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Rates of Reaction with the Valence card game

A 50-minute lesson on what makes a reaction faster or slower for Year 10 (Grades 10–12)

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valence-2b95b.web.app/get

Valence is a free chemistry card game: every card is an element, and students combine cards into real compounds to fight. In **Act 8**, the Catalyst Factory, every enemy carries a **rate gauge** that must be filled within a single turn. Catalysts and burning (combustion) reactions fill it twice as fast.

Learning goals

1. Describe the rate of a reaction as how much reactant is used up, or product made, in a given time.
2. Use collisions between particles to explain how temperature, concentration and surface area change the rate.
3. Say what a catalyst does, and that it is not used up.
4. Read a rate graph, work out an average rate, and say one way the game is simpler than real chemistry.

Before class

- Install Valence: free, no ads, no account, works offline.
- **Act 8 comes after Acts 1 to 7**, so few students reach it in one lesson. Parts A, B and D need no game; Part C prints the rule on page 3.
- Optional demo for the hook: two fizzy (effervescent) tablets, one whole and one crushed, and two beakers of water. Repeat with warm and cold water.
- Optional demo for Part B: a pinch of MnO_2 in 3% hydrogen peroxide. Wear eye protection.
- In Canada, gas volumes are usually written in mL ($1\ mL = 1\ cm^3$).
- Print pages 2 and 3 for each student. Page 4 is the answer key.

HOW THE RATE GAUGE WORKS IN ACT 8

- Each enemy has a rate gauge of 3 to 5 steps, to be filled **within one turn**. When the turn ends it cools back to 0.
- Each compound a student makes fills **1 step**. A single card thrown by itself also counts 1.
- **2 steps for a catalyst**: MnO_2, H_2O_2 + MnO_2 made in one play, any compound with platinum (such as the fuel cell), or a Pt card thrown by itself.
- **2 steps for a burning reaction**, which the game treats as raising the temperature: H_2, CH_4, CO, Na + H_2O, K + H_2O, thermite and a few others. One play never fills more than 2.
- When the gauge is full the enemy **overheats**: it skips a turn, loses its armour, takes 25% more damage and deals 30% less.
- At half health the boss, the Stalled Reactor, gains armour and attack, and its gauge restarts empty with 6 steps.



Sluggish Rust Snail, Stalled Enzyme Blob	**3 steps**
Hydrogen Peroxide Tank, Exhaust Smoke	**4 steps**
Cooled Kiln Giant, Permanganate Spider	**5 steps**
Stalled Reactor (boss, on the right)	**5, then 6**

Example. The Hydrogen Peroxide Tank needs 4 steps: H_2O_2 + MnO_2 in one play (2) and CH_4 (2) in the same turn. H_2O, NaCl and HCl make only 3.

Curriculum links

- **Australia**: Year 10 chemical reactions, AC9S10U07, which includes the factors that affect reaction rate
- **New Zealand**: Year 10 Science (Phase 4), factors that affect reaction rate. NCEA Level 2 Chemistry 91166 (chemical reactivity) builds on this
- **Ontario**: Grade 12 Chemistry SCH4U, D2.8 and D3.5 (factors that affect rate, collision theory). This sheet is a first look, without energy diagrams
- **British Columbia**: Chemistry 12, reaction rate, collision theory and catalysts (also met here as a first look)

Descriptions are our paraphrases. Not endorsed by any education authority.

Lesson plan

`5 min`	Hook. Drop one fizzy tablet whole into water and one crushed. "Which will finish first, and why?"
`12 min`	Part A: the collision idea, then five changes to sort into faster or slower.
`13 min`	Part B: read the hydrogen peroxide graph, work out two average rates, sketch the warmer curve.
`10 min`	Part C: rate gauges, on paper or in Act 8 for pairs who have reached it.
`10 min`	Part D, then the exit ticket. The answer key has an extension question (hydrogen and a spark) to ask aloud.

STUDENT WORKSHEET

Rates of Reaction

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Name _____ Class _____ Date _____

Rate of reaction
How much reactant is used up, or product made, in a given time. Fast: a match burning. Slow: iron rusting.

Collisions
Particles react only when they collide, and only if they collide with enough energy.

Faster reaction
More collisions every second, or a bigger share of collisions with enough energy.

A Faster or slower?

