

## Extra Rates Questions

1. After increasing the concentration of the acid, the rate of hydrogen gas production increased from 0.20 moles/minute to 0.020 moles/s. (No typo; 0.020 moles/s is a greater rate than 0.20 moles/minute. Show why.). Find the ratio of  $t_2/t_1$ , where  $t_2$  is the new reaction time and  $t_1$  is the original reaction time for the lower concentration of acid.

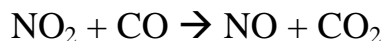
$$R_1 = 0.20 \text{ moles/min} = 0.20 \text{ moles}/(60 \text{ s}) = 0.00333 \dots \text{ moles/s}$$

$$R_1 t_1 = R_2 t_2$$

$$t_2/t_1 = R_1 / R_2 = 0.00333 \dots \text{ moles/s} / 0.020 \text{ moles/s} = 0.17 \text{ (2 SF like 0.20 and 0.020).}$$

Notice the answer has no unit and the answer means that at this faster rate, it will only take about 17% as much time to produce the same amount of hydrogen.

2. If the rate of  $\text{CO}_2$  formation,  $r$ , for the following reaction



$$\text{is given by } r = k[\text{NO}_2]^2$$

- a) what will happen to the rate if we reduce the concentration of CO gas to half of its original concentration?

No change. The reaction is zero order with respect to CO, meaning that CO does not appear in the rate expression

- b) Why?

CO is not involved in the slow, rate determining step.

- c) What will happen to the rate if  $[\text{NO}_2] = 0.125[\text{NO}_2]_{\text{original}}$  ?

$$R_2 / R_1 = [0.125 \cdot \text{NO}_{2\text{original}}]^2 / [\text{NO}_2]_{\text{original}} = 0.0156$$

$$R_2 = 0.0156 R_1.$$

- d) What units will  $k$  have if the rate is expressed in mol/L per second?

$$r = k[\text{NO}_2]^2$$

$$\frac{\text{mol}}{\text{Ls}} = k \left[ \frac{\text{mol}}{\text{L}} \right]^2$$

$$\frac{\text{mol}}{\text{Ls}} = k \left[ \frac{\text{mol}^2}{\text{L}^2} \right]$$

$$k = \frac{\text{mol}}{\text{Ls}} \div \left[ \frac{\text{mol}^2}{\text{L}^2} \right]$$

$$k = \frac{\text{mol}}{\text{Ls}} \times \left[ \frac{\text{L}^2}{\text{mol}^2} \right]$$

$$k = \frac{\text{L}}{\text{mol} * \text{s}}$$

3. Given:

Step 1:	$\text{HBr} + \text{O}_2 \rightarrow \text{HOBr}$	Slow
Step 2:	$\text{HOBr} + \text{HBr} \rightarrow 2 \text{HOBr}$	Fast
Step 3:	$\text{HOBr} + \text{HBr} \rightarrow \text{H}_2\text{O} + \text{Br}_2$	Fast
Step 4:	$\text{HOBr} + \text{HBr} \rightarrow \text{H}_2\text{O} + \text{Br}_2$	Fast
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Overall:	$4 \text{HBr} + \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + 2 \text{Br}_2$	

a) Write the expression for the rate of  $\text{Br}_2$  production.

Based on the slow step:

$$R = k[\text{HBr}][\text{O}_2]$$

- b) Will steam ( $\text{H}_2\text{O}$ ) be produced at the same rate? Why or why not?

Yes. The ratio of bromine to steam is 2:2 or 1:1

- c) What will happen to the rate if we double (2.0) the concentration of oxygen and change the concentration of HBr by a factor of 0.25?

$$\frac{r_2}{r_1} = \frac{k[0.25\text{Br}_2][2\text{O}_2]}{k[\text{Br}_2][\text{O}_2]} = 0.50$$

$$r_2 = 0.50 r_1$$