cells within 3D systems fills the technology gap.

The UK's pivotal role in the preparation of the first documentary publicly available specifications (PAS) for the cell-based therapeutic industry has been supported by leading measurement capability in single cell and 3D stem cell bioprocessing.

CONCLUDING REMARKS

The international picture for measurement science has never been healthier. UK leadership is reflected in its Chair roles for three (inorganic, bio-analysis and gas) of the six consultative committees, and in its founding role in a fourth, of the *Bureau International de Poids et Mesures* (BIPM). This organisation ensures world-wide uniformity of measurements and their traceability to the International System of Units (SI).

It is clear from the rapid increase in attendance of measurement scientists at the annual meeting of BIPM, measurement science is being seen as underpinning economic prosperity globally and is being invested in substantially in the developing countries and in the US. This is particularly strong in the 'newer' bio-analytical areas.

So whilst the UK currently 'punches well above its weight', the wealth of measurement challenges means European and international partnerships are becoming ever more important to ensure differentiated, but complementary, measurement offerings between NMIs.

100 YEARS OF NUCLEAR PHYSICS

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Today the model of an atom with electrons orbiting a central nucleus consisting of protons and neutrons is familiar to many of us and is taught as part of the GCSE science curriculum. One hundred years ago our understanding of the atom was very limited. Based on experiments conducted at The University of Manchester, Ernest Rutherford announced his theory of orbiting electrons and a central nucleus at the March 1911 meeting of the Manchester Literary and Philosophical Society and then published a paper in the May edition of the Philosophical Magazine.

Significant evidence for the Rutherford Model of the atom came from experiments directed by Rutherford and conducted by Hans Geiger and Ernest Marsden. The most famous of these experiments is the alpha scattering experiment where alpha particles (helium nuclei) were fired at thin foils of various metals, including gold. Geiger and Marsden were instructed to use a scintillator to observe the scattering of the alpha particles at various angles around the target. If the prevailing model of the atom (Thomson's plum pudding model with negatively charged electrons dispersed through a central positively charged mass) was correct then some alpha particles, which are positively charged, would be deviated slightly off their incident line.

Slightly deviated alpha particles were duly observed but then Rutherford instructed Marsden to look for any back scattering, ie alpha particles bouncing backwards. Marsden observed a small percentage being scattered backwards, which led to the famous quote from Ernest Rutherford that "It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you." To explain these results Rutherford proposed that the electrons must be orbiting around a central nucleus which contains most of the mass and is positively charged. This is still the basis of our understanding of the nucleus. For hydrogen 99.9% of the mass of the atom in in the nucleus and the sole electron orbits at a distance equivalent to 100,000 times the diameter of the sole proton.

Due to this remarkable insight Rutherford is known as the Father of Nuclear Physics and our understanding of the nucleus, developed from these initial experiments, over the last 100 years has led to some spectacular achievements. Understanding the nucleus allows us to understand phenomena such as radiation and nuclear fission and develop technologies that are beneficial. X-rays were discovered before Rutherford's experiments but his description of the nucleus shows how electrons moving between energy states, or different orbital sizes and shapes, releases the energy. In the nucleus itself the emission of alpha particles (helium nuclei with two protons and two neutrons), beta particles (electrons) or gamma rays is the basis of many everyday technologies such as smoke detectors and the specialist equipment used for medical diagnostics techniques, for example PET (Positron Emission Tomography) Scanners. Radiation is also used in medicine as a therapy in procedures such as cancer treatment.

Another way we have learned to harness the energy within the nucleus is to provide electricity through nuclear fission and in the future through nuclear fusion. The UK is currently undergoing a nuclear renaissance with new reactors due to come online before the end of this decade. This is replicated throughout the world. For example, the United States is preparing to build its first reactor since the 1970s; the United Arab Emirates have ordered reactors from Korea; Vietnam has two reactors on order from Russia and many other countries around the world are either considering renewing their nuclear reactor fleet or building reactors for the first time in their history. New detector technology is also helping us decommission our existing fleet of nuclear reactors in a safe, efficient and cost effective manner.