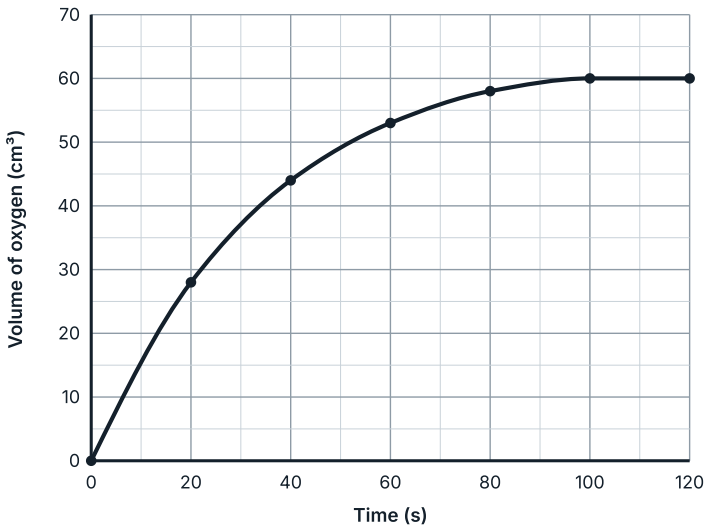


A1. For each change, write **faster** or **slower**, then explain it using collisions between particles.
Marble chips (calcium carbonate) fizz in dilute hydrochloric acid. The first three rows use this reaction.

CHANGE	FASTER / SLOWER	WHY? THINK ABOUT COLLISIONS
Warming the acid from 20 °C to 40 °C	*faster*	*Particles move faster: more and harder collisions*
Marble powder instead of chips (same mass)		
Adding water to the acid before the marble goes in		
Adding a catalyst		
Moving milk from the bench into the fridge		
Burning steel wool in pure oxygen instead of air		

B Reading a rate graph

Hydrogen peroxide breaks down slowly into water and oxygen: $2H_2O_2 \rightarrow 2H_2O + O_2$. A student added 0.5 g of manganese(IV) oxide, MnO_2, a black powder, as a catalyst and measured the oxygen every 20 seconds.



Time (s)	0	20	40	60	80	100	120
O_2 (cm^3)	0	28	44	53	58	60	60

B1. When is the reaction fastest? How does the graph show it?

B2. Average rate = volume of gas made in that time ÷ time taken. Work it out for the first 20 s, and for 60 s to 80 s.

B3. The student repeats the experiment with everything the same, but the hydrogen peroxide is 10 °C warmer. **Sketch the new curve on the graph** and label it W. Where does it finish, and why?

B4. Look back at the graph. Why does the reaction slow down, and at what time has it stopped?

C Rate gauges (Act 8)



The rule. Each Act 8 enemy has a rate gauge. Fill it **within one turn** and the enemy overheats and skips its next turn. When your turn ends, the gauge cools back to 0. Every compound you make fills **1 step**. It fills **2 steps** if it is a catalyst (MnO_2, H_2O_2 + MnO_2 made together, or anything with platinum, Pt) or a burning reaction that raises the temperature (H_2, CH_4, CO, Na + H_2O). One play never fills more than 2.

C1. Add up the steps for each turn. Is the gauge full, so that the enemy overheats?

ENEMY	GAUGE	PLAYED IN ONE TURN	STEPS	OVERHEATS?
Sluggish Rust Snail	3	**H_2O, MnO_2**	*1 + 2 = 3*	*yes*
Hydrogen Peroxide Tank	4	**H_2O_2 + MnO_2 (one play), CH_4**		
Exhaust Smoke	4	**NaCl, H_2O, CO_2**		
Stalled Enzyme Blob	3	**Pt (one card), HCl**		
Cooled Kiln Giant	5	**H_2, MnO_2, NaCl**		
Stalled Reactor (boss)	6	**fuel cell (H_2 + O_2 on Pt), CH_4, H_2O**		

C2. A student fills 3 of the Cooled Kiln Giant's 5 steps, ends the turn, and plays MnO_2 on the next turn. Is the gauge full now? What is the game saying about what "rate" means?

D Where the game simplifies

D1. In the game MnO_2 fills 2 steps against every enemy. In a real lab MnO_2 speeds up the breakdown of hydrogen peroxide, but it does nothing to make iron rust faster. What does this tell you about real catalysts?

D2. In the game, heat always helps. The Stalled Enzyme Blob is an enzyme, a protein catalyst from living things. How does an enzyme's rate change when it is warmed from 20 °C to 37 °C, then to 70 °C? (Hint: heat changes a protein's shape.)



