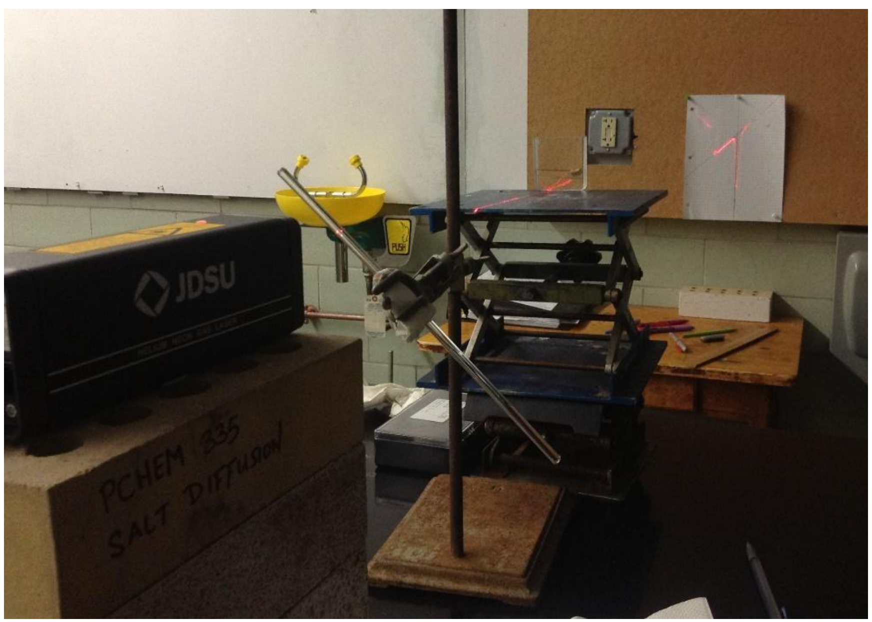
6. Once a stable deep curve appears entirely on your graph paper, trace the curve & record the time on the graph paper.

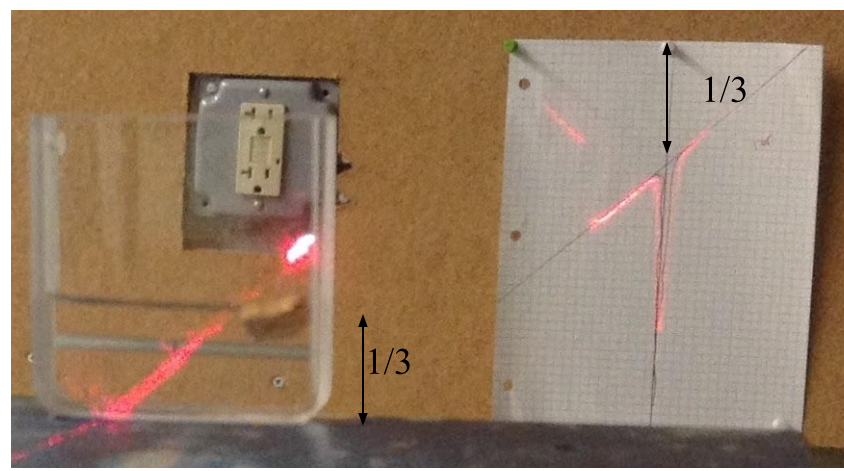


7. Trace new lines at 5 minute intervals for 40 minutes alternating between at least three colored pens (i.e. red, green, blue, red, green, etc.); record times.

