Effective de-risking of scale-up: the Britest approach

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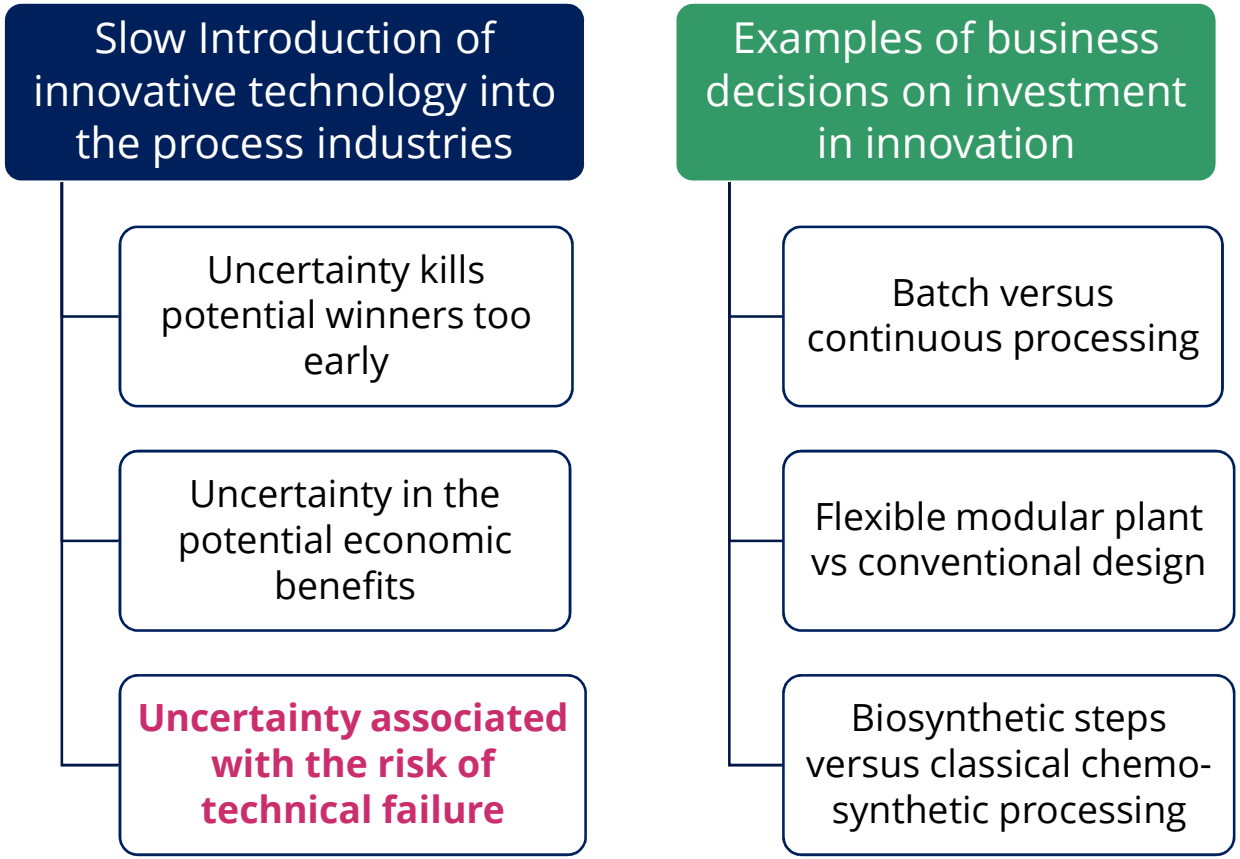
Outline

1. Challenges and opportunities in scale-up
2. An introduction to Britest
3. The Britest approach to scale-up risk assessment
4. Case study

Investment in innovation – the challenge



Can a structured approach guide project development towards better whole process understanding, enabling mitigation of technical failure?

Why do some projects fail?

41 Case Histories in 1998 in Mineral Processing sector

Type 1			Type 4 (7 projects)		
100 % Capacity < 12 months from start-up	Copies of existing processes	Non-innovative	< 60% Capacity > 36 months from start-up	3 plants went out of business	Involved substantial innovation

Why did Type 4 projects fail?

