Some Chemistry and Physics of Explosives and Fireworks

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There is a certain fearful thrilling satisfaction in loud bangs. I know many otherwise apparently quite respectable people who are members of the League of Nations Union, opposed to war under any pretext, and who certainly are opposed to the use of firearms for any purpose, who take the opportunity of the approach of Guy Fawkes' Day or of Empire Day, or of some suitably authenticated fireworks day to purchase crackers for their children, which they proceed to let off for the pleasure and gratification—of those children.

Children are a blessing. Few men would have the courage to give way to their desire for making loud bangs on the back lawn, or illegally in the streets, without being able to hide, metaphorically, behind the skirts or pants of the little ones. But when father brings home a mixed box of Chinese bombs, big bungers, jumping jacks, tom-thumbs, flower-pots, Roman candles and Catherine wheels, mother knows quite well who is going to get the most fun out of letting them off.

The " Roman candle " that explodes with a loud bang at the end is *not* popular, because you frequently have it in your hand, waving it in graceful curves, when the bang takes place, but we feel we have been robbed if the flower-pot, after firing graceful fiery sprays for a while, does not go off like a packet of crackers eventually.

What is an explosion ? Why do we hear the bang ? An explosion is caused by a little thing trying to become a big thing in a very little time. If the explosion is restrained within a strong steel container, as is in the case when tests are being made, the desire of the material to become very great in volume is frustrated, and the glorious bang is missing. Take the case of the simple expansion of water into steam. If you have a cubic foot of water at its boiling point, and turn it into steam by adding heat and boiling it away, it would turn into some 1,600 cubic feet of steam at the same temperature. Ordinarily, if you forget that the kettle has been left on and nearly all the water boils away, nothing is upset by it except the person who pays the gas bill. A little volume has become a big volume 1,600 times as great, but *not* in a very little time, so that the surrounding air can be pushed quietly out of the way by the escaping steam, which also has a chance of losing its heat to its surroundings, so that the walls and objects in the room become wet as the steam condenses yet once again to water. If the small volume of water had become 1,600 volumes of steam in a *very* short time, then it would have pushed the air out of the road so rapidly that the windows and doors might also have been pushed out of the road. With a big enough volume of water charged sufficiently quickly to steam, the roof, and perhaps the walls also, might depart with a rush.

Effects such as this have frequently been produced : If a steam boiler were to run dry and become red hot, then a sudden admission of water might result in such a sudden creation of big volumes of steam that steam escape valves might not be able to handle the rush, and frequently the boiler is ripped open, with plenty of noise. Also, as you know, if the spout of the kettle were corked up and the lid so fixed that steam could not escape, then as the water tried to occupy 1,600 times its volume on going into steam, and found that this was prevented, the internal pressure in the kettle would rise correspondingly. Instead of having easily moved air to push out of the way, its free expansion is prevented by materials that refuse to move—until the development of forces against them leads to such big forces that they give way with a rush, and cork or lid or kettle itself blow out. This is *not* a safe experiment. It reminds me of an heroic action in France : We were a medium trench mortar battery in the mud wallows of " Gun Valley ", on the Somme, during the winter of 1916-1917, and the battery commander (one, Scott) and myself had a tiny surface burrow, dignified by the name of " dug-out ", into which we could both crawl to lie down, and in which we could burn a small fire of broken ammunition cases to cook food and keep ourselves warm. On the night of 12th/13th February, I took a party into the front line, carrying trench mortar bombs—the old 60 pound " plum puddings "—and returned to the dug-out about three in the morning to find Scott lying with his head near the fire, and a tin of McConnachie ration (a tinned rice stew) close to the fire on his side of it. He had put the unpunctured tin there to warm for his supper, and gone to sleep. The tin had bulged out with the steam inside, though of course it fortunately had not reached boiling point, and was itself a nearly round ball bomb, which could be rolled about. With great rapidity I removed the bomb from the proximity of the fire, opened it carefully to release the steam pressure, and ate the contents myself. Even if he had been in danger of damage from an explosion of rice stew, he would not have appreciated being awakened to be told of his escape.

