Rock Cycle Part I
Student Guide

Write your answers on the separate answer sheet provided.

Introduction

Why are there different kinds of rock on Earth? Earth rocks are recycled so that new rock is constantly formed from old rock. Deeply buried metamorphic rock melts and becomes magma that may rise to the surface through volcanoes and vents, cooling and solidifying into igneous rock. Earth's atmosphere and hydrosphere allow for a rapid rate of erosion which breaks down all types of rock into sediments. After being deposited in thick layers by running water, these sediments are compacted into sedimentary rock. Magma rising through the lithosphere (Earth's solid crust) results in movements of Earth's plate. These movements cause mountains to be built as some rock bends and folds while other rock is buried deeply to be melted and turned to magma again. The forces of heat and pressure applied to igneous and sedimentary rocks partially melt those rocks and change them into metamorphic rock.

Does the same rock cycle exist on the Moon? No, our moon is considered geologically dead because it has no heat source. Consequently, it has cooled into solid rock covered with a thin film of sediment. On Earth, the heat is produced by the radioactive decay of elements such as Uranium. On Io, a geologically active moon of Jupiter, the heat source is the tidal pull from Jupiter as Io orbits the giant planet. The first volcano outside of Earth was observed on Io in 1979.

How long does it take for one type of rock to change into another? On Earth, each process can take millions of years. It would be interesting to find out how long it would take for sedimentary rock to travel through the entire cycle to become sedimentary rock again. You will build and use a computer model of the rock cycle on Earth to answer this question.

> **Q1.** To get started, draw a diagram of the rock cycle. Label each rock type and each geologic process.

> **Q2.** The amount of rock in Earth's upper layers is known to be approximately $5974*10^{24}$ grams. It is estimated that sediments are 10% of the total rock, sedimentary rock are 21% of the total rock, metamorphic rock are 22% of the total rock and magma is 16% of the total rock. What percentage of the total rock is igneous rock?

Building the Basic Model

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

2. **Click** on the icon of the world 🌐 once. It should change to an $\boxed{x^2}$.

3. The top tool bar looks like this:

4. **Click** on the stock icon ▢ and slide your pointer out into the open field and click again.
A large stock should appear with the word **Noname 1** highlighted. **Type** the word **Sedimentary Rock.**

5. Locate four more stocks on your screen, spreading them out on the screen and naming each one as shown on your rock cycle diagram: **Sediment, Igneous Rock, Magma,** and **Metamorphic Rock**.

6. Click on the flow icon ⌀ . Slide your pointer inside the **Sediment** stock, **click and drag** toward the **Sedimentary Rock** stock until the pointer is inside the **Sedimentary Rock** stock and the stock has become shaded. Let go of the mouse button. Name the flow **Lithification.**

7. Add flows for **Metamorphism**, **Melting**, **Crystallization**, and **Sedimentation**. If two stocks are not in direct line with one another, you will want to make the flow bend at a right angle. To do that, hold down the **shift** key when you are ready for the turn. Then continue with the **drag** motion until the arrow just touches the stock and the stock becomes shaded.