* Developing innovative technology McNulty, TP, Mining Engineering, October 1998, pp 50-55

The case for technical facilitation to assist risk assessment and mitigation planning

- Pilot Plant (if built) generated commercial samples, NOT design data
- Equipment downsized or operating windows tightened in response to projected cost overruns.
- Process flowsheets were unusually complex with prototype equipment in two or more critical unit operations.
- Process chemistry was misunderstood.

Common factor: failure to manage the technical risk of scale-up

Role of the Technical Facilitator

- Guide the team
  - Defining the project
    - Identify risk associated with scale-up
    - Establish mitigation strategy
- Provide vital element of independence
- Enable communication and understanding between stakeholders in team
- If all functions are not party to the discussion
  - Ensure that the wider picture is considered

Guiding principles for process scale-up*

Begin with the end in mind

- Realistic and accurate view of what the end looks like.
- Without an understanding of the impact of scale, a project is likely to get into big trouble.
- One cannot simply enlarge lab-scale equipment and duplicate lab-scale conditions at large-scale.

Be diligent in the details

- Beware of all kinds of oversights and shortcuts during process scale-up.
- Consequences can range from disruptive to catastrophic.

Prepare for the un-expected

- This is where formal risk assessment and mitigation planning pays off.

*Crater & Lievense, FEMS Microbiology Letters, 2018, Vol. 365, No. 13

Introducing Britest

About Britest

Britest is a highly successful not-for-profit SME. Since its founding in 2001, the application of Britest tools has generated many €millions of productivity gains, driving enhanced business sustainability and competitiveness.

Britest's **expert technical facilitators** use a suite of proprietary tools to help organisations **define, structure, and translate knowledge into process understanding**.

This promotes **effective communication** of the underlying science across disciplines and functions, **enabling knowledge transfer** and allowing organisations to derive tangible **business value**.

Scale-up Risk Assessment Methodology

Methodology overview

Best approached as a facilitated, structured workshop

1. Set goals

- Agree key scale-up objectives and constraints
- Gather input from all key stakeholders

2. Define process

- Overview of **whole process** (Process Definition Diagram)
- Mechanisms of **key chemical steps** (Transformation Map)

3. Identify risks or opportunities

- Use **risk factors** and **impacts** to assess each process task
- Capture risks and opportunities in **risk register**
- **Rich Pictures** to support multi-scale understanding

4. Prioritise risks and opportunities

- Review the whole process, identifying highest risk tasks
- Where appropriate, build a **risk register** to aid action prioritisation

Use when

Changing **scale**

Changing **equipment**

Troubleshooting a **scale-up**

The aim is not to replace current practices, but to enable better cross-disciplinary awareness and communication from the start of process development

1. Set goals

- Session should ideally be led by an independent facilitator
- Ensure that all relevant stakeholders are involved, *e.g.*
  - Process chemist
  - Process engineer
  - Operations
  - Process safety
  - Analyst
  - Business lead

2. Define process

- Capture the **whole process**, focussing on the experience of the materials involved in the process
  - Britest **Process Definition Diagram** can be a useful tool for this
  - Annotate with information on the current level of understanding from all relevant stakeholders
- Capture **key chemical and physical transformations** – don't forget:
  - Any mass transfer processes (essential)
  - Stoichiometries, phases
  - Equilibria, pre-equilibria, pH, pH changes, pKa
  - Known/ strongly suspected side reactions
  - Any information on heat of reactions

Risk factor prompts

Risk factor	Rationale
1. Moving solids	Solids handling can always cause challenges when changing scale
2. Multiple interacting phases	Rule of thumb: complexity increases in proportion to [no. interacting phases]^1.6 (J. Atherton) Some physical forms are particularly challenging, especially solids (*e.g.* sticky or large particles)
3. Human engagement	Any task requiring operator or other human engagement could introduce variability
4. Heat/energy introduction/ removal/change	Potential challenges will depend on the magnitude and rate required
5. Sensitive chemistry	Are any transformations operating in a tight window with respect to driving forces?
6. Chemical incompatibility/ unintended reactions	Impact of unintended chemistry can increase on scale-up
7. Extremes of specification	Is the process sensitive to the grade/source of materials used?

