POLAR TREC

TEACHERS AND RESEARCHERS EXPLORING AND COLLABORATING

What Everything's Made Of – The Structure of Matter

Overview

In this lesson, students will be introduced to the Standard Model, learning key vocabulary such as Fermions, Hadrons, Mesons, Baryons, Quarks, Leptons, particles, and anti-particles. In particular, students will come to understand what a neutrino is and why it is such a unique particle. This understanding connects to the IceCube Neutrino Observatory's search for neutrinos in an effort to learn something new and different about the universe. (This lesson is ideal for an upper-level, i.e. AP or IB, Physics or Chemistry class)

Objectives

1. Understand the organization of the Standard Model.
2. Correctly use relevant vocabulary such as fermion, hadron, lepton, quark, baryon, meson, particle, and anti-particle.
3. Discuss why neutrinos are unique and how this serves as an advantage and disadvantage to the IceCube Neutrino Observatory.
   (Note: This lesson is particularly relevant to the IB Physics curriculum, Subtopic 7.3)

Lesson Preparation

Students should go to www.particleadventure.org and read the section on "The Standard Model" before coming to class. This will give students preview of the content.

Details

Lesson
Antarctic
About 1 period
Download, Share, and Remix
High school and Up

Materials

Worksheet: Build a Particle
Worksheet: Particle Flashcards
Scissors
Markers (Optional)
Quiz
Access to a computer (with internet)

Standards

IB Curriculum

Procedure

1. Review relevant vocabulary from the pre-reading, including fermions, hadrons, leptons, quarks, particles and anti-particles.
2. Discuss how quarks can combine in certain ways to form new, more complex particles.
3. Students explore ways of combining quarks using bit.ly/BuildaParticle. They should record their findings (combination of quarks, was a particle created?, and, if so, the name of the particle) on the provided worksheet. This will help students begin to look for patterns as well become familiar with the names of various baryons and mesons. (see Worksheet: Build a Particle)
4. After giving students time to explore, ask them to pull out patterns they see for mesons and baryons and record at the bottom of the provided worksheet.
5. Discuss these patterns as a class. Students should have discovered that three particles or anti-particles can combined to form a baryon and a particle/anti-particle pair can combine to form a meson.
6. Discuss how each particle has specific properties. Pull on prior knowledge of charge, and add new properties such as lepton number (leptons=+1, anti-leptons=-1, non-leptons=0), baryon number (baryons=+1, anti-baryons=-1, non-baryons=0), and strangeness (strange quark=-1, anti-strange quark=+1).
7. Using the IB Physics Data Booklet (or other online resources if not an IB course), students should create flashcards recording the name, category, charge, lepton #, baryon #, and strangeness of common particles. Option: have students color/decorate the flashcards (see Worksheet: Particle Flashcards) (note to teacher: print the worksheet front-to-back in order to line up the particle with the properties on the back)
   (note to teacher: although students will likely not fully understand lepton #, baryon #, or strangeness at this point in time, later lessons could focus on conservation of these quantitates to further understanding)

IB Physics SL / HL curriculum, Sub-Topic 7.3: The Structure of Matter

Aim 1: the research that deals with the fundamental structure of matter is international in nature and is a challenging and stimulating adventure for those who take part
Aim 4: particle physics involves the analysis and evaluation of very large amounts of data
Aim 6: students could investigate the scattering angle of alpha particles as a function of the aiming error, or the minimum distance of approach as a function of the initial kinetic energy of the alpha particle
Aim 8: scientific and government organizations are asked if the funding for particle physics research could be spent on other research or social needs

8. Discuss what makes neutrinos so special: Students should notice from their flashcards that neutrinos have a charge of 0. Connect this to prior knowledge about about electric and magnetic fields – neutrinos would not change their direction when traveling through electric or magnetic fields. Ask students to look up to the mass of neutrinos – they'll find it's nearly zero. Connect this to prior knowledge about gravitational fields – neutrinos would not change their direction when traveling through gravitational fields.
9. Discuss: Why might these two properties of neutrinos, chargeless and nearly massless, be helpful when trying to study the universe? Why might IceCube be interested in neutrinos in particular? Answer: wherever these neutrinos are coming from, they'll travel in a straight path, unobstructed by fields, to earth. This makes it really easy to trace a detected neutrino back to its source.
10. Discuss: Why might these two properties of neutrinos, chargeless and nearly massless, pose a problem to scientists? Answer: hard to detect!
11. Next, students should cut out the labels on the last page of the worksheet. Using these labels, ask students to organize the flashcards in a way that makes sense to them. (Formative assessment: check that students are correctly using the vocabulary words.)
12. How do physicists organize these particles? Present students with various different Standard Model representations. (suggested links: Table, Web, Traditional table, Traditional Chart). Discuss the pros and cons of each type of representation. What is your favorite? Why?
13. Present alternative way of discussing the standard model by playing the Quark Song.

Extension

Students create another representation that includes the vocabulary fermions, leptons, quarks, mesons, baryons, and hadrons. Encourage creativity! (ideas could include a family album, baseball cards, etc.)

Resources

- Worksheet: Build a Particle (download entire lesson PDF)
- Worksheet: Particle Flashcards (download entire lesson PDF)
- Follow-up Quiz (download entire lesson PDF)
- Pre-reading Website: www.particleadventure.org
- Build a Particle Website: bit.ly/BuildaParticle
- Quark Song:https://youtu.be/U0kXkWXSXRA

Assessment

- Formative Assessment (in #10 in above lesson plan): check that students are correctly using the vocabulary words as they sort their flashcards using the labels

- Formative Assessment: mini-quiz (download entire lesson PDF) given the following class to assess student's knowledge of the Standard Model as well as their use of vocabulary.