8. Check your model against the diagram below. Make any corrections needed.
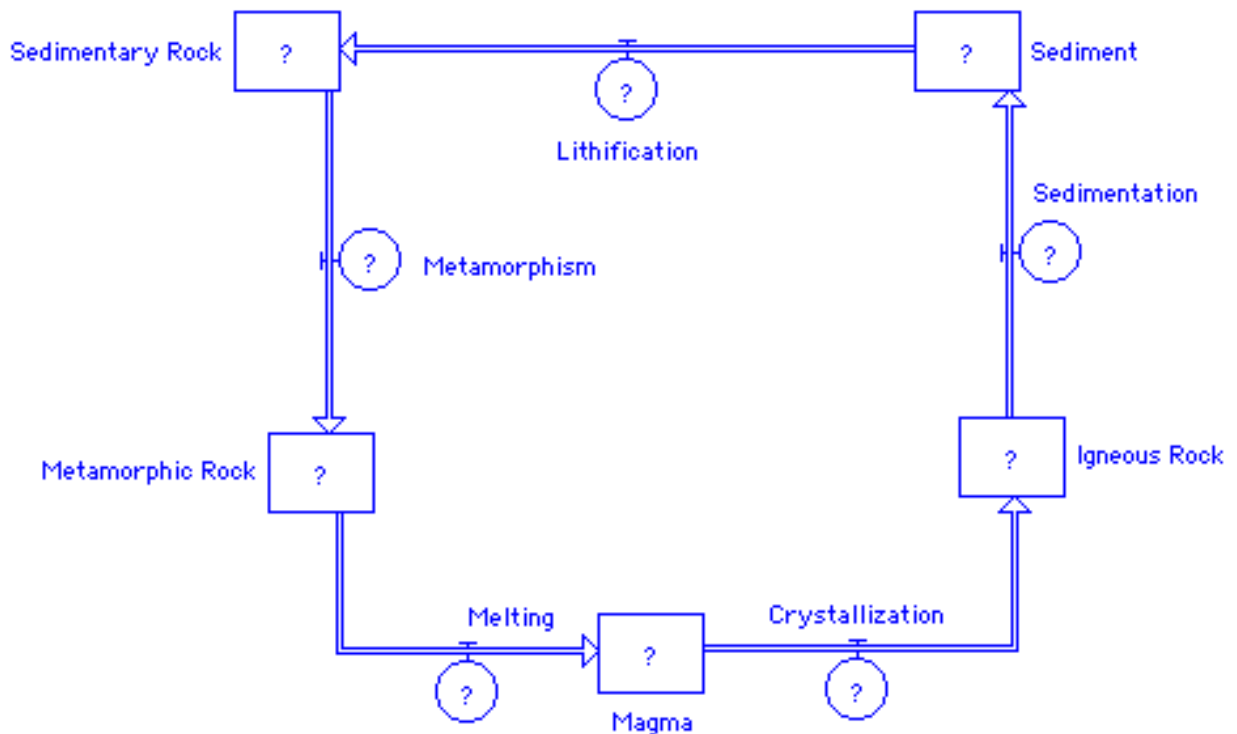
Entering Values for the Stocks

9. **Click** on the converter icon ◯ and place it in the upper right-hand corner of the model. Name it **Total Initial Rock**. **Double-click** on the converter and enter **5974 {10^24 grams}** in the text box as shown below. Then **click** on **OK.**

◯ Total_Initial_Rock = ...

```
5974 {10^24 grams}
```

10. **Double-click** on the **Sediment** stock. When that window opens enter **.1** in the highlighted box, click on the multiplication symbol *, and click on the word **Total_Initial_Rock** inside the Allowable Inputs box (you may have to scroll down to see it). The text box should look like the one below. Then **click** on **OK.**

▢ INITIAL(Sediment) = ...

```
.1*Total_Initial_Rock
```

11. **Double-click** on each remaining stock and enter the appropriate formula from the list below.

> Sedimentary Rock: **.21*Total_Initial_Rock**
> Metamorphic Rock: **.22*Total_Initial_Rock**
> Magma: **.16*Total_Initial_Rock**
> Igneous Rock: **.31*Total_Initial_Rock**

Entering Values for the Flows

Each flow represents a geologic process which takes place over millions of years. To represent how quickly a process occurs, you need to know what fractional amount of each rock type changes into another type during a one million year time period. We will store these fractions in separate converters.

12. Beside each flow circle, place a converter. Name each converter according to the flow to which it belongs. Use these names: **LithRate, MetaRate, MeltingRate, CrysRate, SedRate.**

13. Connect each converter to its corresponding flow by using a connector . For example, place the connector inside the **LithRate** converter. Hold the mouse button down and drag the pointer inside the **Lithification** flow until the flow circle becomes shaded. Release the mouse button. Do similarly for the other four flows.

14. **Double-click** on each converter and enter the appropriate fraction from the list below.

LithRate:	**1/2**
MetaRate:	**1/12**
MeltingRate:	**1/13**
CrysRate:	**1/3**
SedRate:	**1/18**

    Q3. The **Lithification** flow should remove one-half of the **Sediment** stock and add it to the **Sedimentary Rock** stock. STELLA will do the subtraction and addition for us because we have the flow pointing in the right direction, but we must enter the correct formula in the **Lithification** flow. What should the formula for **Lithification** be?

15. In order to include **Sediment** in the formula for **Lithification**, we need another connector. Place the connector inside the **Sediment** stock. Hold the mouse button down and drag the pointer inside the **Lithification** flow until the flow circle becomes shaded. Release the mouse button.