Impact prompts

- For any identified scale-up risk, consider its potential impact on:

Product

- Quality
- Yield

Process

- Operability
- Safety & Environment

Q

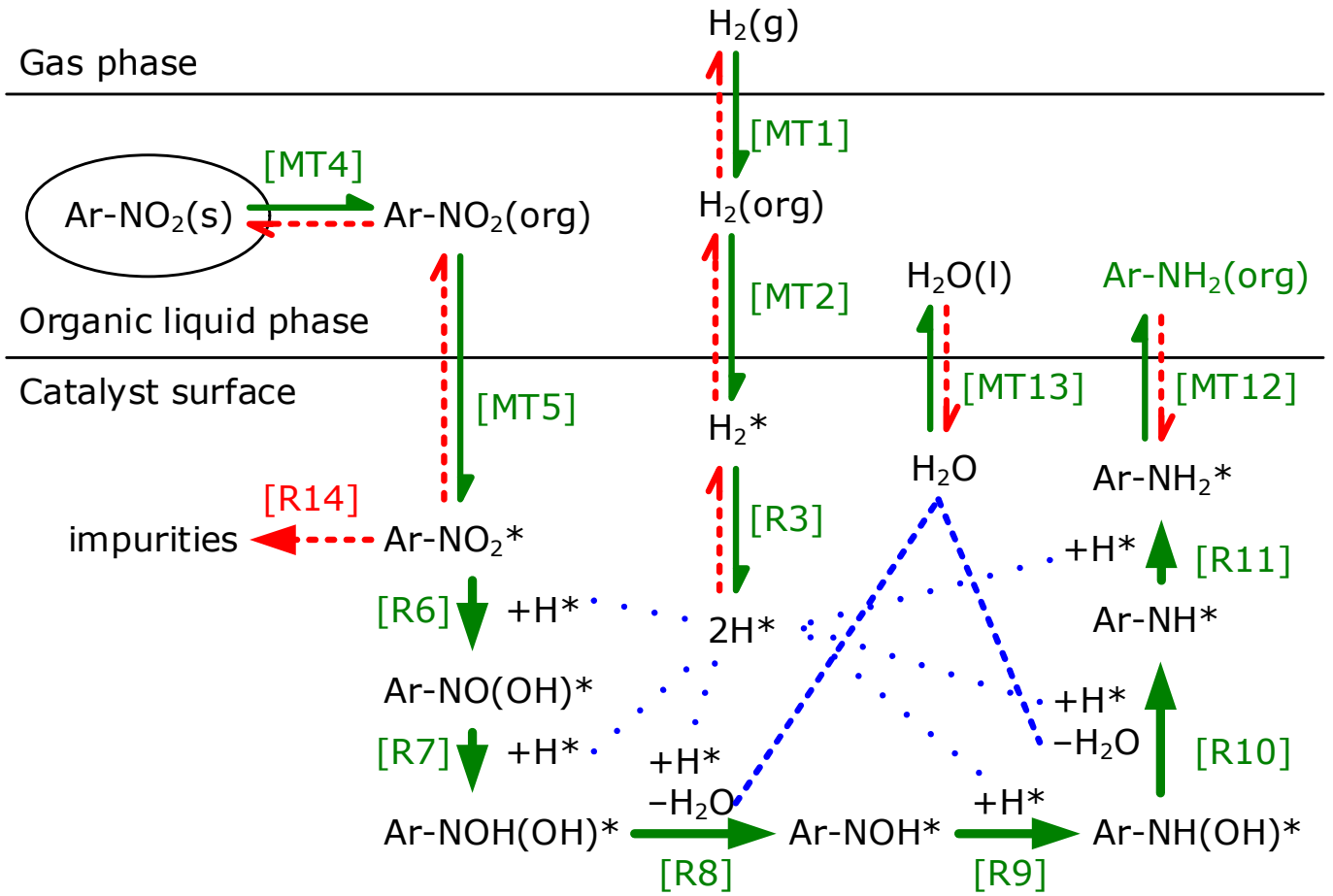
Y

O

S

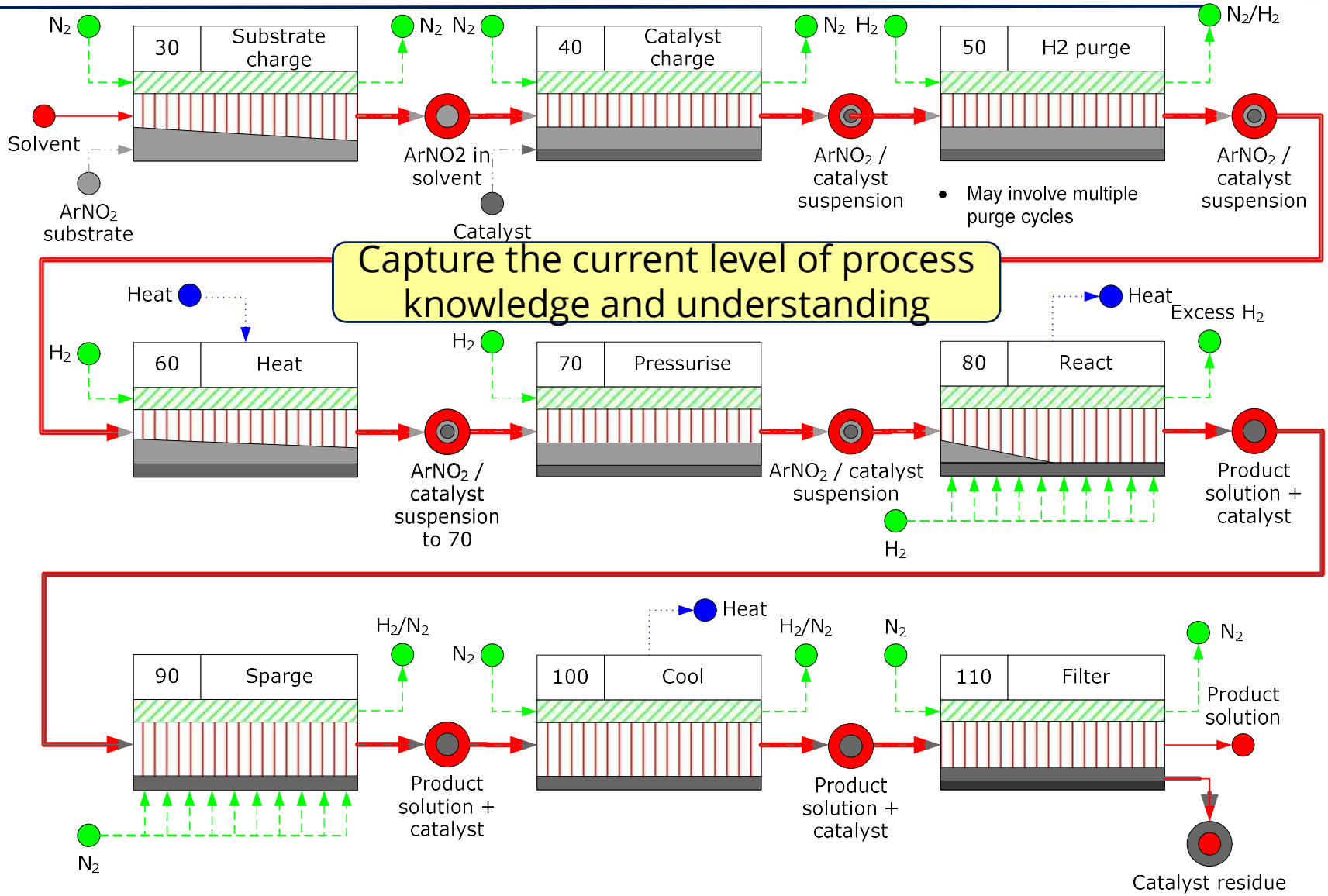
Case Study

Scale-up of a hydrogenation reaction
Transformation mapping

