Measuring Reaction Rates | Teacher Answer Key

Suggested answers. Accept scientifically equivalent wording and sensible alternative experimental precautions.

A | Choosing methods

1. Rate of reaction is the change in amount/concentration of reactant used or product formed per unit time.

2. Gas syringe: volume of gas collected. Balance with escaping gas: decrease in total mass as gas leaves. Colorimeter/light sensor: change in absorbance or transmission. Disappearing cross: time until a fixed cloudiness obscures a cross.

3. Gas syringe. It gives quantitative gas-volume readings at several times, so a rate/curve can be calculated; counting bubbles varies with bubble size and a single time gives less information.

4. Bubble sizes differ, bubbles can merge or be missed, and each bubble does not represent the same volume.

5. Regular intervals permit fair comparison of gas produced over known time periods and show changes in rate.

6. Independent variable: elapsed time (s). Dependent variable: gas volume collected (cm^3).

B | Gas-volume graph and rates

7. Plot (0,0), (10,16), (20,29), (30,38), (40,44), (50,47), (60,48); x-axis = time (s), y-axis = gas volume (cm^3). A smoothly flattening curve passes through/near the points.

8. $(29 - 0) \div (20 - 0) = 1.45\ cm^3/s$.

9. $(44 - 29) \div (40 - 20) = 15/20 = 0.75\ cm^3/s$.

10. $(48 - 0) \div 60 = 0.80\ cm^3/s$.

11. 0–10 s: 16 cm^3 in 10 s = 1.6 cm^3/s, greater than all later 10 s intervals (13, 9, 6, 3, 1 cm^3). Its curve is steepest initially.

12. The rate decreases over time as available reactants are consumed; at/near the plateau the limiting reactant has been nearly or completely used up, so little/no gas forms.

C | Comparing experiments

13. A: $18/15 = 1.20\ cm^3/s$. B: $25/15 \approx 1.67\ cm^3/s$.

14. Trial B is initially faster: $\approx 1.67\ cm^3/s$ versus $1.20\ cm^3/s$ in the first 15 s.

15. No. Both collect 36 cm^3 by 60 s, although B reaches 36 cm^3 earlier. Rate describes how quickly product is made, not necessarily its final amount.

D | Mass-loss method

16. 128.60 − 128.36 = 0.24 g.

17. $0.24/60 = 0.0040\ g/s$ ($4.0 \times 10^{-3}\ g/s$).

18. Escaping CO_2 leaves the open vessel, decreasing measured mass. In a fully sealed flask the total measured mass would remain approximately constant, so the method would not track rate by mass loss.

E | Reliability and repeats

19. Trial 4: 75 s is far from the other readings (39–41 s). Investigate the cause; do not automatically discard without checking.

20. Mean of consistent readings = (41 + 40 + 39 + 40)/4 = 40 s.

21. Average volume-production rate ≈ 30/40 = 0.75 cm^3/s, from the start until 30 cm^3 of gas is collected.

22. Any two justified errors + controls. Examples: gas escapes before bung fitted → fit promptly and use secure gas-tight connections; reaction starts before stopwatch → standardise timing/start and recording; parallax/poor syringe reading → read at eye level; differing acid temperatures → water bath/record temperature; differing marble sizes → uniform chips; human reaction time → data logger.

F | Sample fair-test design

23. Independent variable: acid concentration (e.g. several suitably diluted concentrations). Dependent variable: gas volume produced each 10 s, or initial average rate (cm^3/s) over the same interval. Controls: mass and surface area of marble chips; acid volume; temperature; apparatus and collection time. Method: add a fixed mass of chips to fixed volume of acid, seal gas-tight apparatus quickly, start timing, record gas volume at intervals until no further increase; repeat each concentration at least three times and compare means/graphs. Safety: wear goggles and handle dilute hydrochloric acid carefully.

Extension — suggested response

Gas syringes measure gas volume directly, whereas bubble counting assumes similar bubble sizes. A syringe can still leak, stick, have limited resolution, or miss gas released before its connection is secured.

Assessment notes

Students should distinguish average rate over an interval from instantaneous rate (the tangent gradient at one instant). For gas-volume and mass-loss graphs, use changes between the requested start and end measurements, not always the reading from 0 s. Accept positive rates for reactant disappearance/mass loss.

For trial 4 (75 s), discussing the anomaly as a potential error and excluding it for the explicitly requested mean is appropriate. In real investigations students should investigate anomalies and report justified treatment of data.