Year 12 Science: Rates of reaction and collision theory

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. 40 mL of hydrogen is made in the first 20 s of a reaction. What is the average rate?

2. A flask loses 0.66 g of CO_2 in 3.0 minutes. What is the average rate in g min^{-1}?

3. Which two factors increase the fraction of collisions that have enough energy to react?

4. Why does a graph of gas volume against time level off?

5. A catalyst lowers Ea from 80 kJ mol^{-1} to 50 kJ mol^{-1} for a reaction with $\Delta H = -30$ kJ mol^{-1}. What is ΔH with the catalyst?

Exam-style question: decomposing hydrogen peroxide

Hydrogen peroxide slowly breaks down: $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$. A student adds manganese dioxide powder, a catalyst, to 50 mL of the solution and records the oxygen collected every 20 s: 0, 24, 40, 50, 55, 57 and 57 mL at 0 to 120 s.

6. Calculate the average rate of oxygen production over the first 40 s.

7. Describe how the rate changes over the 120 s, and explain the change using collision theory.

8. Explain how manganese dioxide speeds up the reaction, and state what it does to the final volume of oxygen.

9. Discuss how running the same reaction at a higher temperature would change the graph of volume against time.

Fix the mistake

10. Correct this statement: "A catalyst gives the particles more energy."

11. Correct this statement: "A higher concentration makes the particles move faster."

12. Correct this statement: "Powdered marble makes more gas than chips."

13. Correct this statement: "The rate is the number of collisions."

Answer key (for parents and tutors)

1. 40 mL of hydrogen is made in the first 20 s of a reaction. What is the average rate?
   40 mL ÷ 20 s = 2.0 mL s^{-1}.
2. A flask loses 0.66 g of CO_2 in 3.0 minutes. What is the average rate in g min^{-1}?
   0.66 g ÷ 3.0 min = 0.22 g min^{-1}.
3. Which two factors increase the fraction of collisions that have enough energy to react?
   Temperature and a catalyst: heating gives more particles at least Ea, and a catalyst lowers Ea; concentration and surface area only make collisions more frequent.
4. Why does a graph of gas volume against time level off?
   A reactant has been used up, so no more product forms.
5. A catalyst lowers Ea from 80 kJ mol^{-1} to 50 kJ mol^{-1} for a reaction with ΔH = −30 kJ mol^{-1}. What is ΔH with the catalyst?
   ΔH is still −30 kJ mol^{-1}: a catalyst lowers Ea but does not change the energies of the reactants or products.
6. Calculate the average rate of oxygen production over the first 40 s.
   40 mL ÷ 40 s = 1.0 mL s^{-1} (Achieved).
7. Describe how the rate changes over the 120 s, and explain the change using collision theory.
   The rate is fastest at the start and falls until it stops by about 100 s. As H_2O_2 is used up its concentration falls, so its particles collide with the catalyst surface less often, giving fewer successful collisions per second; once all the H_2O_2 has decomposed no more oxygen forms (Merit for the link between concentration and collision frequency).
8. Explain how manganese dioxide speeds up the reaction, and state what it does to the final volume of oxygen.
   The catalyst provides another pathway with a lower activation energy, so a greater fraction of collisions have enough energy to react, giving more successful collisions per second. It is not used up and does not change the amount of H_2O_2, so the final volume stays 57 mL (Merit, Excellence with the final volume justified).
9. Discuss how running the same reaction at a higher temperature would change the graph of volume against time.
   The curve would be steeper at the start and level off sooner, at the same 57 mL. Particles move faster and collide more often, and a larger fraction of collisions have at least the activation energy, so there are more successful collisions per second; the amount of H_2O_2 is unchanged, so the final volume is too (Excellence).
10. Correct this statement: "A catalyst gives the particles more energy."
    A catalyst provides another pathway with a lower activation energy; the particles' energies are unchanged.
11. Correct this statement: "A higher concentration makes the particles move faster."
    Concentration only changes how many particles are in a volume, making collisions more frequent; only temperature changes their speed.
12. Correct this statement: "Powdered marble makes more gas than chips."
    With the same mass and the acid in excess, both make the same volume; the powder just makes it sooner.
13. Correct this statement: "The rate is the number of collisions."
    The rate depends on the number of successful collisions per second; most collisions lack the energy to react.