Kinetic Tests

- Kinetic tests accelerate weathering and provide acid production and consumption, and effluent chemistry data.
- Many lab and a few field tests are available.
- No single test produces all of the data needed to evaluate all mine wastes under all disposal conditions.
- Test procedures are complex, time-consuming, and require skill to produce consistent results.
Kinetic tests (as of 2003)

- Conventional and modified conventional humidity cells (ASTM).
- Steffan Robertson, and Kirsten humidity cells.
- Soxhlet extractions.
- Column leach tests.
- Shake flask extractions.
- Modified B.C. Research tests.
- Simulated environment studies (tons of waste left on a pad for months or years).
What they do

- They try to make a mine waste sample generate acid.
- They provide data about how long it will take for a sample to generate acid.
- They provide data on sample effluent chemistry.
How they are run

- Samples are leached periodically, the leachate is collected and analyzed.
- Acid generation rates, metals release, and neutralization capacity depletion are computed.
- Sample mass, particle size, test conditions (lab vs. field), and test duration varies greatly among methods.
- Kinetic tests should be supplemented by other test data (e.g., static test data, mineralogy, total metals data, etc.).
Ground rules

- Accepted criteria are generally lacking for interpreting kinetic test results.
- Data ranges from relatively straightforward to extremely difficult to interpret.
- All interpretations should include knowledge of sample mineralogy, static test data, particle size characteristics, and water flow.
Humidity Cells

- The conventional humidity cell (Sobek et al., 1978) is a bench-scale lab test.
- Between 200 to 300 g of crushed sample (<2 mm) is placed in a sealed plastic box.
- Dry air is passed over the sample for 3 days, followed by moist air for 3 days.
- Every seventh day, the sample is flushed with a specified volume of water (e.g., 0.5 or 1.0 liters).
Humidity Cells

- Slightly acidic water may be used to simulate acid rain.
- Leachate is collected and analyzed for sulfate, pH, acidity, alkalinity, and electrical conductivity.
- The 7-day process is repeated for 10 to 20 weeks.
ASTM Humidity Cells

- ASTM procedure D5744-96 was designed for mining wastes and uses a modified column as a humidity cell.
- A kilogram of sample is crushed to particle sizes smaller than 6.3 mm (1/4 inch).
ASTM Humidity Cells

- The test uses the Sobek leaching method and is run for 20 weeks.
- The test requires pre- and post-leach mineralogical and chemical characterization of the sample.
- There is an option for a bacterial spike.
Soxhlet Test

- Soxhlet reactors recirculate water or other fluids through a sample to simulate weathering.
- The test uses distilled water at 25°C to leach a sample over a period of six weeks, although the test duration can vary.
- Soxhlet extractions require sophisticated equipment and considerable operator skill.
- An independent evaluation indicated reliable results for tailings samples are possible.
Column Tests

- Column tests are not standardized.
- They permit a variety of column designs, test material characteristics, leaching cycles, and flow rates.
- “Standard” columns are 15 cm in diameter and 2 m in length but larger diameters and lengths are common.
- Particle size range up to 2 cm and sample masses up to several tons are common.
- The effects of bacteria inoculation, waste blending, flow channeling, etc. may be evaluated using column tests.
Columns model precipitation infiltration into and drainage from mine waste exposed to the atmosphere.

A fixed amount of water may be added in fixed or variable amounts on a regular or irregular basis.

Water may be added to specific portions of the column surface to promote flow along preferred pathways.

Columns model water infiltration into and drainage from mine waste disposed of under water.
Column Tests

- Columns model downward displacement of mine waste pore water by supernatant water to simulate seepage to ground water.
- They can model mine waste behaviour under submarine and deep lake disposal conditions.
- In general, all tests distinguish potentially reactive materials from benign materials but the leachate compositions may not resemble what is produced under natural settings.
Shake Flask (aka batch reactor)

- Samples are powdered and immersed in distilled water, they may be inoculated with bacteria.
- The flask is sealed and vibrated (for days to weeks).
- Samples are removed periodically and analyzed for sulfate, pH and other parameters.
- Water is added for long duration tests.
- The test is simple and inexpensive.
Field tests

- Field test samples range from hundreds of kilos to metric tons.
- Tests are run for years under natural climatic conditions.
- Long duration tests attempt to overcome inherent neutralization, bacterial oxidation lag time, and short term climate variability.
- Effluent samples are collected with lysimeters or from impermeable liner sumps.
- Test piles are constructed similar to actual or proposed waste rock dumps or tailings impoundments.
Field tests

- Field tests provide mass release rates of metals per unit mass of waste data.
- Field tests provide realistic acid generation and neutralization rates and water quality data compared to bench-scale lab tests.
- Control options, such as limestone addition, can be tested under natural conditions.
- Test duration must smooth out short-term climatic variation effects.
- Long test duration makes these tests difficult to use, especially for evaluating proposed actions.
Interpretation

Ground rules

- Accepted criteria are generally lacking for interpreting kinetic test results.
- Data ranges from relatively straightforward to extremely difficult to interpret.
- All interpretations should be based on knowledge of sample mineralogy, static test data, particle size characteristics, and water flow.
Scaling is a significant issue for bench-scale kinetic tests because they accelerate natural weathering. Samples generate acid sooner than waste would in its disposal environment. Test leachates have higher metal concentrations. For bench-scale tests, leachate pH below 3 indicates strong acid generation; leachate pH between 3 and 5 indicates acid generation with some neutralization; and leachate pH above 5 indicates no significant acid generation (or excess alkalinity overwhelms acid generation).
Temporal trends

- Leachate trends (e.g., pH, sulfate, acidity, alkalinity, and trace metals) are used to identify acid drainage progression.

- Leachate composition trends reflect changing sample mineralogy and geochemical equilibrium conditions.

- Equilibrium chemical speciation programs (e.g., MINTEQA2) that take into account precipitation/dissolution reactions, should be used to evaluate leachate composition trends.
Interferences

- Soluble sulfate minerals can mask sulfate produced by sulfide oxidation.
- Oxidation products contribute metals to kinetic test leachates. Metal hydrolysis can lead to acidification unrelated to sulfide oxidation rates.
Test duration

- Kinetic tests must run long enough for neutralizing and accumulated oxidation minerals to dissolve, and to overcome the bacterial oxidation lag-time.

- Test are commonly run 20 weeks but longer test lengths (e.g., 40 weeks to 104 weeks) are gaining favor.

- In long-term studies, some samples did not begin to produce acidic drainage until more than two years into the kinetic tests.
Sample particle size

- Particle size strongly influences kinetic test results.
- Smaller particles have high surface area but low water and air flux rates; both affect reaction rates and drainage quality.
- Acid generating and neutralizing minerals are liberated from finely ground samples.
Summary

- Kinetic test data are equivocally because of differences between samples and wastes (e.g., waste versus sample masses, particle size differences, particle separation distances, infiltration rates, flushing rates, and flushing volumes).
- Extrapolating test results to disposal-length time frames is risky.
- Changes in initial sample mineralogy plays a pivotal role in controlling leachate quality but is not address by kinetic tests.
- Properly applied mathematical models are useful for determining the potential effects of waste rock and tailings piles runoff.
- Modeling, however, is an advanced subject.