Part II: Experimental Procedure
Apparatus







Part III: Data Analysis

Example of Traced Deflection Curves

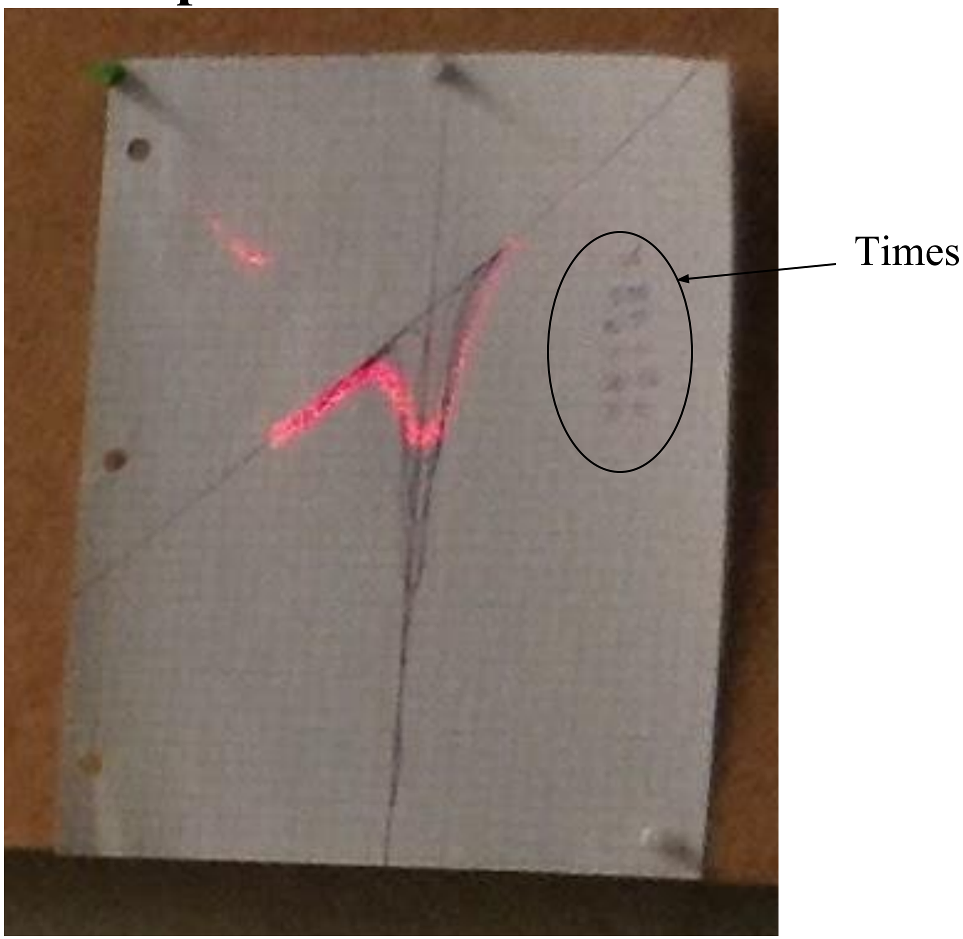
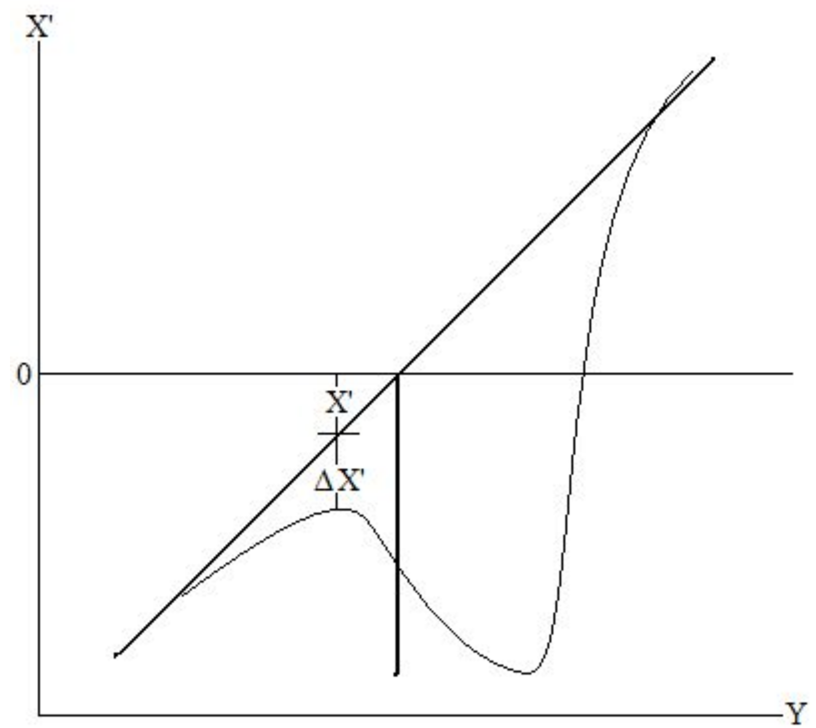
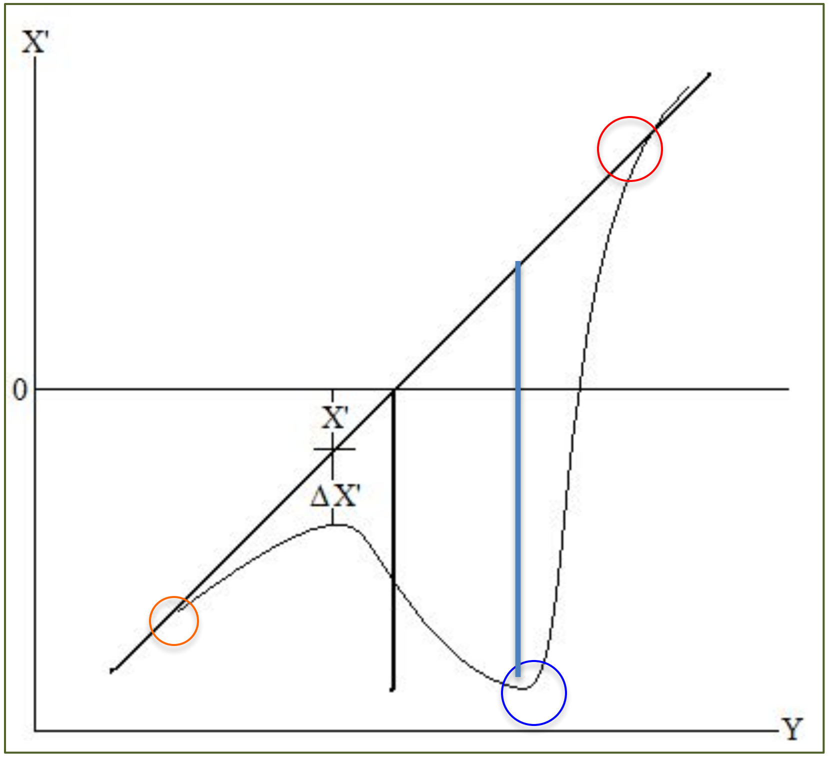


