Urey Medallist Lecture
In Praise of Idleness

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My title comes from a collection of essays by Bertrand Russell[1] but is actually intended as an oblique reference to the noble gases and in particular argon (Greek argos = idle). Study of the noble gases, often in conjunction with neutron irradiations which yield noble gas products, has an important place in isotope geochemistry and, for the main thread of my talk, in cosmochemistry.

Noble gases are playing a part in advancing our knowledge in several important problem areas in cosmochemistry; the details of heavy element synthesis and of processes in the interstellar medium from a study of interstellar grains; the time scale of solar system formation and the reconciliation with astrophysical models; the search for evidence of early solar activity (particle irradiation, stellar outflows) from isotopic effects in the earliest formed solids; the history of water in the solar system; the evolution of the martian interior and atmosphere; the evolution of life on Earth and the search for life elsewhere; the history of impacts on the Earth and their implications for the future.

These problems demand the development of new techniques directed to the ultimate analytical goal of isotope geochemistry, the detection of each and every atom of each isotope in the sample, free from blank contamination, with a spatial resolution limited only by the need to obtain appropriate counting statistics. This goal is being approached for several elements including the noble gas xenon. Using resonance ionisation it is now possible to determine I-Xe age profiles in a manner similar to the Ar-Ar laser probe. With detection limits of a few tens of atoms of Xe it should soon be possible to determine the nucleosynthetic structures of Xe in individual pre-solar SiC grains. Although dominated by s-process xenon, SiC contains an r-process component which is distinct from that in the solar system. The so called xenon-HL component was used in the isolation of nano-diamonds but the extent to which these are really pre-solar is still not clear. Xenon, present in only one nano-diamond in a million, cannot resolve this question and techniques need to be developed to manipulate, atomise and ionise all the atoms in individual nano-diamonds to search for non-solar system carbon isotope ratios. As with the Apollo programme, it is likely that the new generation of extraterrestrial sample return missions will stimulate a new range of technical advances. The 'atom counter' for elements across the periodic table may not be far away

After decades of uncertainty, significant advances have been made in recent years in obtaining I-Xe ages which are both accurate and meaningful. This has come about partly through the use of separated minerals and partly through a better understanding of the factors affecting I-Xe systematics. The possible mobilisation of 'dead' iodine and/or 'parentless' ^{129}Xe leads to subtle differences in comparison with K-Ar systematics. I-Xe ages can be related to chondrule formation, presumed by many to be a primary nebular processes. In the equilibrated meteorites I-Xe ages provide a time scale of secondary recrystallisation and in particular, the growth of secondary feldspar and apatite. The formation times of the refractory CAI are not susceptible to I-Xe dating. In general I-Xe ages of these complex objects reflect later alteration and the formation of secondary minerals such as sodalite. Most recently I-Xe ages of microgram crystals of halite containing aqueous fluid inclusions have demonstrated the presence of liquid water on proto-planetary bodies within a few million years of formation of the solar system. Time scales based on short-lived 'extinct' isotopes are relative but significant progress has been made in linking these relative time frames of I-Xe, Al-Mg and Mn-Cr to each other and to the absolute U-Pb scale. The picture which emerges is of chondrule formation, early igneous activity, aqueous and other alteration processes overlapping in the first 5-10 Ma, and postdating the earliest formation of CAI by no more than 2 Ma.

A spin off from advances in I-Xe dating is the ability to measure iodine abundances at sub ppb levels in microgram samples, while stepped heating permits the separation of in-situ iodine from surface contamination. In the Earth's crust iodine is concentrated predominantly in sediments as a result of biochemical processes. The ability to measure iodine distribution at a microscopic level promises a way of investigating the evolution of iodine biochemistry and more generally of early life. If iodine biochemistry is a feature of extraterrestrial life it may be a potential biomarker.

The major technical advances in Ar-Ar dating have been in the use of laser ablation, to reduce blank levels and hence sample size and minimum sample age, and in the ubiquitous computer automation. However, in contrast to xenon (and krypton), the underlying mass spectrometry techniques have changed little in 40 years. That may be about to change with the development of the compressor ion source and the first multi-collector noble gas instrument. Neutron reactions on the halogens have proved to be a useful extension of the Ar-Ar methodology where noble gases are associated with saline fluids, in samples as diverse as diamonds and ore minerals. Neutron reactions on tellurium, producing ^{131}Xe, are also providing a method for dating telluride ores based on the 10^{20}yr double β-decay half life of ^{130}Te.

An intriguing puzzle, which dates back almost forty years to the very earliest Ar-Ar work, is the significance of the clustering of outgassing ages of the common L-chondrites at around 400 to 500 Ma. The heating required to produce widespread Ar loss in a high proportion of L-chondrites seems to require the break-up of a major asteroidal body with whatever that may have entailed for the recent bombardment history of the Earth!

[1]Russell B. (1935) In Praise of Idleness and Other Essays, Unwin Books, London, 144p