What Is Reaction Rate?

TEACHER ANSWER KEY • SUGGESTED RESPONSES

Marking guidance Accept scientifically equivalent wording. Students should show calculations and units. The process rankings in Question 4 are illustrative: actual rates depend on conditions.

A | Understanding reaction rate

1. Definition

Reactants; products; change; time. Reaction rate is the change in the amount or concentration of a reactant or product per unit time.

2. Matching

Gas syringe → A (gas volume). Cloudy sulfur precipitate → C (time for a cross to disappear). Purple to colourless → D (colour change). Gas escaping from a flask on a balance → B (mass lost).

3. Rate units

A and C: cm^3/s and g/min. cm^3 alone is a volume; s alone is a time.

B | Fast and slow reactions

4. Rank

Paper burning = 1; effervescent tablet fizzing = 2; iron nail rusting = 3; silver jewellery tarnishing = 4. Relative order of rusting and tarnishing is condition-dependent; accept a reasoned alternative.

5. Observable sign

Examples: bubbles, temperature change, colour change, precipitate. A visible sign shows that a change occurs but gives no numerical rate unless a measurable quantity is tracked over time.

C | Calculations and graph interpretation

6. Average rates

a) $(22 - 0) \div 10 = 2.2\ cm^3/s$. b) $(38 - 22) \div 10 = 1.6\ cm^3/s$. c) $(64 - 58) \div 20 = 0.30\ cm^3/s$.

7. Graph

Plot (0,0), (10,22), (20,38), (30,50), (40,58), (50,62), (60,64); use labelled axes, units and a smooth concave-down curve. The curve steepens no further; it gradually levels off.

8. Fastest interval

0–10 s: 22 cm^3 formed, the greatest increase per 10-second interval (2.2 cm^3/s).

9. Why the curve flattens

Reactants are used up, so their concentration (or the exposed amount of a limiting solid) tends to decrease. Fewer successful collisions per unit time generally occur. The rate approaches zero when a limiting reactant is exhausted.

D | Factors affecting rate

Predictions for the factors table (assuming other relevant conditions remain constant):

Change	Rate	Why
Increase temperature	Faster	Particles move faster; more collisions have sufficient energy.
Increase acid concentration	Faster	More reactant particles per unit volume; more collisions.
Crush solid reactant	Faster	Increased surface area exposed to collisions.
Add catalyst	Faster	Alternative pathway with lower activation energy.
Dilute acid	Slower	Fewer acid particles per unit volume.

10. Catalyst question

A suitable catalyst increases rate by providing an alternative reaction pathway of lower activation energy; it is regenerated overall. It does not necessarily change the final amount of product when reactant amounts and the final extent of reaction are unchanged. For reversible reactions it does not change equilibrium position.

E | Designing a fair test

11. Investigation plan

Independent variable: calcium carbonate particle size (chips vs powder). Dependent variable: initial gas production rate, e.g. CO_2 volume collected per time (cm^3/s), or time to produce a specified volume. Controls: mass of $CaCO_3$ (2.0 g), acid concentration/volume, temperature, apparatus, mixing.

12. Same gas, different speeds

The powder has a larger total exposed surface area than large chips of the same mass. More frequent successful collisions occur at the solid–solution interface, so gas forms more rapidly. Both can make the same final gas volume if the same 2.0 g of calcium carbonate reacts completely and the acid is in sufficient excess.

F | Comparing data

13. Average rates over 0–20 s

X: (18 − 0) ÷ 20 = 0.90 cm^3/s. Y: (32 − 0) ÷ 20 = 1.60 cm^3/s.

14. Faster initial rate

Experiment Y. From 0–10 s, Y forms 20 cm^3 (2.0 cm^3/s) while X forms 10 cm^3 (1.0 cm^3/s).

G | Reasoning and application

15. Amount versus speed

Total gas produced tells us the extent of the reaction, not how quickly it occurred. For instance, 100 cm^3 in 200 s averages 0.50 cm^3/s, whereas 60 cm^3 in 20 s averages 3.0 cm^3/s. The smaller yield can have a faster rate.

16. Horizontal curve at 90 s

No further increase in measured gas volume: the gas-production rate is approximately zero. One possibility is that the limiting reactant has been consumed. Another is that the reaction has effectively stopped under the conditions. Other factors (including leakage or apparatus limits) should be considered if results are unexpected.

17. Concentration data

a) Increasing acid concentration decreases the time for Mg to disappear; reaction is faster. b) Average rate = 0.20 g ÷ 44 s = 0.00455 g/s (≈ 4.5×10^{-3} g/s). c) Only an overall/average rate can be calculated; it does not show changes in rate during the reaction and judging disappearance can be subjective.

18. Extension

P: 60 ÷ 30 = 2.0 cm^3/s. Q: 60 ÷ 50 = 1.2 cm^3/s. Ratio P : Q = 2.0 ÷ 1.2 ≈ 1.67. P is about 1.67 times as fast on average.

Exit ticket

Rate = how quickly reactants disappear or products form. Measurements: gas volume/time, mass loss/time, concentration change/time, or timed colour/opacity change. Factor: higher temperature, higher concentration, greater exposed surface area, appropriate catalyst (or pressure for gases).