Simple Kinematics Calculations for Nuclear Reactions

W.N. Catford (University of Surrey)

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Relativistically Correct 2-Body Kinematics Calculations Using CATKIN

The code *catkin* is a simple two-body kinematics code, written in *MS excel* so as to be as portable as possible. If you want to plan an experiment, you don't want to be in need of a computer, but you can't do the calculations in your head. A good idea for an experiment is useless unless it turns out to be possible experimentally. With *catkin* you can do that check, and plan the general experiment.

The code comes originally from a programme RELKIN that came from Daresbury, but has some corrections. Importantly, it uses actual mass tables for all nuclei, to get the reaction Q-value accurately. It is possible to update the mass tables, but not to hack the code, so any version of *catkin* that you find should be guaranteed to work.

Provided that you can open *excel* files and have full function operability, and enable macros, you can run catkin. If you don't enable the macros, it simply removes a few options in the additional computation pages but still allows full kinematics calculations. No add-ons to excel are required.

You can **download the up-to-date version** of *catkin* from here (or google *catkin kinematics*):

http://personal.ph.surrey.ac.uk/~phs1wc/kinematics/

which has the *excel* spreadsheet to download, and also a descriptive introduction file.

The **main kinematics sheet** has data entry cells coloured in yellow. The beam energy is absolute in MeV (not per nucleon). The residual nucleus and Q-value are calculated automatically. There is then an upper section to the output that allows you to zoom in on a range of angles of particular interest. The properties of the ejectile are given, as a function of laboratory scattering angle, followed in other columns by the recoil particle properties and the second kinematical solution if such a solution exists. Note that the ejectile or the recoil nucleus can carry excitation energy, in the final state.

The **main kinematics page** also includes a complete set of solutions for laboratory angles from zero to 180 degrees, below the zoom-in table. You can cut/paste solutions from these lines into another spreadsheet for making your own plots. Use "past special" and "values" to do the paste.

A page called "**small plots**" automatically plots various quantities from the zoom-in range of angles. There are then pages that give the properties of the ejectile and recoil particles (the angle in the laboratory and the kinetic energy) as a function of centre of mass scattering angle. Both the laboratory and the centre of mass angle are defined relative to the beam direction. Note that in inverse kinematics, the complement of the catkin centre of mass angle is the correct centre of mass angle for the reaction, e.g. to compare with reaction cross section calculations.

The **plectrum plots** page is a plot of laboratory kinetic energy versus laboratory angle, produced automatically, and works for cases with one solution or with two solutions, but when there are two solutions the plot is sometimes a bit messy, due to the simplicity of the plotting algorithms.

The Calculator Page

A number of additional simple calculations can be performed using this page, and with the benefit of being able to look up the masses on the mass table. You can jump to the different calculations from the top of the *Calculator* page. As in the kinematics page, the yellow cells are those where user-entry is permitted. Macros are required for one or two of the calculations.

- mass value from isotope symbol – look up mass and mass excess (M−A) in MeV or amu
- separation energy to remove a particle or cluster (neutron is nn for element symbol)
- reaction Q-value for two-body reactions
- reaction Q-value for three-body, sequential breakup reaction
- simple calculator of magnetic rigidity, momentum and time of flight, when you enter the energy and charge state of the particle (LISE++ is normally used for this)
- velocity (as percentage of speed of light) calculated from energy (in various units)
- calculate other properties, given the magnetic rigidity
- get counts per second and probability of interaction for a given target, given the cross section, or get the cross section from the observed counting rate
- get coulomb barrier heights and safe energies for coulex, as function of scattering angle
- estimate the heavy ion transfer angular momentum matching using the Brink matching conditions
- estimate the multiple angular scattering of charged particles when going through thin targets, using formulae from the venerable book by Marion & Young, and returning the sigma and fwhm in degrees and milliradians.

Wilton Catford

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