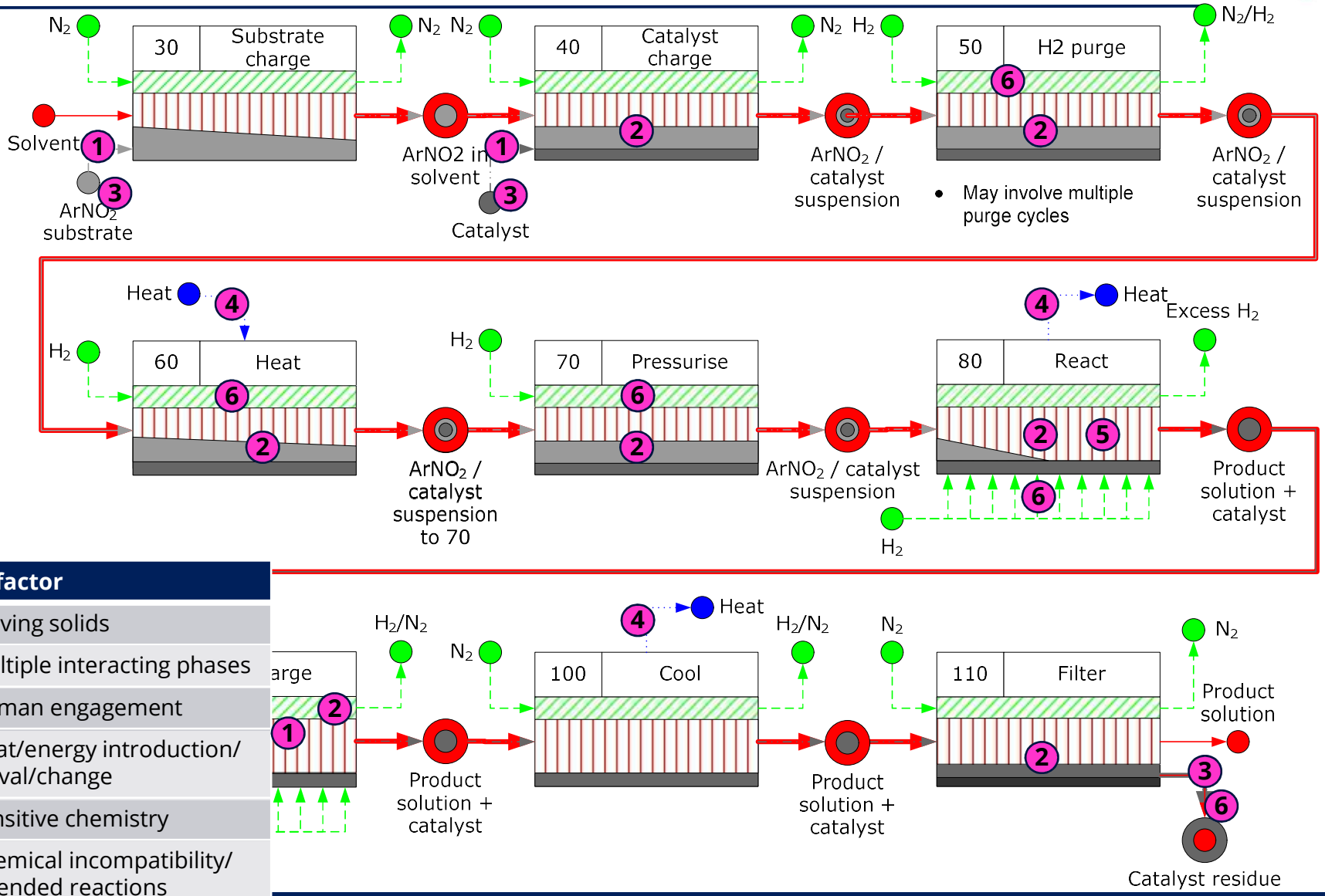


(Hydrogenation mechanism from Gelder, E, 2005. *The hydrogenation of nitrobenzene over metal catalysts.* PhD thesis, University of Glasgow)

