

## Teacher and Student Instructions

### Instructor guide

As students begin the game, they will struggle with the initial concept and with the procedure. After a few minutes, students figure out the directions and are able to quickly complete the tasks for both Rounds 1 and 2. After the rounds are complete and students are preparing their plots, it's helpful to have them include  $R^2$  values on their plots. The  $R^2$  value can be used to assist them in selecting the appropriate rate order from the data.

Typically, students will complete Round 1 in about two minutes. Typical "rate constants" hover around 0.1 screws/second. In general, the zero-order data (i.e., the plot of loose screws vs. time) produce a linear curve with an  $R^2$  value  $> 0.97$ .

Round 2 usually takes between two and six minutes. As Round 2 progresses, students will express frustration as they try time and again to thread the incorrect nut onto the screw. It is sometimes difficult to see how a zero-order plot and a first-order plot differ when plotting Round 2 data. Thus it's best to use the  $R^2$  parameter to determine which plot gives the best linear fit.

Scoring this exercise for points can be left to the individual instructor. However, emphasis should be placed on

1. generation of a correct plot (with axis labels),
2. interpretation of the data, and
3. use of the results to help explain the physical process of a chemical reaction.

All parts are equally important, so it would be reasonable to assign equal credit to each of these three assessment skills.

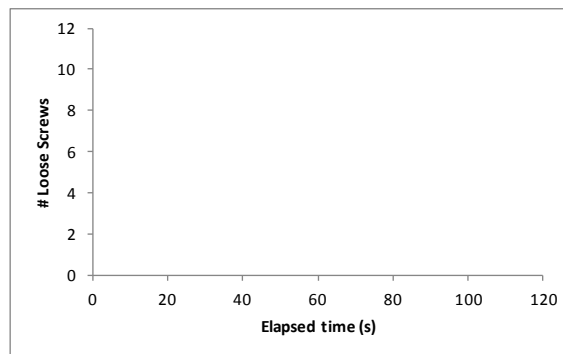
## Student instructions

**Round 1:** Use only the Round 1 container, which contains 10 nuts and 10 screws. Keep all pieces inside the container; only remove them once a nut is threaded onto a screw. General instructions are shown below. Read the instructions carefully all the way through before starting this activity. Be sure you understand what you're being asked to do. If you have questions, ask your instructor.

### Instructions:

- 1) Select from your team one member to keep track of time. The rest of the team will serve as "threaders."
- 2) When the round begins, start the stopwatch and have the first threader reach into the container, retrieve a nut and screw, and thread the nut onto the screw at least halfway up the screw's barrel. When the task is complete, the threader shouts "Done!" and passes the container to the next threader, and the time keeper records the total elapsed time.
- 3) The second threader now reaches into the container, retrieves a nut and screw, and threads the nut onto the screw just as the previous threader did. When the task is complete, the threader shouts "Done!" the container is passed, and the timekeeper records the total elapsed time.
- 4) Play continues until each nut has been threaded onto its own screw.
- 5) When play is complete, make a plot by hand or by using computer software of the number of loose screws vs. elapsed (total) time (an example is shown below).

screws free	elapsed time (s)
10	7
9	20
8	32
7	41
6	51
5	60
4	70
3	78
2	90
1	100



### Data collection:

Screws left	Total elapsed time	Screws left	Total elapsed time
10		5	
9		4	
8		3	
7		2	
6		1	

### Data analysis:

- 1) What rate order does your data display?
- 2) What rationale can you provide for why your data displays that order?

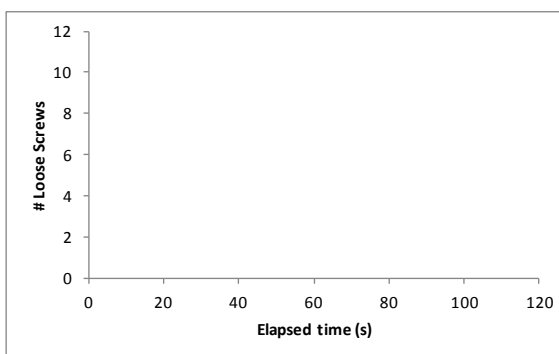
- 3) What is the rate constant?
- 4) What factor determines the magnitude of the rate constant?
- 5) If you repeated the procedure, what differences would you expect to see in the data?
- 6) Why might you see differences between your data and those from another group?

**Round 2:** Use the Round 1 container, which contains 10 unthreaded nuts and 10 screws, but dump the contents in the Round 2 container into the Round 1 container as well. Keep all pieces inside the Round 1 container; only remove them once a nut is threaded onto a screw. General instructions are shown below. Read the instructions carefully all the way through before starting this activity. Be sure you understand what you're being asked to do. If you have questions, ask your instructor.

**Instructions:**

- 1) Select from your team one member to keep track of time. The rest of the team serves as “threaders.”
- 2) When the round begins, start the stopwatch and have the first threader reach into the container, retrieve a nut and screw, and thread the nut onto the screw at least halfway up the screw’s barrel. If a nut cannot be threaded onto the screw, that nut **MUST** be dropped back into the container before another nut can be chosen. When the task is complete, the threader shouts “Done!” passes the container to the next and threader, and the time keeper records the elapsed (total) time.
- 3) The second threader now reaches into the container, retrieves a nut and screw, and threads the nut onto the screw just as the previous threader did. When the task is complete, the threader shouts “Done!” the container is passed, and the timekeeper records the (total) elapsed time.
- 4) Play continues until each nut has been threaded onto its own screw.
- 5) When play is complete, make a plot by hand or by using computer software of the number of loose screws vs. elapsed (total) time (an example is shown below).

screws free	elapsed time (s)
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**Data collection:**

Screws left	Total elapsed time	Screws left	Total elapsed time
10		5	
9		4	

8		3	
7		2	
6		1	

**Data analysis:**

- 1) What rate order does your data display? How should you modify your plot to obtain rate order information?
- 2) What rationale can you provide for why your data displays that order?
- 3) What is the rate constant?
- 4) Compare your data to that from Round 1. What are the differences in the data and what are the differences in the system being studied?
- 5) Why might you see differences between your data and those from another group?