Hot Packs

Cartoon of Experiment Setup

Time Required:

- ☒ 0-30 minutes
- ☐ 30-60 minutes
- ☐ 60-120 minutes (1-2 hours)
- ☐ 120-180 minutes (2-3 hours)
- ☐ 180-240 minutes (3-4 hours)
- ☐ > 4 hours

Materials Needed:

- One package of hand warmers

Optional Materials:

Gloves, if trying the experiment outside and the outside temperature is less than 50 °F (10 °C)

Concepts:

- ☒ Thermodynamics
- ☒ Combustion
- ☒ Redox reactions

Parental Supervision:

- ☒ Recommended for children under 5
- ☒ Recommended for children under 12
- ☐ Highly recommended for children under 12
- ☐ Recommended for children under 18
- ☐ Adults Only

Age Recommendation:

- ☒ 0-3
- ☒ 3-8
- ☒ 8-12
- ☒ 12-18
- ☒ Above 18

Location of Experiment:

- ☒ Indoors
- ☒ Outdoors

Is Heat Needed?

- ☐ Microwave
- ☐ Stove Top/Oven
- ☐ Refrigerator
- ☐ Freezer

Safety:

Chemical hand warmers can obtain temperatures greater than 100 °F (38 °C), and can feel very hot if left exposed to direct skin contact for extended periods of time.

Please check the expiration date of the hand warmer, as it will often not work if the expiration date has passed.

Procedure:

1. Open the hand warmer package and rub together in your hands to activate.
2. The hand warmer should start to feel warm after about 60 seconds and will start to feel hot after 15-30 minutes.
3. Depending on the size of the hand warmer, the heat given off rapidly diminishes after 1–2 hours, but can be felt for up to 12 hours after it has been activated.

Optional:

1. Examine the observed temperature of the hand warmer inside a glove and outside of a glove. You will note that the hand warmer will feel warmer inside of a glove.

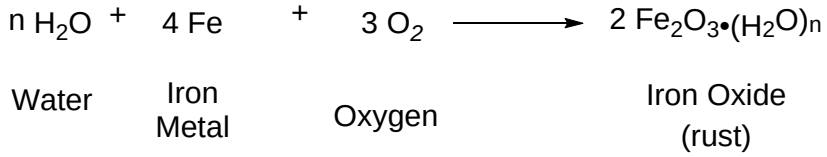
Clean Up:

Upon completion of the experiment, the hand warmer can be placed in the trash can and can be disposed of in the same manner as conventional household waste. No special waste handling is needed.

What is going on?

Each hot pack contains: salt (1-5 %), water (30-40 %), activated charcoal (5-10 %), iron powder (50-60 %), and vermiculite (hydrated magnesium aluminum silicate, $(Mg^{2+},Fe^{2+},Fe^{3+})_3[(Al,Si)_4O_{10}](OH)_2{\cdot}4H_2O$) (5-10 %). The contents of the hot pack are sealed in a porous pouch because the heating process starts when the oxygen in the air enters into the hot pack and starts to react with the iron powder. As the iron powder reacts with the water in the pouch and the oxygen in the air, it produces iron oxide, or rust. Rust consists of hydrated iron(III) oxides $Fe_2O_3{\cdot}(H_2O)_n$ and iron(III) oxide-hydroxide ($FeO(OH)$, $Fe(OH)_3$).

Rust is generated from the oxidation of iron powder. The oxidation of iron powder results in iron atoms losing electrons resulting in the iron +3 ion. The electrons generated from the oxidation of iron are transferred to the oxygen molecules to gerenerate oxide ions (O^{2-}). This transfer of electrons is called a reduction, where the oxygen atoms are reduced. The combination of the Fe^{3+} ions with the O^{2-} ions generates rust. The oxidation of iron releases heat (exothermic reaction), which is what is felt from the hand warmer. The presence of sodium chloride helps speed up the oxidation and heat generating process. The small pieces of activated charcoal stores the water needed for the reaction, and also helps spread the heat. Vermiculite serves as an insulator, regulating the heat coming from the reaction, to keep the hand warmer from getting too hot and burning your hand. The hand warmer will generate heat for as long as the oxidization reaction occurs, usually between 4 and 12 hours. Tempertures as high as 100 °F (38 °C) are common.



Questions and Discussion

1. In the chemical hot pack experiment, the heat generated comes from the oxidation of iron. Why can these hot packs not be reused?

   Answer: The oxidation reaction of iron powder to Fe^{3+} ions results in an exothermic reaction that is irreversible. An irreversible reaction only occurs in one direction. In this experiment, it is very favorable to generate rust from iron powder, but it is very difficult to regenerate iron metal from rust. The fact that this reaction is highly irreversible is the main reason why many rust cars are seen, as once iron starts to rust, it cannot be easily reversed/stopped.

2. If iron reacts with oxygen, why is water needed to promote the oxidation reaction?

   Answer: As can be seen around you, not all iron exists as rust. If iron is placed in an oxygen atmosphere, it will not rust. If iron is placed in water, it will not rust unless oxygen is present. The water molecules are needed to aid in the oxidation of iron and to generate a hydrated iron oxide, which means that the water molecules are bonded to the iron centers in addition to the oxygen atoms.

3. What is a catalyst and how does sodium chloride act as a catalyst in the oxidation of iron?

   Answer: A catalyst is a compound that speeds up a reaction and it is not consumed in the reaction. Sodium chloride acts as a catalyst for the oxidation of iron by acts as an electrolyte (any substance containing free ions that allows the substance to conduct electricity) allowing for iron to lose electrons more easily, which speeds up the rusting process.