Oxidation of Organic Contaminants on Nanoparticulate Zero-Valent Iron

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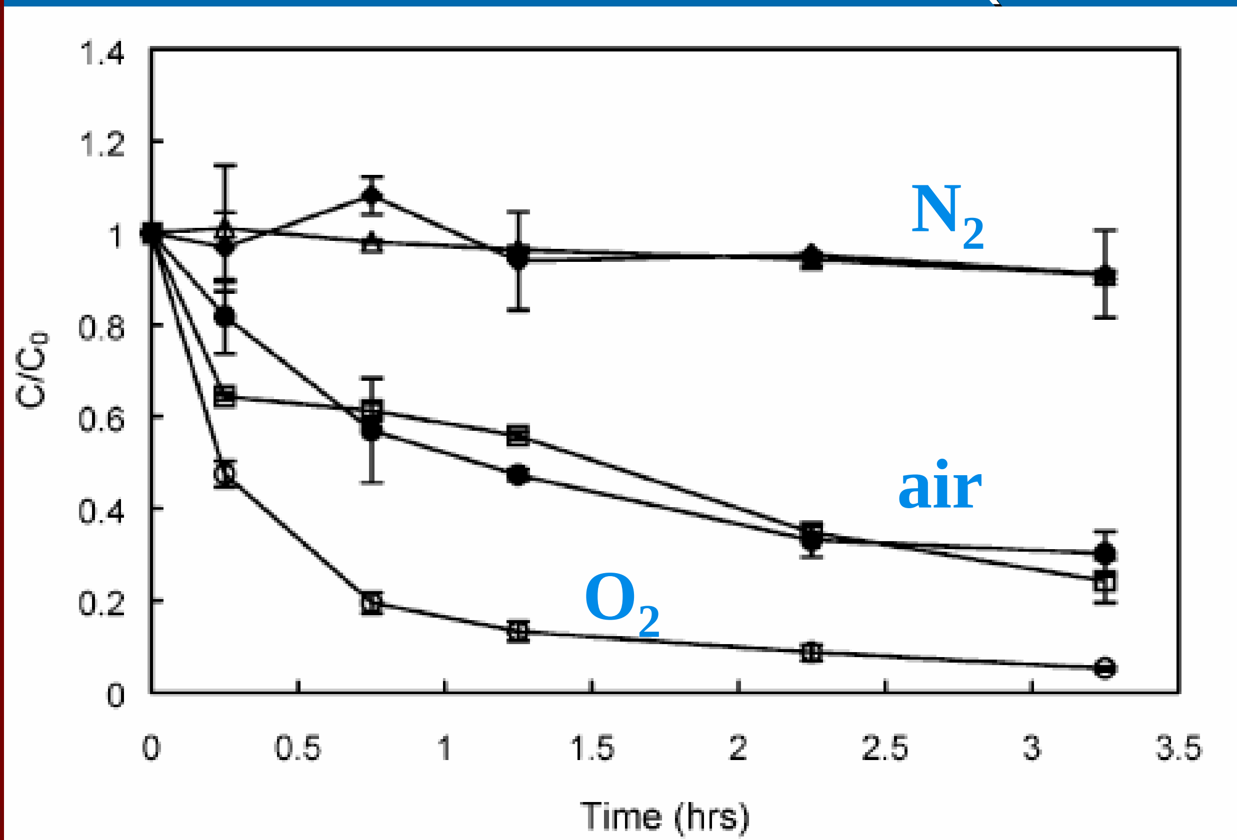
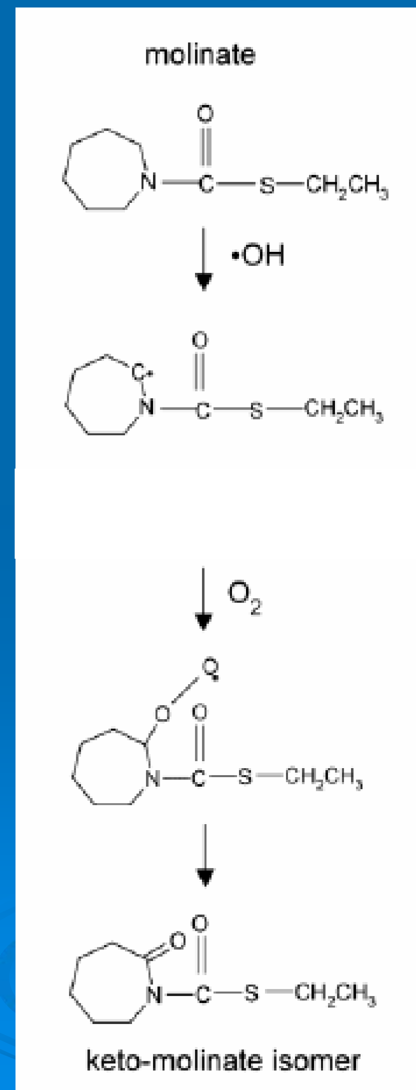
Zero-Valent Iron (ZVI) Applications

