Reaction of Potassium Permanganate and Glycerin.

Potassium Permanganate ($KMnO_4$) is a dark purple solid that is used as a very powerful oxidizing agent. An oxidizing agent is a substance which, in its traditional sense, adds molecular oxygen to a compound (this definition has been upgraded to mean an oxidizing agent removes an electron from a compound, however, this is not necessary to understand this demo).

The molecular addition of oxygen (O_2) is often a very exothermic process. This can be understood by simply striking a match and placing it in an empty jelly jar.

$$\text{MATCH} + O_2 \rightarrow \text{Fire} + \text{Ash} + CO_2 + H_2O$$

Matches are made of wood, which is composed of carbon and hydrogen atoms. By starting the reaction, the match will consume oxygen to form carbon dioxide and water.

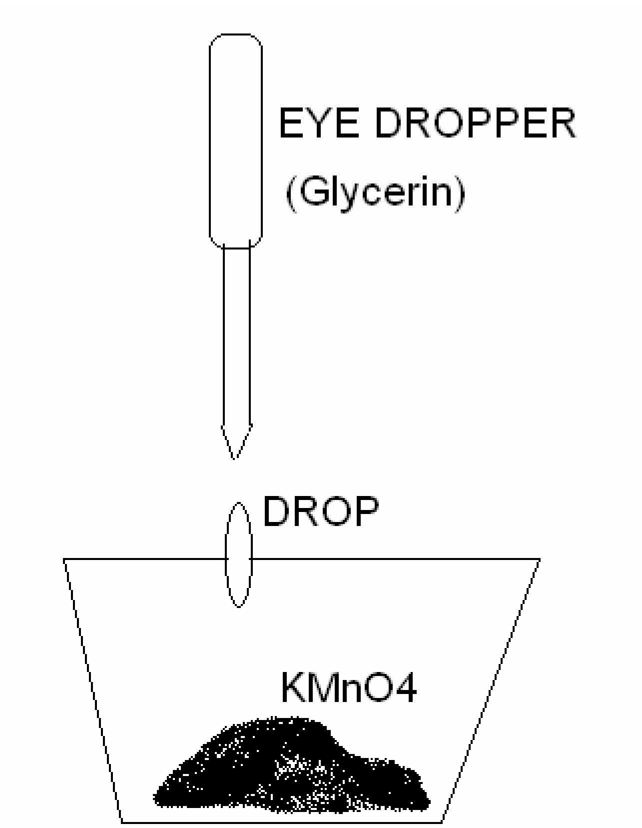
The oxygen is necessary for the reaction to continue. Proof of this can be seen by closing the lid on the jar. Once the oxygen is used up, the flame will extinguish.

Potassium permanganate is a much stronger oxidizing agent than molecular oxygen (4 oxygen atoms vs. 2). By adding this to a substance which has a lot of carbon-hydrogen bonds, a similar effect to burning a match will occur.

$$KMnO_4 + \text{Glycerin (high concentration of C-H bonds)} \rightarrow \text{Fire} + \text{Ash} + CO_2 + H_2O$$

The setup for this demo is simple:

MATERIALS: Potassium Permanganate- $KMnO_4$, Glycerine, mortar and pestal, small ceramic dish



1) A small pile of finely ground KMnO4 is placed in the bottom of a reaction dish.
    a. The KMnO4 *must be finely ground*. Coarse crystals take a long time to react or may not react at all. The more finely ground the crystals, the faster the reaction occurs.
    b. A reaction dish is recommended to keep the crystals piled and contained. The pile should be about the size of a quarter.
2) A few drops (5) of glycerin are added to the center of the pile.
3) Allow about 30 seconds for the reaction to occur before adding more glycerin. Smoke should appear first followed by eruption of a small purple flame. WARNING: Caution should be used at all times around the fire and smoke. This should be done in a well ventilated room! Have proper fire-containment precautions readily available. In the event the fire becomes too large, douse with water or sand. It is recommended that the scale of the reaction be kept small (no more than 10 g of KMnO4).

SECONDARY EXPERIMENT:

1) The $KMnO_4$ can be added to a solution of a strong base, (10 g NaOH in 100 mL of H_2O) to give a nice, dark purple color.
2) The ash of the flame-producing reaction can also be added to a solution of a strong base (see above) to produce a nice yellow-green color.
3) This demonstrates that the products of the reaction are different, and that the energy exerted during the course of the reaction was also utilized to change one of the chemicals (the reactant) into a different form of chemical (the product).