Before passing to what you will designate as real explosives, let us look at one other slow type. It used to be quite a common thing in " gassy " mines to employ cartridges of quick-lime. Holes were drilled down into the material, just big enough to take the cartridges, which were then flooded from the upper part of the drill hole with water. The quick-lime cartridges heated up, expanded relatively slowly, and heaved the masses of coal out of the way without any dangerous flash. Of course, if they had not been confined, they would merely have pushed the surrounding air out of the way without doing noticeable work.

Now I will pass to quick action explosives, repeating first of all my earlier statement : " An explosion is caused by a little thing trying to become a big thing in a very little time ". (That, of course, has no political significance.) If we burn charcoal in air, it takes up oxygen from the atmosphere, and forms the gas carbon dioxide. Even at ordinary atmospheric temperatures, the original volume of charcoal would be spread out into about a thousand times the volume in this gas at ordinary atmospheric pressure. But the charcoal burning gives out heat, as you know, so that the gas, if formed quickly in a confined space, can be raised to more than a thousand degrees centigrade, which makes it try to occupy some five times as great a volume again as if it were cold. The method adopted to make the charcoal oxidise very rapidly is to mix it thoroughly with some chemical rich in oxygen, and which will give up its oxygen rapidly to the charcoal once you start it off by a flame, spark, or sufficiently great concussion. The chemical used is potash (saltpetre, nitrate of potash).

The gunpowder used in black powder cartridges, in fuses, in your crackers, and frequently still for certain types of quarrying is a mixture of charcoal, sulphur, and saltpetre. The sulphur also oxidises, or burns rapidly, to form the unpleasant gas sulphur dioxide. The percentages vary, but an ordinary mixture is, by weight, 74 parts of saltpetre, 10 parts of sulphur, and 16 parts of charcoal.

If you break open a bunger and put a match to the exposed fine grain gunpowder, it just hisses fiercely and pushes the air out of the way as the gas escapes. The explosion takes place rather slowly. When it is confined in the bunger, not only does the explosion take place quicker under the greater pressure generated, but it has to burst its way out after the inside forces have reached a high value—hence the bang.

These *relatively* slow acting explosives are frequently used as *propellants* for that reason ; the cordite and smokeless powders used with guns and rifles are other examples. Cordite we will meet in a moment.

Let us look next at these so-called high explosives. We may divide them all up into propellant, blasting and detonating explosives. The first two tend to rend and hurl material away ; the last has its violence confined to a very limited zone. The two most frequently employed are those containing nitroglyercine and those containing gun cotton and trinitrocellulose. Nitroglycerine by itself is an unpleasantly dangerous material, which deteriorates, so that it is likely to explode with slight knocks, is a liquid which gives you fearsome headaches if it gets on to your skin, and which is unduly violent in its explosion. It is made by acting on glycerine with nitric acid, sulphuric acid being added to mop up the water which is liberated during the nitration of the glycerine, and extreme care is taken with regard to temperature control and the formation of other chemicals which would make it unstable. It is easy enough to make it in your own backyard, but if you feel the urge to depart with a big noise, you should remember that your neighbours do not want to go with you. **All home laboratory or backyard experiments with explosives, beyond letting off crackers to amuse the children, are silly and dangerous.**

Dynamite is nitroglycerine soaked up by an absorbent earth. Most countries had forbidden the use of nitroglycerine as an explosive, when in 1866 Nobel discovered that it could be rendered comparatively safe by mixing it with the inert diomataceous earth, kieselguhr. This earth absorbs about three times its weight of nitroglycerine, and usually has a little carbonate mixed with it to neutralize acids which are formed from the nitroglycerine on storage. This mud pie is then squeezed into sausages, called cartridges, and wrapped in parchment paper. Some " dynamites " have other materials added to them, such as wood pulp and saltpetre, but the dynamites are essentially nitroglycerine mopped up by very absorbent non-gritty earth, and squeezed into cartridges.

