

Crystal Size Versus Cooling Time, and What a Dice Game Says About Rock

Learning target: I can graph and calculate from data to show how cooling time controls crystal size, and I can use a tally from a rock-cycle game to judge what the game models well and poorly.

Data and graphing

About 45 min

Individual

MS-ESS2-1 · practice

data analysis

independent practice

Name

Date

Period

Directions

Both datasets on this sheet are teaching datasets: the numbers were invented to be realistic, not measured in a real laboratory. Part A is about a classroom melt that grows crystals as it cools. Part B is a tally from a rock-cycle dice game played by a class. Graph with a ruler, show every calculation with units, and answer in complete sentences when a question asks you to explain.

You will need: This worksheet, Pencil, Ruler, Calculator (optional)

Part A: How does cooling time change crystal size?

A science class melted a safe, low-melting-point solid in a warm water bath and let samples cool for different lengths of time before the crystals stopped growing. Students measured the ten largest crystals in each sample under a hand lens and recorded the average length. Two trials were run for every cooling time. The melt is a stand-in for magma: it is not rock, but its crystals grow by the same rule.

Average crystal length after different cooling times (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

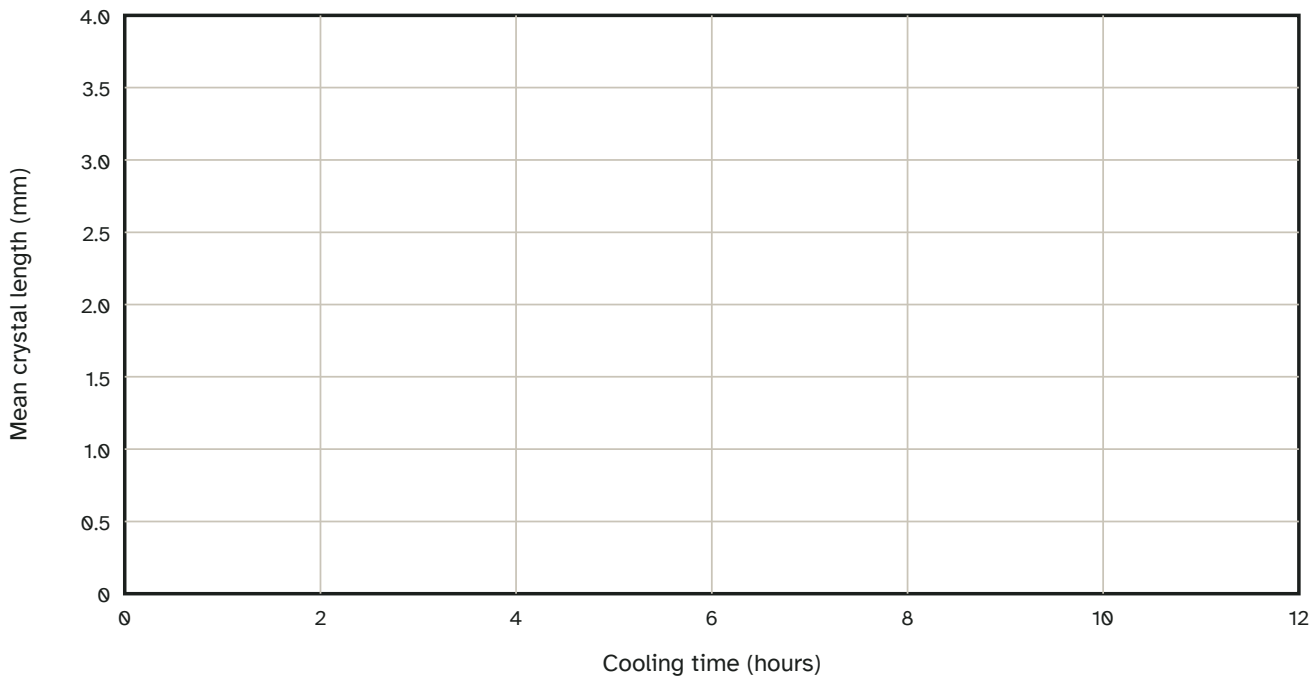
Cooling time (hours)	Trial 1: average crystal length (mm)	Trial 2: average crystal length (mm)
2	0.6	0.5
4	1.1	1.2
6	1.8	1.6
8	2.3	2.2
10	2.7	2.9
12	3.4	3.3

Simulated data for teaching. The pattern, not the exact numbers, is what matters.