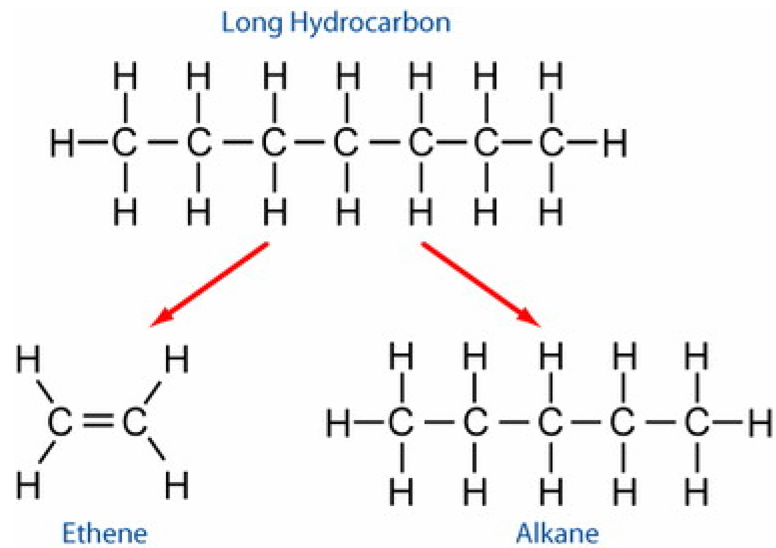
$KMnO_4$ (reactant) + Glycerin (reactant) ➔ Flame (product) + Ash (product)

Questions concerning this demo:

1) Is the reaction spontaneous? *Yes. The reaction occurs at room temperature spontaneously if the crystals are ground finely enough. If they are too coarse, they reaction may need to be heated. The flame should erupt spontaneously though.*
2) Is the reaction exothermic or endothermic? *The reaction is exothermic. The production of the flame is also accompanied by the production of intense heat, characteristic of an exothermic reaction.* ***Remember, an endothermic reaction requires heat, an exothermic reaction releases heat.***
3) Can the reaction be utilized in the production of work? *Most likely not. The reaction causes a flame to be produced, however the reaction is self catalyzing – meaning that once it is started, it can speed itself up without a secondary energy input. (Much like a snowball rolling downhill and continuously gaining speed as the size of the ball grows). This is different from other combustion reactions which produce gas expansions (explosions) that can be harnessed to do work. However, this reaction could be used to heat water to create steam...which could be used to do work.*

Combustion of Gasoline:

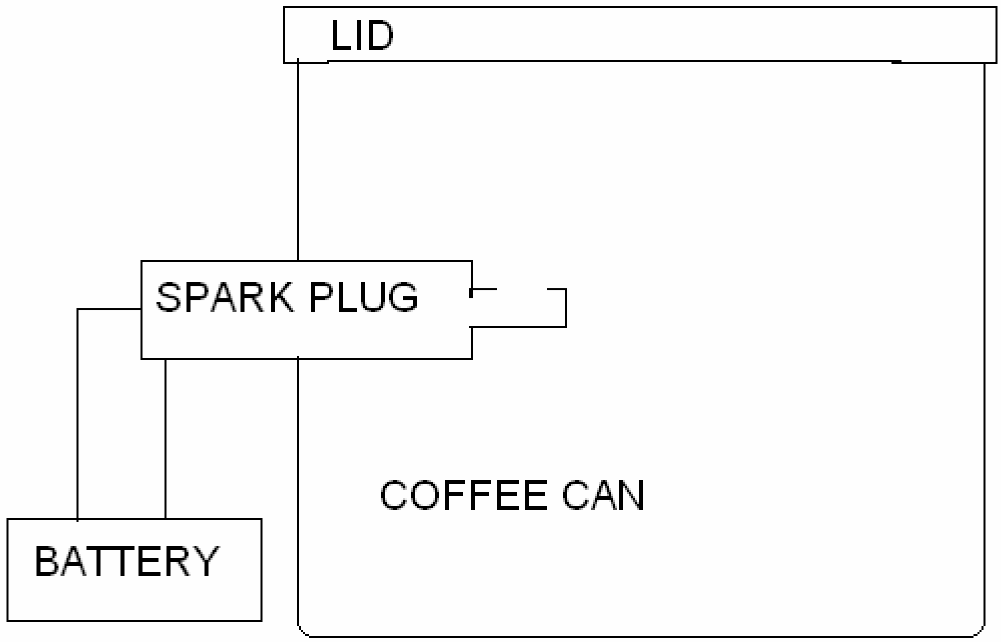
This is an example of a non-spontaneous reaction that occurs after a *reaction barrier* is overcome. Everyone knows that gasoline is a combustible, flammable liquid. Gasoline is made of *hydrocarbons*, which are long strings of carbon atoms attached to lots of hydrogen atoms and look similar to the following:



As you can see, the hydrocarbon can be broken down into smaller hydrocarbons. This, coupled with the addition of oxygen, can result in the formation of CO2 and H2O.