- Permeable reactive barriers
  - Reduction of halogenated organics
  - Sequestration of metals
- Iron nanoparticles
  - In situ remediation (Zhang, Tratnyek et al.)
  - Oxygen is undesireable

Oxidative ZVI Reactions

- Molinate transformation (Joo et al. 2004)

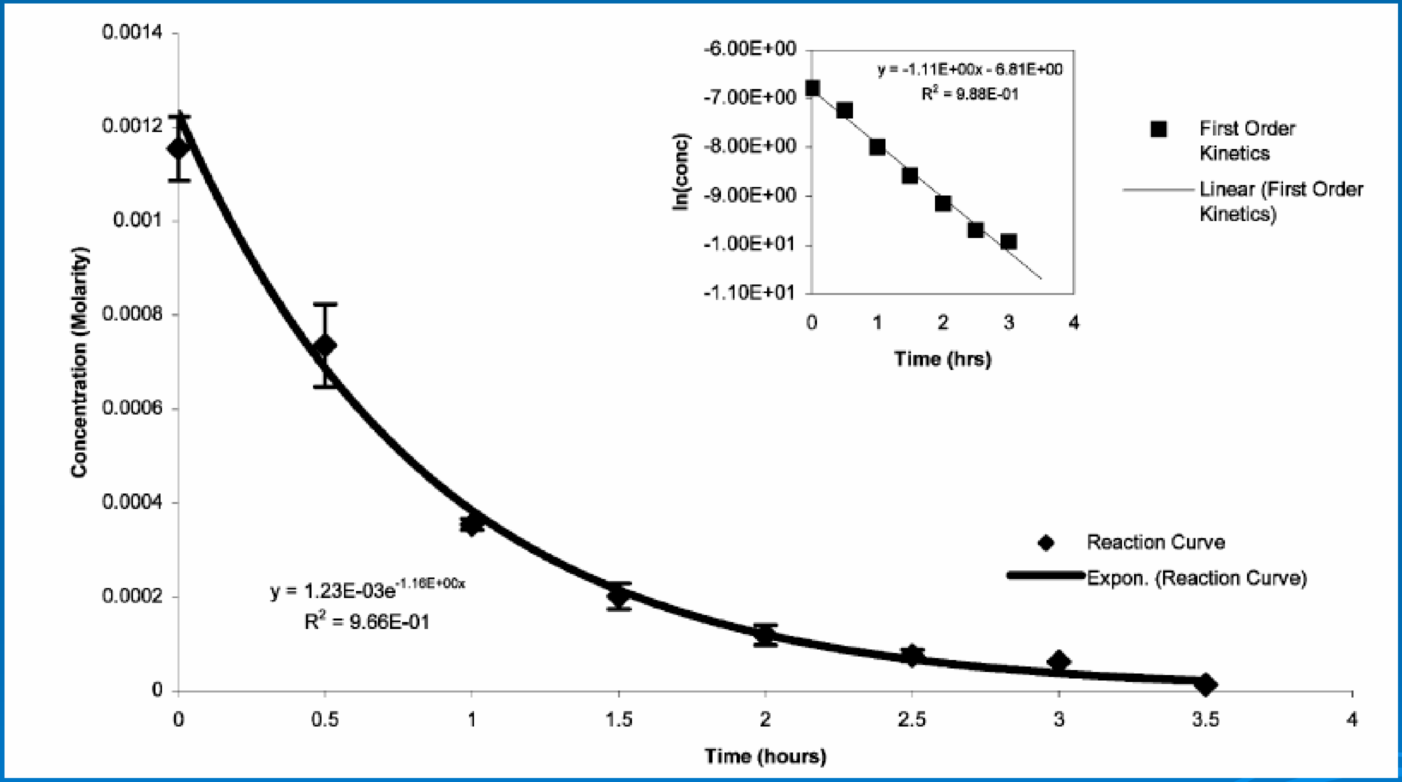




[molinate]=0.2 mg/L
[nZVI] = 560 mg/L; pH 4

Oxidative ZVI: Granular Fe

- Chlorophenol transformation (Noradoun et al. 2003)



[Chlorophenol]=0.14 g/L
[ZVI] = 50 g/L; 0.32 mM EDTA

Questions

- How does oxidative ZVI work?
- How efficient is it?
- What are the potential applications?

