

POSSIBLE BIOLOGICAL EFFECTS OF WEAK STATIC AND HIGH FREQUENCY MAGNETIC FIELDS

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Examination of the effects of low static magnetic fields and rf- exposure
on biochemical reactions by *the radical pair mechanism*,
the only known potentially active mechanism.

Background knowledge

It is well known

- ▶ that chemical reactions in liquids and micelles depends on magnetic fields.
- ▶ that this effect requires an intermediate radical pair step
- ▶ that model calculations agree with experimental result
- ▶ that biochemical/biological reactions contain radical steps

- ▶ We have a long traditions for such calculations
- ▶ Theoretical results are more accurate and much easier to obtain than experimental ones

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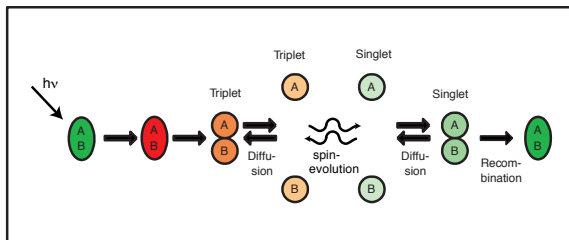
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Radicals are very reactive species

- ▶ that can react with other radicals to produce unreactive molecules
- ▶ can react with molecules to produce other radicals

An increased or decreased production of radicals may disturb the natural balance.

The radical pair mechanism



is a **quantum mechanical, non-thermal mechanism**, that requires

- ▶ a magnetic interaction: hyperfine, Zeeman (static and rf-fields)
- ▶ that the radicals separate and later recombine
- ▶ that the time scale of the different processes match

The effect of weak rf-fields

- ▶ is to induce transitions between non-degenerate states where the transition frequency equals the rf-frequency
- ▶ in zero static magnetic field (for a nuclear spin $\frac{1}{2}$),
the rf-frequency must be equal to the hyperfine constant.

Orders of magnitude

$B_0 \approx 50 \mu\text{T}$; the earth magnetic field

$B_1 \approx 1-23 \mu\text{T}$ for a mobile phone, i.e. $B_1 \ll B_0$

$f = 850, 900, 1800, 2100$ MHz for mobile phones

$A \in [0.1, 53]$ mT $\approx 3 - 1600$ MHz; *hyperfine constant*

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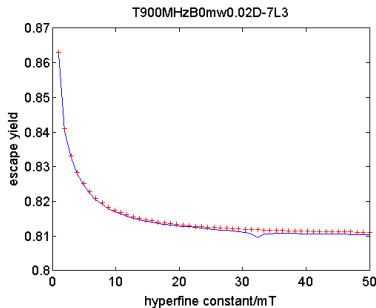
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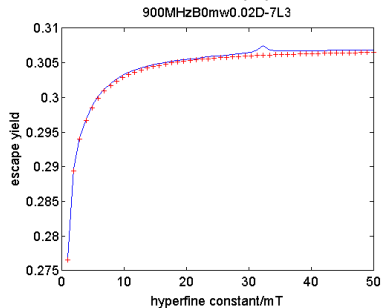
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Solvent reactions, 900 MHz

The escape yield of a radical pair with a reactive singlet (S) state



Triplet initially

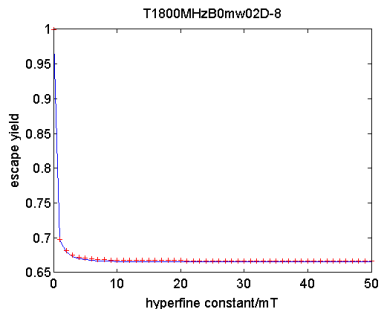
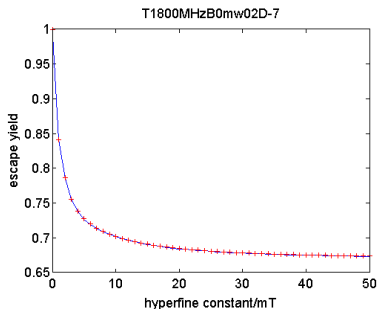


Singlet initially

Conclusion: **No effect of rf-fields from mobile phones!**

Diffusion controlled reactions, 1800 MHz

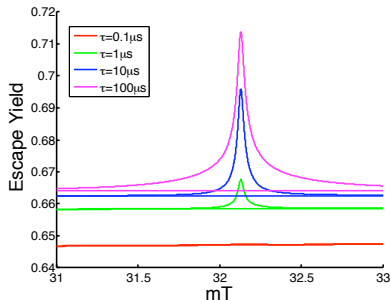
$$D = 10^{-7} \text{ and } 10^{-8} \text{ cm}^2/\text{s}$$



