The Science of Fire

What is Fire?!

We can see the multi-coloured flames, the glowing embers and charring fuel. We can hear the crackling and popping of wood, smell the swirling smoke and feel the warmth coming from it, perhaps even taste the food that has been cooked on it. Fire will mean something different to each of us. It is something that we are all instinctually connected to, but what is it?

From a scientific perspective; fire is a chemical reaction between oxygen and a fuel source (oxidation), and there are actually 2 separate reactions occurring. The result is exothermic (meaning it gives out energy in the form of heat and light). There is a sequence of events;

1. Something heats the fuel (let's say wood), this heat source could come from varying places (see fire lighting below)
2. Once the wood gets to about 150^0C, the cellulose in it starts to decompose and releases volatile gases (which we refer to as smoke). These volatile gases or smoke are compounds made up of the elements hydrogen (H), carbon (C) and Oxygen (O).
3. Once the gases are released the rest of the fuel material forms char, which is nearly pure carbon (C) and ash, which is all the unburnable minerals in the fuel (like calcium, potassium etc).

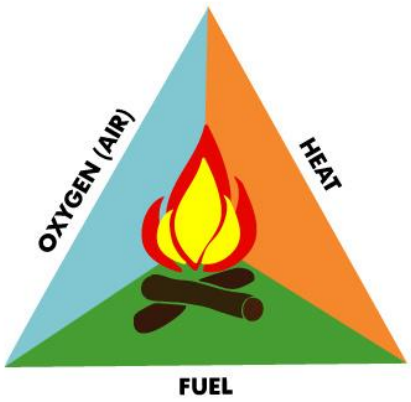
$$6C_{10}H_{15}O_7 \text{ (Wood)} + \text{Heat} \longrightarrow C_{50}H_{10}O \text{ (Char)} + 10CH_2O \text{ (Gas)}$$

4. Once the volatile gases (smoke) reach about 260^0C the compound breaks apart and a second chemical reaction occurs with the oxygen in the atmosphere to create water, carbon dioxide and other waste products. This reaction gives off a lot of heat energy (exothermic), which then feeds further chemical reactions, hence fire is a self-perpetuating reaction (as long as there is fuel and oxygen present).

$$\underset{\text{(Gas)}}{6CH_2O} + \underset{\text{(oxygen)}}{3O_2} \longrightarrow \underset{\text{(Water)(Carbon Dioxide)(Carbon Monoxide)(Carbon)}}{6H_2O + 2CO_2 + 2CO + 2C} + \text{Heat}$$

5. The carbon in char will also react with oxygen, but this is a slower reaction and why the embers of a fire or charcoal hold heat for long time.
6. Light is created by the heated carbon atoms (and other waste elements) being released. The atoms rise due to gravity as the hot gases are less dense than the surrounding air. Which is why flames move up and have the characteristic flame shape. The colour of flames is determined by the temperature and the elements being heated.

Creating a flame - The Fire Triangle



As the science bit above explains there are 3 things that a fire needs to burn;

- Fuel
- Oxygen
- Heat

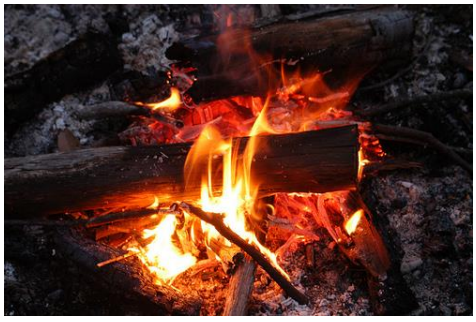
This is often referred to as the fire triangle. A fire cannot burn if any one of these things is removed.