The Process Definition Diagram

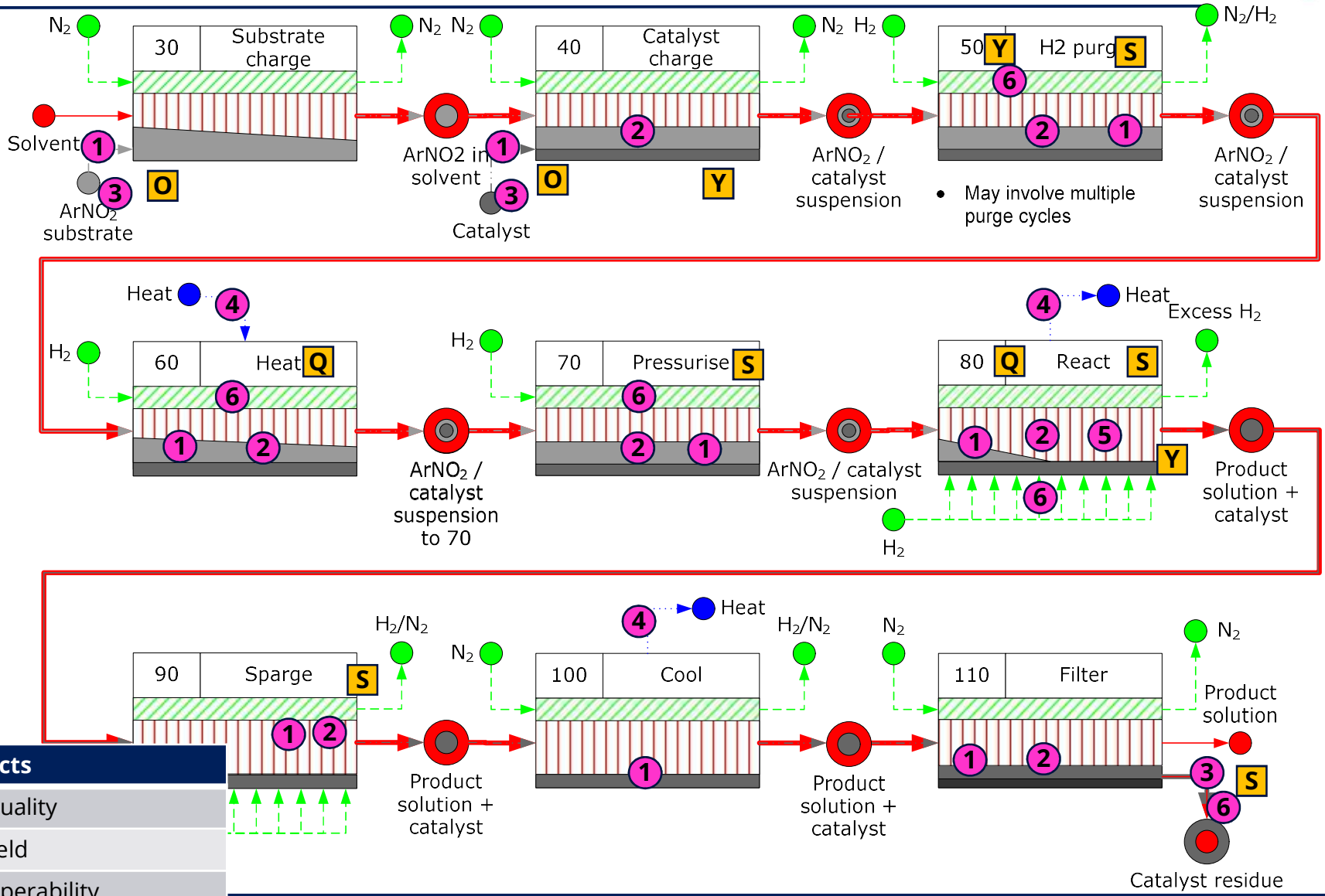


Consider scale-up risk factors



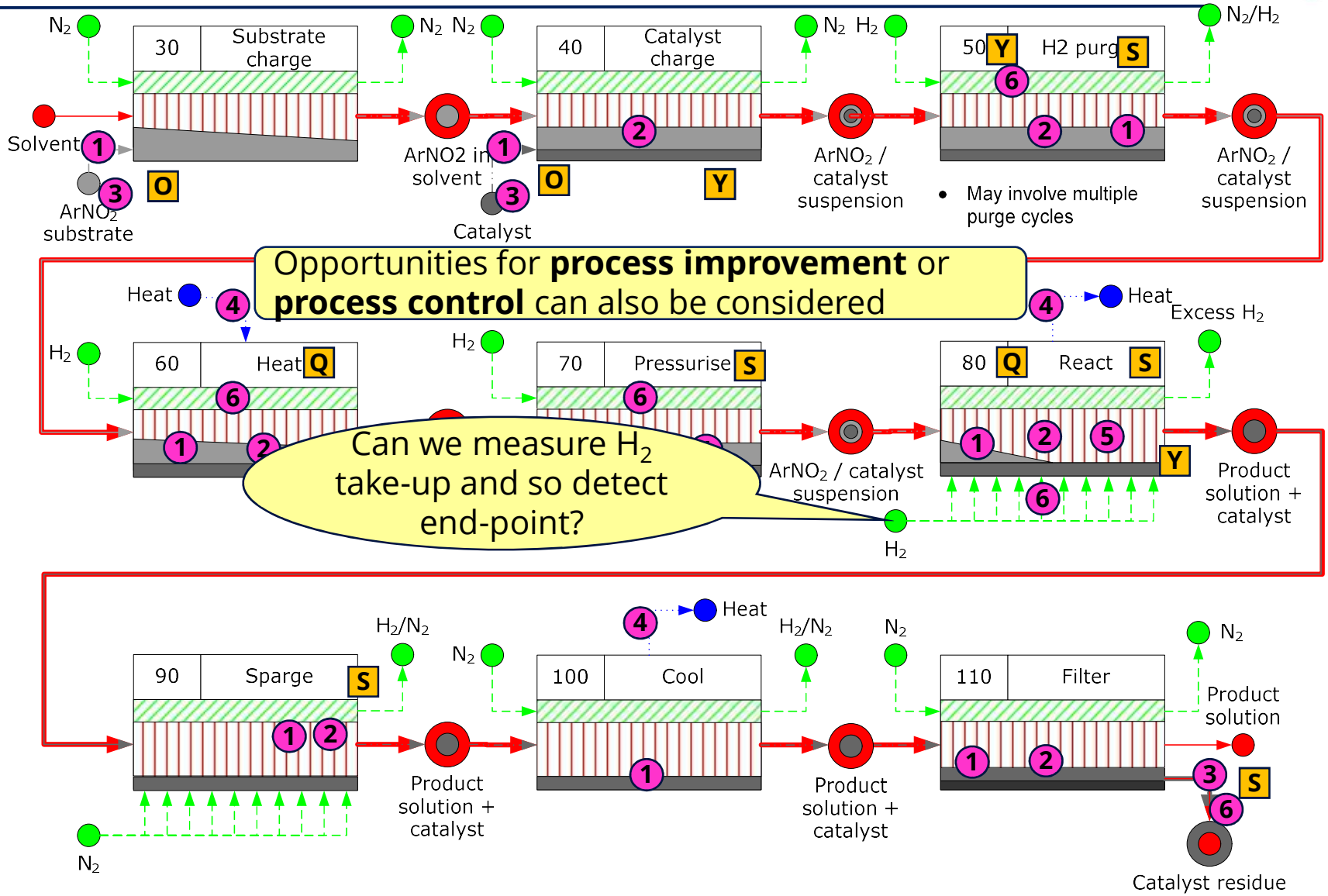
Risk factor
1. Moving solids
2. Multiple interacting phases
3. Human engagement
4. Heat/energy introduction/ removal/change
5. Sensitive chemistry
6. Chemical incompatibility/ unintended reactions
7. Extremes of specification

