FLAME TESTS (A QUALITATIVE TECHNIQUE)

Some metallic elements and metallic salts (ionic compounds) will emit light of a particular colour or wavelength when exposed to a Bunsen burner flame. This results in the flame having a characteristic colour that can be used to identify the metallic element present. That is, different elements will produce different colours in a flame.

Metal (atom or ion)	**Flame Colour observed**
Potassium (K)	Lilac
Calcium (Ca)	Red
Lithium (Li)	Crimson
Barium (Ba)	Yellow-green
Copper (Cu)	Green
Strontium (Sr)	Scarlet
Sodium (Na)	Yellow

PERFORMING A FLAME TEST IN THE LAB

Below is a procedure that could be used to analyse a metallic salt by performing a flame test.

Step 1: Clean a platinum or nichrome wire

This is done in 2 stages:

- A platinum or nichrome wire is dipped in concentrated HCl. The acid will dissolve any impurities present on the wire. Platinum and nichrome are used because they are inert (unreactive) metals that will not produce colours in a Bunsen burner flame.

- The wire is then heated using a blue Bunsen burner flame. The heat will vapourise (turn into a gas) any impurities on the wire. The wire should now be clean and ready to be used for anlaysis.

Step 2: Moisten the wire in concentrated HCl and place it in the sample to be analysed

The wire is dipped in concentrated HCl for a second time. The moistened wire will now be dipped into the metallic salt that is to be analysed. The metallic salt will dissolve in the acid, causing the separation of the ions present.

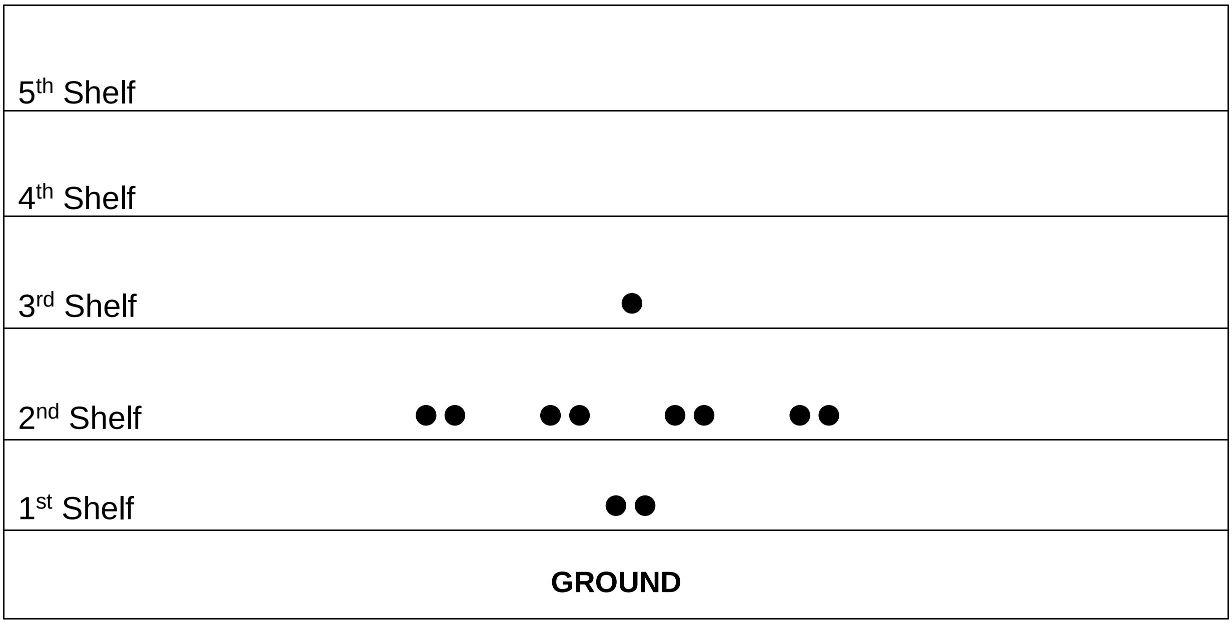
Step 3: Place the wire containing the sample in a blue bunsen burner flame

The ions in the salt will be vapourised by the flame. The flame will change colour. The sample can be identified by comparing the colour of the flame with those colours emitted by known samples.

WHY DO SOME METALLIC ATOMS AND IONS RELEASE COLOURED LIGHT WHEN EXPOSED TO A FLAME?

To answer this question we need to look at what happens to atoms and ions when they interact with the energy from a flame. To help us understand the chemistry involved we will look at a model that is set in a different context but follows the same principles:

Imagine a wall unit that contains 5 shelves. The first shelf holds 2 billiard balls, the second 8 billiard balls and the third shelf is holding 1 billiard ball. The fourth and fifth shelves are empty.



1. These balls are all attracted to the ground because of gravity. If it weren't for the shelves all the balls would come crashing to the ground.

2. Let's say that we wanted to move the ball sitting on the 3rd shelf up to the 4th shelf. The ball will not move up there of its own accord. It needs to be physically picked up and placed on the shelf. That is, the ball needs an **input of energy that is equal to or greater than the force of gravity** attracting it to the shelf.

3. For the ball to go back down to the 3rd shelf again, it does not need any input of energy. If the ball is moved to the edge of the shelf it will fall back down to the 3rd shelf.

4. As it falls it **will release the energy that it had gained** when it was placed on the 4th shelf.

5. This energy is in the form of kinetic energy as the ball is falling and sound as it hits the shelf. There will also be a small amount of heat given off due to friction between the ball and shelf. **The total amount of energy released by the ball falling back to the 3rd shelf is equal to the amount of energy absorbed when the ball was lifted up to the 4th shelf.**

In atoms (sodium will be used as an example), there are **electrons** instead of billiard balls, **shells** instead of shelves and a positively charged **nucleus** that attracts electrons in a similar way that the ground attracts billiard balls. The scientific principles that applied to promoting a billiard ball to a higher shelf are similar to those involved in promoting an electron to a higher energy level.

