**Integrated Activities – High School Level**

The following activities are linked to the Nebraska Mathematics Standards (2009), English Language Arts Standards (2009), and Science Standards (2010).

**Isotopes:**

This is a 3 part lesson that focuses on chemical isotopes, radioactive decay (half-life), and the uses of radioactive isotopes. Analogies and simulations are used along with hands-on investigations and computer searches.

**Just the Right Size:**

Organisms must take in food, water, gases, and chemicals, as well as excrete waste products to live. As cells grow larger, the surface area and volume both increase. At some point, cells grow so large that they can no longer efficiently exchange materials through the plasma membrane. This is because the volume of the cell contents increases faster than the surface area of the cell.

**Rolling Ramps:**

Ramps are used in multiple ways to make our lives easier and safer. Students will explore the construction of ramps to meet a specific purpose. They will also apply their data to determine acceleration. Acceleration is equal to the change in velocity divided by the elapsed time. A = ΔV/Δt

**Chemical Isotopes**



High School Chemistry or Physics

**Estimated Time:**

5 class periods or more depending upon which optional activities are selected

**Materials:**

Part I:

3 old pennies (prior to 1982) and 5 new pennies (made after 1982) for each pair of students

Balance

Sealed 35 mm film canisters that contain random amounts of old pennies and new pennies

Part II:

50 pennies per pair of students

Small cup to hold and shake pennies

Part III:

Ice cubes

Graduated cylinder, 100mL

Stop watch

Funnel

Ring stand

Iron ring to hold funnel

**Conceptual Background:**

This is a 3 part lesson that focuses on chemical isotopes, radioactive decay (half-life), and the uses of radioactive isotopes. Analogies and simulations are used along with hands-on investigations and computer searches.

Note: Background information and lesson plans can be obtained from The United States Nuclear Regulatory Commission <http://www.nrc.gov/reading-rm/basic-ref/teachers.html>

**Mathematics Standards:**

MA 12.1.3.a Compute accurately with real numbers

MA 12.1.3.b Simplify exponential expressions

MA 12.1.3.c Multiply and divide numbers using scientific notation

MA 12.1.3.d Select, apply, and explain the method of computation when problem solving using real numbers

MA 12.1.4.a Use estimation methods to check the reasonableness of real number computations and decide if the problem calls for an approximation or an exact number

MA 12.1.4.b Distinguish relevant from irrelevant information, identify missing information and either find what is needed or make appropriate estimates

MA 12.2.2.a Use coordinate geometry to analyze geometric situations

MA 12.2.5.a Use strategies to find surface area and volume of complex objects

MA 12.2.5.b Apply appropriate units and scales to solve problems involving measurement

MA 12.3.1.a Represent, interpret, and analyze functions with graphs, tables, and algebraic notation and convert among these representations

MA 12.3.1.c Identify the slope and intercepts of a linear relationship from an equation or graph

MA 12.3.1.d Identify characteristics of linear and non-linear functions

MA 12.3.1.e Graph linear and non-linear functions

MA 12.3.1.f Compare and analyze the rate of change by using ordered pairs, tables, graphs, and equations

MA 12.3.2.a Model contextualized problems using various representations

MA 12.3.2.c Analyze situations to determine the type of algebraic relationship

MA 12.3.2.d Model contextualized problems using various representations for non-linear functions

MA 12.4.1.a Interpret data represented by the normal distribution and formulate conclusions

MA 12.4.1.b Compute, identify, and interpret measures of central tendency when provide a graph or data set.

MA 12.4.2.a Compare data sets and evaluate conclusions using graphs and summary statistics

MA 12.4.3.a Construct a sample space and a probability distribution

MA 12.4.3.e Determine the relative frequency of a specified outcome of an event to estimate the probability of an outcome

**Science Standards:**

SC 12.1.1.a Formulate a testable hypothesis supported by prior knowledge to guide an investigation

SC 12.1.1.d Select and use lab equipment and technology appropriately and accurately

SC 12.1.1.e Use tools and technology to make detailed qualitative and quantitative observations

SC 12.1.1.f Represent and review collected data in a systematic, accurate, and objective manner

SC 12.1.1.g Analyze and interpret data, synthesize ideas, formulate and evaluate models, and clarify concepts and explanations

SC 12.1.1.j Share information, procedures, results, conclusions, and defend findings to a scientific community

SC 12.1.1.l Use appropriate mathematics in all aspects of scientific inquiry

SC 12.1.3.b Assess the limits of a technological design

SC 12.2.1.f Recognize the charges and relative locations of subatomic particles

SC 12.2.1.g Describe properties of atoms, ions, and isotopes

SC 12.2.3.h Recognize that nuclear reactions convert a fraction of the mass of interacting particles into energy, and this amount of energy is much greater than the energy in chemical interactions

**Language Arts Standards:**

LA 12.1.5.a Determine meaning of words through structural analysis, using knowledge of Greek, Latin, and Anglo-Saxon roots, prefixes, and suffices to understand complex words, including words in science, mathematics, and social studies

LA 12.1.5.b Relate new grade level vocabulary to prior knowledge and use in new situations

LA 12.1.6.d Summarize, analyze, synthesize, and evaluate informational text

LA 12.1.6.f Analyze and evaluate information from text features

LA 12.1.6.g Analyze, evaluate, and make inferences based on the characteristics of narrative and informational genres and provide evidence from the text to support understanding

LA 12.1.6.i Use narrative and informational text to develop a national and global multi-cultural perspective

LA 12.1.6.j Generate and/or answer literal, inferential, critical, and interpretive questions by analyzing, synthesizing, and evaluating prior knowledge, information from the text, and additional sources to support answers

LA 12.1.6.n Make complex or abstract inferences or predictions by synthesizing information while previewing and reading text

LA 12.2.2.a Write in a variety of genres, considering purpose, audience, medium, and available technology

LA 12.2.2.c Select and apply an organizational structure appropriate to the task

LA 12.3.2.a Apply listening skills needed to summarize and evaluate information given in multiple situations and modalities.

