Unit 4, Lesson 02: Answers to Homework on Factors Affecting Reaction Rates

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1. The rate of a chemical reaction is fastest at the beginning of a reaction because the concentration of the reactants is higher. The higher the concentration of the reactants, the faster the reaction. As the reactants are consumed, the rate of the reaction decreases.

2. $$\text{Rate} = \frac{\text{final concentration} - \text{initial concentration}}{\Delta t}$$

   If the reactant is being used up, the final concentration will be less than the initial concentration so the rate will be a negative number. We ignore the negative sign for rate because, by convention, rates are reported as positive values.

3. A reactant will decrease at the same rate that a product increases if the reactant and product have the same molar coefficient in the balanced chemical equation.

   For example: $4\ CO_2\ (g) \rightarrow 4\ CO\ (g) + 2\ O_2\ (g)$

   Because carbon dioxide and carbon monoxide both have the same molar coefficient, the rate that CO_2 (g) is consumed is equal to the rate that CO (g) is produced.

4. For the reaction:

   $2\ HCrO_4^{1-}\ (aq) + 3\ HSO_3^{1-}\ (aq) + 5\ H^+\ (aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ SO_4^{2-}(aq) + 5\ H_2O\ (l)$

a) The rate of production of $SO_4^{2-}(aq)$ is 1.25 x 10-3 mol/L/s. Because $SO_4^{2-}(aq)$ and $HSO_3^{1-}(aq)$ both have the molar coefficient "3" in the balanced chemical equation, the rate that $HSO_3^{1-}(aq)$ is consumed is equal to the rate that $SO_4^{2-}(aq)$ is produced, which is at 1.25 x 10-3 mol/L/s.

b) $\underline{2\ HCrO_4^{1-}}\ (aq) + 3\ HSO_3^{1-}\ (aq) + 5\ H^+\ (aq) \rightarrow 2\ Cr^{3+}(aq) + \underline{3\ SO_4^{2-}(aq)} + 5\ H_2O\ (l)$

$$\frac{2}{x} = \frac{3}{1.25 \times 10\text{-}3\ \text{mol/L/s}}$$

$$3x = 2\ (1.25 \times 10\text{-}3\ \text{mol/L/s})$$

$$x = 0.000833\ \text{mol/L/s} \quad (3\ \text{sig digs})$$

Therefore, $HCrO_4^{1-}$ (aq) decreases at a rate of 0.000833 mol/L/s

5a) A pH meter can be used to monitor the rate of a reaction if there is a change in the acidity or basicity during a reaction. H+ or OH- ions must be produced or consumed in order to have a change in pH.

b) You can use a spectrophotometer to monitor the rate of a chemical reaction if there is a change in colour during the reaction.

c) You can use a conductivity meter to monitor the rate of a chemical reaction if there is a change in the number (concentration) of ions during the reaction.

d) You can use pressure change to follow reactions in which the number of moles of gaseous reactants or products changes during the reaction (ie. a gas is either formed or consumed).

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7a) This reaction can be monitored by measuring colour change of bromine. Recall from the organic chemistry unit that bromine is an orangy-brown colour. In the presence of a double bond, the bromine is added across the double bond and the orangy-brown colour disappears, so we can monitor the progress of the reaction by measuring the rate of the colour change with a spectrophotometer.

b) The decomposition of aqueous hydrogen peroxide can be monitored by measuring the rate of production of oxygen gas. The easiest way to do this would be to measure the increase in volume or pressure as oxygen is produced. Or, the reaction could be carried out on a balance and the change in mass as the gas escapes could be measured

c) The reaction of calcium carbonate and acid produced carbon dioxide gas, so this reaction could be monitored by measuring the change in the volume or pressure of gas. Alternatively, sulfuric acid is consumed by this reaction, so the change in pH could be used. Or, the reaction could be carried out on a balance and the change in mass as the gas escapes could be measured.

d) Recall from the organic unit that the permanganate ion is a deep purple colour, so the reaction could be monitored by measuring the rate of disappearance of MnO_4^{1-} using a spectrophotometer. The reaction also consumes acid (H+), so the reaction could be followed by measuring the change in pH.

e) For the reaction of nitrogen and hydrogen to produce ammonia gas, a total of four molecules of reactant gases combine to produce a total of two molecules of ammonia, so the pressure or volume of the system will decrease as the reaction proceeds. This could be used to follow the rate of the reaction.