5^{th} Shell (O)	
4^{th} Shell (N)	
3^{rd} Shell (M)	● (1 electron)
2^{nd} Shell (L)	●● ●● ●● ●● (2 electrons)
1^{st} Shell (K)	●● (2 electrons)
NUCLEUS (11 PROTONS)	

1. The electrons are attracted towards the nucleus. This attraction is not gravitational in nature but **electrostatic**. That is, the negatively charged electrons are attracted to the positively charged nucleus.

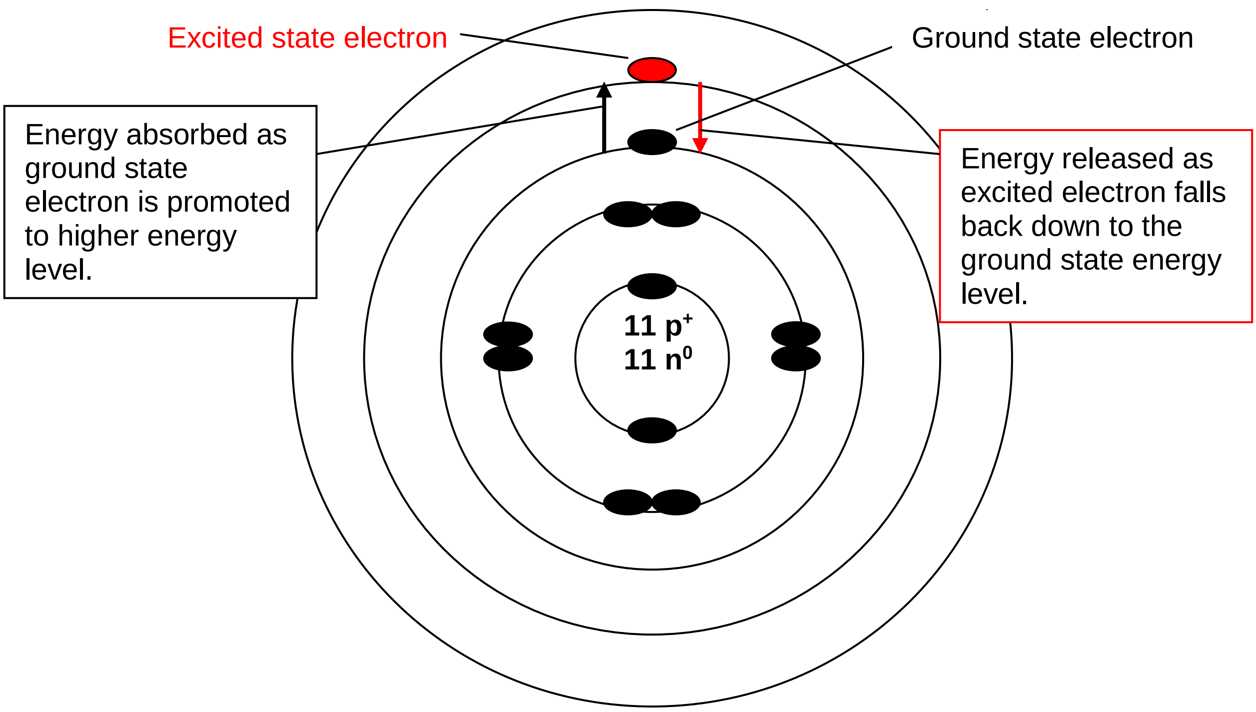
2. The electron in the 3^{rd} shell can move up to the 4^{th} if it receives an amount of energy that is equal to or greater than the electrostatic attraction holding it in the 3^{rd} shell. If sodium is placed in a Bunsen burner flame the electron in the 3^{rd} shell will gain this energy and be promoted to the higher level. Electrons that gain energy and move up to a higher energy level or shell are said to be in the **excited state.**

3. Excited electrons are unstable and will not stay in the higher energy level for long. They will eventually fall back to their original energy level or **ground state.**

4. When the electron falls back to the 3^{rd} shell it releases the energy that it absorbed from the flame.

5. This energy is equal to the amount of energy required to promote it to the higher energy level in the first place. This released energy is in the form of coloured light of a particular **wavelength. It is very important to realise that excited electrons do not give off coloured light. When they are excited they are just carrying or storing the energy they absorbed. It is only when they fall back to their original ground state that the stored energy is given off.**

Of course, we would never represent a sodium atom using the above model. The shell model of the sodium atom is the one that we are familiar with:



Different metallic atoms contain different numbers of protons in their nuclei. For example, Na has 11 protons and K has 19 etc. This means that the magnitude (size) of the electrostatic attraction that the electrons have towards the nucleus will vary from atom to atom. As a consequence it will take varying amounts of energy to excite the electrons from different metals and this will naturally result in different amounts of energy being released as the electrons move back down to the ground state. The different colours produced when metallic atoms and ions are vapourised in a flame are a direct consequence of this. Each colour corresponds to energy of a certain magnitude.

SOME LIMITATIONS OF FLAME TESTS

- Flame tests can only be used to analyse a limited number of metals (group I and II metals only). This is because some metals will emit light that is not visible or the Bunsen burner flame is not strong enough to excite their electrons.
- Flame tests cannot be used to analyse a mixture of metallic samples. The colour of one sample will mask the colour of another making the identification of different metals almost impossible.
- Some of the colours that metals produce during a flame test are very similar.

Some of the limitations of flame tests have been overcome by a similar procedure known as **Atomic Emission Spectrometry.**