LA 12.3.2.b Listen and respond to messages by expressing a point of view on the topic using questions, challenges, or affirmations

LA 12.3.2.c Listen to and evaluate the clarity, quality, and effectiveness of important points, arguments, and evidence being communicated

LA 12.3.3.b Solicit and respect diverse perspectives while searching for information, collaborating, and participating as a member of the community

LA 12.4.1.a Select and use multiple resources to answer questions and defend conclusions using valid information

LA 12.4.1.b Demonstrate ethical and legal use of information by citing sources using prescribed formats and tools

LA 12.4.1.c Practice safe and ethical behaviors when communicating and interacting with others

LA 12.4.1.e While reading, listening, and viewing, evaluate the message for bias, commercialism, and hidden agendas

**Purpose/Objective:**

The purpose of Part I is to demonstrate that the isotopes of an element have different masses and that the atomic mass is the weighted average of the naturally occurring isotopes of an element. The purpose of Part II is to simulate the half-life of radioactive isotopes. Students apply their knowledge of half-life to solve problems. In Part III students research the uses of radioactive isotopes, safety issues, and the recent nuclear disaster in Japan.

Procedure:

**Part I. Isotopes**

1. In pairs, students should examine a sample of pennies that consist of 3 pennies made prior to 1982 (old) and 5 pennies made after 1982 (new). The students should visually examine the pennies to compare and contrast similarities and differences. Record. (SC 12.1.1.d)
2. Determine the mass of the individual coins. Record. (SC 12.1.1.d)
3. Calculate the average mass of the OLD (3) pennies. Record. (MA 12.1.3.a) (SC 12.1.1.d)
4. Calculate the average mass of the NEW (5) pennies. Record. (MA 12.1.3.a) (SC 12.1.1.d)
5. Determine the mass of the 5 old pennies using the average mass (5 times the average found in step 3) for a new total for the old pennies. Add this result to the total mass of the 20 new pennies (20 times the average found in step 4) and divide by 25. This is the weighted average mass of the 25 pennies. (MA 12.1.3.a) (SC 12.1.1.l)
6. Compare average mass of the old pennies (step 3) and the average mass of the new pennies (step 4) with the weighted average mass (step 5).

 Write a paragraph describing how weighted average mass is similar to atomic mass of elements listed in the Periodic Table. (MA 12.1.1.3.d) (MA 12.1.4.a) (SC 12.1.1.g) (LA 12.2.2.a)

1. Construct a table with class data on the old pennies which includes the mass of each penny and the group average mass.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Group | Penny 1 | Penny 2 | Penny 3 | Average |  |  |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |

1. The analysis of this data collection provides an opportunity to discuss the variables that may contribute to the differences in the mass of the pennies; the need to establish standardized procedures for the use of equipment; the use of appropriate scale of the unit of measure; and the precision of the equipment being used will determine the number of significant digits. (MA 12.1.3.a) (MA 12.4.1.a) (MA 12.2.5.b) (SC 12.1.1.d) (SC 12.1.1.e) (SC 12.1.1.l)
2. Pennies made before 1982 were made mostly of copper (95%) and some tin (5%). Today, pennies are made of zinc coated with copper. The old and new pennies have different masses. Chemical isotopes vary in mass due to a varying number of neutrons. Write a paragraph describing how pennies are analogous to isotopes. (SC 12.2.1.f) (SC 12.2.1.g) (LA 12.2.2.a)
3. Obtain a sealed canister from your teacher. Record the identifying number and the mass of the empty canister. This information is located on the canister label.
4. Determine the mass of the sealed canister. (MA 12.1.3.a) (SC 12.1.1.d)
5. Calculate the number of old and new pennies in the canister. The total number of pennies in the canister is 10. Create an equation and solve for x. Record all work. Hint: determine the mass of the pennies in the canister. Use the average mass of old pennies and the average mass of new pennies that you determined earlier. (MA 12.1.3.a) (MA 12.1.4.a) (MA 12.1.4.b) (SC 12.1.1.f) (SC 12.1.1.l)
6. Now apply your knowledge by calculating the average mass of calcium using the following information: (MA 12.1.3.a) (MA 12.1.3.d) (MA 12.1.4.a) (SC 12.1.1.l)

|  |  |  |
| --- | --- | --- |
| Element | Abundance | Atomic Mass |
| 40Ca | 96.94% | 39.963 |
| 42Ca | 0.647% | 41.959 |
| 43Ca | 0.135% | 42.959 |
| 44Ca | 2.09% | 43.959 |
| 46Ca | 0.004% | 45.954 |
| 48Ca | 0.187% | 47.953 |

1. The atomic mass of silver (Ag) is 107.868 a.m.u. It is composed to two stable isotopes 107Ag with an atomic mass of 106.901 and 109Ag with an atomic mass of 108.905. What is the relative abundance (%) of these isotopes in naturally occurring silver? (MA 12.1.3.a) (MA 12.1.3.d) (MA 12.1.4.a) (SC 12.1.1.l)
2. Only certain isotopes are radioactive. Those that decay are called radioactive or unstable isotopes. Students should analyze the band of stability graph to determine the relationship between the number of neutrons and protons and unstable isotopes. Use the graph to identify the atomic number, Z, of elements that are stable. Use the graph or Periodic Table to predict whether the following elements are stable or unstable: potassium, copper, argon. The graph and additional information and questions are can be found at [http://www.algebralab.org/practice/practice.aspx?file=Reading\_TheBandOfStability.xml](http://www.algebralab.org/practice/practice.aspx?file=Reading_TheBandOfStability.xml%20)  (MA 12.1.4.b) (MA 12.2.2.a) (MA 12.3.1.a) (MA 12.4.1.a) (MA 12.4.1.b) (SC 12.1.1.g)

Students should note that atoms that have an even number of protons and neutrons or an odd number of protons and neutrons are typically stable isotopes. Typically atoms that have odd numbers of protons and an even number of neutrons are unstable or radioactive.

