Radioactive Decay
Student Guide
Section I

Purpose: To determine the half-life of a radioactive isotope called M&Mium.
                 To draw an exponential decay curve.

Background:

    Q1. In this lab, the M&M's represent _____.

    Q2. When an M&M is facing upward, it is removed from the box because it has
_____ and turned into a new kind of atom.

    Q3. The time it takes to remove exactly 1/2 of the M&M's is called the _____.
We will read this half-life from a graph that we draw.

Procedures:

1. Count out exactly 100 M&M's and put them into a box and cover the box.
   Record 100 M&M's under time trial 0 on the data chart on the answer sheet.
2. Shake the box.
3. Remove the cover.
4. Take out all of the M&M's where the letters are pointing up. Set them aside or eat them.
5. Count the remaining M&M's and record under the next time trial on the data chart.
6. Repeat steps 2 - 5 until there are no M&M's left in the box. Record the number
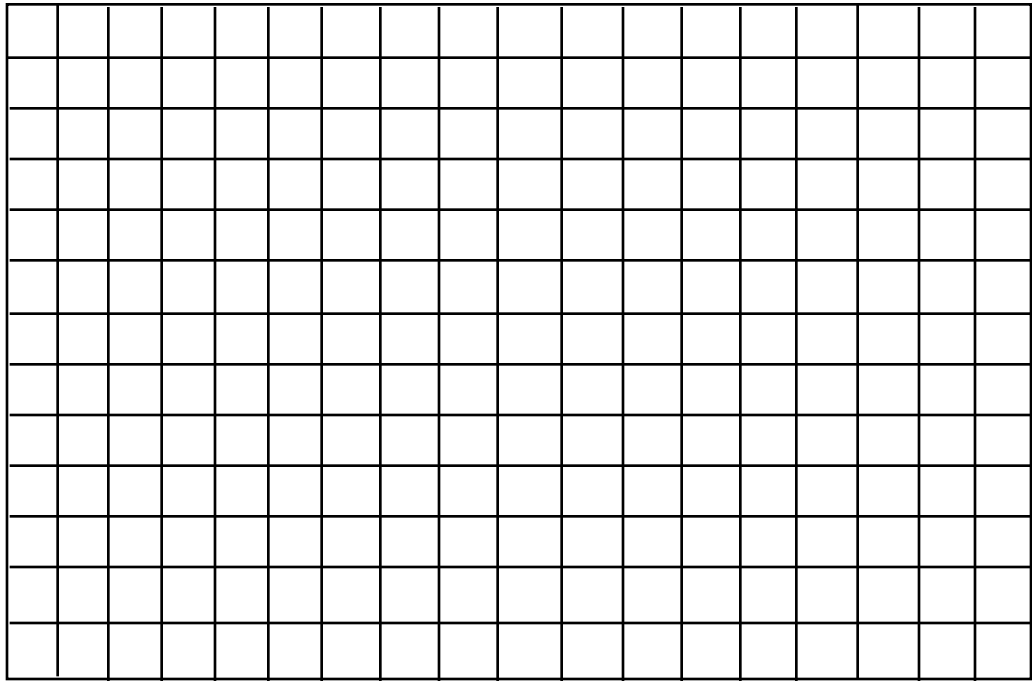   remaining in the box each time you remove those with the letter pointing up.

    Note:
- Never put M&M's back in the box.
- If none of the M&M's have the letter pointing up, record the same number twice.

Data:

Time (trial)	0	1	2	3	4	5	6	7	8	9	10	11	12
Number M&M's in box	100												

Graph:

Q4. Using your graph, determine how many time trials it took to remove 50 M&M's.

Extension:

Q5. Suppose that an M&M was shaped like a cube and only one side was marked with M&M. Would it take more, less or the same amount of time trials to remove half of the M&M's? Explain your reasoning.

