H₂ production by anoxygenic purple nonsulfur bacteria

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Purple non-sulfur bacteria produce $\text{H}_2$ via nitrogenase

**Chemical Reaction:**

$$\text{N}_2 + 8\text{H}^+ + 8\text{e}^- + 16\text{ATP} \rightarrow \text{H}_2 + 2\text{NH}_4^+$$

$$8\text{H}^+ + 8\text{e}^- + 16\text{ATP} \rightarrow 4\text{H}_2$$

This is mode of photosynthesis does not produce oxygen
Current state of the technology

• \( \text{H}_2 \) yields
  – Growing: 10 – 25% of theoretical maximum
  – Non-growing: 40 – 91% of theoretical maximum

• \( \text{H}_2 \) production rates
  – 10 – 82.5 ml \( \text{H}_2 \) L\(^{-1}\) h\(^{-1}\)
  – 67 ml \( \text{H}_2 \) L\(^{-1}\) h\(^{-1}\) over 4000 h
    • Immobilized in 70 \( \mu \text{m} \)-thick latex film.

• Photosynthetic efficiency: 1 – 2%

Summary of barriers and important developments

• Inhibition of H₂ production by NH₄⁺
  – Bypassed using *nifA* and DraT mutations

• Other pathways that compete against H₂ production for electrons
  – e.g., Calvin cycle identified and eliminated
    (Wang et al. 2010 Int J H2 Energ 35: 7377-85, McKinlay and Harwood 2011 mBio 2)

• Biosynthesis efficiently competes against H₂ production
  – Understanding of non-growing cells that produce highest H₂ yields is improving
Summary of barriers and important developments

• Light penetration into cultures
  – Improved using pigment-defective strains  
    (Gosse et al. 2007. Biotechnol. Prog. 23: 124-30)
  – Novel bioreactor designs  (Posten 2009 Eng Life Sci 9:165-77)

• Integration with ‘waste’ feedstock streams
  – Consolidating fermentations with photosynthetic production of H₂  
Key Research needs

• System-wide approaches to understand genetic and metabolic factors involved in H₂ production, particularly H₂ production rate

• Examination of the physiology of non-exponential phase cells (e.g., starving cells, subpopulations, communities)

• Biological and physical solutions to address light limitation with scale up
  – Design principles of light harvesting units
  – Interactions with groups that offer physical solutions (e.g., light conducting plastics)