Author/Credits

This lesson was modified by Kate Miller (contact: kate.miller@polartrec.com) from resources produced by the KSTF IB Physics Collaboration (including Heather Hotchkiss, Mark Hartman, Jennifer Goetz, Nick Guendel, Christine Scott, and Katelyn Warner)

Name:_____ date: _____ period: _____

Build a Particle

1. Go go **bit.ly/BuildAParticle** --- click **skip intro** --- then
2. **Click "Play with elementary Particles"** on the left side, under "Generations of elementary particles".
3. **Click "Game".** There will only be 3 (out of the 6) quarks represented in this game.
4. Begin experimenting with different ingredients of quarks in combinations of 2 (mesons) and 3 (baryons). Below, record the quarks you tried, and what particle they created!

   To create a particle:

   A. Select the quarks you wish to build with
   B. When you have your ingredients, click "Done" for feedback on if the particle is possible. If it is, it will tell you which you have created!

Quarks Combined	Particle Created? (Y/N)	Name of Particle

What patterns do you see as creating valid particles for…

Mesons?	Baryons?

Name: _____

Particle Flashcards

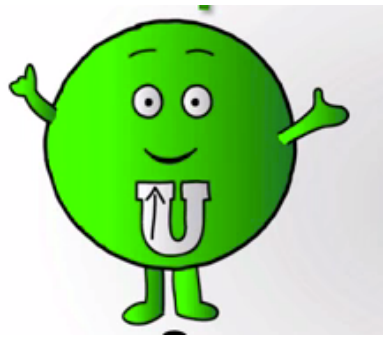
Welcome to the zoo! Today's activity will introduce you to most of the particles found in the Standard Model.

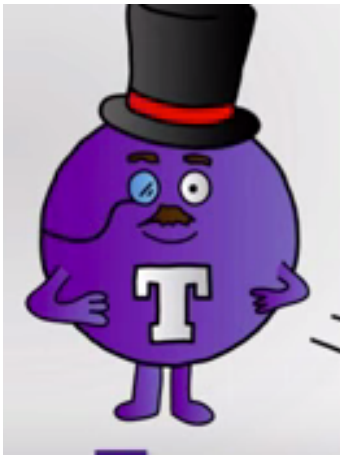
Procedure:

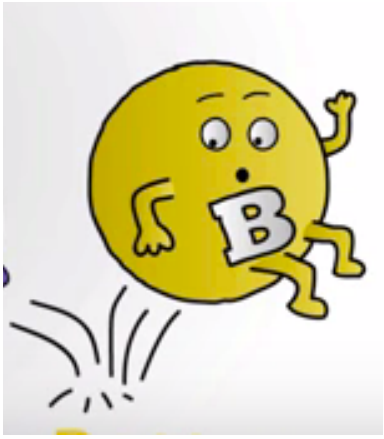
1) Cut out each particle.
2) Using your data booklet (or other online resources), fill in as much information about each particle as possible.

Break for discussion of neutrinos

3) Cut out the labels on the last page.
4) Create a visual of the zoo, using the labels and properties to organize them into groups and a hierarchy (ex: flow chart, grid, etc.)







Proton

Neutron

Name: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

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Strangeness: _____

Name: _____

Quarks: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Quarks: _____

Cat: _____

Charge: _____

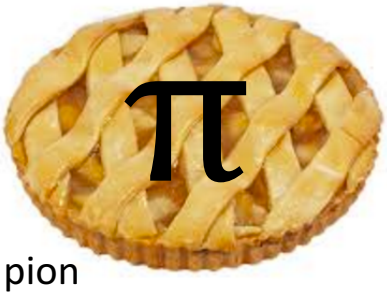
Lepton # : _____

Baryon #: _____

Strangeness: _____

Neutrino

Anti- Neutrino



pion

Kaon

Name: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Cat: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Cat: _____

Pairs With: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____

Cat: _____

Pairs With: _____

Charge: _____

Lepton # : _____

Baryon #: _____

Strangeness: _____

Name: _____ Cat: _____

3 Types: 1) _____ Quarks: _____ Charge: _____ L#: _____ B#:_____ S#: ____

2) _____ Quarks: _____ Charge: _____ L#: _____ B#:_____ S#: ____

3) _____ Quarks: _____ Charge: _____ L#: _____ B#:_____ S#: ____

Name: _____ Cat: _____

3 Types: 1) _____ Quarks: _____ Charge: _____ L#: _____ B#:_____ S#: ____

2) _____ Quarks: _____ Charge: _____ L#: _____ B#:_____ S#: ____

3)_____ Quarks: _____ Charge: _____ L#: _____ B#:_____ S#: ____

Quarks

Leptons

Fermions

Mesons

Baryons

Hadrons

Name_____

Quiz

1. What is the charge of an up quark? _____
2. What is the charge of an anti-up quark? _____
3. What is the lepton number of an electron? _____
4. What is the lepton number of an anti-electron (positron)? _____
5. What is the baryon number of a proton? _____
6. What is the strangeness of a down quark? _____
7. Which is bigger: quark OR baryon ?
8. Which has other things inside of it: lepton OR quark OR meson ?
9. What two traits make a neutrino unique? _____ _____
10. Discuss how these two traits make neutrinos both ideal and difficult to detect for IceCube.

KEY:

1. +2/3e
2. -2/3e
3. +1
4. -1
5. +1
6. 0
7. baryon
8. meson
9. chargeless; nearly massless
10. because neutrinos are chargeless and nearly massless, they are not effected by electric, magnetic, or gravitational fields. They travel from their source to earth is a straight line, so if we can detect one we can easily trace back to its sources. But, because they're chargeless and nearly massless, neutrinos can be difficult to detect.