Diagram for Data Analysis



Construct data table from each curve

Measure X’ and ΔX’ at 11 points on each curve.



X’	ΔX’
-	0
-	+
-	+
-	+
-	+
+	Max
+	+
+	+
+	+
+	+
+	0

Two points with ΔX’ =0

One point with ΔX’ at maximum.

8 points with X’ Distributed on the Curve.

Part III: Data Analysis

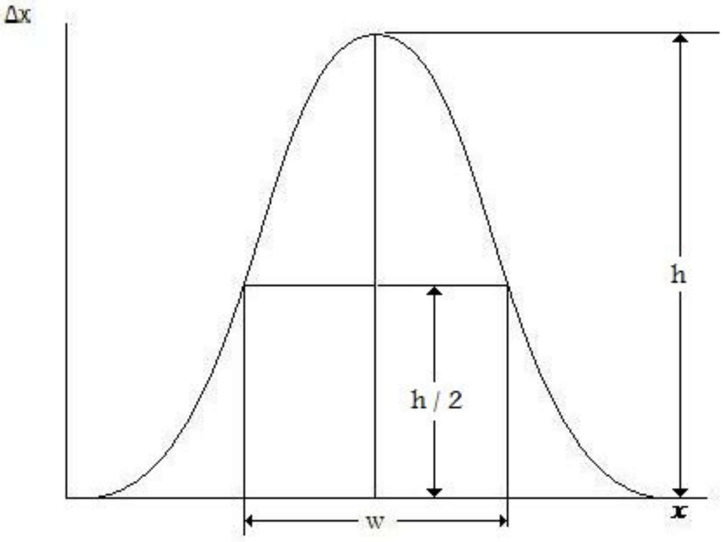
Create plots from Tables.