Oxygen Activation by ZVI

- 4 e^- pathway

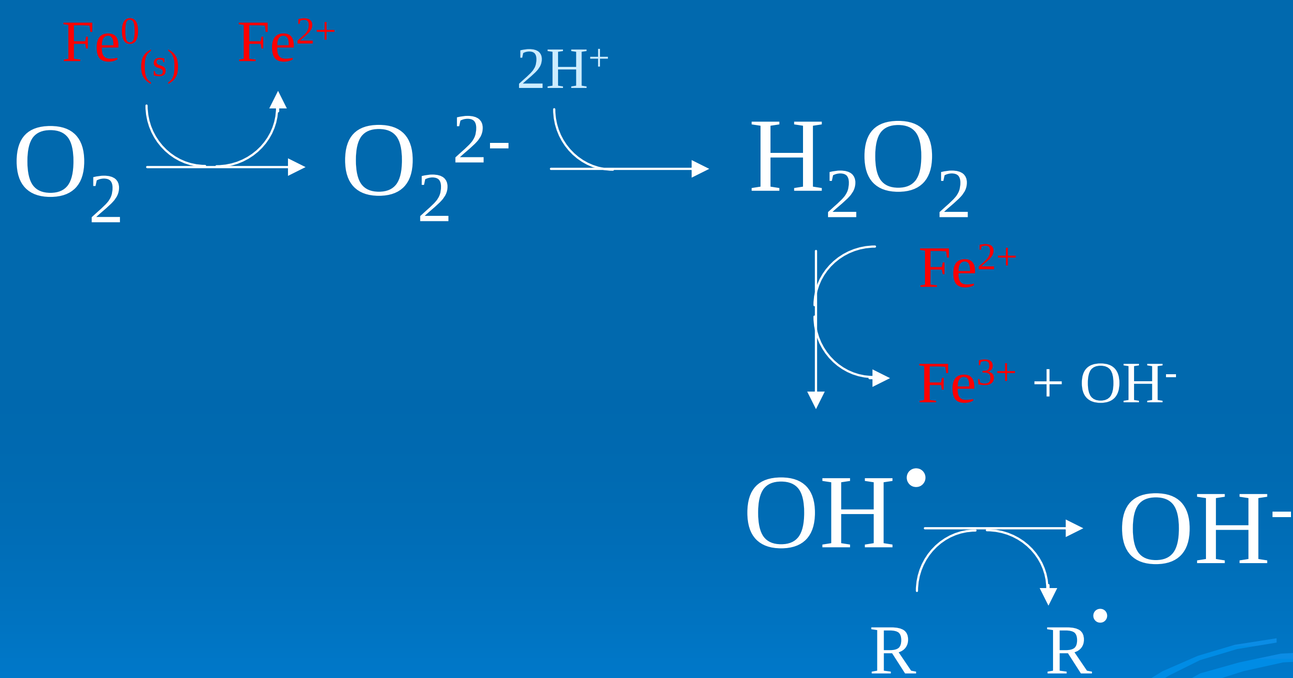
$$O_2 \xrightarrow[]{Fe^0_{(s)} \rightarrow Fe^{2+}} O_2^{2-} \xrightarrow[]{2H^+} H_2O_2 \xrightarrow[]{2H^+ + Fe^0_{(s)} \rightarrow Fe^{2+}} 2\,H_2O$$

Overall:

$$O_2 + 2\,Fe^0_{(s)} + 4\,H^+ \longrightarrow 2\,H_2O + 2\,Fe^{2+}$$

Oxygen Activation by ZVI

- 2 e^- pathway

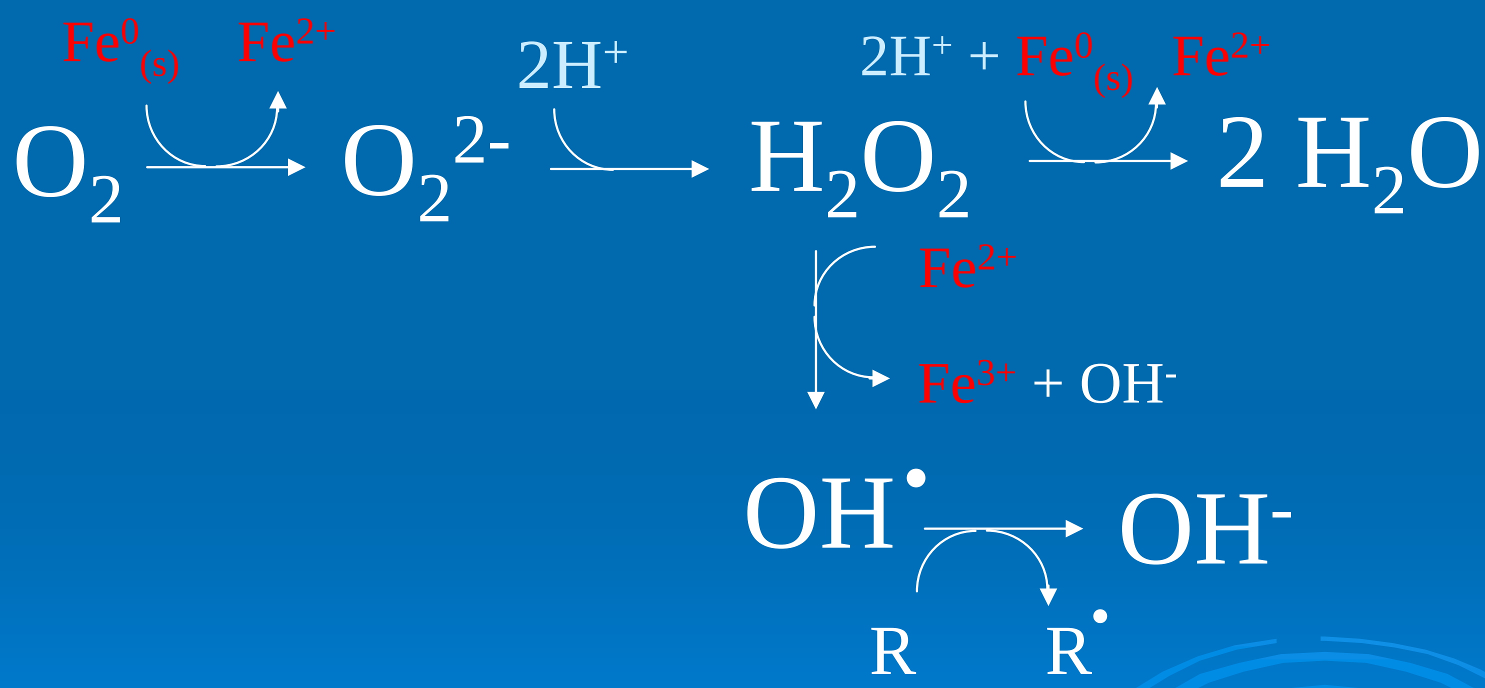


Overall:

$O_2 + Fe^0_{(s)} + 2\,H^+ + R \longrightarrow 2\,OH^- + Fe^{3+} + R^\bullet$

Oxygen Activation by ZVI

- Efficiency determined by branching ratio



Oxygen Activation by ZVI

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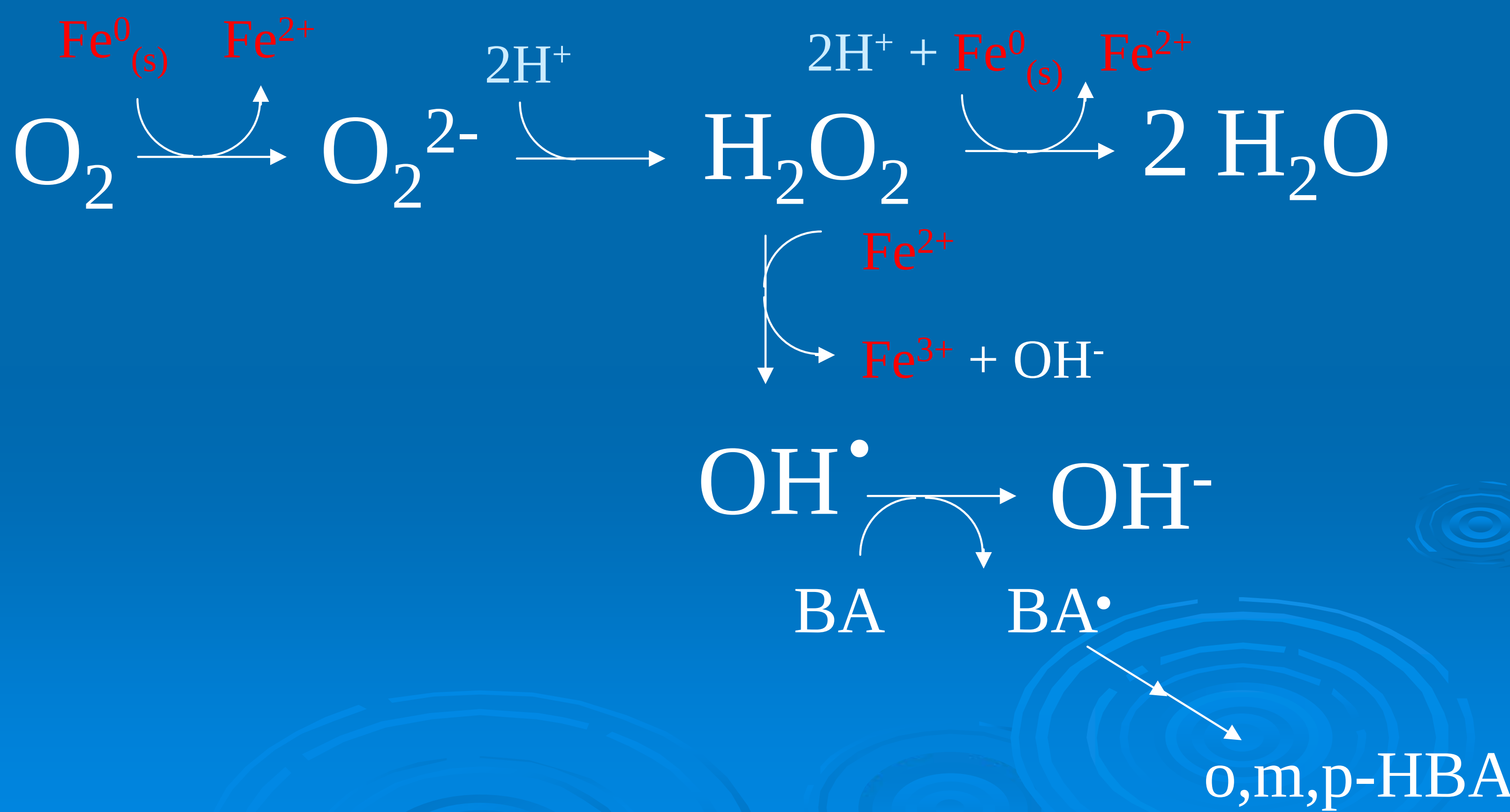
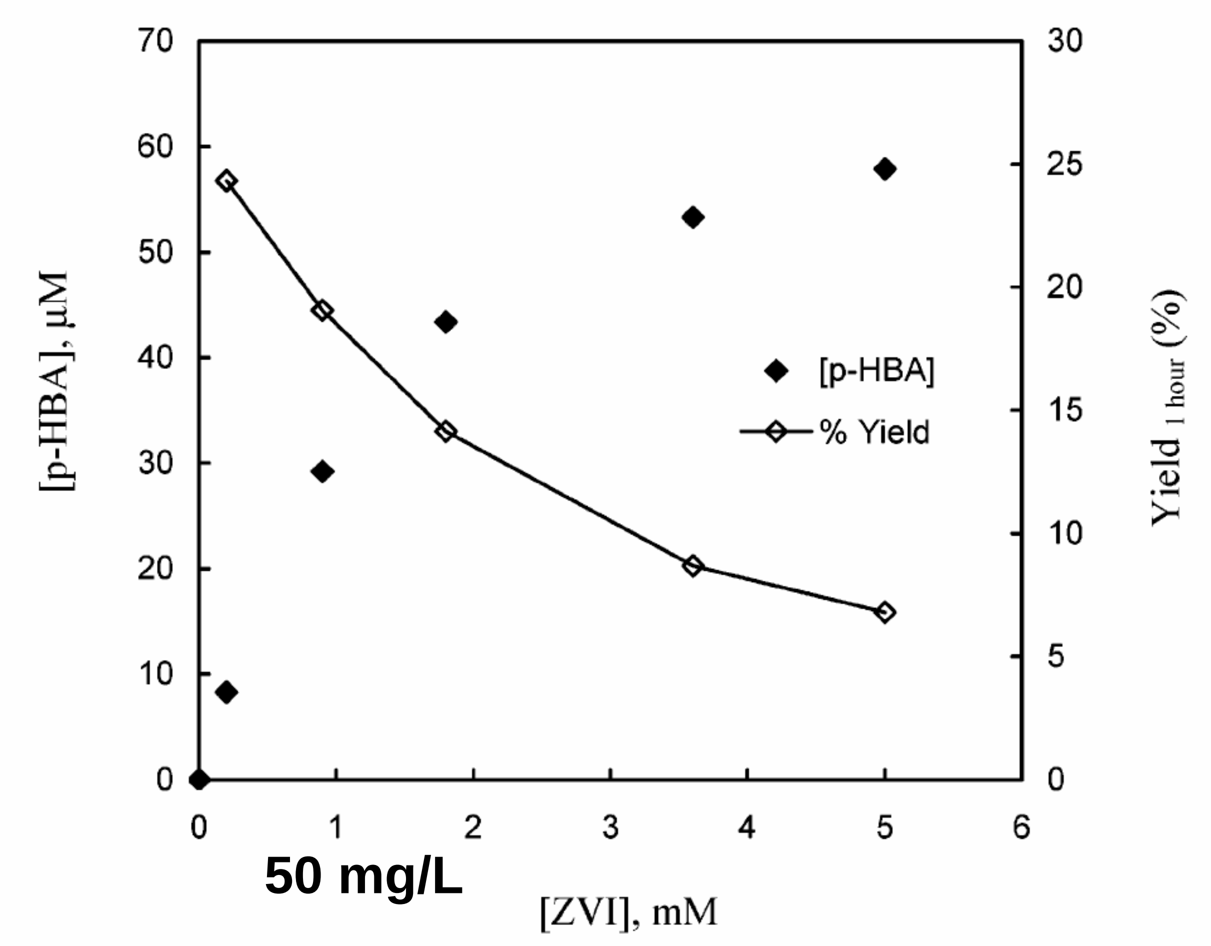


