

HydroGEN STCH Benchmarking Questionnaire

Background and motivation: We aim to develop standards for benchmarking performance, so that the community can make comparisons between concepts from different research groups in the future. In addition to setting operating and other conditions, we anticipate that the community-accepted standards developed through this exercise to be strongly encouraged to include in publications. Your involvement in this and related exercises will be greatly appreciated.

* Required

1. Email address *

2. Please list your name: *

3. Please list your affiliation: *

Skip to question 3.

What standard conditions should we use to benchmark redox active metal oxides for solar thermochemical water splitting?

4. 1) Do you think reporting the performance of a material given a specific thermodynamic operating cycle (or cycles) at fixed standardized conditions, in addition to "favored" testing conditions, would be useful?

Mark only one oval.

Yes

No

5. If no, please explain:

6. 2) Should we choose a minimum material batch size (and permit multiple measurements and round robins), with fixed form factor (porosity, size)?

Mark only one oval.

- A minimum size is unnecessary
- Milligram
- 10 Milligrams
- 100 Milligrams
- Other

7. If unnecessary or Other, please explain:

8. 3) Should we choose a fixed form factor (porosity, size)?

Mark only one oval.

- A fixed form factor is unnecessary
- Powders mean 100 micron +/- 50 micron
- Powders mean 250 micron +/- 50 micron
- Particles, dense, 1 mm
- Particles, porous, 1 mm, 50% porosity
- Other

9. If unnecessary or Other, please explain:

10. **4) Should we choose one or several standards for operating partial pressures of oxygen in reduction? If so, what pO₂ values should ALWAYS be reported for benchmarking? (Choose all that apply)**

Check all that apply.

- No standard, just a range of measurements from a minimum up to a maximum
- pO₂ = 1 Pa
- pO₂ = 0.00001 Atm
- pO₂ = 10 Pa
- pO₂ = 0.0001 Atm
- pO₂ = 100 Pa
- pO₂ = 0.01 Atm
- pO₂ = 1000 Pa
- pO₂ = 0.1 Atm
- pO₂ = same as air
- pO₂ = 1 Atm
- pO₂ = Other

11. **If No Standard or Other, please specify:**

12. **5) Should we choose one or several standards for reduction temperature? If so, what reduction temperature values should ALWAYS be reported for benchmarking? (Choose all that apply)**

Check all that apply.

- No standard, just a range of measurements from a minimum up to a maximum
- Reduction Temperature: 1200 C
- Reduction Temperature: 1300 C
- Reduction Temperature: 1400 C
- Reduction Temperature: 1500 C
- Reduction Temperature: Other
- Report Onset Temperature at fixed pO₂

13. If No Standard or Other, please explain:

14. 6) Should we choose one or several standards for re-oxidation temperature? If so, what re-oxidation temperature values should ALWAYS be reported for benchmarking? (Choose all that apply)

Check all that apply.

- No Standard, just a range of measurements from a minimum up to a maximum
- Re-oxidation Temperature: 700C
- Re-oxidation Temperature: 800 C
- Re-oxidation Temperature: 900 C
- Re-oxidation Temperature: 1000 C
- Re-oxidation Temperature: 1100 C
- Re-oxidation Temperature: 1200 C
- Re-oxidation Temperature: Other

15. If No Standard or Other, please explain:

16. 7) Should we choose one or several standards for excess steam flow over stoichiometric reactant? If so, what excess values should ALWAYS be reported for benchmarking? (Choose all that apply)

Check all that apply.

- No Standard, just a range of measurements from a minimum up to a maximum
- Excess: 10x
- Excess: 100x
- Excess: 1000x
- Excess: Other

17. If No Standard or Other, please explain:

18. 8) Should we choose one or several standards for concentration of reactant steam in a carrier gas? If so, what values should ALWAYS be reported for benchmarking? (Choose all that apply)

Check all that apply.

- No standard, just a range of measurements from a minimum up to a maximum
- $x = 1$
- $x = 0.75$
- $x = 0.5$
- $x = 0.25$
- $x = \text{Other}$

19. If No Standard or Other, please explain:

20. 9) Should we choose a standard carrier gas for re-oxidation? If so, what carrier gas?

Mark only one oval.

- Sweep gas: Argon
- Sweep gas: Nitrogen
- Other

21. If No Standard or Other, please explain:

22. 10) Should we standardize gas flow rates for kinetic measurements? If so, what kind of standards?

Mark only one oval.

- No standard
- Standard range from a minimum to a maximum sccm/mol M.
- Fixed standard value
- Other

23. Please explain

What standard method should we use to achieve low partial pressure of oxygen when benchmarking redox active metal oxides for solar thermochemical water splitting?

24. 11) Should we choose one or several standard approaches for achieving low partial pressures of oxygen? (Choose all that apply)

Check all that apply.

- No Standard, just report the approach
- Mechanical vacuum pump
- Sorption pump
- Sweep Gas (Argon)
- Sweep Gas (Nitrogen)
- Chemical Reduction (e.g., H₂)
- Other

25. If No standard or Other, please explain

What standard heat flux should we use to report kinetics of reduction?

26. **12) Should we choose a standard heat flux for reporting kinetics of reduction? (Choose all that apply)**

Check all that apply.

- No Standard, just report the approach
- Equivalent to 100 Suns
- Equivalent to 1000 Suns
- Equivalent to 3000 Suns
- Equivalent to 10000 Suns
- Other

27. **If No standard or Other, please explain:**

What standard number of cycles should we use to report cyclability?

28. **13) Should we choose a standard number of cycles and should we always ignore the first one, two or three cycles? (Choose all that apply)**

Check all that apply.

- No Standard, just report the approach
- 5 ignoring the first one
- 5, ignoring the first two
- 10, ignoring the first one
- 10, ignoring the first two
- 10, ignoring the first three
- 100, ignoring the first one
- 100, ignoring the first two
- 100, ignoring the first three
- 500, ignoring the first one
- 500, ignoring the first two
- 500, ignoring the first three
- 1000, ignoring the first one
- 1000, ignoring the first two
- 1000, ignoring the first three
- Other
- Other: _____

29. **If No standard or Other, please explain:**

30. **14) Should we have standards and benchmarks for computational thermodynamics?**

Mark only one oval.

- Yes
- No

31. **If Yes, please suggest what standards and benchmarks:**

32. **If No, please explain:**

What metrics should we always report?

33. **15) What metrics should we always report? (Choose all that apply)**

Check all that apply.

- No specific ones
- Solar to hydrogen (with fixed optical efficiency and fixed operating cycle(s))
- Total hydrogen per mole of oxide (suitably normalized, such as per metal cation, or per oxygen in the fully oxidized state)
- Other

34. If No specific ones or Other, please explain:

Further Input?

35. 16) Comments and/or questions that we missed regarding standards and benchmarking conditions:

36. 17) If you want to participate in the development of the test framework, please opt in here and we will send you the test framework for your input.

Mark only one oval.

- Yes
- No
- Maybe

A copy of your responses will be emailed to the address you provided

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