- One table per traced line
- Plot y= ΔX’ vs. x=X’

X’	ΔX’
-	0
-	+
-	+
-	+
-	+
+	Max
+	+
+	+
+	+
+	+
+	0

Create graphs from tables

- By hand (no computers)
- Gaussian curves
  - One per table
- Width (w) is the full width at half the height (maximum).



Part III: Data Analysis

Create table from graphs

- Table of w, t, ln w, & ln t
- One row for each traced line

w	t	ln w	ln t

Create graph from table

- Plot ln w vs. ln t (one per table) using excel
- Get the linear regression trend line using excel
- Determine slope

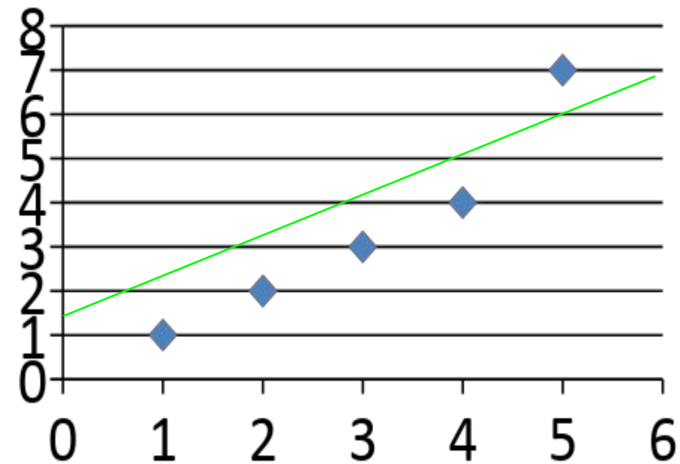
Part III: Data Analysis
Determining Standard Deviation

- The width of a Gaussian (and consequently standard deviation) curve is time dependent.
- From Fick's Law, we see

$$\frac{\partial c}{\partial x} \propto \Delta x(x) = Ae^{-x^2 / 2\sigma^2(t)}$$

and

$$w \propto \sigma(t) = Kt^{\alpha}$$



- We solve for α via:
  - Notice similarities to $\ln w = \alpha \ln t + \ln K$

$$y = mx + b$$

Part IV: Laboratory Report

1. A cover page giving your name, the title of the experiment, the date experiment was performed, and the name of your laboratory partner.
2. Your procedure signed by your TA.
3. A description of how you solved the "riddle." Be sure to include a description of the physical principles used to solve the "riddle." These principles should of course relate to the rest of the experiment and be communicated in complete grammatically correct sentences.
4. The raw data [the original or a **COLOR** copy of the graph paper signed by your TA].
5. A table of 10 values of X' and $\Delta X'$ calculated from the graph paper for each time.
6. Graphs of $\Delta X'$ as a function of X' for each time.
7. A grammatically correct statement (in words) of the precise definition you used for the width w for each graph.
8. A table of w, t, $\ln w$, $\ln t$.

Part IV: Laboratory Report

9. Plot the values of ln w as a function of ln t using the calculated points.
10. Draw a straight best fit line to illustrate the linear relationship between ln *w* and ln *t* (do not just connect end points).
11. Determine the slope of your best fit line. Round off the value of your slope to the nearest half integer.
12. Express the dependence of the width as a power law. It is important to recognize that the width *w* is proportional to the standard deviation (σ) of Gaussian curves.
13. Summary and Discussion: Briefly summarize in grammatically correct sentences the experiment and your findings. Include *all* key numerical results (e.g. power law). Examine Eq. 17.18 of the CHM 431 textbook, and compare your measured value of α with the power law of the mean squared displacement in diffusion processes as a function of time.
14. Upload the electronic copy of your lab report.

Few things to remember

- Make sure to dispose the salt solution in to the labeled waste container
- Be careful with your eyes
- Next week meet in room 472 for the pre lab lecture on error analysis