Benzoic Acid Experiments

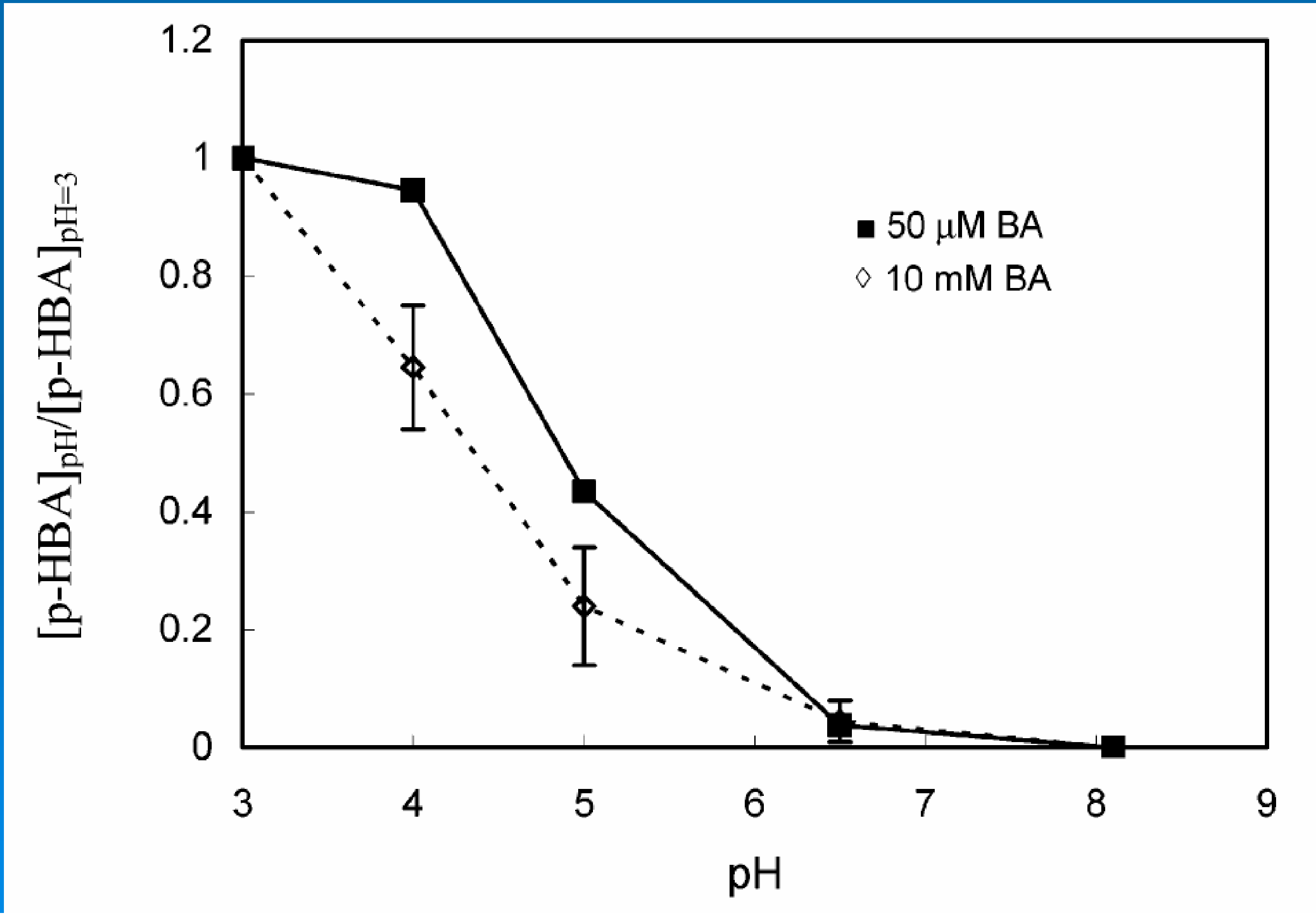
- Yields 5-25% (Joo et al. 2005)