CXHY + O2 ➔ CO2 + H2O + ENERGY (BANG!!!)

You will notice that the above reaction is not balanced. Remember- to decompose the hydrocarbon you have to **break the carbon – carbon bonds.** Breaking these bonds results in the release of **ENERGY!**...and lots of it. This energy release is the explosion that moves the piston and powers your automobile.



DEMO:

MATERIALS: Coffee can + lid (peanut can sufficient), spark plug, 9V battery, eyedropper of gasoline.

The setup is quite simple.

1. Take a coffee can (Mr. Peanut can) and bore a small hole large enough to put a spark plug through, but no larger. (If you have to push on it a little to get it completely through, that is ok).
2. Take some sealant (glue or epoxy work fine) and seal off the edges of the hole so you have a nice, air-tight seal in the can.
3. Attach some copper wire to the spark plug but DO NOT ATTACH TO BATTERY.
4. Add 1-2 DROPS of gasoline to the can and close the lid. (WARNING: Gasoline in highly combustible!!! Make sure that you have not attached the wires to the battery at this step.)
    a. Also, adding more than 1-2 drops of gasoline could cause saturation of the oxygen needed in the combustion chamber thus causing "vapor lock" or "flooding" the engine.

   b. This could also lead to discussion about how *only* vapors burn, not liquids.

5. Move slightly back from the coffee can and attach the two wires to the (+) and (-) poles of a 9V battery. This should cause the plug to spark igniting the gasoline vapors in the chamber and blowing the lid off of the coffee can. BANG!!!
6. If the explosion fails to ignite, try opening the lid and closing it quickly again to try and introduce some more oxygen into the chamber (thin the mix). (See #4-a).

Questions concerning this demo:

1) Is the reaction spontaneous? *No. It is not spontaneous. If it were, the gasoline would ignite in the air. This reaction has a reaction barrier, known as an" impetus". Energy must be added to the gasoline + oxygen mixture in the form of a spark to begin the reaction. Once it has begun, however, it proceeds quite rapidly.*
2) Is the reaction exothermic or endothermic? *Exothermic. If you do not see the fire produced by the explosion, think about the number of bonds in gasoline (roughly 20 C – C bonds) that must be broken producing a LOT of energy. This is more than enough to cover the energy needed to form CO2 and H2O. *You can also feel the heat produced by placing you hand near the coffee can shortly after the reaction has taken place.*
3) Can the reaction be used to perform work? *Yes. When this explosion is contained, the force of the reaction can be used to move a cylinder much like it blew the lid off of the coffee can. This is what powers an automobile.*

Glow stick Demo

Glow sticks are a fun novelty item that can be purchased at almost any hardware, grocery, or sporting-goods store. They contain chemical reactions that produce "chemiluminescent" (chemically-light producing) products which will emit a photon of energy that we see as light.

