Homogeneous Catalysis

\[
\text{Me}_2\text{Si} \quad \text{Me} \quad \text{Me} \\
\text{Me} \quad \text{Ti} \quad \text{Cl} \\
\text{N} \quad \text{CMe}_3
\]

Heterogeneous Catalysis

\[
\text{H} \quad \text{C} = \text{C} \quad \text{H} \\
\text{H} \quad \text{C} - \text{H} \\
\text{H} \quad \text{C} - \text{H}
\]
Homogeneous Catalysis

Glovebox

Pyrophoric Reagents

Alkali metals for drying

Schlenk Line

Solvent Purification Systems
Heterogeneous Catalysis

Catalytic Materials

Reactants & Products

Reactor
Heterogeneous Catalysis – Catalytic Materials

**Materials**
- Novel materials of unknown toxicity
- Fine particles handled on the benchtop
- Spent catalysts may differ from native materials (sintering, oxidation/reduction, pyrophoricity)

**Powder**

**Extrudates**
Heterogeneous Catalysis – Reactants & Products

Reactants & Products
- Toxicity
- Flammability
- Oxidizers
- Unknown products

Exhaust
- Emissions
- Scrubbers
- Ductwork
Heterogeneous Catalysis - Reactor Design

- Compressed Gas Management
- Controls
- Heating
- Plumbing
- Electrical
Lockout • Prevent accidental mixing of incompatible gases

Transportation • Hand trucks

Engineering Controls • Walk-in hood • Gas Cabinet • Snorkel

Gas Source • Tanks • Generators

Reactor Design - Compressed Gas Management
Reactor Design - Controls

**Automated**
- Easy to determine gas flow path
- Expensive
- Difficult to modify
- Difficult to troubleshoot
- Easier emergency shutdown

**Manual**
- Difficult to determine gas flow path
- Less expensive
- Easier to modify
- Easier to troubleshoot
- Difficult emergency shutdown
Reactor Design - Heating

**Furnaces**
- Commercial
- Homemade

**Heat Tapes**
- Cold spot/condensation
- Burning

**Temperature Controllers**
- Limit controllers
- Exothermic reactions
Reactor Design - Plumbing

Pressure Relief

Leak Detection
Reactor Design - Electrical

**Electrical Service**
- High power consumption
- Multiple circuits per reactor
- Understanding circuits & why tripped

**Cords**
- Integrity
- Materials of composition
- Extension cords
Parts Bin

**Contamination**
- Unknown residue
- Sticky reactants (sulfur)
- Oxygen service
- Valves difficult to clean
- Metals not 100% inert

**Composition**
- Stainless vs. brass
- Warped threads
- Improper use of PTFE tape
Catalysis Safety Training Opportunities in Academia

**Current Training**
- Knowledge passed down in group
- Senior level ChemE industrial-scale process safety

**Electrical Safety**
- Inspecting equipment & outlets
- Power cords & extension cords
- Circuit breakers

**Valves & Tube Fittings**
- Valve & fitting types
- Swagelok, NPT, others
- Sizing
- Materials of construction

**Incidents**
- Hot plate fires
- Other smaller lab incidents
What if the fail-safes fail?

- Control board managing two reactors
- Error caused power to be sent to one reactor and temperature read from the other
  - Never tripped the high temperature shutoff
- Melted aluminum heating block on unattended empty reactor
- Do we need an independent temperature controller which would cut the power? What level of redundancy is needed?
Acknowledgements

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