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Section II

Introduction:

In the hands on activity with M&M's, the half-life was equal to one "shake and removal", the time for 1/2 of the M&M's to "disappear". This was true because the M&M's could be either up or down so you removed 1/2 of them each time you shook the box. We would call 1/2 the removal fraction and 1 "shake and removal" the half-life.

In this activity, using STELLA computer modeling, we will duplicate what we have learned about half-life with M&M's and apply it to another model which more closely represents radioactive decay in real atoms. The model we will use to represent radioactive atoms is dice. Since dice have six distinct sides, we can determine the half-life for removal fractions such as 1/6, 1/3 or 1/2. Each of these removal fractions will have a different half-life.

The Model:

Imagine that we have a very large container which contains 1000 six-sided dice. Just as in the previous activity, we are going to shake this container and remove the dice, but we are going to do three different experiments.

Experiment 1: Each time we open the container, we are going to remove all the dice showing an **even number of spots**.

Q1. Approximately what fraction of the dice will be removed each time in Experiment 1? _____

Experiment 2: Each time we open the container, we are going to remove all the dice showing either **one or three spots**.

Q2. Approximately what fraction of the dice will be removed each time in Experiment 2? _____

Experiment 3: Each time we open the container, we are going to remove all the dice showing exactly **four** spots.

Q3. Approximately what fraction of the dice will be removed each time in Experiment 3? _____

Building the Model:

1. **Double-click** on the **STELLA** icon.

2. **Click once** on the icon of the world [🌐]. It should change to an [x²].

3. The tool bar looks like this:

[toolbar icons]

4. **Click once** on the stock icon [□]. Slide your pointer out into the open field and click again. A large stock should appear with the word **Noname 1** highlighted. Before doing anything else, **type** the words **Dice Remaining.**

5. **Click once** on the flow icon [⚬]. Position your pointer **inside** the stock, then **click and drag** to a point a couple of inches to the right of the stock. Let go of the mouse button. Type the word **Number Removed.**

6. Next **click once** on the converter icon [○]. Position your pointer near the **Number Removed** flow and click again. Name this **Removal Fraction**. Since the number of dice removed depends on the removal fraction and the number of dice remaining in the box, you will need to show these relationships in your model.