16. **Double-click** on the **Lithification** flow. Notice the box titled Required Inputs. Click on the word **Sediment** inside the box. Then click on or type the multiplication symbol *. Return to the Required Inputs box and click on **LithRate**. The lower box should now look like this:

⇌ **Lithification = ...**

Sediment*LithRate

17. Follow steps 15 and 16 for each of the other four flows. First, insert a connector from the appropriate stock to the flow. Then, double-click on the flow to enter the appropriate formula as listed below:

Metamorphism:	**Sedimentary_Rock*MetaRate**
Melting:	**Metamorphic_Rock*MeltingRate**
Crystallization:	**Magma*CrysRate**
Sedimentation:	**Igneous_Rock*SedRate**

Your model should look something like this:
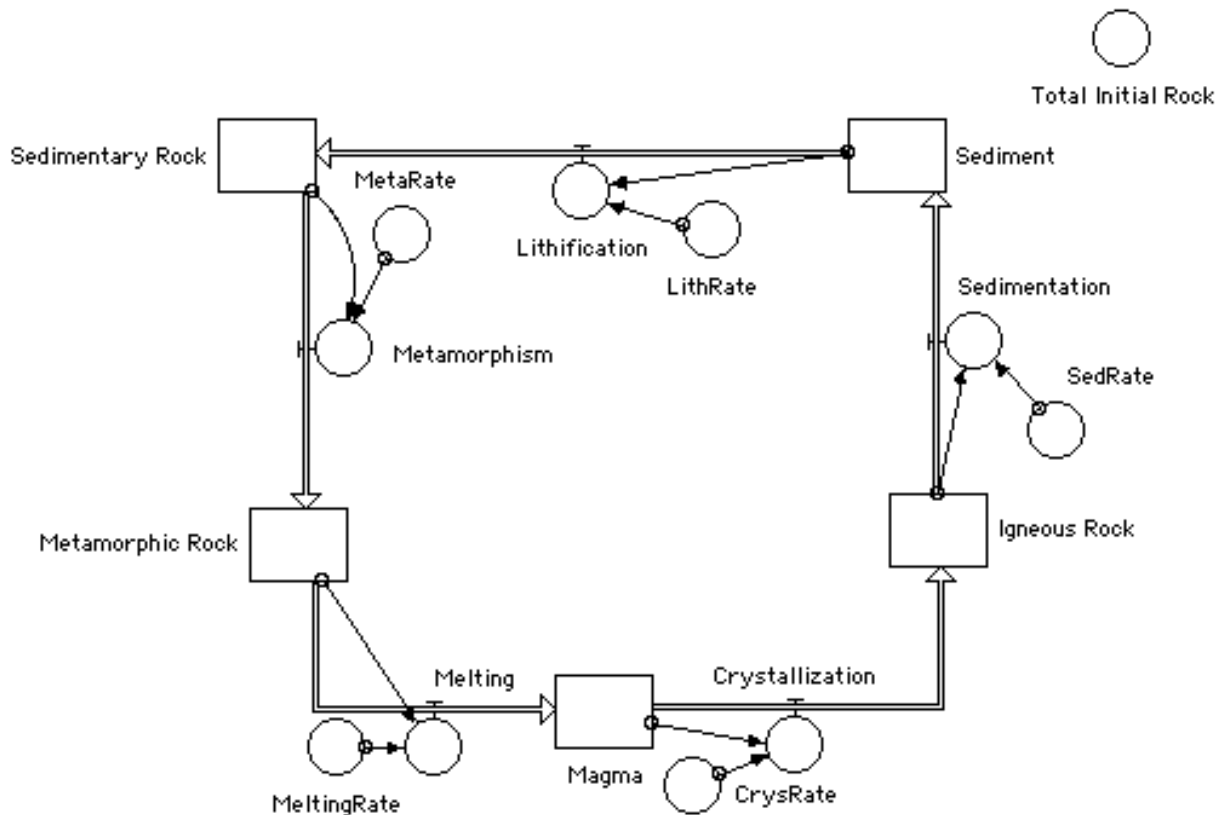
Setting Time Specs:

18. Go the the **Run** menu and drag down to select **Time Specs...**

19. In the boxes under **Length of Simulation**, set **To: 50** instead of 12. Set **DT: 0.125**. Under **Unit of Time**, type **Million Years** in the text box containing Time. Click OK.

