WKS **Name** _____
Factors Affecting Reaction Rates **Period** _____

1. A chemist heated a sample of steel wool in a burner flame exposed to oxygen in the air. He also heated a sample of steel wool in a container of nearly 100% oxygen. The steel-wool sample in the container reacted faster than the other sample.
   a) Explain why.

   b) What would the chemist have observed if he had used a block of steel instead of steel wool? Explain your answer.

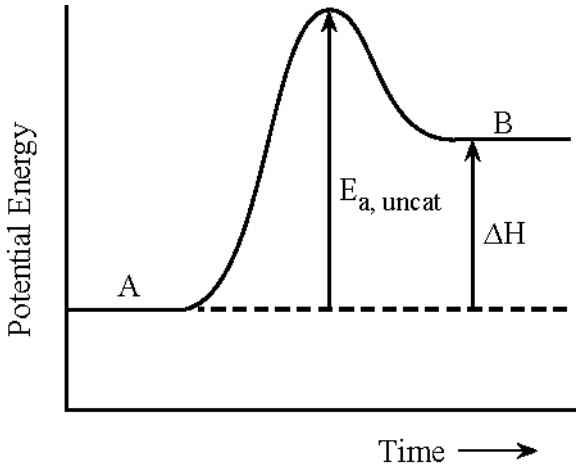
   c) How would the reaction have differed if the steel wool were not heated?

2. Explain the following statements using collision theory:
   a) Gaseous reactants react faster under high pressure than under low pressure.

   b) Ionic compounds react faster when in solution than as solids.

   c) A class of heterogeneous catalysts called surface catalysts work best as a fine powder.

3. At the right is the energy diagram for the reaction A→B when it occurs without a catalyst. On the same diagram, draw what the energy curve would look like if the reaction was done with a catalyst.
4. Is it correct to say that a catalyst affects the speed of a reaction but does not take part in the reaction? _____ Explain your answer.



5. On the back of this sheet is a short article concerning the Oklahoma City Bombing that occurred on April 19, 1995. Please read the article and then answer the questions below and on the next page.
   a) What are the two main components in the ANFO explosive used in the bombing?

b) Which component of ANFO by itself releases the most heat per gram when it reacts?
To support your answer, state ΔH values for each component alone.

c) Which component of ANFO by itself reacts the fastest?

The Oklahoma City Bombing

On April 19, 1995, a bomb exploded next to the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma. This explosion produced a crater about 20 feet wide and 8 feet deep, virtually destroyed the Murrah Building (Figure 5.19), and killed 168 individuals. As of this writing, authorities are still investigating this deadly attack.

Investigators have determined that the bomb was constructed from inexpensive, readily available materials. Authorities estimate that as much as 4000 lb of explosives were placed in a rented truck and detonated. The main component of the explosive material was ammonium nitrate, NH_4NO_3, a salt that is commonly used as a fertilizer. Fuel oil, used in home furnaces for heating, was added to the ammonium nitrate, producing an explosive mixture called ANFO (ammonium nitrate-fuel oil), which is used in commercial blasting. Ironically, although ANFO is strictly regulated by law, its components, ammonium nitrate and fuel oil, are not; both substances have important and widespread uses that would be severely hindered by stringent regulation.

How can two common and widely used substances lead to such devastation? We can answer this question in part by examining the enthalpies of reactions involving the components of ANFO. Ammonium nitrate is a stable compound at room temperature. When heated to 250°C, however, it decomposes to nitrous oxide and water gases with the evolution of heat (expressed here as kJ per *gram* of reactant):

$$NH_4NO_3(s) \longrightarrow N_2O(g) + 2H_2O(g) \qquad \Delta H° = -0.45 \text{ kJ/g } NH_4NO_3$$

At slightly higher temperatures, around 300°C, the decomposition of NH_4NO_3 produces N_2, O_2, and H_2O and is much more exothermic:

$$NH_4NO_3(s) \longrightarrow N_2(g) + 2H_2O(g) + \tfrac{1}{2}O_2(g) \qquad \Delta H° = -1.5 \text{ kJ/g } NH_4NO_3$$

These decompositions of NH_4NO_3 are very rapid, and the extremely fast production of large amounts of gas and heat lead to an explosion.

Fuel oil, like other hydrocarbons, has a very high heat content; the combustion of hydrocarbons to form $CO_2(g)$ and $H_2O(g)$ typically releases 40–50 kJ of heat per gram of hydrocarbon, far more heat per gram than that produced by NH_4NO_3. Fuel oil itself is a fairly viscous liquid that tends to burn slowly rather than explode. When mixed with ammonium nitrate in the right proportions, however, fuel oil forms an explosive mixture and produces nearly three times as much heat per gram as does ammonium nitrate alone. Thus, ANFO combines the explosive nature of ammonium nitrate with the high heat content of fuel oil to produce a mixture of terrifying destructive power. Scientists are developing additives to ammonium nitrate that will make it less subject to explosions, while retaining its properties as a fertilizer.

In Chapter 8 we will discuss other explosive compounds that are organic molecules rather than salts. These compounds share something in common with NH_4NO_3, in that most of them contain nitro (NO_2) or nitrate (NO_3) groups. When bonded to carbon, these groups store large amounts of energy that can be released quickly in an explosion.

The tragedy at Oklahoma City is a reminder that we must consider *all* the properties of a substance in trying to understand its behavior. Ammonium nitrate, as a fertilizer, increases crop production, and fuel oil, as a home heating fuel, keeps us warm during the winter. Both substances therefore allow us to use chemistry to maintain our existence. It seems terribly paradoxical that a combination of the two could lead to the terrible destruction witnessed in Oklahoma City.

▼ **FIGURE 5.19** The aftermath of the April 1995 bombing of the Alfred P. Murrah Federal Building in Oklahoma City.