7. **Click once** on the connector icon [↘]. Position your pointer **inside** the stock again, then **click and drag** the connector to the bubble of the flow. Once the bubble is highlighted, release the mouse button. Place another connector going from the converter to the bubble of the flow. Your diagram should look like this:
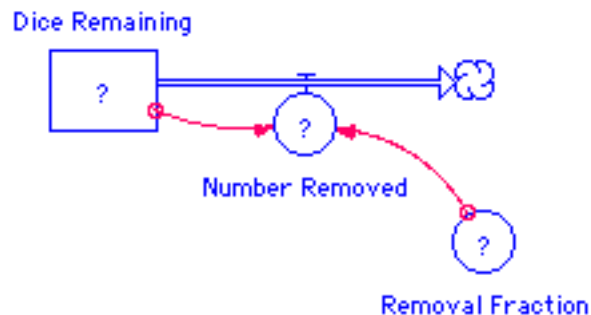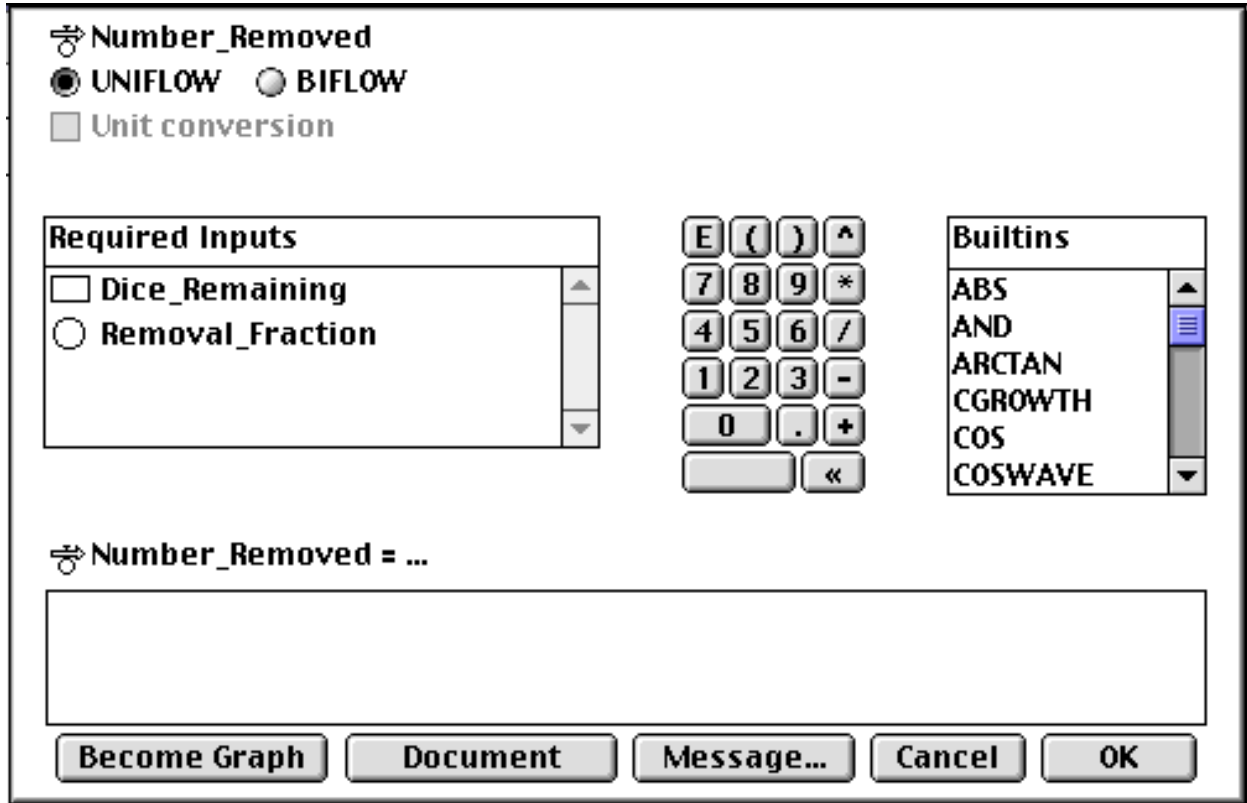

8. **Double-click** on the **Dice Remaining** stock and enter the value 1000, then click **OK.**

9. **Double-click** on the **Removal Fraction** converter and enter the value 1/2, then click **OK**.

Q4. How would you use Removal Fraction and Dice Remaining to calculate Number Removed?