Setting up a Graph:

20. In order to plot all five types of rock, follow these directions.

• Click on the graph icon [graph icon].

• Slide the icon to an open spot in the window and click again.

• Double-click on the large blank graph that appears. A new window will open. You will see two boxes, which look like this:

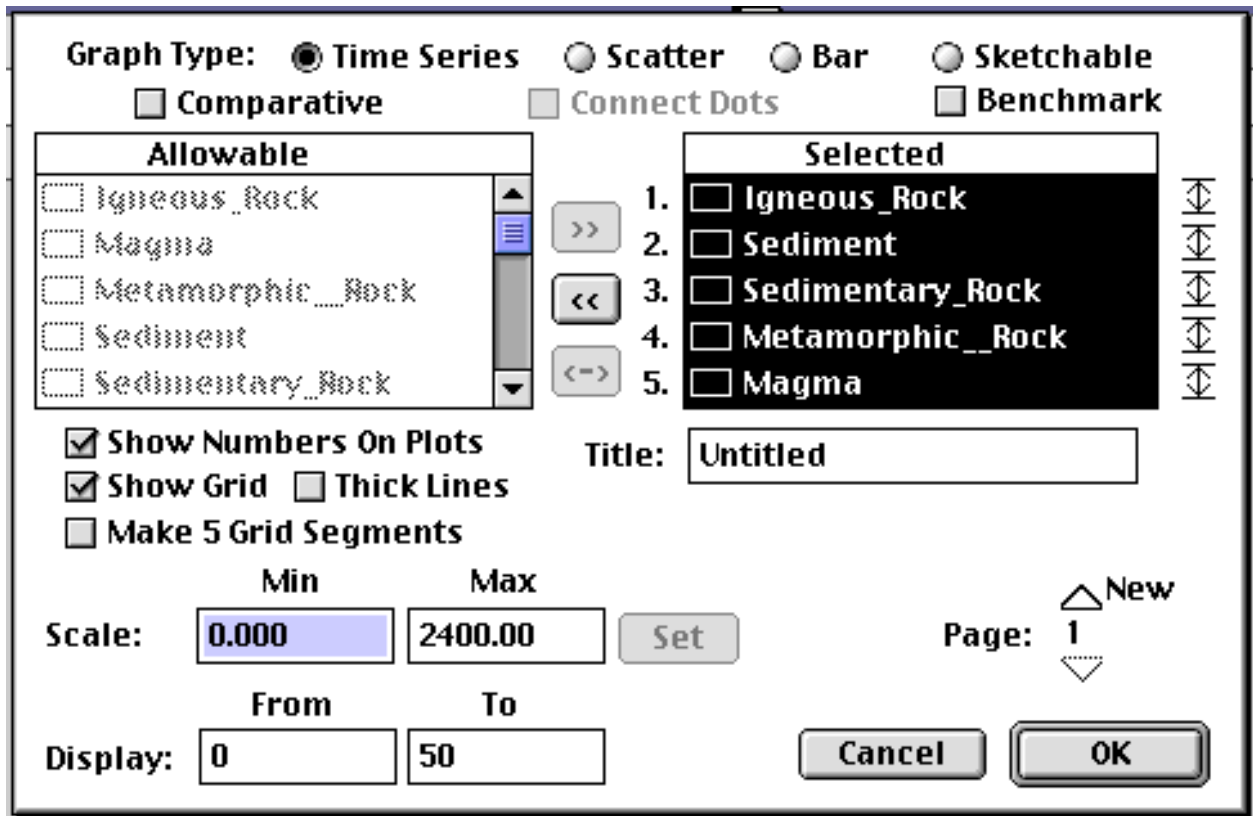| Allowable		Selected
☐ Igneous_Rock ▲	1.	
☐ Magma ▤	⟩⟩ 2.	
☐ Metamorphic_Rock	⟨⟨ 3.	
☐ Sediment	4.	
☐ Sedimentary_Rock ▼	⟨−⟩ 5.	
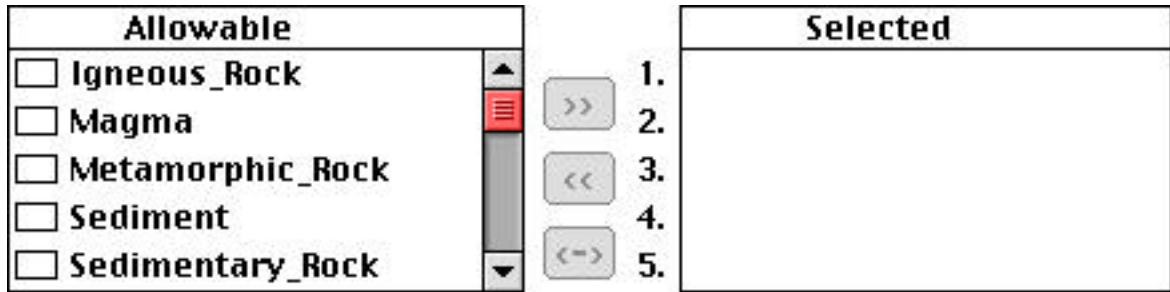
- Click on Igneous_Rock, then click on the **>>** symbol (or double-click on Igneous_Rock) to tell STELLA® to move the Allowable input you have chosen into the Selected box.