Gun cotton, or trinitrocellulose, is also easily made. If cotton wool, or cotton waste, or sawdust, or similar celluloses be acted upon by nitric acid, they are nitrated and form nitrocelluloses. As in the case of the manufacture of nitroglycerine, water is formed during the nitration, so to make gun cotton we act on cottons with a mixture of nitric and sulphuric acids. The stuff still looks like cotton, and is washed thoroughly and pressed into slabs, generally kept wet. When dissolved in a mixture of ether and alcohol, it forms the collodion cotton you put on a cut to form a " new skin " ; even when the ether and alcohol evaporate off, it remains in its modified form, but still a high explosive, gun cotton in the form " collodion cotton ".

In 1875 Nobel found that by mixing some 7 % to 8 % of dry collodion cotton with the liquid nitroglycerine it became a gelatinous solid. The blasting gelatine used by quarrymen and others is a mixture of these two high explosives, turned out through a sausage machine and wrapped in parchment paper. Though still a high explosive, it is slower in its action than either the nitroglycerine or nitrocellulose comprising it. Cordite, the propellant in guns and rifles, is also this mixture, with other slowing additions.

Before considering any other explosives, let us put a match to a lump of dry gun cotton. It merely flares up like a bit of celluloid. Celluloid *is* only modified nitro-cellulose, camphor being one of the materials added.

Now take a little bit of blasting gelatine and light it ; it flares up also. Whilst *frozen* dynamites are liable to explode on heating, all these blasting explosives are actually fired by detonation. The ordinary detonator used is a little copper cap containing fulminate of mercury at the bottom. It is, in the case of the commercial No. 6 detonator, a cylinder one and three-eighths inches long and one-quarter of an inch in diameter, and is very dangerous, being easily detonated by a sharp blow, or by picking at the fulminate. The lead azide detonators, contained in corresponding aluminium cylinders, are now coming into general use, and are much safer, though still to be treated with respect. A fuse is crimped into the detonator so that the end from which the flash comes when the gunpowder in the fuse burns down to its limit will go on to the mercury or lead salt. This detonator is then carefully pressed into a hole made in the sausage of dynamite or blasting gelatine, or into a hole in a " primer " of dry gun cotton. This would *not* be an experiment to perform here, but we will now imagine ourselves out in the open. On lighting the " safety fuse ", the gunpowder in its core burns down till it reaches the far end, when the flame spits on to the material in the detonator, which detonates—that is, explodes—with intense violence and rapidity. The shock of this explosion is transmitted as a high velocity "explosion wave" through the dynamite, blasting gelatine, or other explosive, which explodes throughout its whole volume in a minute fraction of a second, with a very loud bang. (Wet gun cotton is not even fired by a detonator, but requires to be fired by a primer of dry gun cotton, which itself is fired by a detonator, which is fired by a flash into the contained detonating material.)

We hear all sorts of stories of some explosives striking upwards and some striking downwards. It all comes to a question of " tamping " or provision of material to push out of the way. If I tied a few plugs of blasting gelatine or dynamite on to a large standing tree and fired them, they would not cut the tree down, because it would be far easier for the expanding hot gases to push the surrounding air out of the way than to push the tree away. But if I place a few 15 oz. slabs of wet gun cotton on the tree, primed with a 1 oz. dry gun cotton primer, and detonate that, the big tree is cut right through and falls. The explosion takes place so rapidly that before the air can be pushed away an enormous force is applied to the tree, so that it is shattered. If we drilled a hole in a rock, put in a plug of dynamite, and fired it with a detonator, naturally it would be far simpler for the hot gases formed to get away by blowing the air out of the shot hole rather than by heaving away the surrounding rock. So we fill the hole up, generally stamping the filling firmly in once we are clear of the explosive. This is called " tamping ". Explosives are very effective under water, on account of the difficulty of heaving the water out of the way ; the water affords an efficient tamping.

[This is a brief outline of a subject interesting from many points of view, and I would like to tell you of the use of explosives by artillery, in mining, in bombing and in other sections of useful activities, but that will have to be postponed till some other issue].