pH = 3
[BA] = 10 mM

Effect of pH

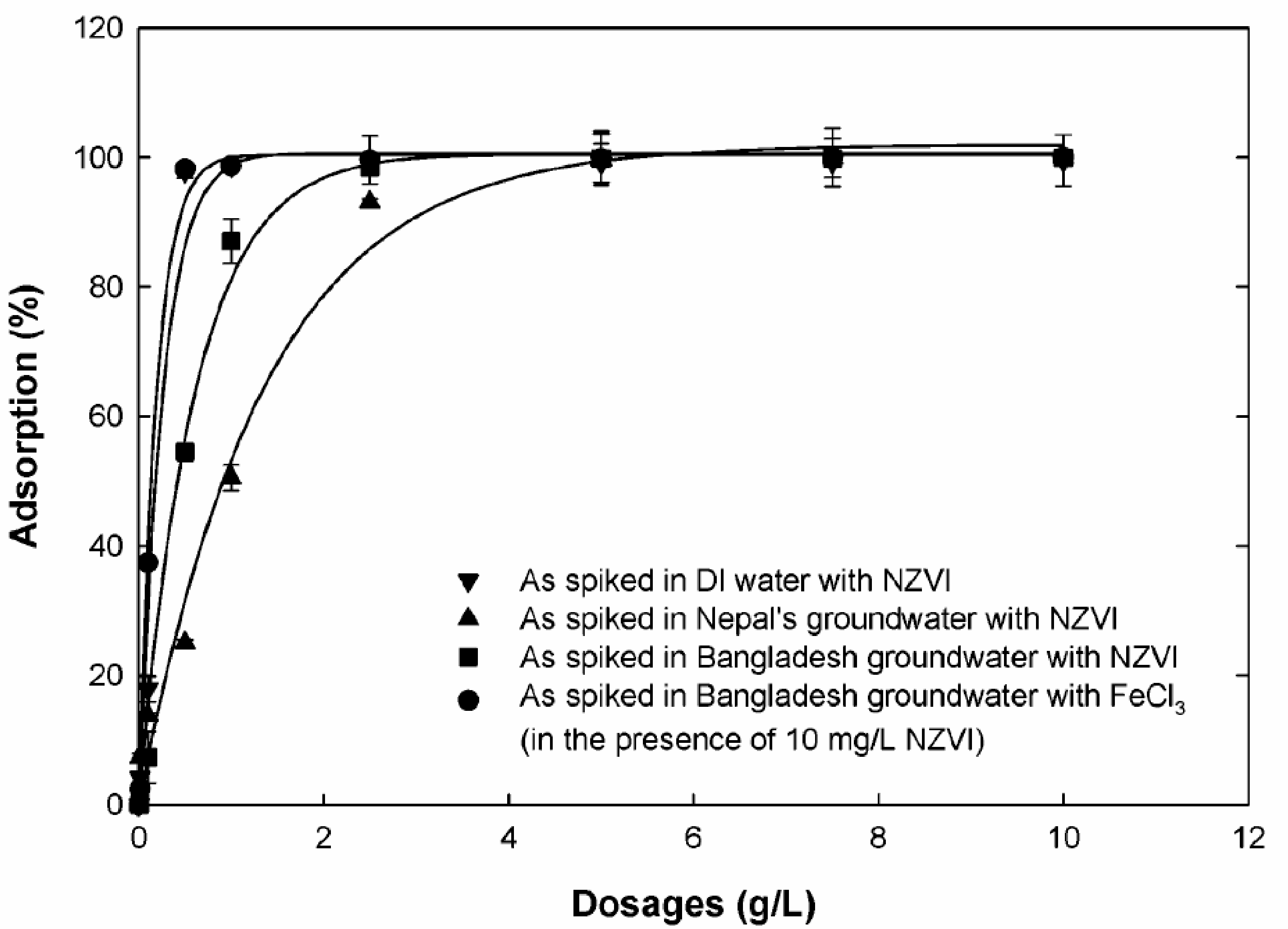
- pH slows corrosion processes
- efficiency at high pH unknown



50 mg/L nZVI
1 hr reaction

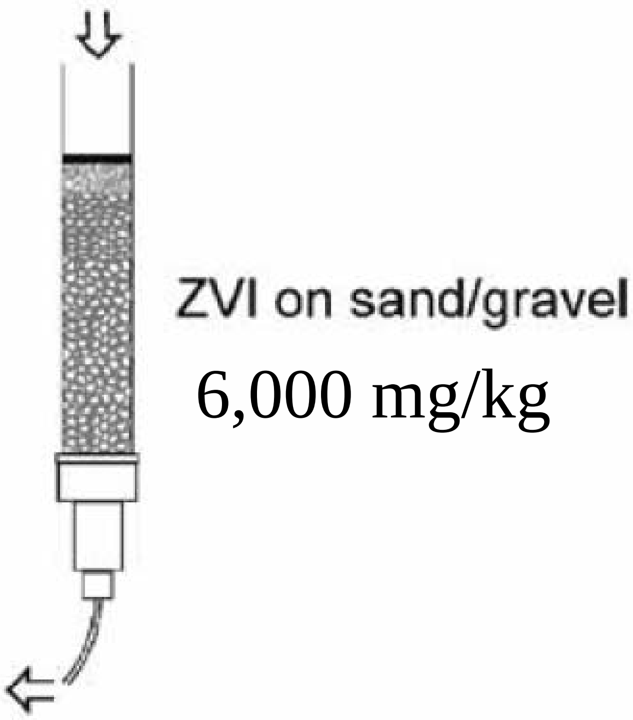
Potential nZVI Applications

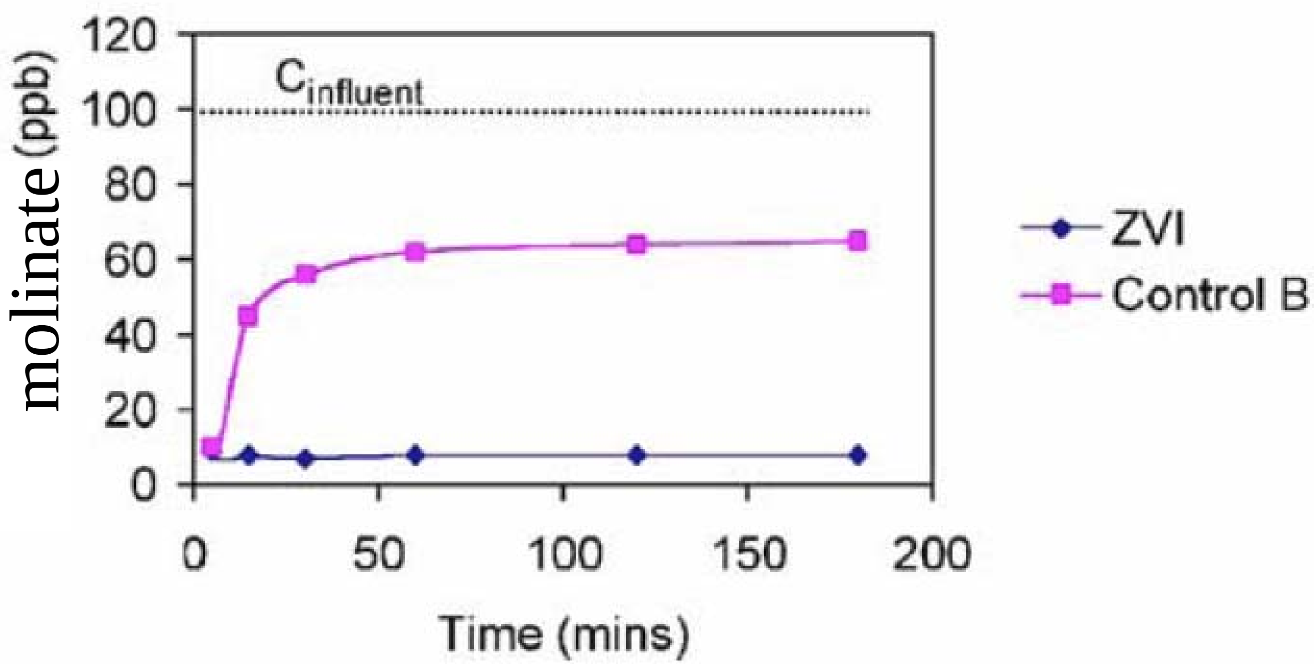
As(III) removal (Kanel et al. 2005)