**Part II. Determining Half-Life**

Radioactive decay involves the spontaneous transformation of one element into another. This happens by changing the number of protons in the nucleus. Radioactive elements disintegrate at a known rate. The process of radioactive decay is spontaneous and irreversible. The rate of radioactive disintegration is called half-life. The units of half-life are time. A half-life is the time it takes for half of the radioactive isotopes to decay. If we know the half-life of an isotope, we can use the number of radiogenic isotopes that have been generated to determine age. In pairs, students explore the concept of half-life by doing a coin toss activity.

1. Give each pair of students 50 pennies. In this simulation of radioactive decay, the “heads” will represent radioactive nuclei. The “tails” are decayed nuclei. Count your nuclei or pennies.
2. Record in a data table. (SC 12.1.1.f) (LA 12.2.2.c)
3. Predict how many pennies will be “head” or radioactive when the pennies are mixed and then dumped out. Record in your data table. (MA 12.4.3.e) (SC 12.1.1.a) (SC 12.1.1.f)
4. Place the nuclei (all the pennies) into a paper cup, cover with your hand, shake, and dump onto your desk or lab bench. Separate the nuclei into 2 piles – heads and tails. Count the nuclei in each pile. Record in the data table the number of radioactive nuclei (heads). Predict how many radioactive nuclei (heads) you will have after the next toss. (MA 12.4.3.a) (SC 12.1.1.a)
5. Place only the radioactive nuclei (heads) into the cup, cover with your hand, shake, and dump onto your desk or lab bench. Again separate the nuclei into 2 piles – heads and tails. Count the nuclei in each pile. Record in the data table the number of radioactive nuclei (heads). Predict how many radioactive nuclei (heads) you will have after the next toss. (SC 12.1.1.a) (SC 12.1.1.f)
6. Continue this procedure until there are no radioactive nuclei (heads) remaining.
7. Pool the class data. (MA 12.4.2.a) (SC 12.1.1.j)
8. Create a graph by plotting the number of radioactive nuclei on the y-axis and the number of tosses on the x-axis. The number of tosses repreents half-lives. When a penny is flipped we have a 50% chance of getting heads and a 50% chance of getting tails. Suppose you had 100 pennies (nuclei of a radioactive element), how many heads would you expect with the first toss? These 50 pennies represent the half-life of pennies. How many pennies will be left after the second half-life? How many would be left after the third half-life? Examine the graph to determine if these expectations were met. Write a paragraph explaining your results. (MA 12.1.4.b) (MA 12.2.2.a) (MA 12.3.1.a) (MA 12.3.1.f) (MA 12.4.1.a) (MA 12.4.1.b) (SC 12.1.1.f) (SC 12.1.1.g) (LA 12.2.2.a)
9. If you started with 800 radioactive nuclei, how many would remain undecayed after 1 half-live, 2 half-lives, 3 half-lives? Explain your reasoning. (MA 12.1.3.a) (MA 12.1.3.d) (MA 12.1.4.a) (MA 12.4.1.b) (SC 12.1.1.l)
10. A sample of 12,000 nuclei has 3755 undecayed nuclei remaining. How many half-lives have passed? Explain your thinking in solving this problem. (MA 12.1.3.a) (MA 12.1.3.d) (MA 12.1.4.a) (MA 12.4.1.b) (SC 12.1.1.l)
11. How many half-lives would it take for 4x1020 nuclei to decay to 30% of the original number of nuclei? Explain how you solved this problem. (MA 12.1.3.b) (MA 12.1.3.c) (MA 12.1.3.d) (MA 12.1.4.a) (MA 12.1.4.b) (MA 12.4.1.b) (SC 12.1.1.l)
12. Which of the following samples would decay the most in 5 years: 14C, 40K, 87Rb, and 238U? Which would decay the least? Explain your reasoning. (MA 12.1.4.b) (MA 12.4.1.b) (LA 12.2.2.a)

**Part III Uses of Radioactive Isotopes**

1. Carbon-14 is used to calculate the age of something that once was living (contains organic carbon). The half-life of 14C is 5730 years; therefore it is not used for dating materials older than 35,000 years. 14C is being constantly produced and is incorporated into the carbon cycle. This means that all living things contain some radioactive 14C. When organisms die, no additional 14C is formed. The 14C that was originally in the organism disintegrates. By measuring the radioactivity of the sample and the amount of 14C remaining, we can calculate when the organism died. To gain an understanding of this concept give each pair of students an ice cube, 100mL graduated cylinder, stopwatch, funnel, ring stand and iron ring.