- Do the same for Sediment, Sedimentary_Rock, Metamorphic_Rock and Magma in exactly that order so that the boxes look like the ones in the dialog box on the next page.

21. In order for the y-axis scales to be the same for all five rock types, do the following:

- In the Selected box, click on Igneous_Rock and drag the mouse downward to highlight all five rock types.

- Click once on the arrow ↕ to the right of Igneous_Rock. The arrow should now have horizontal bars at its top and bottom.

- The Min box should now be highlighted. Type 0 in the Min box.

- Click inside the Max box and type 2400.

- Click on the Set button.

- If the dialog box looks like the one on the next page, click on OK.

Graph Type: ● Time Series ○ Scatter ○ Bar ○ Sketchable
☐ Comparative ☐ Connect Dots ☐ Benchmark

Allowable	Selected
☐ Igneous_Rock	1. ☐ Igneous_Rock
☐ Magma	2. ☐ Sediment
☐ Metamorphic__Rock	3. ☐ Sedimentary_Rock
☐ Sediment	4. ☐ Metamorphic__Rock
☐ Sedimentary_Rock	5. ☐ Magma

☑ Show Numbers On Plots
☑ Show Grid ☐ Thick Lines
☐ Make 5 Grid Segments

Title: Untitled

Scale: Min: 0.000 Max: 2400.00 Set   Page: 1 △New ▽

Display: From: 0 To: 50   Cancel   OK

22. You should be back at the graph with the five rock types listed across the top.

Running and Interpreting the Model:

23. From the top menu bar, click and hold at the word Run, then slide down to Run on the menu and release. You should see curves forming on the graph.

> **Q4.** Sketch the graph on the axes provided, labeling all parts as described in the Level I Generic Graph Questions.
>
> **Q5.** Referring to your copy of the Graph Interpretation Guidelines, describe in full each curve.
>
> **Q6.** Explain the relationship between the Igneous Rock curve and the Magma curve.
>
> **Q7.** Explain the relationship between the Sediment curve and the Sedimentary Rock curve.
>
> **Q8.** According to the graph, the amount of rock in each category 50 million years from now will be different from the current amounts. Does this imply that the total amount of rock on Earth will change in the future? Justify your answer.

24. Close the graph by clicking on the close box in the upper corner of the graph window.

25. Go back to the tool bar and **click** on the numeric display icon: ⊏⊐ . Slide your mouse pointer to a clear spot and **click** again. **Double-click** on the numeric display strip to see a dialog box.

- **Double-click** on Igneous Rock in the **Allowable** box to move it to the **Selected** box.
- Be sure that the **Retain Ending Value** and **Show Name** boxes are checked.
- **Click** on **OK**.

26. Repeat step 25 four more times for **Sediment, Sedimentary Rock, Metamorphic Rock** and **Magma.**

27. Run the model again.

> **Q9.** Using the values in the numeric displays, find the sum of the masses of rock 50 million years from now.

> **Q10.** Does your answer to Q9 reflect the Law of Conservation of Mass? Please explain why or why not.