Consider impacts

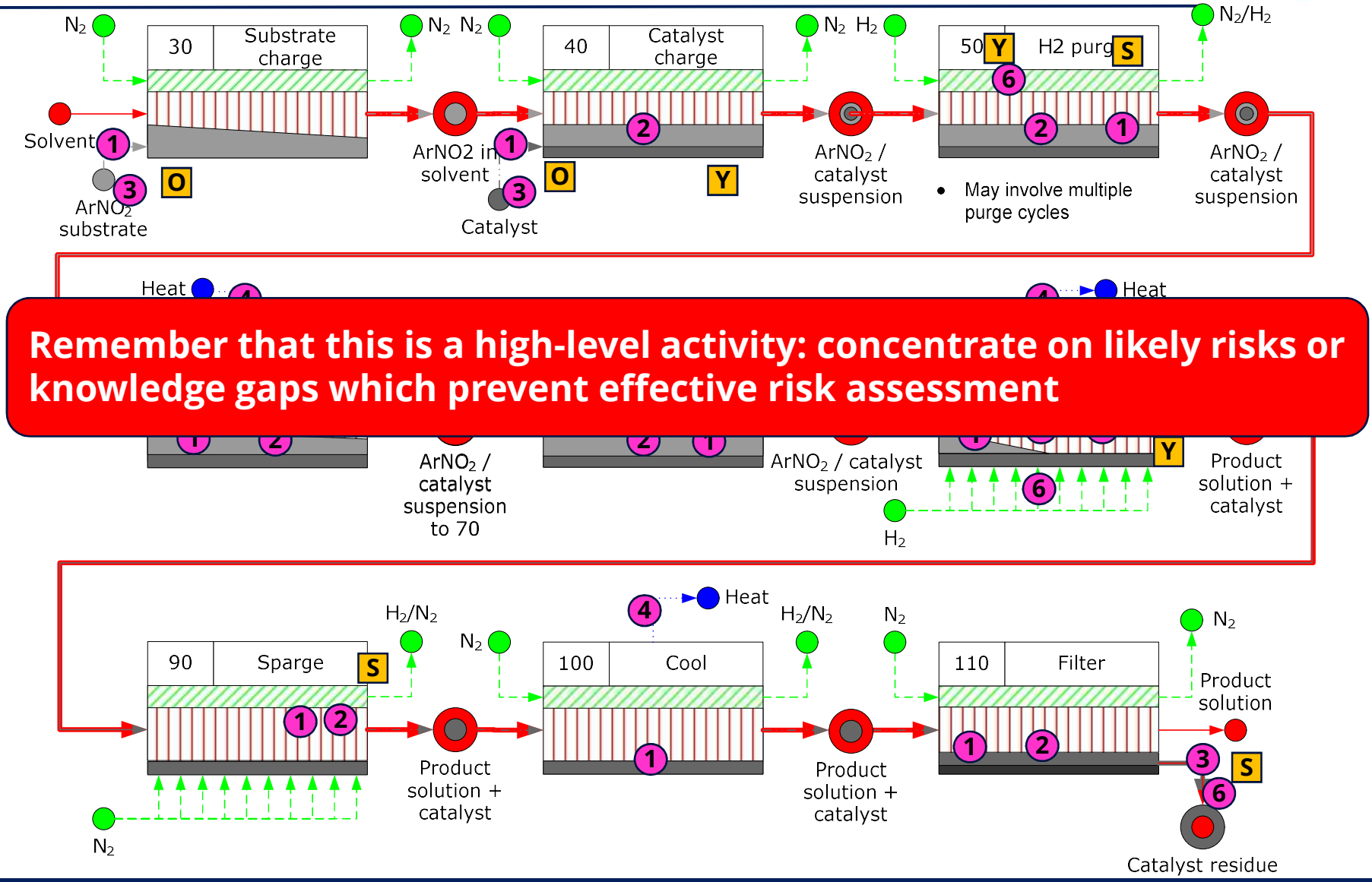


Impacts
Q – Quality
Y – Yield
O – Operability
S – Safety & Environment

Risk/opportunity assessment



Risk/opportunity assessment



Remember that this is a high-level activity: concentrate on likely risks or knowledge gaps which prevent effective risk assessment

Summary

In general…

- it is never too early to start assessing the risks, or opportunities, for process scale-up
- consider the whole system, not just the chemical reactions
- it is important to collate input from all relevant stakeholders

Britest…

- has developed a highly flexible methodology, which enables assessment of scale-up risks and opportunities from early stages and throughout the development cycle

Thanks to my colleagues Mark Talford and Charlie Gordon for their help in preparing this presentation, and the input of many Britest collaborators in developing the methodology.