* 1. Determine the volume of the ice cube. Record the volume and the time. (MA 12.2.5.a) (SC 12.1.1.d)
	2. Make a data table to record the time and the volume of water that will collect in the graduated cylinder as the ice melts. Determine the time intervals and record for 20 minutes. (SC 12.1.1.f) (LA 12.2.2.c)
	3. What are the units for the rate at which the ice cube melts? (MA 12.2.5.a) (MA 12.4.1.b)
	4. Use your data to create a graph. Which axis will be used for volume and which axis for time? Hint: slope is rise (y-axis) over run (x-axis). (MA 12.2.2.a) (MA 12.3.1.a) (MA 12.3.1.c) (MA 12.3.1.d) (MA 12.3.1.e) (MA 12.3.2.a) (SC 12.1.1.l)
	5. Use the graph to predict when the ice cube would be completely melted. (MA 12.2.2.a) (MA 12.3.1.a) (MA 12.3.1.f) (MA 12.4.1.b) (SC 12.1.1.f)
	6. Describe the shape of the graph. (MA 12.3.2.c) (MA 12.3.2.d) (LA 12.2.2.a)
	7. Explain how the graph helps you determine the rate at which the ice cube melts and the rate of radioactive decay. (MA 12.2.2.a) (MA 12.3.1.a) (MA 12.3.1.f) (MA 12.4.1.b) (SC 12.1.1.l) (LA 12.2.2.a)
	8. Application: Determine the age of a rock that has 45% of the original 40K present. Show your work.(MA 12.1.3.d) (MA 12.1.4.a) (MA 12.1.4.b) (SC 12.1.1.l)
1. Research some of the many uses of radioactive isotopes such as dating of rocks, X rays, CAT scans, activation analysis, carbon dating, sterilization of foods and medical equipment, control of insect populations, radiography, power space crafts, seeds of plants, track ocean currents, clean up toxic pollutants, radioisotopic gauges, diagnose of illnesses, locate underground natural resources (oil and gas), their use in smoke detectors, ice cream, nonstick frying pans, and reflective signs, measure air pollution, prove age of works of art and help determine authenticity. Students should identify the isotopes involves, how radioactivity is used, and safety concerns involved. Present your findings to the class. (MA 12.1.4.b) (SC 12.1.1.j) (SC 12.1.3.b) (LA 12.1.5.a) (LA 12.3.2.a) (LA 12.3.2.b) (LA 12.3.2.c) (LA 12.3.3.b) (LA 12.4.1.a) (LA 12.4.1.b) (LA 12.4.1.c) (LA 12.4.1.e)
2. When isotopes decay they release energy. Explain how this energy can be converted into a useful form, for example, electricity. Think about which radioactive isotopes can be used. (MA 12.1.4.b) (SC 12.1.3.b) (SC 12.2.1.g) (SC 12.2.3.h) (LA 12.1.5.a) (LA 12.1.6.f) (LA 12.1.6.j) (LA 12.2.2.a) (LA 12.4.1.a)
	1. Would it better for an isotope chosen to produce energy to have a short or long half-life? Explain your reasoning.
	2. How can a radioactive reaction be maintained so a constant supply of energy is produced?
	3. Research how 235U decays. Explain the chain reaction of 235U decay using a diagram. (SC 12.2.3.h)
	4. How can a chain reaction be controlled? If the reaction is not controlled properly a meltdown can occur. Describe what is meant by a meltdown
3. Show the short Times video (1.33 min) “Japanese Nuclear Plant in Jeopardy”. (<http://learning.blogs.nytimes.com/2011/03/16/crisis-in-japan-understanding-nuclear-energy-and-reactors/>) Discuss thoughts and questions. (SC 12.2.1.g) (LA 12.1.6.i) (LA 12.3.2.a)
4. The people living near the nuclear plant disaster in Japan are at risk of exposure to strontium-90. 90Sr can easily get into the water and milk supply which is then ingested by people. The half-life of 90Sr is 28.8 years. How long will it take for half of the strontium to decay? Explain your reasoning. (MA 12.1.3.d) (MA 12.1.4.a) (MA 12.1.4.b) (MA 12.4.1.b) (SC 12.1.1.l)
5. Optional: Students can investigate two cases involving radon exposure. This Radon Quest requires students to prepare a report addressing: the probable causes of elevated radon values; the extent of the potential problem; the possible routes and effects of human exposure to radon. (LA 12.1.6.d) (LA 12.1.6.g) (LA 12.2.2.a) <http://www.rst2.edu/ties/radon/index.htm>
6. Optional: The Half-life GizmoTM is a simulation in which students explore half-life by observing and measuring radioactive decay. Data is collected, graphed, and analyzed. (MA 12.1.4.b) (MA 12.3.1.a) (MA 12.4.1.a) (MA 12.4.2.a) (SC 12.1.1.e) (SC 12.2.1.g) (LA 12.1.5.b) (LA 12.1.6.f) (LA 12.1.6.n) <http://www.explorelearning.com/index.cfm?method=cResource.dspDetail&ResourceID=369>

Just the Right Size

High School Biology

**Estimated Time:**

3 class periods

**Materials:**

Phenolphthalein agar blocks

0.1% NaOH

Beakers 250 mL

Plastic spoon and knife

Paper towels

1 wood cube 2 cm x 2 cm

4 wood cubes 1cm x 1 cm

Small metric ruler

**Conceptual Background:**

Organisms must take in food, water, gases, and chemicals, as well as excrete waste products to live. As cells grow larger, the surface area and volume both increase. At some point, cells grow so large that they can no longer efficiently exchange materials through the plasma membrane. This is because the volume of the cell contents increases faster than the surface area of the cell.

**Mathematics Standards:**

MA 12.1.3.a Compute accurately with real numbers

MA 12.2.5.a Use strategies to find surface area and volume of complex objects

MA 12.2.5.b Apply appropriate units and scales to solve problems involving measurement

MA 12.2.5.f Determine surface area and volume of three-dimensional objects

MA 12.3.1.a Represent, interpret, and analyze functions with graphs, tables, and algebraic notation and covert among these representations

MA 12.3.1.e Graph linear and non-linear functions

MA 12.4.1.b Compute, identify, and interpret measures of central tendency when provided a graph or data set

MA 12.4.1.c Explain how sample size and transformations of data affect measures of central tendency

MA 12.4.1.d Describe the shape and determine spread and outliers of a data set

MA 12.4.2.a Compare data sets and evaluate conclusions using graphs and summary statistics

MA 12.4.2.b Support inferences with valid arguments

**Science Standards:**

SC 12.1.1.a Formulate a testable hypothesis supported by prior knowledge to guide an investigation

SC 12.1.1.b Design and conduct logical and sequential scientific investigations with repeated trials and apply findings to new investigations

SC 12.1.1.c Identify and manage variables and constraints

SC 12.1.1.d Select and use lab equipment and technology appropriately and accurately

SC 12.1.1.e Use tolls and technology to make detailed qualitative and quantitative observations

SC 12.1.1.f Represent and review collected data in a systematic, accurate, and objective manner

SC 12.1.1.g Analyze and interpret data, synthesize ideas, formulate and evaluate models, and clarify concepts and explanations

SC 12.1.1.h Use results to verify or refute a hypothesis

SC 12.1.1.i Propose and/or evaluate possible revisions and alternate explanations

SC 12.1.1.j Share information, procedures, results, conclusions, and defend findings to a scientific community