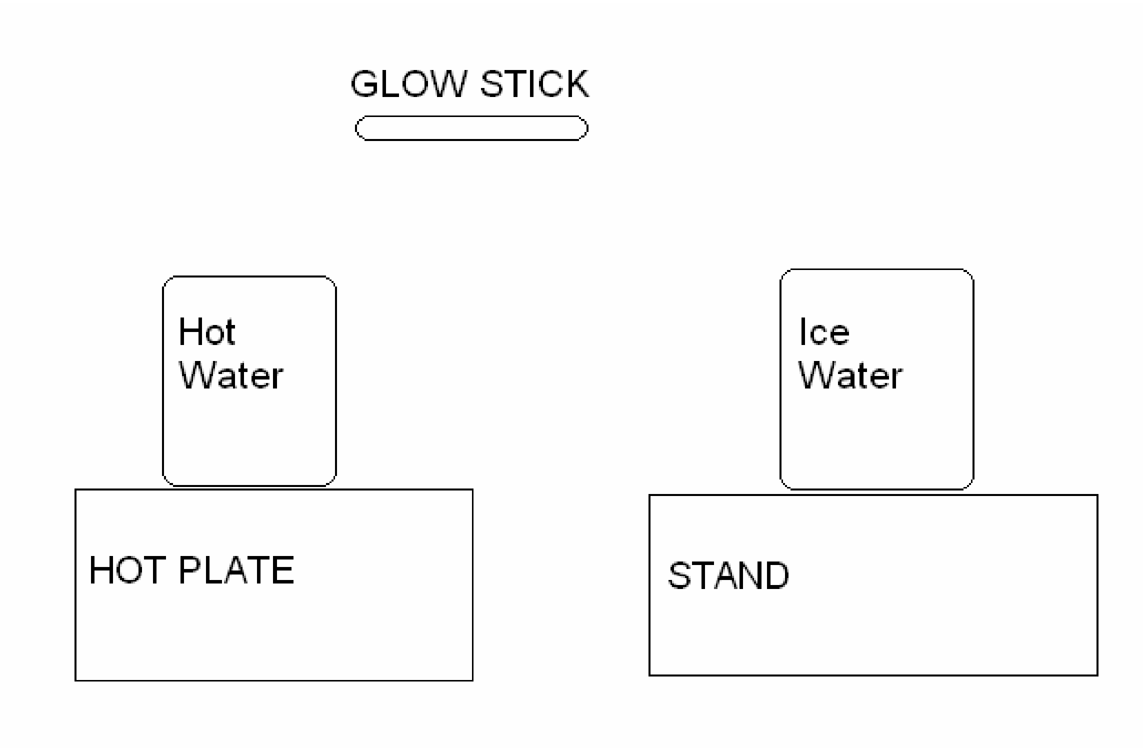
While the chemistry of glow sticks is interesting, (albeit not entirely well understood), students should understand that not all energy must come in the form of heat. LIGHT IS A FORM OF ENERGY, and glow sticks produce light energy via *chemical* means (unlike a light bulb which uses *heat* to produced light).

However, this demo shows that heat energy (measured as "temperature") can also effect the reaction which produces light.

DEMO:

MATERIALS: Ice water, Boiling water, hot plate, glow stick, tongs.

The setup is simple:



1) A glow stick is first activated according to the manufacturer's directions. (Crack the glow stick by breaking the internal chemical chamber and shake vigorously).
2) Turn off the lights so students will appreciate the full scope of this demo.
3) You can now discuss the light energy that is being produced by a chemical means inside the glow stick. As the students can see, you are

able to hold the glow stick in your hands, thus indicating that it is not hot. This can be compared to a hot light-bulb which uses heat energy to make light energy.

4) ***Using tong<u>s</u>***, submerge the glow stick in the ice water bath. After a few seconds, the glow stick should begin to dim. This is because ALL CHEMICAL REACTIONS require heat in some form (some just produce more heat than they require).
    a. By limiting the heat that the reaction requires, you are slowing down the reaction rate, and thus causing less light energy to be produced.
5) Now quickly remove the glow stick from the ice bath and place in the hot water (boiling water works best). CAUTION: Use tongs to transfer the glow stick to the hot / boiling water. This should cause the glow stick to glow MUCH brighter.
    a. By increasing the heat that the reaction requires, you are increasing the rate at which the reaction occurs. This causes the increased production of light energy, and thus a stronger glow.
6) Once the demonstration is over, the glow stick may be disposed of in the trash.

Questions regarding this demo:

1) Is the reaction spontaneous or non-spontaneous? *Spontaneous. By cracking the inner chamber and thus mixing the chemicals inside the glow stick, the reaction occurs on its own, i.e. no external energy must be added. The reaction rate can be altered by increasing / decreasing external heat, but the reaction will continue regardless.*
2) Does the reaction produce a product which can be used in work? *No. The glow stick reaction produces light energy, which, while useful, cannot be utilized in the form of work. Remember, work means lifting, moving something. Light cannot accomplish these functions.*
3) Is the reaction endergonic or exergonic? *Endergoinc. Remember, endergonic means work/energy absorbing and exergonic means work/energy producing. This reaction produces light, which falls into neither of these categories, however, by placing the stick in hot water you can see that the rate of the reaction is increased, thus some form of energy (in this case heat) is affecting the reaction. So, the reaction is using the heat from the surroundings to help produce light.*