EXIT TICKET

A car's catalytic converter is a honeycomb coated with platinum. Hot exhaust gases pass through it. Give one reason the harmful gases react quickly there, and say why the platinum does not run out.

Rates of Reaction

A Faster or slower?

CHANGE	RATE	WHY
Powder, not chips	faster	Larger surface area: more marble is exposed, so more collisions each second
Water added to acid	slower	Lower concentration: fewer acid particles in each cm^3, so fewer collisions
Catalyst added	faster	An easier route that needs less energy, so more collisions are successful
Milk into the fridge	slower	Lower temperature: slower particles, so fewer and gentler collisions
Pure oxygen, not air	faster	Higher concentration of oxygen (air is about 21%): more collisions

Also accept "more frequent collisions" and "more successful collisions". For the catalyst accept "lowers the activation energy" or "more of the collisions have enough energy". Do not accept "the catalyst gives the particles more energy": that is heating.

B Reading a rate graph

B1. At the start (the first 20 s). The curve is steepest there: the most gas is made in each second.

B2. First 20 s: 28 ÷ 20 = **1.4 cm^3/s**. From 60 s to 80 s: (58 − 53) ÷ 20 = 5 ÷ 20 = **0.25 cm^3/s**. Accept mL/s. If a student divides 58 by 80, show why the change in volume is needed.

B3. Curve W starts at 0, is steeper than the first curve, and goes flat earlier, at the **same 60 cm^3**. The amount of hydrogen peroxide is the same, so the same amount of oxygen is made; it is only made sooner. A curve that ends above 60 cm^3 shows the common mistake "faster means more product". Ignore the tiny expansion of the warmer gas. Worth asking: what mass of MnO_2 is left at the end? Still 0.5 g, because a catalyst is not used up.

B4. The hydrogen peroxide is being used up, so its concentration falls and there are fewer collisions each second. It has stopped by 100 s, where the curve goes flat at 60 cm^3: all the hydrogen peroxide has broken down. Accept "between 80 s and 100 s".

C Rate gauges (Act 8)

ENEMY	GAUGE	STEPS	OVERHEATS?
Hydrogen Peroxide Tank	4	2 + 2 = 4	yes. Accept 1 + 2 + 2 = 5 (counted as three plays): still yes
Exhaust Smoke	4	1 + 1 + 1 = 3	no: three ordinary compounds, one step short of 4
Stalled Enzyme Blob	3	2 + 1 = 3	yes: platinum by itself counts as a catalyst
Cooled Kiln Giant	5	2 + 2 + 1 = 5	yes
Stalled Reactor	6	2 + 2 + 1 = 5	no: one play is never more than 2

C2. No. The gauge cooled to 0 when the turn ended, so it now shows 2 of 5. Rate is how much happens **in a given time**, not how much happens in total: five steps spread over two turns is a slower rate than five steps in one. Accept "it has to be fast enough, not just enough".

D Where the game simplifies

D1. Real catalysts are specific: each one works for particular reactions only. MnO_2 suits hydrogen peroxide; platinum suits the exhaust gases in a car; each enzyme usually has one job. Accept "a catalyst does not work for every reaction".

D2. From 20 °C to 37 °C the rate rises, as for any reaction (more collisions, with more energy). Most human enzymes work fastest at about 37 to 40 °C. By 70 °C the rate falls to almost nothing: heat changes the shape of the protein (it is denatured), so it can no longer act as a catalyst. Accept "stops working"; if a student writes "it is killed", point out that an enzyme is not alive. In the game the Blob is weak to burning reactions for this reason.

Extension to ask aloud. In the game H_2 counts as burning the moment it is made, yet a real mixture of hydrogen and air can sit for years, then explode at one spark. Why? At room temperature hydrogen and oxygen molecules collide all the time, but almost never with enough energy to react. A spark gives a few molecules enough energy; their reaction releases heat, which does the same for their neighbours, so the reaction spreads in an instant. The minimum energy a collision needs is the activation energy. Making hydrogen is not burning it: the game skips the spark.

The hook. The crushed tablet finishes first: the same mass has a far larger surface area. Both make the same amount of gas.

Exit ticket. Any one of: platinum is a catalyst for these reactions; the honeycomb has a very large surface area, so more gas particles meet the platinum each second; the exhaust is hot, so collisions are more frequent and energetic. The platinum does not run out because a catalyst is not used up. The converter turns carbon monoxide and nitrogen oxides into carbon dioxide and nitrogen.