- **Set up:** What is the "equilibrium constant" for the "reaction" we're studying?

$$inside \rightleftarrows out$$

$K = \frac{[OUT]}{[IN]}$

FOR REST OF EXERCISE I DID $OUT \rightleftharpoons IN$: $K = \frac{[IN]}{[OUT]}$ OOPS!

- **Predict:** what is the ratio of the time the robot spends inside versus outside the circle ($t_{inside}/t_{outside}$)? The circle's radius is 20 *in* and the square's sides are 200 *in*. Once you have an answer, raise your hand and one of us will check it.

$$\frac{A_{IN}}{A_{OUT}} = \frac{\pi r^2}{l^2 - \pi r^2} = \frac{\pi (20)^2}{200^2 - \pi 20^2} =$$

$$\frac{t_{inside}}{t_{outside}} = 0.032$$

- **Interpret:** Circle an answer and be prepared to defend it. We think $t_{inside}/t_{outside}$ is determined by:

ENTROPY or ENTHALPY

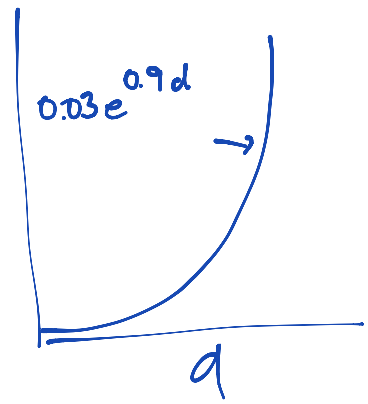
MORE STATES OUTSIDE RELATIVE TO INSIDE. THIS IS ENTROPY

- **Predict:** What do you predict would happen if we introduced a "hole" of depth d inside the circle?

ROBOT MIGHT GET STUCK.

- **Observation**. Plot t_{in}/t_{out} against d in a spreadsheet program. Fit a trend line to the data, choosing the model that best fits the data.

d	t_{in}/t_{out}
0	0.03
1	0.08
2	0.19
3	0.48
4	1.20
5	2.97
6	7.39
7	18.35



- Combine the fit you just did with the equation you found in the top part. What do you think each of the terms of your fit mean?

0.03: AREA RATIO ~> d=0.6
0.90: TEMPERATURE. "KICK" GIVEN TO ROBOT. HARDER KICK, EASIER TO ESCAPE. LESS TIME "IN".

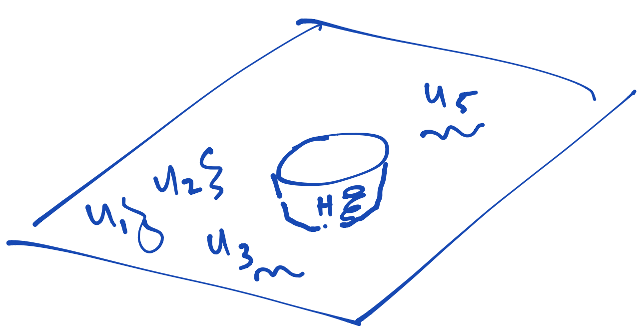
- Circle an answer and be prepared to defend it. We think the hole adds:

ENTROPY or ENTHALPY

to the robot system.

"INTERACTION" ~> NO CHANGE IN AREA OF STATES.

- Imagine, instead of a robot exploring a plane, we have a peptide chain exploring arrangements of bonds (conformations). (See the video on the screen). Draw a plane with a hole below. Can you label different conformations from the video on the drawing? What is the *in* state? What is the *out* state?



Our final relationship is:

$$\frac{t_{inside}}{t_{outside}} = \frac{A_{inside}}{A_{outside}} \cdot e^{d/C}$$

- $A_{inside}/A_{outside}$ is ENTROPY: the amount of time a robot spends in a region depends on the region's area. *The amount of time a molecule spends in a "state" (region) depends on the number of microstates (area) within that state.*
- d is ENTHALPY: a region is more favorable for the robot, so it will spend more time there. *The amount of time a molecule spends in a state depends on how favorable interactions are in that state (the depth of the hole).*
- C is TEMPERATURE (RT, ACTUALLY): at higher C, the robot is less likely to get stuck. If C is large, the robot can always climb out (as $C \to \infty$, $e^{d/C} \to 1$). If C is small, the robot is stuck (as $C \to 0$, $e^{d/c} \to \infty$). *A molecule can break favorable interactions if the temperature is high enough.*

Using simple algebra, we can turn our equation into $\Delta G = \Delta H - T\Delta S$.

1. Take the natural log of both sides:

$$ln\left(\frac{t_{inside}}{t_{outside}}\right) = ln\left(\frac{A_{inside}}{A_{outside}} \cdot e^{d/C}\right)$$

2. Use the log rule $log(A \cdot B) = log(A) + log(B)$:

$$ln\left(\frac{t_{inside}}{t_{outside}}\right) = ln\left(\frac{A_{inside}}{A_{outside}}\right) + ln\left(e^{d/C}\right)$$

3. Simplify using the log rule $ln(e^x) = x$:

$$ln\left(\frac{t_{inside}}{t_{outside}}\right) = ln\left(\frac{A_{inside}}{A_{outside}}\right) + \frac{d}{C}$$

4. Multiply both sides by $-C$:

$$-C \cdot ln\left(\frac{t_{inside}}{t_{outside}}\right) = -C \cdot ln\left(\frac{A_{inside}}{A_{outside}}\right) - d$$

5. From above, $C = RT$. Substitute this in:

$$-RT \cdot ln\left(\frac{t_{inside}}{t_{outside}}\right) = -RT \cdot ln\left(\frac{A_{inside}}{A_{outside}}\right) - d$$

6. Now we just give all of the terms in our equation special names:

$$\Delta G \equiv -RTln\left(\frac{t_{inside}}{t_{outside}}\right)$$

$$\Delta S \equiv Rln\left(\frac{A_{inside}}{A_{outside}}\right)$$

$$\Delta H \equiv -d$$

7. Finally, we're left with:

$$\Delta G = -T\Delta S + \Delta H$$