Nuclear Magnetic Resonance (NMR)

• Simplistic theory, certain atomic nuclei act as tiny magnets and align in magnetic fields.

Applied Field

Nuclei

More realistically nuclei PRECESS about field.

• Energy ($\Delta E$) required to flip nuclei is:-

$$\Delta E = h \cdot \omega_o = 2\mu \cdot H_o$$

Precession Frequency
Magnetic Moment
Applied Field Strength
• Supply energy to nuclei by irradiating with electromagnetic radiation of frequency $\nu$. Then at some value of applied field strength ($H_0$), nuclei will adsorb energy ($h\nu$) and flip.

$h\nu = \Delta E = 2H_0\mu$
Isolated proton will flip if 
$H_0 = 9,400$ gauss; 
$\nu = 40$ MC/s 
Single energy adsorption 
spike.

With a pair of protons $H_0$ 
is affected by the other 
proton ($H_0 \pm \Delta H$) 
2 possible adsorption 
energies.
With many protons there are many possible interactions.

Many possible adsorption energies.

- Because of instrumental factors only see the derivative curve for NMR.
• Broad adsorption from stationary protons;
  – crystals or glass.

• At liquid-like speeds proton positions 'average out';
  so all protons experience the same environment.
  – Narrow adsorption peaks for mobile protons
    including polymer melts or amorphous polymeric
    material above Tg.

• For semicrystalline polymers
  – broad signal from fixed protons in the crystal,
  – narrow signal from mobile protons in the
    amorphous phase. (Tg < T < Tm)
• Area under curve proportional to number of protons involved in the process. Measure number of protons in crystal and amorphous regions – % crystallinity.

• Sometimes these curves are separated into three components:-
  Stationary – nuclei in the crystal.
  Liquid like – nuclei in cilia and loose loops.
  Semi-rigid – nuclei in tight folds or at the crystal-fold interface.

<table>
<thead>
<tr>
<th>Samples</th>
<th>NMR crystallinity</th>
<th>Other Methods</th>
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<tbody>
<tr>
<td></td>
<td>2 phase</td>
<td>3 phase</td>
</tr>
<tr>
<td>A</td>
<td>97</td>
<td>91</td>
</tr>
<tr>
<td>B</td>
<td>93</td>
<td>85</td>
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<tr>
<td>C</td>
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<tr>
<td>D</td>
<td>97</td>
<td>89</td>
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