SC 12.1.1.k Evaluate scientific investigations and offer revisions and new ideas as appropriate

SC 12.1.1.l Use appropriate mathematics in all aspects of scientific inquiry

**Language Arts Standards:**

LA 12.2.2.a Write in a variety of genres, considering purpose, audience, medium, and available technology

LA 12.2.2.c Select and apply an organizational structure appropriate to the task

LA 12.3.1.a Communicate ideas and information in a manner appropriate for the purpose and setting

LA 12.3.2.b Listen and respond to messages by expressing a point of view on the topic using questions, challenges, or affirmations

LA 12.3.2.c Listen and evaluate the clarity, quality, and effectiveness of important points, arguments, and evidence being communicated

LA 12.3.3.a Interact and collaborate with others in learning situations by contributing questions, information, opinions, and ideas using a variety of media and formats

LA 12.4.1.a Select and use multiple resources to answer questions and defend conclusions using valid information

LA 12.4.1.b Demonstrate ethical and legal use of information by citing sources using prescribed formats and tools

LA 12.4.1.c Practice safe and ethical behaviors when communicating and interacting with others

**Purpose/Objective:**

To determine the relationship between cellular surface area and volume. Explain how cell shape is related to cell function.

**Procedure:**

1. It is estimated that humans have 5 trillion cells. Brainstorm the reason organisms aren’t composed of just a few large cells. Record all responses and review them at the end of the activity so students can see their growth in understanding. (LA 12.3.1.a) (LA 12.3.2.b) (LA 12.3.3.a)
2. In pairs, students should measure the two wooden cubes and then calculate surface areas and volumes of two wooden cubes using the following formulas:

Surface area of a cube (cuboidal cell) = 6 s2 (s = side of cell)

Volume of a cube (cuboidal cell) = s3

(MA 12.1.3.a) (MA 12.2.5.a) (MA 12.2.5.b) (MA 12.2.5.f) (SC 12.1.1.d) (SC 12.1.1.l)

1. Organize the data in a table. (SC 12.1.1.f) (LA 12.2.2.c)
2. Calculate the surface area to volume (SA:V) ratio. Record in your data table. (MA 12.1.3.a)
(SC 12.1.1.f) (SC 12.1.1.l)
3. Pool student data. Calculate the mean. Is the class mean similar to your results? Identify some of the variables and how they could be controlled. (MA 12.3.1.a) (MA 12.4.1.b)
4. Use the class mean to determine error analysis. Use the following formula: (class average minus your results divided by class mean x 100) (MA 12.1.3.a)
5. Create a graph. Analyze the graph and write a paragraph explaining the relationship between surface area and volume. What happens to the surface area as the volume increases? Describe the relationship shown in the graph. (MA12.3.1.a) (MA 12.3.1.e) (SC 12.1.1.l) (LA 12.3.1.a)
6. Analyze and discuss the relationship as well as the need for repeated trials. (MA 12.4.1.c)
(MA 12.4.1.d) (SC 12.1.1.g) (LA 12.3.1.a) (LA 12.3.2.b) (LA 12.3.3.a)
7. Human bodies contain over 220 different cell types. One of the basic cell types is epithelial cells. Epithelial cells have three possible shapes: cube, columnar, and squamous. In pairs, students will use the three different shapes to investigate the relationship between surface area and volume in living organisms. Use the metric ruler and plastic knife to make the representative cells (for simplicity sake a rectangular shape will be used to represent the squamous cell). Be sure to wash up both the ruler and plastic knife soon after using. Record the cell sizes in a table.
(MA 12.2.5.b) (SC 12.1.1.d) (SC 12.1.1.f) (SC 12.1.1.l)
8. Calculate the total surface area of each of the cell models using the following formulas and record in a data table: (MA 12.1.3.a) (MA 12.2.5.a) (MA 12.2.5.f) (SC 12.1.1.l) (LA 12.2.2.c)

Surface area of a cube (cuboidal cell) = 6 s2 (s = side of cell)

Surface area of a cylinder (columnar cell) = 2 πr2 + 2πrh

Surface area of a squamous cell = 2[(L\*W) + (L\*H) + (W\*H)]

1. Calculate the volume of each agar shape. Show all calculations and record your answers in a data table. (MA 12.1.3.a) (MA 12.2.5.a) (SC 12.1.1.l) (LA 12.2.2.c)
Use the following formulas:

Volume of a cube (cuboidal cell) = s3

Volume of a cylinder (columnar cell) = πr2h

Volume of a squamous cell = L\*W\*H

1. Calculate the surface area to volume (SA: V) ratio for each agar shape. Record in the data table. (MA 12.1.3.a) (SC 12.1.1.f) (SC 12.1.1.l)
2. Develop a hypothesis about how far the NaOH will travel into each cell shape. Think about the answers to these questions when developing your hypothesis. Which of the agar shapes has the greatest SA: V ratio? Which agar shape will have the greatest amount of diffusion? How will the amount of diffusion compare to the total volume of each agar shape. State your hypothesis as a sentence in your lab notebook. (SC 12.1.1.a)
3. After writing your hypothesis, use a plastic spoon to place the agar shapes in the beaker. (SC 12.1.1.d)
4. Pour enough sodium hydroxide (NaOH) to cover the agar shapes. (SC 12.1.1.d)
5. Record your starting time. Allow the agar shapes to remain in the NaOH for 10 minutes. Do not disturb the beaker. Observe. Do you see any color change? Describe. Record. (SC 12.1.1.e) (SC 12.1.1.f) (LA 12.2.2.a)
6. After 10 minutes, remove the agar shapes with the spoon and immediately blot the agar shapes dry with paper towels. (SC 12.1.1.d)
7. Cut the agar shapes in half with your plastic knife. (SC 12.1.1.d)
8. Measure the distance from the edge of the agar shape to the end of the color change (which is the distance the NaOH traveled). Repeat for each agar shape. Record this distance in your data table. Was your hypothesis correct? Explain. (MA 12.2.5.b) (SC 12.1.1.d) (SC 12.1.1.e)
(SC 12.1.1.f) (SC 12.1.1.h) (SC 12.1.1.l) (LA 12.2.2.a)
9. Pool class data by creating a table from large to small cells in each of the three cell shapes. Discuss the variance in results. Write a paragraph discussing the importance of repeated trials and managing variables. Identify possible sources of error and ideas for controlling these variables. (MA 12.3.1.a) (MA 12.4.1.b) (MA 12.4.1.c) (MA 12.4.2.a) (SC 12.1.1.b) (SC 12.1.1.c) (SC 12.1.1.g) (SC 12.1.1.i) (SC 12.1.1.j) (SC 12.1.1.k) (LA 12.2.2.a) (LA 12.2.2.c) (LA 12.3.1.a) (LA 12.3.2.b) (LA 12.3.2.c) (LA 12.3.3.a)
10. Make a graph using class data (found in #20). Analyze the graph to determine the relationship between cell size and shape and diffusion. Write an explanation of the relationship. (MA 12.3.1.e) (SC 12.1.1.g) (SC 12.1.1.l) (LA 12.2.2.a)
11. Which increases at a faster rate, cell volume or cell size? Explain your reasoning using data collected in this investigation. (MA 12.4.2.a) (MA 12.4.2.b) (SC 12.1.1.g) (LA 12.2.2.a)
12. Compare the amount of diffusion to the total volume of each agar shape. Write an explanation. Consider the answers to the following questions: What is the trend? How does the volume of the cell relate to the rate of diffusion? When cells reach a volume when diffusion slows down, it divides undergoes mitosis. (SC 12.1.1.g) (LA 12.2.2.a)
13. Relate cell size and shape to the function of cell. For instance, as the surface area of a cell increases, the cell becomes increasingly fragile. Cell shape also affects metabolic rates in organisms. Research the relationship of cell shape and metabolism. Report your findings to the class. (SC 12.1.1.j) (LA 12.3.1.a) (LA 12.3.2.b) (LA 12.3.3.a) (LA 12.4.1.a) (LA 12.4.1.b)
(LA 12.4.1.c)
14. The human respiratory system contains columnar, cuboidal, and squamous epithelial cells. Bronchi are lined with cuboidal cells while tracheal cells are lined with columnar shaped cells and alveoli are lined with squamous shaped cells. Write a paragraph describing the relationship between cell shape and cell function. To answer this question, you will need to research the function of each of these cells and connect that information to the data you have collected in this lab. (LA 12.2.2.a) (LA 12.4.1.a) (LA 12.4.1.b) (LA 12.4.1.c)
15. Organisms have a variety of modifications to survive inefficient SA: V ratios. Using a variety of sources to find and report to the class on 3 modifications. Hint: examine transport systems, respiration, digestion, and internal structures to increase surface area. (SC 12.1.1.j) (LA 12.3.1.a) (LA 12.4.1.a) (LA 12.4.1.b) (LA 12.4.1.c)
16. How do organelles help compensate for a small SA: V ratio? Using a variety of sources to find and write about three examples. Report to the class. (SC 12.1.1.j) (LA 12.2.2.a) (LA 12.3.1.a) (LA 12.3.2.b) (LA 12.3.2.c) (LA 12.3.3.a) (LA 12.4.1.a) (LA 12.4.1.b) (LA 12.4.1.c)

**Teacher Information:**

Agar cubes are cheap and easy to make. In a 2L flask, mix 37.5g agar with 1.25 L water.  Bring to ~80C on a hot plate while stirring. **Do not over heat, as the agar will burn and stick to the flask.** This is a huge mess to clean up.  Under heating will cause the agar to be too mushy and not work for this lab.  It is actually easy to tell when agar is ready, as it changes consistency and becomes more viscous.  Once the stir bar no longer creates large vortex, the agar is probably ready to be poured.   Add 0.1g phenolphthalein/ flask (wear gloves) and stir until dissolved (or at least evenly distributed- the phenolphthalein is only slightly soluble in the agar).  This can be done at the beginning or end of the process, just as long as it is thoroughly distributed in the agar mixture before pouring.  Pour into pans (rectangular cake pans work well) when agar is ready.  Pour so agar fills pans to ~3-4 cm depth.  This will take about 2.5 L of agar (two of the flasks) if using the 11x13 inch pans (20cm x 30cm). Agar pans will be cut into sections that are 4cm x 6cm (and 3-4cm deep).  One 11x13 (20 x 30cm) cake pan requires 2.5 L to fill up to 3.5 cm depth.  Each pan yields 25 agar blocks (100 students).

The color change that occurs is related to cube size.

 **Rolling Ramps**

High School Physics

**Estimated Time**

3 or 4 class periods

**Materials:**

Assorted items for ramp construction (books, wood, cardboard)

Assorted ramp covers: wax paper, foil, plywood, sand paper, carpet, artificial grass

Assorted items to roll: toy cars, assorted ball (ping pong ball, marble, baseball), marbles, tin cans, toilet paper rolls, pencils, crayons, ball bearings, etc.

Masking tape

Calculators

Stopwatch or watch with second hand

**Conceptual Background:**

Ramps are used in multiple ways to make our lives easier and safer. Students will explore the construction of ramps to meet a specific purpose. They will also apply their data to determine acceleration. Acceleration is equal to the change in velocity divided by the elapsed time. A = ΔV/Δt

**Purpose/Objective:**

To investigate how properties of a ramp must be adjusted for purpose and distance. To measure the changing speed of an object and graphically analyze its acceleration.

