(Teacher Page)

Activity Five:
The Rules of the Game

Goal: Students learn that conservation laws are made up to explain what is and what is not observed, and are called laws only after many tests confirm their validity.

This activity is designed to introduce students to some fundamental concepts of particle physics that are the "rules of the game" played by nature -- the conservation laws and the nature of particle events. By completing the puzzle exercises on this activity sheet, students will learn that part of the theory and practice of particle physics is simple counting, and that an "event" in particle physics is comparable to a reaction in chemistry, in that one set of particles is formed from another. Further, they learn that this is how physicists discover the rules -- they are formulated to explain the data, not given a priori; to illustrate, refer to the rules of interactions that students encountered in Activity Two, Psyching Out the System!

You can introduce this activity by asking students to pretend that they are scientists -- who devise rules that explain observed phenomena and then use these rules to interpret new observations. Ask students to work in groups to find examples of "rules of nature" that explain the lists of processes seen and not seen.

Distribute the activity sheet and explain that the particle table can be used to identify the types of particles and charges in each event.

When the students understand how to read the particle charts, have them begin working on the activity in small groups, as do particle physicists.

You may want to explain that two types of "observed" events are represented on the list. Events 1, 5 and 6 are particle decays: a particle such as a neutron spontaneously decays to form two or more other particles. The other "observed" events (2, 3, 4, 7,8, 9 and 10) are collisions: the two particles to the left of the arrows come close enough together to interact and transform the incoming particles into two or more outgoing particles.

The following hints can also be given to simplify this activity. You may want to disclose them immediately, or give them one at a time as they seem to be needed, or you may choose to challenge the students to work without any hints at all.

Hints:

1. The conserved Quantities are not complicated combinations of things.

2. Students can check whether a quantity is conserved in an event by comparing the sum of that quantity on the left of the arrow to the sum of the same quantity on the right of the arrow.

3. In counting particle types, add the number of particles and subtract the number of antiparticles.

4. In addition to electrical charge, there are only two other conserved quantities shown by these examples.

5. If the counts match on the left and right of the arrows in all the "observed" events but not in all the "events never observed," this quantity is conserved.

6. Students should try counting numbers of particles of a given class (baryons, leptons, mesons) before and after a given event. It may be helpful to have students make a table to keep track of the counting for each quantity on the left and right sides of the equation in all 20 processes.

Answers:

1. When a quantity is "conserved ," it is the same after an event as it was before the event.

2. The following conserved quantities can be found: (a) electric charge; (b) number of baryons minus number of antibaryons, which is called "baryon number;" (C) number of leptons minus number of antileptons, which is called "lepton number."

3. An "event" is the basic type of observation in particle physics; it is a single collision of two particles (producing a transformation into two or more outgoing particles), or the decay of a single particle into two or more other particles. An event is similar to a chemical reaction in chemistry, in the sense that one set of particles is formed from another.

4. Events 1,5 and 6 are decays.

5. Events:

11. Electric charge

12. Baryon number

13. Baryon number and electric charge

14.-18. Baryon number

19.-20. Lepton number

Follow-up Activities:

1. After students have completed the activity sheet, discuss what the experience taught them about particle physics and how scientists conduct these experiments. Students should be able to recognize that part of the theory and practice of particle physics is simple counting, and that physicists infer the conservation laws from the data to explain what is and is not observed to occur.

2. Ask students to provide other examples of conservation laws in nature. Discuss

how "conservation of mass" as taught in chemistry is an approximate result that is in fact a consequence of conservation of baryon number. (Mass is only approximately conserved in chemical reactions, since binding energies differ before and after the reaction.)

3. Discuss the difference between the term "conservation" as used in "conservation law" and the popular usage in reference to "conservation of resources." Since "energy conservation" is a law of physics, why do we need to worry about "conserving energy" in our daily lives? Where does "wasted energy" go?