Potential nZVI Applications

Treatment of runoff (Feitz et al. 2005)





Potential nZVI Applications

- Treatment of dilute plume (e.g., MTBE, 1,4-dioxane)

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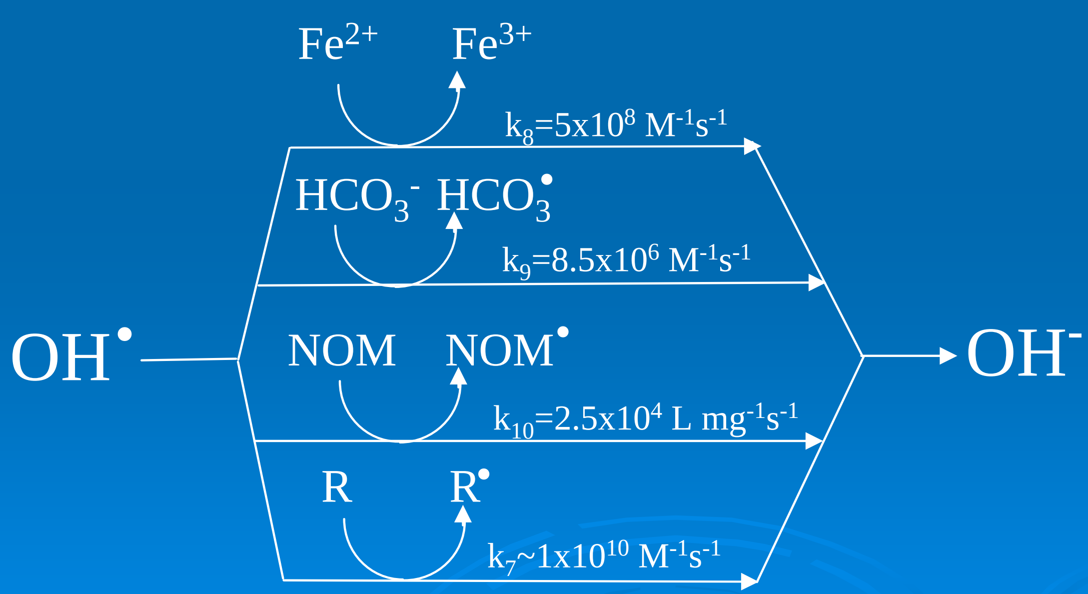
  - $\Delta[O_2] = 0.25$ mM
  - 20% yield (2 e^- pathway) = 50 μM $OH^\bullet$

Potential nZVI Applications

- Treatment of dilute plume (e.g., MTBE, 1,4-dioxane)
  - $\Delta[O_2] = 0.25$ mM
  - 20% yield (2 e^- pathway) = 50 μM $OH^{\bullet}$
  - $OH^{\bullet}$ scavengers: 0.1 mM Fe(II), 1 mM HCO_3^-, 2 mg/L NOM, 1 μM R
  - ~8% of $OH^{\bullet}$ to R (4 μM)



Conclusions

- OH formed by nZVI reactions with O_2
- Efficiency depends on pathway
- Preliminary results suggest applications
  - As(III) removal
  - Runoff/soil treatment
  - Dilute groundwater plumes

References

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Joo SH, Feitz AJ, Sedlak DL, Waite TD (2005) Quantification of the oxidizing capacity of nanoparticulate zero-valent iron. *Environ. Sci. Technol.*, 39, 1263-1268.

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Kanel SR, Manning B, Charlet L, Choi H (2005) Removal of arsenic(III) from groundwater by nanoscale zero-valent iron. *Environ. Sci. Technol* 39 (5): 1291-1298.

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