

- (b) Double replacement; $2\text{CrBr}_3 + 3\text{K}_2\text{SO}_4 \rightarrow \text{Cr}_2(\text{SO}_4)_3 + 6\text{KBr}$
 (c) $\text{AuI}_3 \rightarrow \text{Au} + \text{I}_2$

■ USING THE FEATURE

Science Watch: Stainless Steel, p. 270

Rust is oxidized iron. It has no strength and flakes off. But this is not true of all oxides. Aluminum, for example, is much more reactive than iron. Yet, it forms a transparent protective layer of aluminum oxide at its surface. This prevents further corrosion of the aluminum under many conditions. Now consider chromium—its oxide is as good as aluminum at protecting its surface. In addition, it has a higher lustre and makes a better finish than aluminum. So why not just chrome-plate everything? The answer is that it works well until the metal gets scratched. Then, the iron below is exposed and will corrode.

That is why stainless steel is such an excellent product. The chromium is melted right into the iron. Every part of the alloy has both iron and chromium present. You cannot tell by looking whether it is chromium or iron you see on the surface. What happens with steel is that, at the surface, the iron corrodes away, leaving an invisible layer of chromium oxide that protects the object from corrosion. When this metal is worn away, such as when a knife is sharpened, more iron and chromium atoms are exposed. Again, the iron corrodes away and a new layer of pure chromium oxide forms. In this way, steel is said to “heal” itself.

Science Watch Answers

1. Iron contains only iron atoms; steel contains carbon as well as iron; and stainless steel contains other elements, such as chromium. Iron is soft, steel is hard, and stainless steel is hard and resistant to corrosion.
2. (a) Iron oxide
(b) Rust has no strength of its own and flakes off, exposing new iron to the possibility of corrosion.
3. Chromium atoms react with oxygen to form chromium oxide, which forms a thin, invisible layer on the surface of steel. This layer protects steel from corroding further.

■ SECTION 6.1 ASSESSMENT, p. 271

Check Your Understanding Answers

Checking Concepts

1. (a) Neutralization
(b) Synthesis
(c) Double replacement
(d) Synthesis
(e) Combustion
(f) Double replacement
(g) Single replacement
(h) Neutralization
(i) Decomposition
(j) Single replacement

Understanding Key Ideas

2. In combustion, the compound is an organic compound containing carbon, hydrogen, and possibly oxygen. Also, the element in a combustion reaction is oxygen. In a single replacement reaction, the compound is inorganic. There is a slight overlap between these two classifications, in that a rapid reaction of anything with oxygen can be called combustion. (For the purpose of this course, combustion is restricted to an organic compound reacting with oxygen.)
3. The reaction of iron metal with oxygen is classified as synthesis in this course. However, if the reaction happens quickly, it could be considered combustion.
4. (a) Synthesis

$$4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$$

 (b) Double replacement

$$\text{Na}_2\text{SO}_4 + \text{CaCl}_2 \rightarrow 2\text{NaCl} + \text{CaSO}_4$$

 (c) Combustion

$$\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$$

 (d) Neutralization

$$\text{H}_2\text{SO}_4 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}$$

 (e) Decomposition

$$2\text{AlCl}_3 \rightarrow 2\text{Al} + 3\text{Cl}_2$$

 (f) Single replacement

$$3\text{Cd} + 2\text{Au}(\text{NO}_3)_3 \rightarrow 3\text{Cd}(\text{NO}_3)_2 + 2\text{Au}$$

 (g) Double replacement

$$\text{Sr}(\text{OH})_2 + \text{PbBr}_2 \rightarrow \text{SrBr}_2 + \text{Pb}(\text{OH})_2$$

