Name _____ Date _____ Period _____

ZornScience
zornscience.org

Kinetics and Collision Theory Virtual Lab

Chemistry and AP Chemistry

Open **activities.zornscience.org/kinetics-lab/** and follow each step. Change one condition at a time. Show your work with units.

Objective

Use a particle model to find how **temperature**, **concentration**, **activation energy** and a **catalyst** change the rate of the reaction A + B → C + D, and explain each change with collision theory.

NGSS alignment: HS-PS1-5. Apply scientific principles and evidence to explain the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Practices and concepts: Planning and carrying out investigations; Analyzing and interpreting data; Using mathematics; Constructing explanations; Cause and effect; Patterns.

AP alignment: 5.1 Reaction Rates; 5.2 Introduction to Rate Law; 5.3 Concentration Changes Over Time; 5.5 Collision Model; 5.6 Reaction Energy Profile; 5.11 Catalysis. Skills 5.C and 6.E.

Meet the simulation

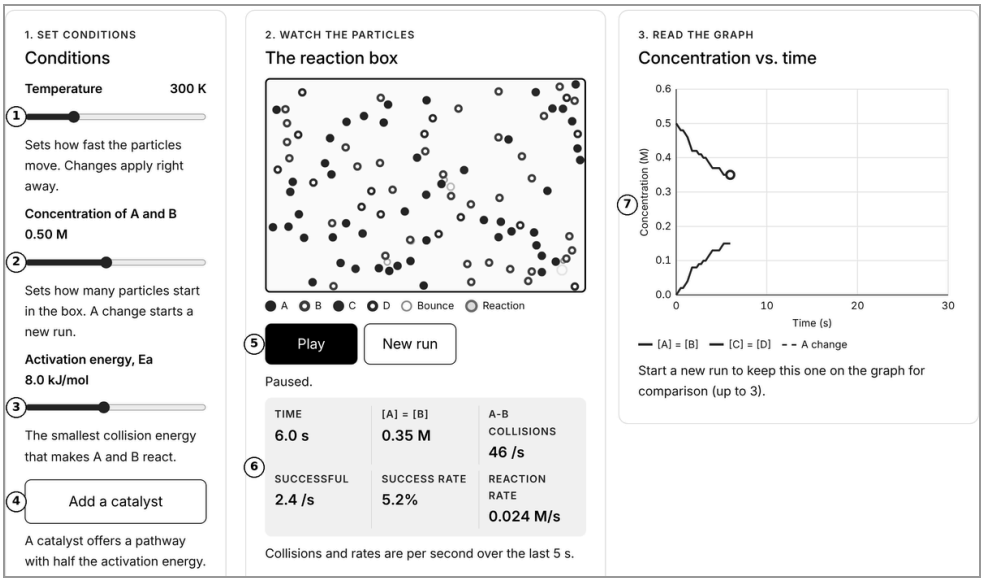


Figure 1. The Kinetics and Collision Theory Sandbox.

(1) Temperature (200 to 600 K): how fast the particles move.

(2) Concentration of A and B. Each particle is 0.01 M. A change starts a new run.

(3) Activation energy, E_a.

(4) Adds or removes a catalyst.

(5) Play / Pause and New run. The status line under them says when half of A has reacted.

(6) Readouts, per second over the last 5 s.

(7) Concentration vs. time graph. Earlier runs stay as gray dashed lines.

Pre-lab

1. Define **activation energy** and **successful collision**.

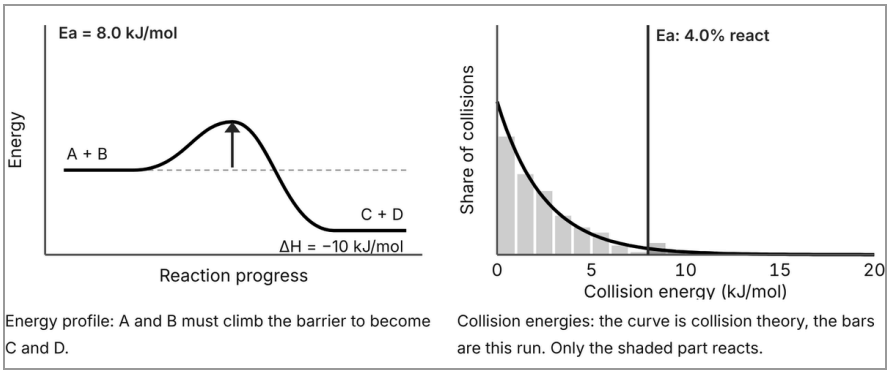
2. The average collision energy in the simulation is RT. Calculate RT at 300 K in kJ/mol (R = 8.314 J/(mol·K)). Is it larger or smaller than the default E_a of 8.0 kJ/mol? What does that tell you about most collisions?

