Doing Chemistry with Muons

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Outline

- Muons in materials
- Why do chemistry with muons?
- What we might learn?
- Examples
Muons in materials

$\mu^+$

Diamagnetic
(bare positive muon)

Muonium, paramagnetic
(bound muon and electron)

States formed by fraction of muons on implantation
States often coexist
Why do chemistry with Muonium?

- Chemically equivalent to H-atom
  (similar Bohr radius, ionisation energy and reduced mass)
- Greatly extends isotopic mass comparison
  \( \frac{m_{\mu}}{m_H} \sim \frac{1}{9}; \frac{m_{\mu}}{m_D} \sim \frac{1}{18} \)
- High sensitivity … measurements in extreme dilution
  (we’re detecting the muon decay positron)
Chemically equivalent to H-atom …

Mu with undergo the same reactions as an H-atom …

Addition: Mu + R₂C=CH₂ → R₂ĊCH₂Mu

Abstraction: Mu + RX → MuX + R·

Radical Combin.: Mu + ·OH → MuOH

E- transfer: Mu + Xⁿ⁺ → µ⁺ + Xⁿ⁻¹⁺

...
Hyperfine coupling (hfc), $A_\mu$ and $A_p$, makes for an extremely sensitive probe species.
What we might learn?

Study atoms and molecules containing muons

- Reaction Rates
- Molecular structure
- Molecular dynamics
- Molecular environment
Reaction Kinetics …

Reaction rate constants, $k_{Mu}$, Activation energy, $E_a$, can be investigated …

Example: formation of cyclohexadienyl radical

Isotope effects seen both in $k_{Mu}$ and in $E_a$

Molecular Structure …

Muon Avoided Level Crossing allows investigation of unpaired spin density across the $\text{C}_{60}$ molecule …

Molecular Dynamics …

The dynamics of molecules tagged with a muon (in this case Benzene in a zeolite cage) can be investigated …

Line shape reflects mode of reorientation

Molecular Environment …

Solvent effects can be investigated. In this case Benzene in dilute aqueous solutions has been studied …

Signal shift defines shift in hyperfine parameters

Iain McKenzie will be talking about all this (and a great deal more) during his lectures on *Saturday morning*