Factors Affecting Reaction Rate

TEACHER ANSWER KEY

A • Temperature

1. Collide; energy; orientation. A collision is effective when it has enough energy to overcome the activation barrier and the appropriate molecular orientation where required.

2. Increasing temperature usually increases reaction rate.

3. Particles have greater average kinetic energy. A larger fraction of collisions exceeds activation energy, and collisions are generally more frequent, so there are more successful collisions each second.

4. 40°C. At the higher temperature more collisions have sufficient energy to react (and particles generally move faster).

5. Lower temperature decreases reaction rates involved in spoilage because fewer particle collisions have enough energy to react. Refrigeration can also slow biological activity.

B • Concentration

6. Amount of dissolved solute per unit volume of solution (often expressed in mol/L).

7. More acid reactant particles are present per unit volume, so acid particles collide with the solid surface more frequently; this usually increases successful collisions per second.

8. For 0.50 mol/L: 12 cm^3 ÷ 20 s = 0.60 cm^3/s. For 2.00 mol/L: 38 cm^3 ÷ 20 s = 1.90 cm^3/s.

9. 2.00 mol/L (1.90 cm^3/s).

10. Any two: mass of marble, its size/surface area, temperature, acid volume, apparatus, measurement interval. Acid concentration is the independent variable.

C • Surface area

11. The total area of a solid available for contact and collisions with another reactant.

12. Fastest to slowest: C (powder), B (small chips), A (one chunk).

13. Breaking the same mass into smaller pieces exposes more surface to acid, so there are more collisions at the solid surface per second and usually a faster initial reaction.

14. Yes, if all $CaCO_3$ reacts and all other relevant conditions are the same, the number of moles of CO_2 formed is the same. Surface area changes speed, not the total reactant amount.

15. Accept a sketch showing one larger object versus many smaller objects, with visibly more total exposed boundary in the second diagram. Labels/explanation should identify surfaces accessible to acid.

D • Pressure and gaseous reactions

16. The number of reacting gas particles per unit volume increases.

17. At constant temperature and composition, compression generally increases gas number density and collision frequency, so the frequency of effective collisions and the reaction rate usually rise.

18. B (0.50 L). The same particles occupy less volume, so gas reactants collide more frequently.

19. No. Solids are not readily compressed, so the large gas-density mechanism does not generally apply in the same way to two solid lumps.

20. False. Raising total pressure by adding an inert gas at constant volume and temperature does not increase the reactant gases' partial pressures or concentrations, so it need not speed up their reaction. The effect depends on HOW pressure is changed.

E • Predicting reaction-rate changes

Change	Prediction	Collision-theory reason
Warm the reaction mixture	↑	More energetic collisions; more exceed Ea.
Dilute the acid	↓	Fewer acid particles per unit volume; fewer collisions.
Crush solid to powder	↑	More exposed surface for collisions.
Compress reacting gases at same T	↑	Higher reactant number density and collision frequency.
Expand reacting gases at same T	↓	Lower number density and fewer collisions.
Cool the reaction mixture	↓	Fewer collisions have sufficient energy.
Change only vessel colour	=	No relevant collision or energy change.

22. Answers vary. Example: Crushing the same mass of calcium carbonate increases its exposed surface area; more acid particles can collide with the surface per second, so the initial rate increases.

23. No. Both independent variables changed. Either or both may have caused the rate increase; change one variable at a time for a fair test.

F • Planning a fair experiment

24. Marble particle size / total exposed surface area.

25. Dependent variable: CO_2 gas volume collected over time (cm^3), using a gas syringe and stopwatch. Calculate average rate as Δgas volume ÷ Δtime in cm^3/s, preferably over the same initial interval.

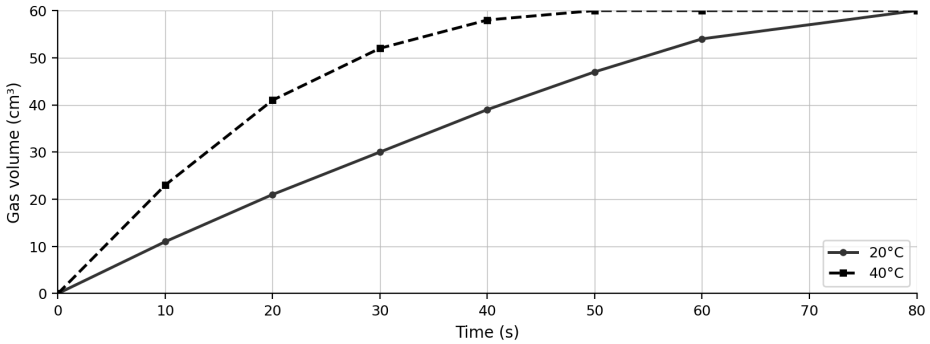
26. Any three: marble mass (5.0 g), acid volume (50 cm^3), acid concentration, acid temperature, same gas syringe/apparatus, mixing procedure and time intervals. Acid must remain in excess.

27. Use equal masses of a single chunk, small chips and powder. Maintain the same excess acid volume/concentration and temperature. Add marble, immediately seal flask and start timer, record CO_2 volume at equal intervals, repeat each size several times, compare early average rates. Use gas-tight connections and consistent starting technique.

28. Hydrochloric acid can irritate/burn skin and eyes: wear goggles and handle carefully, rinse splashes immediately. Also avoid inhaling fine powder and check that the gas syringe cannot overpressurise.

G • Experimental data and graph interpretation

29. Example of correctly plotted data (solid line: 20°C; dashed line: 40°C):



30. 20°C: (21 − 0) cm^3 ÷ 20 s = 1.05 cm^3/s. 40°C: (41 − 0) cm^3 ÷ 20 s = 2.05 cm^3/s.

31. 2.05 ÷ 1.05 = 1.95, so approximately twice as fast.

32. At 40°C reactants are used up faster, so gas production finishes earlier and the volume stops rising.

33. The same amount of limiting reactant is used in both, so the total CO_2 produced is unchanged if reaction goes to completion; temperature changes rate, not stoichiometric yield in this simplified setup.

34. An interval average can hide changes within the interval and does not give the instantaneous rate at a chosen time. Shorter intervals or a data logger can resolve the curve more accurately.