1. For each cooling time, calculate the mean of Trial 1 and Trial 2. Show one calculation below the table.

Mean of the two trials (mm)
2 hours
4 hours
6 hours
8 hours
10 hours
12 hours

Mean crystal length versus cooling time



2. Calculate how fast the crystals grew, in millimeters per hour, using the means at 2 hours and 12 hours. Show your work.

3. Describe the shape of your graph. What does it tell you about the relationship between cooling time and crystal size?

4. Predict the mean crystal length after 24 hours if the pattern continues. Show the calculation.

5. The class melt is a model of magma. Give one way it is like magma and one way it is not. Say how the difference might affect how far you can trust the 24-hour prediction for real rock.

One common grain-size scale for igneous rocks (reference values; cut-offs vary a little between textbooks)

Texture name	Typical crystal size	Usual meaning
Glassy	No crystals large enough to see; mostly glass	Cooled almost instantly, as in an explosive eruption
Fine-grained	Crystals smaller than about 1 mm	Cooled quickly at or near the surface (extrusive)
Medium-grained	About 1 mm to 5 mm	Cooled at a moderate rate, often in a shallow intrusion
Coarse-grained	Larger than about 5 mm	Cooled slowly, deep underground (intrusive)

6. Using the reference scale and your means from q1, which cooling times in the class model would count as fine-grained, and which as medium-grained? Did any sample reach coarse-grained?

7. Using your growth rate from q2, calculate about how many hours the melt would need to reach the coarse-grained boundary of 5 mm. Show your work.

8. A geologist finds two igneous rocks: Rock 1 has crystals about 0.1 mm across; Rock 2 has crystals about 8 mm across. Using the pattern in your data and the reference scale, explain which rock cooled faster, where each probably cooled, and why 'faster' does not mean the cooling happened in a few hours for real rock.

Part B: What a rock-cycle dice game can and cannot show

A class of 24 students played a rock-cycle game. Each student started at a station (magma, igneous rock, sediment, sedimentary rock or metamorphic rock), rolled a die, and followed a rule card that said whether to stay or which station to move to. Every student rolled ten times, for 240 rolls in total. The tally below records what happened at each station.

Tally of 240 rolls in the rock-cycle game (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Station	Rolls made there	Stayed	Moved to magma	Moved to igneous	Moved to sediment	Moved to sedimentary	Moved to metamorphic
Magma	40	20	0	20	0	0	0
Igneous rock	48	24	4	0	5	0	15
Sediment	44	22	0	0	0	22	0
Sedimentary rock	48	24	4	0	3	0	17
Metamorphic rock	60	30	13	0	17	0	0

Simulated data for teaching. 'Stayed' means the roll told the student to remain at the same station for another turn.

9. Calculate the total number of 'stayed' rolls and what percentage of all 240 rolls that is. What idea about real rock do you think the game designer was trying to build in with so many 'stay' results?

10. Name the process that each of these moves stands for: igneous rock to sediment; sediment to sedimentary rock; sedimentary rock to metamorphic rock; metamorphic rock to magma.

11. Using only moves that appear in the tally, write the shortest route from sedimentary rock to igneous rock, and name the process on each step. What does the existence of this route show about the rock cycle?

12. There is no move from metamorphic rock straight to igneous rock, and none from igneous rock straight to sedimentary rock. Explain why the game is right to leave those out.

13. Metamorphic rock had the most rolls (60). A student concludes, 'So most of Earth's rock must be metamorphic.' Explain why the tally cannot support that conclusion, and describe one change to the game that would make it a better model of how long rock really spends at each stage.

Rates in two steps

A rate is a change divided by the time it took. Step 1: subtract to find the change (for q2, the mean at 12 hours minus the mean at 2 hours). Step 2: divide by the time between them ($12 - 2 = 10$ hours). The unit is millimeters per hour. For a percentage (q9), divide the part by the whole and multiply by 100: $\text{part} \div \text{whole} \times 100$. For q7, you are asking 'how many hours at this rate make 5 mm?', so divide 5 mm by the rate.

Redesign the rule cards

Rewrite the rule card for the sediment station so that it includes two routes the current game lacks: dissolved material crystallizing straight into rock (chemical sedimentation) and sediment being carried farther before it is deposited. Decide what die rolls trigger each route and write a one-sentence justification for each probability you chose. Then predict how your new card would change the 'stayed' percentage for the sediment station after 44 rolls, and explain whether that change makes the model more or less realistic.