It is important to remember the fire triangle when extinguishing a fire as all methods remove one or more of these 3 things. Examples of extinguishing methods:

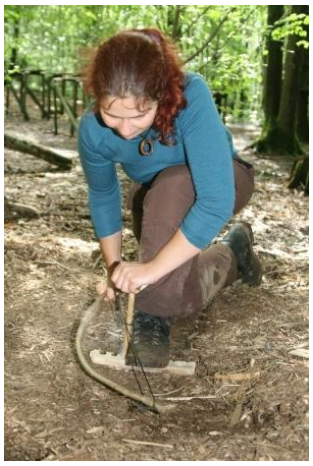
- Separating the **fuel** out will reduce flames. On a larger scale this is also why some managed woodlands may have a series of rides as fire breaks.
- Smothering a fire using a fire blanket or sand, will prevent the **oxygen** reaching the fire.
- Using water or wind (e.g. blowing out a candle) cools the fire and reduces the **heat** enough to stop the burning.

When lighting a fire all 3 components must be considered to be successful;

- Fuel – The drier the wood the easier it will be to heat to the required temperature. Wet wood will burn, however energy must be spent to drive out the water and dry the wood before the gas is given off. In wet weather it is often worth splitting logs for kindling, as the inside of logs will be drier than the outside. Fuel size is also important, as the thinner the sticks the greater surface area and the quicker the wood dries out and reaches the ignition temperature. So starting with lots of very fine kindling gives a good start to a fire. Remembering that some species of tree have volatile resins or oils within them is also useful (such as larch, pine, birch etc)
- Oxygen – Is all around us in the atmosphere. In fire lighting it is important to ensure good air flow into the fire so oxygen can reach the fire. Raising the fire off the ground by using a bed of sticks and lighting up-wind of your kindling will assist air flow. Height is also essential in fire management as heat rises and as wood is added it will dry out above the fire. If a fire collapses flat it will smother itself and go out.
- Heat – Once alight a fire will self-perpetuate and generate its own heat, but to start a fire there needs to be a source of ignition that provides sufficient initial heat. There are many methods of generating enough heat; focusing the sun's heat, creating heat through friction, chemical reactions, electrical current, compression of gas and using a hot spark of metal.

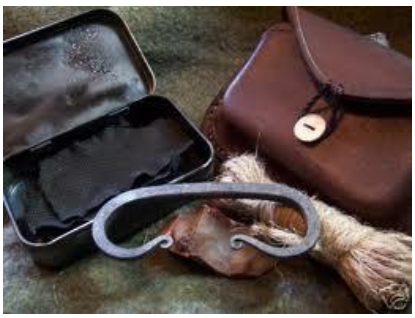


Methods of Creating a Flame – Ignition sources



There are 6 main ways of creating sufficient heat to start a fire;

1. **Chemical** – heat and flame is produced through chemicals reacting e.g. potassium permanganate and glycerine or a match strike.
2. **Compression** – rapid compression of air can increase temperature enough to ignite tinder e.g. fire piston and char-cloth to create an ember which can be turned into flame through a tinder bundle
3. **Electrical** – the electricity heats the wire sufficiently e.g. wire wool and battery, to glow hot, which can be turned into flame through a tinder bundle
4. **Friction** – the friction between the wood generates the heat e.g. bow drill, hand drill, fire plough, fire saw, fire thong, to create an ember which can be turned into flame through a tinder bundle
5. **Solar** – heat focused from solar radiation (sunlight) e.g. through parabolic mirror, lens or magnify glass, onto a tinder
6. **Sparks** – striking steel (or iron ore in case or iron pyrites) against a rock/mineral that is harder than the metal, shaves off tiny pieces of metal and the friction to heat it (sparks). This can create an ember when they land on and heat tinder sufficiently e.g. flint and steel, iron pyrites and flint, Swedish fire steel used with char-cloth, fine tinder (plant downs or birch bark) or crampball fungi e.t.c.



Ember to Flame - Using Tinders

Depending on the method of ignition and the fuel available, various tinders need to be considered. They can be man made or natural. Some methods of ignition are hot enough to create flame immediately (e.g. chemical reaction on a matchhead or sparks from a fire steel onto fine birch bark shavings), however other methods create an ember or coal that needs tinder to create flame. The heat is held in the ember (which will smoulder and build heat e.g. on charcloth or charred wood dust) which is then used to create flame using fine materials or tinders.