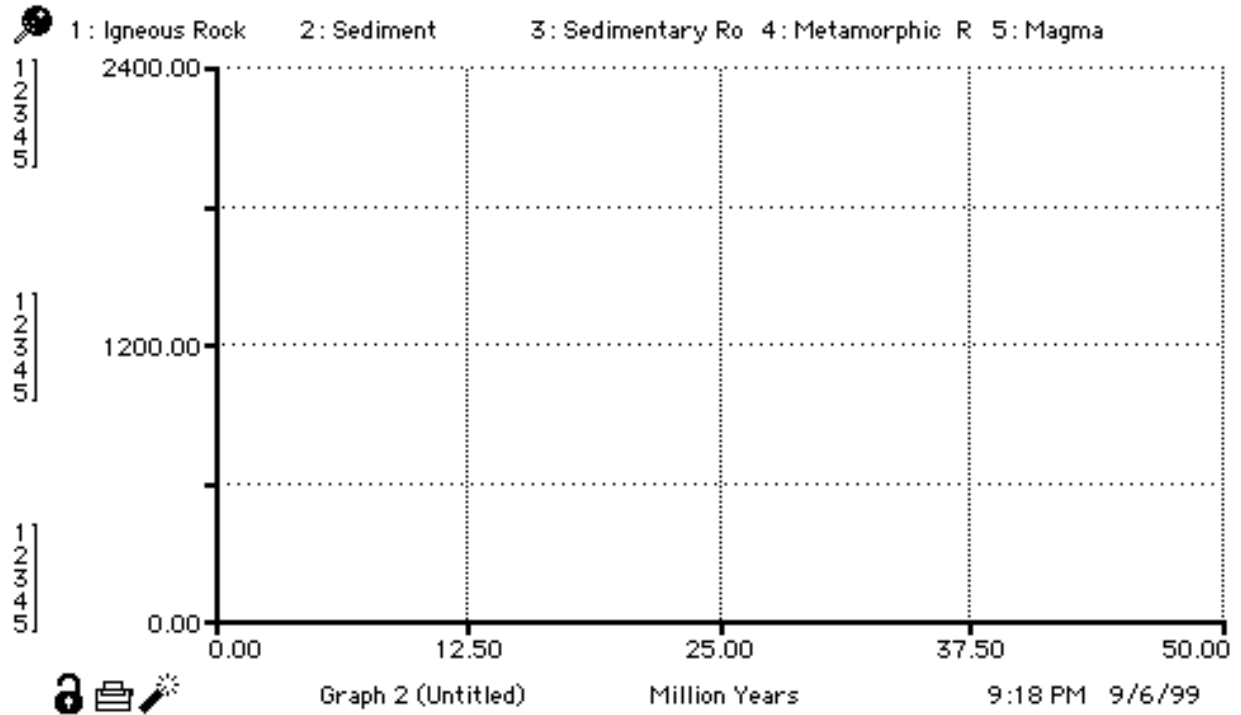28. Save your model as directed by your teacher.

Rock Cycle Part I
Student Answers

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Q2. The amount of rock in Earth's upper layers is known to be approximately $5974*10^{24}$ grams. It is estimated that sediments are 10% of the total rock, sedimentary rock are 21% of the total rock, metamorphic rock are 22% of the total rock and magma is 16% of the total rock. What percentage of the total rock is igneous rock?

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Q4. Sketch the graph on the axes provided, labeling all parts as described in the Level I Generic Graph Questions.

1 : Igneous Rock   2 : Sediment   3 : Sedimentary Ro 4 : Metamorphic R 5 : Magma

```
1]
2
3   2400.00 ┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄
4
5]

1]
2
3   1200.00 ┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄┄
4
5]

1]
2
3
4
5]    0.00
        0.00         12.50        25.00        37.50        50.00
```

Graph 2 (Untitled)   Million Years   9:18 PM 9/6/99

Q5. Referring to your copy of the Graph Interpretation Guidelines, describe in full each curve.

Q6. Explain the relationship between the Igneous Rock curve and the Magma curve.

Q7. Explain the relationship between the Sediment curve and the Sedimentary Rock curve.

Q8. According to the graph, the amount of rock in each category 50 million years from now will be different from the current amounts. Does this imply that the total amount of rock on Earth will change in the future? Justify your answer.

Q9. Using the values in the numeric displays, find the sum of the masses of rock 50 million years from now.

Q10. Does your answer to Q9 reflect the Law of Conservation of Mass? Please explain why or why not.