_____

10. Double-click on the **Number Removed** flow, and you will see a window like this:

By using the mouse to click on **Dice_Remaining** and **Removal_Fraction** from the **Required Inputs** box and the multiplication sign ***** from the keypad, you can enter the equation
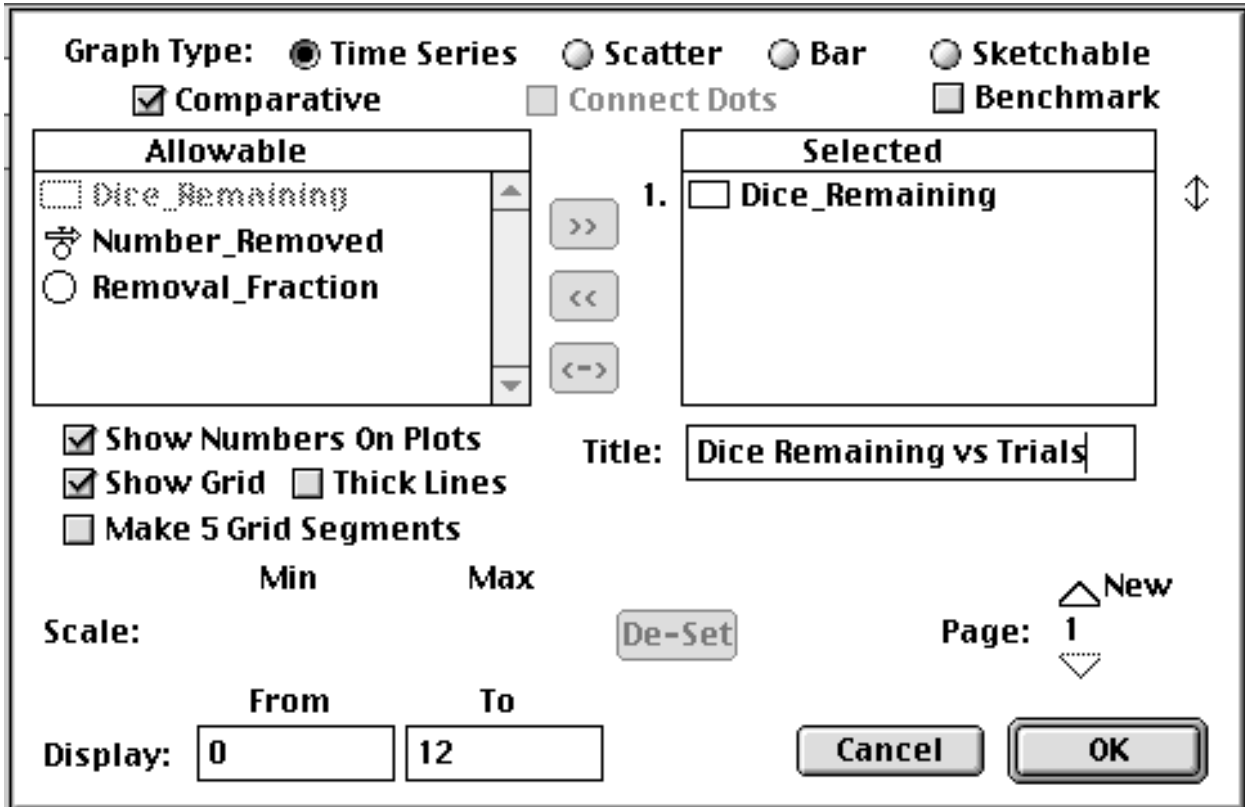
Number_Removed =
       Dice_Remaining*Removal_Fraction

Click OK.

Setting up a Graph:

11. Go to the tool bar and **click once** on the graph icon [graph icon]. Slide your mouse pointer to a clear spot in the window and **click once** again. **Double-click** anywhere in this graph and a new window will open.

12. **Click once** on the **Comparative** box to put a checkmark there. **Double-click** on **Dice_Remaining** in the **Allowable** box to move it to the **Selected** box. Type a meaningful title for the graph in the **Title** box. When your window looks like the one below, **click OK.**

Pinning Down the Graph:

13. To prevent the graph box from disappearing every time you run the model, you should pin down the graph window.

- **Move your pointer to the horizontal bar at the top of the graph window.**
- **Drag the graph so it fits on the white space below the model.**
- **Click once on the black circle (looks like a push pin) in the upper left-hand corner of the graph.**

Running and Interpreting the Model:

14. To run the model, **click and hold** the **Run** option on the menu bar and **drag down to Run**.

Q5. The M&M activity had a removal fraction of 1/2. Removing all dice with an even number of spots also gives a removal fraction of 1/2. Compare the graph you drew for the M&M activity with the graph on your computer screen.

      a) Are the scales the same on the two graphs? Consider both axes in your answer and explain the similarities and differences in the context of the activities.

      b) Are the shapes of the curves the same? Explain why they should or should not be the same.

      c) Which part of the curve shows the greatest change?

      d) How is the steepest part of the curve related to the number of dice being removed from the box in a single "shake and removal" trial?

      e) Reading from the graph for the M&M experiment, what is the half-life measured in "shake and removal" trials?

      f) Reading from the graph for Experiment 1 of the Dice Model, what is the half-life measured in "shake and removal" trials?