CC BY-NC-SA 4.0 | zornscience.org

Part A. Temperature

1. Keep concentration at **0.50 M**, E_a at **8.0 kJ/mol**, and no catalyst. Set the temperature below, then select **New run** (and **Play** if it is paused).
2. Read the sentence under the energy charts (Figure 2). Record the **predicted** percent of collisions with at least E_a.
3. Let the run go until the status line says **Half of A had reacted at ... s**. Record that time. Select **Pause** and record the measured percent from "So far this run, ... of ... A-B collisions (...%) were successful."

Temperature (K)	Average collision energy RT (kJ/mol)	Predicted collisions with at least E_a (%)	Measured successful collisions (%)	Time for half of A to react (s)
300				
400				
500				
600				



Energy profile: A and B must climb the barrier to become C and D.

Collision energies: the curve is collision theory, the bars are this run. Only the shaded part reacts.

Figure 2. Energy profile (left) and collision energies (right) at 300 K. Only collisions to the right of the E_a line react.

3. In Figure 2, where are most collisions on the collision energy graph? Use the graph to explain why only 4.0% of collisions at 300 K are successful.

4. From 300 K to 600 K, by what factor did the predicted percent change? How did the time for half of A to react change? Explain with collision theory why a higher temperature makes the reaction faster.

5. (AP extension) The simulation predicts the fraction of collisions with at least E_a as $f = e^{-E_a/RT}$. Calculate f for E_a = 8.0 kJ/mol at 400 K and compare it with your table.

CC BY-NC-SA 4.0 | zornscience.org

Part B. Concentration

1. Set the temperature to **300 K** and E_a to **8.0 kJ/mol**, with no catalyst. Changing the concentration starts a new run by itself.
2. Select **Pause** when the Time readout is between 2 and 3 s. Record the **A-B collisions** readout. Then select Play and record the time for half of A to react.

Concentration of A and B (M)	Particles of A at the start	A-B collisions per second (at 2 to 3 s)	Predicted collisions with at least E_a (%)	Time for half of A to react (s)
0.25				
0.50				
1.00				

6. When you doubled the concentration from 0.50 M to 1.00 M, by about what factor did the collisions per second change? Did the predicted percent change? Explain why doubling both A and B has this effect.

7. (AP extension) The reaction is elementary: rate = k[A][B]. What is the overall order? Use your half times to show that the half-life of this reaction depends on the starting concentration, and explain why that fits the order.

Part C. Activation energy and a catalyst

1. Set **300 K** and **0.50 M**. Set each E_a below, then select **New run**. For the last row, set E_a to 8.0 kJ/mol and select **Add a catalyst** before New run.
2. Record the E_a the reaction actually uses (the catalyst line shows it), the predicted percent, and the time for half of A to react.

E_a slider (kJ/mol)	Catalyst?	E_a used (kJ/mol)	Predicted collisions with at least E_a (%)	Time for half of A to react (s)
4.0	No			
8.0	No			
10.0	No			
8.0	Yes			

CC BY-NC-SA 4.0 | zornscience.org

8. Compare the first and last rows of the Part C table. Why does the reaction with the catalyst behave like the reaction with E_a = 4.0 kJ/mol? Is the catalyst used up?

9. Sketch the energy profile for A + B → C + D (ΔH = −10 kJ/mol, E_a = 8.0 kJ/mol). Label the reactants, products, E_a and ΔH. Add a dashed path for the catalyzed reaction.

Analysis

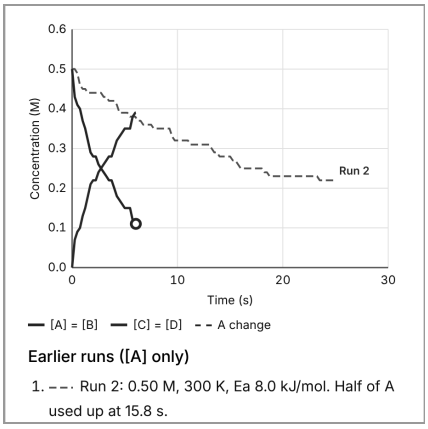


Figure 3. Run 2 (300 K, dashed) and run 3 (600 K, solid).

10. In Figure 3, the solid [A] and [C] curves cross. What is true at the crossing point, and at about what time does it happen? The list under the graph says run 2 (300 K) reached this point at 15.8 s. Which run was faster, and why?

11. Each [A] curve gets less steep as time goes on. Explain why with collisions.

12. Give two ways the simulation is simpler than a real reaction.

Conclusion

13. Write a claim that answers the objective. Support it with evidence from Parts A, B and C (specific numbers), then explain your reasoning with collision theory.

CC BY-NC-SA 4.0 | zornscience.org