**Mathematics Standards:**

MA 12.1.3.a Compute accurately with real numbers

MA 12.1.4.a Use estimation methods to check the reasonableness of real number computations and decide if the problem calls for an approximation or an exact number

MA 12.1.4.b Distinguish relevant from irrelevant information, identify missing information and either find what is needed to make appropriate estimates

MA 12.2.4.a Sketch and draw appropriate representations of geometric objects using ruler, protractor, or technology

MA 12.2.4.b Use geometric models to visualize, describe, and solve problems

MA 12.2.5.b Apply appropriate units and scales to solve problems involving measurement

MA 12.3.1.a Represent, interpret, and analyze functions with graphs, tables, and algebraic notation and convert among these representations

MA 12.3.1.c Identify the slope and intercepts of a linear relationship from an equations graph

MA 12.3.1.d Identify characteristics of linear and non-linear functions

MA 12.3.1.e Graph linear and non-linear functions

MA 12.3.1.f Compare and analyze the rate of change by using ordered pairs, tables, graphs, and equations.

MA 12.3.2.a Model contextualized problems using various representations

MA 12.3.3.k Multiply, divide, and simplify rational expressions

**Science Standards:**

SC 12.1.1.a Formulate a testable hypothesis supported by prior knowledge to guide an investigation

SC 12.1.1.b Design and conduct logical and sequential scientific investigations with repeated trials and apply findings to new investigations

SC 12.1.1.c Identify and manage variables and constraints

SC 12.1.1.d Select and use lab equipment and technology appropriately and accurately.

SC 12.1.1.e Use tools and technology to make detailed qualitative and quantitative observations

SC 12.1.1.f Represent and review collected data in a systematic, accurate, and objective manner

SC 12.1.1.g Analyze and interpret data, synthesize ideas, formulate and evaluate models, and clarify concepts and explanations

SC 12.1.1.h Use results to verify or refute a hypothesis

SC 12.1.1.i Propose and/or evaluate possible revisions and alternate explanations

SC 12.1.1.j Share information, procedures, results, conclusions, and defend findings to a scientific community

SC 12.1.1.k Evaluate scientific investigations and offer revisions and new ideas as appropriate

SC 12.1.1.l Use appropriate mathematics in all aspects of scientific inquiry

SC 12.2.2.a Describe motion with respect to displacement and acceleration

SC 12.2.2.c Make predictions based on relationships among net force, mass, and acceleration

**Language Arts Standards:**

LA 12.2.2.a Write in a variety of genres, considering purpose, audience, medium, and available technology

LA 12.2.2.b Write considering typical characteristics of the selected genre

LA 12.2.2.c Select and apply an organizational structure appropriate to the task

LA 12.3.2.a Apply listening skills needed to summarize and evaluate information given in multiple situations and modalities

LA 12.3.2.b Listen and respond to messages by expressing a point of view on the topic using questions, challenges, or affirmations

LA 12.3.3.a Interact and collaborate with others in learning situations by contributing questions, information, opinions, and ideas using a variety of media and formats

LA 12.3.3.b Solicit and respect diverse perspectives while searching for information, collaborating, and participating as a member of the community

LA 12.4.1.c Practice safe and ethical behaviors when communicating and interacting with others

Procedure:

