The science of airport bomb detection

December 10 2014, by Martin Boland

You have gas chromatography and mass spectrometry to thank for keeping you safe from explosives in air travel. Credit: Dustin Ground/Flickr, CC BY-SA

As the holidays draw near, many of us will hop on a plane to visit friends and family – or just get away from it all. Some will be subjected to a swab at the airport to test clothes and baggage for explosives. So how does this process work?

The answer is chromatography – a branch of separation chemistry – along with mass spectrometry (which I will address in a later article).

The word "chromatography" is roughly translated from Greek as "the science of colours". The reason for the name becomes obvious when you realise that most people have accidentally performed a simple chromatography experiment.

If you've ever spilled water onto a hand-written shopping list, then held it up to let the water run off, you've probably noticed the ink diffuses across the paper, and that the pen's colour is made up from several pigments (if you've not, you can do the experiment – try it with a couple of pens of different brands, but the same colour). This separation is chromatography.

There are several different types of chromatographic separation. What they all have in common is that a mixture of materials that need to be separated (the analytes) is washed over a solid material (called the matrix), causing the analytes to separate.

That may sound like chromatography is just filtration, or separation by particle size. In some cases, that is almost exactly what happens (size exclusion chromatography is often referred to as gel filtration chromatography).

But most chromatography methods work by some other chemical effect than just the size of the materials being separated, including (but not limited to):

- normal-phase chromatography, such as ink on paper
- reverse-phase chromatography, often used in university lab experiments
- gas chromatography, seen in airport bomb detectors
- "capture" chromatography, used to purify drugs.

Each of these can be performed with one solvent, such as dropping water

on your shopping list – known as isocratic (Greek for "equal power") or with a changing mixture of solvents (known as a gradient).

So how does it work?

Technically speaking, it is the differential affinity of the analyte for the solvent and the solid matrix that drives chromatographic separation. So what does that mean, really?

You'll need to bear with me here.

Have you ever been shopping with someone who stops to look at things while you're trying to move though the store as quickly as possible?

That differential attraction to the stuff surrounding you – that's what drives chromatography. You walk though the aisles only rarely interacting with the goods on sale, while your shopping partner has much greater affinity for the shelves and stops frequently. By the time you're at the exit they are still only halfway through the shop – you've separated!

That is what happens to molecules. The solvent flows over the matrix (in the shopping list case, the paper) carrying the analytes. The relative affinity of the analyte for the matrix compared with the solvent determines the separation.

If a compound is totally insoluble in the solvent, it stays fixed to the matrix (you may have seen this when spilling water on a shopping list written in pencil). If the analyte is very soluble, it may move as fast as the solvent.

The shopping list example is called planar chromatography. The running ink seems to defy gravity, moving up the paper due to the capillary

effect. More common in high-performance chromatography, the matrix is a column with the solvent forced over it, by gravity or pumping.

Using a column makes it easier to change the ratio of solvents by using a pump that can mix multiple materials (usually a mixture of water and a soluble organic solvent such as acetonitrile).

In the case of a gradient separation, the analyte has much higher affinity for the matrix than for the initial solvent mixture. As the solvent mix is changed, the analyte dissolves in the solvent and is carried out of the column separated from materials that are soluble in different solvent ratios.

Sometimes it's a gas, gas, gas

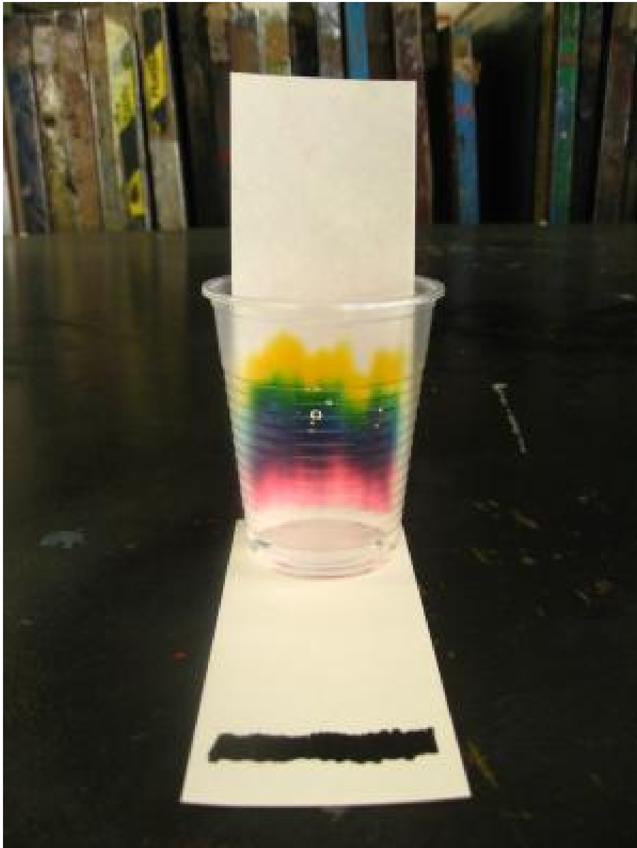
For gas chromatography, the set up is a little different. The analytes are gases or volatile liquids (think petrochemicals, plant oils, chemical weapons). Such compounds are usually non-polar and hydrophobic – in other words, they don't mix well with water.

The compounds are evaporated into an inert carrier gas (analogous to dissolving in a solvent). The carrier gas transports the compound over a hydrophobic matrix contained in a coiled column (often tens of metres long but only micrometres wide).

To improve separation, and allow analysis of materials with a higher boiling point (up to around 300C), the column is placed in an oven. Changing the temperature of the oven affects separation in a similar way to changing the mixture of solvents in liquid chromatography.

Quality control

When separating coloured compounds it's pretty obvious when the process has worked. But how do you know if you've separated two colourless compounds, or separated microscopic amounts of analyte?



There are several ways to detect the analytes depending on their chemical and/ or physical properties. Among the more common are:

- ultraviolet or infrared (non-visible but optical wavelength) absorbance
- non-visible fluorescence
- conductivity or pH (how acidic the solution is)

- collect samples and perform chemical tests
- mass spectrometry.

Probably the most useful of these is mass spectrometry as it allows the analyst to work out exactly what compound they are seeing without needing prior knowledge of what was in the original analyte mixture.

An ever-developing world

Although instrumental chromatography is a mature technology (the first instruments were produced just after WWII), new applications frequently pop up.

Some are a matter of scale. Pharmaceutical companies that produce monoclonal antibodies (often used in cancer treatments) make use of capture chromatography to purify their products. On an industrial scale these can be tens of centimetres in diameter and metres in length (typical lab scale systems are a few millimetres diameter and 5-30cm long).

Other uses can either be in a specific new application, such as detecting cocaine on bank notes using the gas chromatography systems often seen at airports as bomb and drug detectors.

And even more exciting experiments are being done by chromatography instruments on board the Philae probe that detected organic chemicals on the comet 67P/Churyumov–Gerasimenko.

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