Normal liquids have $D \approx 10^{-5} \text{ cm}^2/\text{s}$, and **an even smaller effect.**

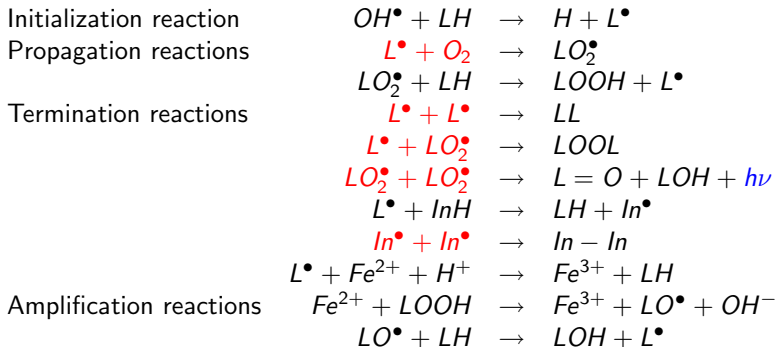
Membrane reactions, $D=10^{-8}\text{cm}^2/\text{s}$, $f = 900\text{ MHz}$

τ is the lifetime of the radical pair.



There can be a non-negligible effect, but only for radicals with a long lifetime. The dangerous radicals have short relaxation times so there is **no effect**.

Lipid destruction by radicals¹



Red reactions depend on magnetic fields !

Amplification can enhance effect, but resonance condition is not satisfied!

¹Doktorov, Lukzen, and Pedersen, in preparation

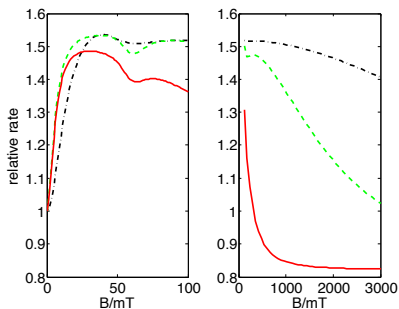
Magnetic effects on ATP synthesis in mitochondria

- ▶ A huge magnetic isotope effect (factor of 3) has been observed for Mg for the enzymatic phosphorylation²
- ▶ We showed that this could be explained quantitatively as due to the very large hyperfine constant (21 mT \approx 700 MHz) of $^{25}\text{Mg}^+$
- ▶ We predicted that the rate would be affected by a small static magnetic field³ (\approx 100 mT); this has recently been experimentally confirmed.
- ▶ Our recent calculations of the effects from mobile phones show negligible effect.

²Buchachenko *et al*, Proc. Nat. Acad. Sci., USA, CCB, 48, (2005), 886-894.

³Buchachenko, Lukzen and Pedersen, Chem Phys Lett, 434 (2007) 139-143.

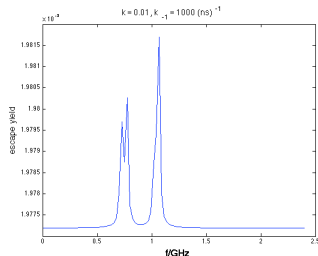
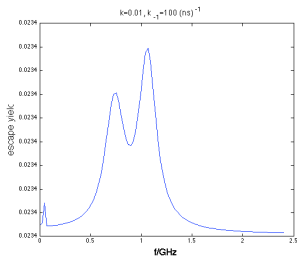
The rate is affected by static magnetic fields⁴



- ▶ different colors corresponds to different parameter values of the forward and backward electron transfer rates (k and k_{-1}).
- ▶ these predictions have recently been experimentally confirmed.

⁴Buchachenko, Lukzen and Pedersen, Chem Phys Lett, 434 (2007) 139-143.

The dependence of the rate of ATP production on the frequency of the rf-magnetic field



- ▶ results for two sets of values of the forward and backward electron transfer rates; field strength is that of a cell phone.
- ▶ the effect of the rf-field is 0.1 % or smaller!

Summary of effects of rf-fields from mobile phones

Normal solvents. **No effect of rf-fields** are found.

Membrane reactions Measurable effects might be found for radicals with long lifetimes and very large hyperfine constants.

No reactions satisfying these conditions are known.

The lipid peroxidation (and similar chain reactions) might show an effect due to the existence of a trigger (critical) point, the position of which is still unknown. However, the involved hyperfine constants **do not satisfy the resonance condition.**

Enzymatic reactions often contain radicals with large hyperfine constants and thus may be affected. The reactions are cyclic so no net production of radicals are involved. Instead, an increase or decrease of the enzymatic activity result. Our calculations show **no effects** from cell phone radiation on the rate of ATP production.

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