1. In pairs, students construct a ramp by taping two meter sticks together and several books. Place the ramp on the books. Measure the height of the ramp and record. (MA12.2.5.b) (SC 12.1.1.d) (LA 12.2.2.c)
2. Students choose a variety of objects. Make a hypothesis as to whether they will or will not roll down the ramp. Record your hypothesis. (SC 12.1.1.a)
3. Which will travel the fastest? Record your hypothesis and your reasoning. (SC 12.1.1.a)
4. Test your hypotheses. Record all results. Precaution: make sure that students release the object without pushing. Students also need to think about how they will standardize the timing of the event. One student should be responsible for timing the time of the “roll”. Was your hypothesis correct? Write an explanation including factors or knowledge that you may not have included when writing your hypothesis. (MA 12.2.5.b) (SC 12.1.1.h) (LA 12.2.2.a) (LA 12.2.2.c)
5. Change the height of the ramp and re-test objects chosen in number 2. Record all data. Repeat using a third ramp height. Write responses to the following questions in your notebook: What is the effect of changing the angle of the ramp? What factors could make a difference between your predictions and the actual results? Sketch each of the ramps. Include the angle of the ramp in each of the sketches. (MA 12.2.4.a) (MA 12.2.4.b) (MA 12.2.5.b) (SC 12.1.1.b) (SC 12.1.1.g) (SC 12.1.1.i) (LA: 12.2.2.a) (LA 12.2.2.c)
6. For the final investigation, put carpet on the ramp. Repeat all 3 trials. What is the effect of adding carpet to the ramp? Record your written response in your notebook. (MA 12.2.5.b) (SC 12.1.1.b) (SC 12.1.1.g) (LA 12.2.2.a)
7. Construct a graph using height of the ramp versus distance the object traveled. What patterns are observed? Write a conclusion that summarizes your findings regarding the relationship between ramp height and distance traveled. Compare the time measurements for light and heavier objects. Also compare the height or angle of the ramp. Record your written response in your notebook. (MA 12.1.4.a) (MA 12.1.4.b) (MA 12.3.1.a) (MA 12.3.1.e) (MA 12.3.1.f) (MA 12.3.2.a) (SC 12.1.1.f) (SC 12.1.1.g) (LA 12.2.2.a)
8. Experiment to determine other factors that make an object roll the farthest or shortest distance. Record all observations and strategies. (MA 12.2.5.b) (SC 12.1.1.d) (SC 12.1.1.i) (LA 12.2.2.c)
9. Communicate results to the class. This is a great time to remind students that when surfaces move against one another a force called friction resists motion. All moving objects, including fluids such as air and water, have friction between them and any surface they touch. Different surfaces create different amounts of friction. If there is not a lot of friction between an object and the surface over which it moves, the object moves easily. In general, as friction increases, ease of movement decrease. One way friction can be reduced is by lubricating the surfaces between moving objects. (SC 12.1.1.f) (SC 12.1.1.j) (SC 12.1.1.k) (LA 12.2.2.c) (LA 12.3.2.a) (LA 12.3.2.b) (LA 12.3.3.a) (LA 12.3.3.b)
10. Give each pair of students a golf ball. They have 15 minutes to experiment with the ramp and golf ball to determine the factors that affect the distance traveled. The goal is for the students to be able to adjust the ramp so that the golf ball will roll an arbitrary distance provided by the teacher. Once the distance is give, each pair will record their strategy and results. Sketch the ramp used. Record the angle of the ramp and distance traveled. Discuss your results with the class. (MA 12.2.4.a) (MA 12.2.4.b) (MA 12.2.5.b) (SC 12.1.1.c) (SC 12.1.1.d) (SC 12.1.1.f) (SC 12.1.1.g) (SC 12.1.1.i) (LA 12.2.2.a) (LA 12.2.2.c) (LA 12.3.2.b) (LA 12.3.3.b) (LA 12.3.3.a) (LA 12.3.3.b)
11. Calculate the acceleration of the ball rolling down the ramp. (SC 12.1.1.d) (SC 12.1.1.e) (SC 12.2.2.a)
	1. Create a ramp with a low incline. Sketch the ramp. Include the angle measurement. (MA 12.2.4.a) (MA 12.2.4.b)
	2. Mark four 20 cm intervals on the ramp with masking tape.
	3. Record the time it takes for the ball to travel from A to B. (MA 12.2.5.b)
	4. Record the time it takes for the ball to travel from B to C. (MA 12.2.5.b)
	5. Record the time it takes the ball to travel from C to D. (MA 12.2.5.b)
	6. Calculate the average speed of the ball at each interval. (MA 12.1.3.a) (MA 12.1.4.a) (MA 12.1.4.b) (SC 12.1.1.l)
	7. Calculate the average acceleration by dividing the change in speed by the change in time. Hint: A table with the following columns will greatly enhance data collection: Distance Interval, Time, Total time, Speed (m/s), and Acceleration (MA 12.1.3.e) (MA 12.1.4.a) (MA 12.1.4.b) (MA 12.3.3.k) (SC 12.1.1.f)
	8. Repeat for three trials. (MA 12.2.5.b) (SC 12.1.1.b) (SC 12.1.1.l)
	9. Repeat using a higher incline. Sketch the ramp. Include the angle measurement. Do a minimum of three trials using the higher incline. (SC 12.1.1.b) Analyze the results by making a graph of distance traveled versus total time for a low and high incline ramp. (MA 12.2.4.a) (MA 12.2.4.b) (MA 12.2.5.b) (SC 12.1.1.f) (SC 12.1.1.i) (SC 12.1.1.l)
	10. Compare the slope of the distance versus total time for both the low and high incline ramps. Does the slope change or stay constant? Record your written response in your notebook. (MA 12.3.1.d) (SC 12.1.1.g) (SC 12.1.1.l) (LA 12.2.2.c)
	11. Construct a graph of speed versus total time for both the low and high incline ramps. Does the slope change or stay constant? Record your written response in your notebook. (MA 12.3.1.a) (MA 12.3.1.c) (MA 12.3.1.f) (MA 12.3.2.a) (SC 12.1.1.g)
12. Optional: Test different types of golf balls or ramp surfaces. Create a design for your investigation including data collection and analysis. Sketch the ramp. Include the angle measurement. Communicate your results to the class. (MA 12.2.4.a) (MA 12.2.4.b) (MA 12.2.5.b) (SC 12.1.1.c) (SC 12.1.1.d) (SC 12.1.1.g) (SC 12.1.1.l) (LA 12.2.2.c) (LA 12.3.2.a) (LA 12.3.2.b) (LA 12.3.3.a) (LA 12.3.3.b)
13. Optional: Roll empty cans down the ramp. Compare to full cans. Does mass affect acceleration? Take this a step further by adding weights to the cars in regular intervals. For example, no added mass, 5 washers, 10 washers, 15 washers. It is essential that all washers stay on the vehicle. Predict which mass will travel the greatest distance. Perform 3 trials for each mass. How does increasing the mass affect the distance of the cars (force of objects in motion)? Record your written response in your notebook. Use your data from the chart to explain your answer. Create a graph to analyze the rate of change. (MA 12.2.5.b) (MA 12.3.1.a) (MA 12.3.1.c) (MA 12.3.1.f) (MA 12.3.2.a) (SC 12.1.1.b) (SC 12.1.1.d) (SC 12.1.1.g) (SC 12.1.1.i) (SC 12.1.1.l) (SC 12.2.2.c) (LA 12.2.2.a) (LA 12.2.2.c)
14. Explain your answer to number 13 in terms of Newton’s Second Law. (SC 12.2.2.c) (LA 12.2.2.a)
15. Where do we find ramps? How are they used? Create a brochure to promote ramps or create a web page/blog or news article that informs the general public about ramps, ramp design, and safety concerns. **Hint:** Don’t forget skateboarding, waterparks, and slides. (LA 12.2.2.b) (LA 12.2.2.c)
16. Explain how playground slides are constructed so that they are safe. **Hint:** Think about how friction and angles can be controlled for the purpose intended. Record your written response in your notebook. (MA 12.2.4.b) (SC 12.1.1.c) (LA 12.2.2.a)
17. Optional: List all the ramps found in a specific location such as a school or mall. Measure the angle of the ramp. Discuss how ramps help us. What do you discover about the angle of the ramps? Is there a minimum or maximum or all they all the same? Record your written response in your notebook. (MA 12.2.4.a) (MA 12.2.4.b) (MA 12.2.5.b) (SC 12.1.1.g) (SC 12.1.1.l) (LA 12.2.2.a) (LA 12.2.2.c)
18. Optional: Read *Pig Pig Grows Up* by David McPhail
19. Optional: Imagine you are sledding. You and your friends are having a contest to see who can go down a hill the farthest. You will be starting at the top of the hill at the same time. Build a hill that you think would make your sled go the farthest. Provide a justification for your design along with a sketch. Share with the class. (MA 12.2.4.a) (MA 12.2.4.b) (SC 12.1.1.k) (LA 12.2.2.a) (LA 12.2.2.c) (LA 12.3.2.a) (LA 12.3.2.b) (LA 12.3.3.a) (LA 12.3.3.b) (LA 12.4.1.c)