 (h) Combustion

$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$$

 (i) Synthesis

$$2\text{N}_2 + 3\text{O}_2 \rightarrow 2\text{N}_2\text{O}_3$$

 (j) Single replacement

$$2\text{HNO}_3 + \text{Zn} \rightarrow \text{Zn}(\text{NO}_3)_2 + \text{H}_2$$
5. (a) Synthesis

$$6\text{Na} + \text{N}_2 \rightarrow 2\text{Na}_3\text{N}$$

- (b) Decomposition
 $2\text{AlF}_3 \rightarrow 2\text{Al} + 3\text{F}_2$
- (c) Single replacement
 $3\text{CuSO}_4 + 2\text{Al} \rightarrow \text{Al}_2(\text{SO}_4)_3 + 3\text{Cu}$
- (d) Combustion
 $\text{H}_2\text{SO}_4 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}$
- (e) Combustion
 $2\text{C}_4\text{H}_{10} + 13\text{O}_2 \rightarrow 8\text{CO}_2 + 10\text{H}_2\text{O}$
- (f) Double replacement
 $\text{AgNO}_3 + \text{NaBr} \rightarrow \text{NaNO}_3 + \text{AgBr}$
- (g) Single replacement
 $2\text{CsI} + \text{Cl}_2 \rightarrow 2\text{CsCl} + \text{I}_2$
- (h) Neutralization
 $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
- (i) Double replacement
 $\text{K}_2\text{Cr}_2\text{O}_7 + 2\text{AgNO}_3 \rightarrow \text{Ag}_2\text{Cr}_2\text{O}_7 + 2\text{KNO}_3$
- (j) Combustion
 $\text{C}_5\text{H}_{10}\text{O}_5 + 5\text{O}_2 \rightarrow 5\text{CO}_2 + 5\text{H}_2\text{O}$
6. $2\text{Fe} + 3\text{Cl}_2 \rightarrow 2\text{FeCl}_3$

Pause and Reflect Answer

It is not useful to look for the presence of water in the products to help classify the reaction as water can be formed in synthesis, neutralization, and combustion reactions.

Other Assessment Opportunities

- Assessment Checklist 1, Making Observations and Inferences
- Assessment Checklist 4, Laboratory Report
- Assessment Checklist 25, Safety Checklist
- Process Skills Rubric 7, Predicting
- Process Skills Rubric 8, Interpreting Data
- Assessment Rubric 5, Conduct an Investigation Rubric
- Assessment Rubric 11, Communication Rubric
- Assessment Rubric 12, Using Tools, Equipment, and Materials Rubric

6.2 FACTORS AFFECTING THE RATE OF CHEMICAL REACTIONS

BACKGROUND INFORMATION

This section is different from the other chemistry topics studied in this course because, unlike chemical equations, which focus on the reactants and then on the products (before and after the reaction), a study of rates focusses on what is going on during the reaction. In a sense, the part of a chemical equation that

has to do with rates is the arrow in the middle.

Although the rate of any reaction depends on the particular nature of the reactants, there are certain aspects that are predictable regardless of their identity. For example, increasing temperature always speeds up reaction rates. This is because an increase in temperature at the atomic level corresponds to particles moving faster, on average. This results in more collisions between particles occurring at a higher energy than before heating. Increasing the concentration of a gas or an aqueous substance increases the number of collisions as well, so increasing concentration always increases the rate of a reaction as well. Similarly, for those reactions that take place at a surface, such as when a piece of solid zinc sits in a solution of hydrochloric acid, the greater the surface contact, the greater the chance of collisions between reactant particles, so increasing surface area always increases rate. Not all systems have a surface. For example, methane and oxygen gases mix so that surface area is not an issue in this case.

Lastly, catalysts always help to speed up a reaction. They do not create more collisions, but they make the collisions that do happen produce product more frequently than in the absence of a catalyst. They do this by improving the geometry of the collisions. For example, in the case of an enzyme, or biological catalyst, the enzyme often literally attaches to both reactants and then changes its own shape to cause the reactant molecules to approach each other perfectly lined up. Better geometry means the energy barrier to the reaction is lower than it otherwise would be, so more collisions have sufficient energy to produce products than without the catalyst. After the reaction, an enzyme simply releases the product and then is free to do the same thing with more reactants. In this way, the catalyst is not used up by the reaction. There are other ways in which catalysts work, but they all speed up reactions by providing a way to lower the energy barrier. At the end of the reaction, catalysts are present unchanged from their initial state.

COMMON MISCONCEPTIONS

- Students sometimes fail to make the connection that a high reaction rate is connected to a short reaction time and, conversely, a low reaction rate means a long reaction time. Avoid mixing terms, such as “a fast time” or a “long rate.”
- It is not possible to increase the concentration of a solid in any practical sense. This is because solids do not compress or expand significantly.