Running Experiments 2 and 3:

15. **Double-click** on the **Removal Fraction** converter and enter the fraction for Experiment 2. Then **run** the model. You should see a second curve on your graph.

16. Then **double-click** on the **Removal Fraction** converter again and enter the fraction for Experiment 3. **Run** the model and see a third curve on the graph.

Using a Text Box:

17. In order to interpret the graphs, we need to label which curve goes with which removal

fraction. To do this, you will use a text box. Go back to the tool bar and **click once** on the A

icon. Move the cursor an inch above the graph and **click once** again. Move your cursor inside the box and type the key below.

> **Removal Fraction 1 = 1/2**
> **Removal Fraction 2 = 1/3**
> **Removal Fraction 3 = 1/6**

Analyzing the Graph:

Q6. Describe in full each curve on the graph.

Q7. Which of the removal fractions causes the dice to disappear at the fastest rate? _____

Q8. Which of the removal fractions results in the shortest half-life? _____

Q9. Which of the removal fractions causes the dice to disappear at the slowest rate? _____

Q10. Which of the removal fractions results in the longest half-life? _____

**Q11.** From the graph, estimate the half-life (including the units) and fill out the table provided.

Removal Fraction	Half-Life
1/2	_____
1/3	_____
1/6	_____

Q12. What is the relationship between half-life and the removal fraction?

Q13. Suppose we wanted to remove 1/8 of the dice on each shake. Where on the comparative graph would the curve appear relative to the three curves we already have showing?

a) Sketch the comparative graph on the axes provided, labeling each curve with its corresponding removal fraction.

b) Sketch your prediction and label this curve 1/8.
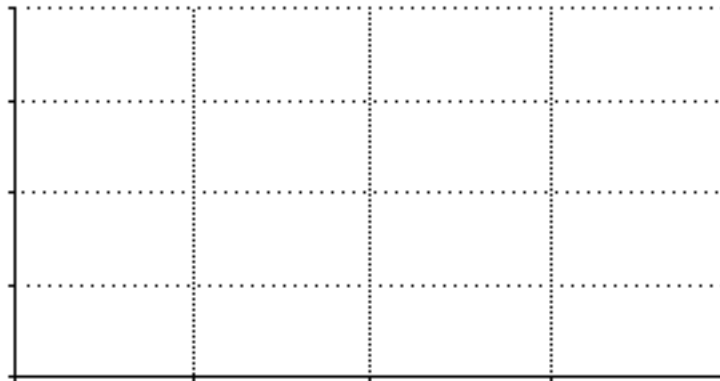
Q14. Using the graph from Q13, sketch the curve that might appear if you used a removal fraction of 1/4. Label this curve 1/4.

Use the model to check your predictions in **Q13** and **Q14**.

Q15. Give a written description of a rule regarding the size of the removal fraction and the shape of the dice remaining curve.

Radioactive Decay - Section III
Student Answers

Q1. Write the nuclear equation for the P-32 reaction and label the parent nuclide and the daughter nuclide.

_____ ➤ _____ + _____

Q2. What should the Dice Remaining stock represent? _____

Q3. What should the Removal Fraction converter represent? _____

Q4. What should the Number Removed flow represent? _____

Q5. Can you estimate the half-life of P-32 from this graph? Justify your answer.

Q6. Referring back to your copy of the Graph Interpretation Guidelines, describe in full the decay curve for P-32.

Q7. How does the P-32 decay curve compare to the curves from the dice model?

Q8. From the graph, estimate the half-life of P-32 (including units).

Q9. Using the table, what is the half-life of P-32 (including units)?

Q10. How do the actual half-life, the half-life estimated from the graph, and the half-life from the table compare?

Q11. Does the dice model correctly demonstrate what really occurs in radioactive decay? How do you know?