CHEMISTRY 12 REACTION RATES WORKSHEET

KEY

1. The following data were collected for the reaction: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$

in which zinc metal was reacted with 0.200 M $HCl_{(aq)}$:

| Time (seconds) | Mass Zn (grams) |
|---|---|
| 0.0 | 31.0 |
| 60.0 | 24.6 |
| 120.0 | 20.2 |
| 180.0 | 17.4 |

negative because mass is ↓

a) Calculate the average reaction rate, in g/s, from time 0 to 60 s. $\frac{24.6-31.0}{60} = -0.107$ g/s

b) Calculate the average reaction rate, in g/s, from time 120 to 180 s. $\frac{17.4-20.2}{60} = -0.0467$ g/s

c) Calculate the average reaction rate in g/s, from time 0 to 180 s. $\frac{17.4-31.0}{180} = -0.0756$ g/s

d) Explain why the average rate in (b) is less than in (a)

• rate ↓ over t as [HCl] ↓

2. In each of the following pairs of reactions, which would have the faster reaction rate?

a) $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$ **or** $Ag^+_{(aq)} + I^-_{(aq)} \rightarrow AgI_{(s)}$ (aq)

b) $Fe_{(s)} + 2H_2O_{(l)} \rightarrow Fe(OH)_{2(s)}$ **or** $CH_3COOH_{(aq)} + H_2O_{(l)} \rightarrow CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$

2 liq. > s/e

c) $Cu_{(s)} + S_{(s)} \rightarrow CuS_{(s)}$ **or** $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$

s & l

d) $C_{(s,\ powder)} + O_{2(g)} \rightarrow CO_{2(g)}$ **or** $C_{(s,\ chunk)} + O_{2(g)} \rightarrow CO_{2(g)}$

powder > S.A.

e) $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$ **or** $2H_2O_{(aq)} + 2H^+_{(aq)} \rightarrow 2H_3O^+_{(aq)} + O_{2(g)}$

$= H^+ + OH^- \rightarrow H_2O$ faster!

3. Which of the reactions in #2 are HOMOGENEOUS reactions?

a, b, e

4. One piece of magnesium is reacted with 3.00M hydrochloric acid at 25°C. Another piece of magnesium of equal size and shape is reacted with 1.00 M hydrochloric acid at 25°C. Predict which reaction occurs at a faster rate. Explain using collision theory. 3.00M - greater [HCl] to react w

5. A chunk of zinc is reacted with 3.00 M hydrochloric acid at 25°C. An equal mass of powdered zinc is reacted with 3.00 M hydrochloric acid at 25°C. Compare the reaction rates. powder-faster ↑S.A.

6. State two ways that the number of effective collisions between reactants can be increased.

↑T, P, SA, [ ], catalyst

7. The following reaction occurs at constant temperature and constant volume in a closed system:

$CaCO_{3(s)} + 2H^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + Ca^{2+}_{(aq)} + 2Cl^-_{(aq)}$

How could you experimentally measure the rate of this reaction?

closed system

→ gas is being produced

⇒ measure ↑ in P as rxn proceeds

1. Which of the following has the greatest reaction rate?

a. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$
b. $2H_2O_{2(l)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$
c. $2Al_{(s)} + 3CuCl_{2(aq)} \rightarrow 2AlCl_{3(aq)} + 3Cu_{(s)}$
d. $NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

aq.

2. Which of the following has the lowest rate of reaction?

a. $Pb_{(s)} + CuCl_{2(aq)} \rightarrow Cu_{(s)} + PbCl_{2(aq)}$
b. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$
c. $H_2SO_{4(aq)} + Ba(OH)_{2(aq)} \rightarrow 2H_2O_{(l)} + BSO_{4(s)}$
d. $Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \rightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$

} rest are aq.

3. Consider the following reaction: $N_2H_{4(l)} + 2H_2O_{2(l)} \rightarrow N_{2(g)} + 4H_2O_{(l)}$
In 5.0 seconds, 0.015 mol of $H_2O_2$ is consumed. The rate of production of $N_2$ is:

a. $1.5 \times 10^{-3}$ mol/s
b. $3.0 \times 10^{-3}$ mol/s
c. $6.0 \times 10^{-3}$ mol/s
d. $1.5 \times 10^{-2}$ mol/s

$N_2: \left(\frac{0.015 \text{ mol } H_2O_2}{5\text{ s}}\right)\left(\frac{1 N_2}{2H_2O_2}\right) = 0.0015$

$= 1.5 \times 10^{-3} \frac{\text{mol}}{\text{s}}$

4. At 25°C and considering only the nature of the reactants, which one of the following reactions most probably has the highest rate?

aq.

a. $Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_{3(s)}$
b. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$
c. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$
d. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

5. The following reaction occurs at constant temperature and constant volume in a closed system: $CaCO_{3(s)} + 2H^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + Ca^{2+}_{(aq)} + 2Cl^-_{(aq)}$

Changes in which one of the following would be useful in experimentally measuring the rate of this reaction?

a. The mass of the system
b. The pressure of the system
c. The concentration of water
d. The concentration of the $Cl^-_{(aq)}$

gas

6. Which one of the following reactions is most likely to have the highest reaction rate?
   a. $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$
   b. $Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$
   c. $C_2H_5OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}$
   d. $2MnO_4^-{}_{(aq)} + 16H^+_{(aq)} + 5C_2O_4^{2-}{}_{(aq)} \rightarrow 2Mn^{2+}_{(aq)} + 10CO_{2(g)} + 8H_2O_{(g)}$

*aqueous*

7. A 25.0 mL sample of hydrogen peroxide decomposes producing 50.0 mL of oxygen gas in 137 seconds. The rate of formation of $O_2$ in mL/min is
   a. 0.182 mL/min
   b. 0.365 mL/min
   c. 10.9 mL/min
   d. 21.9 mL/min

*$\left(\frac{50.0\,mL}{137\,s}\right)\left(\frac{60\,s}{min}\right) = 21.9\,\frac{mL}{min}$*

8. At 10°C, a small piece of Zn reacts with 2.0 M HCl to produce 15.0mL of $H_2$ gas in 25 seconds. What is the rate of this reaction?