After 100 years of nuclear physics research we have a much more detailed model of the nucleus but the essence of the Rutherford model with a nucleus and orbiting electrons is still at its core. If he could visit The University of Manchester today he would still see a thriving School of Physics and Astronomy, and a dedicated team of nuclear physicists continuing to probe the nucleus and attempting to reveal more of its secrets. Although the UK no longer has a nuclear structure research accelerator, its nuclear physicists are still advancing this fundamental science at international facilities in France, Switzerland, Finland, Germany and the United States.

SHALE GAS – A HOME-GROWN SOURCE OF ENERGY AND FUEL

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Mike Stephenson publishes with the permission of the Director of the BGS (NERC)

Shale – usually thought of by geologists as a rather boring, uninteresting rock – might be an important source of methane gas for power and fuel in Britain into the future.

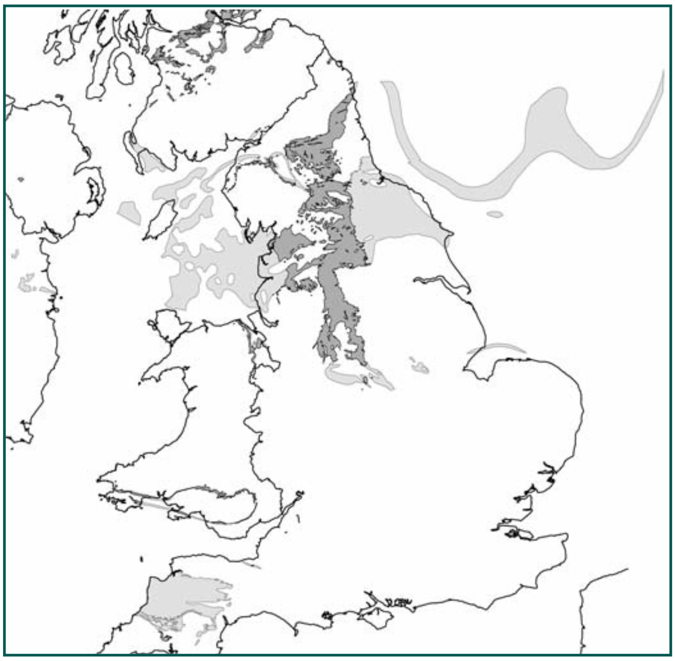
Shale is the most common sedimentary rock, and Britain has a lot of it – in northern England, the Midlands, Wales and southern England. It's a soft rock so often isn't seen at the surface, though it underlies much of the country. The British Geological Survey (BGS) has just finished an assessment of the amount of shale gas that might be present in these areas and has come up with some impressive figures[1]. The shale of the millstone grit rock sequence alone, for example, may contain 4.7 trillion cubic feet (TCF) of shale gas, which is about half of Britain's estimated reserves of more 'conventional' natural gas.

There is so much interest in shale gas that the last few years have been known as the 'dash for gas'. In the United States where much of the technology for shale gas extraction was developed, shale gas production has been a great success story. In 1996, shale gas wells in the US produced 0.3 TCF – only 1.6% of US gas production; but by 2006 production had more than tripled to 1.1 TCF per year, 5.9% of US gas production. One recent study has suggested that natural gas will provide 40% of America's energy needs in the future, from 20% today, thanks in part to abundant shale gas. Many people welcome shale gas particularly because of the increasing security of supply it brings, helping to make the US independent of energy producers in Russia and the Middle East.

The key to getting the gas out is hydraulic fracturing (also called 'fracking' or 'fraccing'). This technique, developed in the US, involves pumping high pressure water (or nitrogen) into the shale to crack it and release the gas. A simple well without fracking will not release much gas. The shale itself is very rich in organic matter from deposition in ancient seas and rivers, but the gas which is generated from the organic matter, can't move easily in the rock because it is so fine grained and impermeable. So fracking is generally essential.

The shale gas business is not so well-developed in Britain. There is only one shale gas well – near Blackpool – drilled by the American company Cuadrilla and there is no gas production yet. However, as the BGS study suggests, there might be shale gas over wide areas of Britain just waiting to be drilled.

The millstone grit is perhaps the best prospect. The millstone grit itself – famous for the millstones of the Peak District – is a sandstone, but between the layers of sandstone are layers of shale. One of these shale layers has been targeted by Cuadrilla. Another area is the Jurassic shale of the Weald and Wessex in the south of England. The BGS estimates that the onshore



Distribution of millstone grit in Britain