*$Zn + 2HCl \rightarrow ZnCl_2 + H_2$*

   a. 0.060 mol Zn per second
   b. 0.4 C per second
   c. 0.60 mL $H_2$ per second
   d. 0.80 mol/L HCl per second

*$\frac{15.0\,mL\,H_2}{25\,s} = \frac{0.6\,mL\,H_2}{s}$*

9. A sample of magnesium having a mass of 0.360 g is dropped into dilute hydrochloric acid. At the end of 4.00 minutes, the magnesium is removed and it is found to have a mass of 0.240 g. The average rate at which the reaction took place was:

*$Mg + HCl \rightarrow MgCl_2 + H_2$*

   a. 0.003 mol/min
   b. 0.120 mol/min
   c. $2.06 \times 10^{-5}$ mol/sec
   d. $8.33 \times 10^{-5}$ mol/sec

*$\frac{\Delta m}{\Delta t} = \frac{.360 - 0.240\,g\ Mg}{4.00\,min} =$*

*$\left(\frac{0.12\,g\ Mg}{4.00\,min}\right)\left(\frac{mol}{24.3\,g}\right) = 0.00123\,\frac{mol}{min}$*

*$\left(\frac{1\,min}{60\,sec}\right) = 2.06 \times 10^{-5}\,\frac{mol}{s}$*

ANSWERS:

1. a) -0.11 g/s
   b) -0.047 g/s
   c) -0.076 g/s
   d) In (b) there are less reactants, including $HCl_{(aq)}$, which decreases the rate of reaction due to fewer collisions.

2. a) $Ag^{+}_{(aq)} + I^{-}_{(aq)} \rightarrow AgI_{(s)}$ Aqueous ions react faster than gases because there is less space between them and they actually attract one another rather than just having to collide randomly.
   b) $CH_3COOH_{(aq)} + H_2O_{(l)} \rightarrow CH_3COO^{-}_{(aq)} + H_3O^{+}_{(aq)}$ The two liquids form a fast-reacting homogenous mixture, whereas $Fe_{(s)}$ and water can only react at the surface of the iron.
   c) $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$ A liquid and sollid are expedted to react faster than two solid reactants.
   d) $C_{(s, powder)} + O_{2(g)} \rightarrow CO_{2(g)}$ A powder has greater surface area than a solid chunk.
   e) $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$ This is what we call a "formula equation" and we often write it for simplicity's sake. But in reality ionic substances dissolved in water are actually present as separate ions. So we can rewrite the equation as follows:

   $H^{+}_{(aq)} + Cl^{-}_{(aq)} + Na^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow H_2O_{(l)} + Na^{+}_{(aq)} + Cl^{-}$
   (the "complete ionic equation")

   As you can see, only the $H^{+}$ and the $OH^{-}$ are actually reacting.
   So you could write the reaction as:

   $H^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow H_2O_{(l)}$
   (the "net ionic equation")

   We are now looking at two oppositely charged aqueous ions which will react faster than a neutral aqueous molecule and an aqueous ion because the two opposite charges will attract one another and will not have to wait for a random collision.

3. Both reactions in (a) are homogeneous (the solid AgI is irrelevant since the REACTANTS are in the same phase in each case).

   The second reaction in (b) is homogeneous because $H_2O_{(l)}$ is liquid water and $CH_3COOH_{(aq)}$ refers to acetic acid dissolved in water.

   Both reactions in (e) are homogeneous.

   **Note:** in (c) the reaction between $Cu_{(s)}$ and $S_{(s)}$ is NOT homogeneous because Cu and S are different solid "phases" (have different properties depending on where one takes the sample).

4. In order for any reaction to occur, those particles must first collide. The reaction of zinc in 3.00 M HCl will have the faster rate because with the greater number of particles there is a higher chance of collisions occurring.

5. The reaction with the powdered zinc will be faster because there is significantly more surface area. By increasing the surface area, there are more sites available for collision resulting in a higher chance of collision and a faster reaction rate.

6. Collision theory is an aspect of the kinetic-molecular theory and is strongly connected with chemical kinetics. The theory is used to explain how different variables affect the rate of reaction. This theory is built on the idea that reactant particles must collide for a reaction to occur, but only a small percentage of the total collisions have appropriate energies and "orientations" to effectively cause the reactants to form into the products.

   Effective (successful) collisions can be increased by:

   - Increasing the total number of collisions (increase temperature, concentration, pressure, or surface area)
   - Increasing the energy of the collision (increase temperature of reaction)
   - Optimize collision geometry (use a catalyst)

7. As the reaction is carried out at constant temperature and constant volume in a closed system, the easiest property to measure to determine reaction rate would be the pressure change of the system. As $CO_2$ gas is being produced, the pressure of the system will be increasing as the reaction proceeds.

Multiple Choice Answers:

1. d
2. a
3. a
4. a
5. b
6. b
7. d
8. c
9. c