Period 8 Activity Sheet: Mass and Energy

8.1 What is the Relationship between Energy and Mass?
Your instructor will discuss Einstein’s equation, $E = Mc^2$, which is probably the most important equation of the 20th century.

1) Einstein’s Equation applied to physical changes: stored potential energy
Should adding energy to a spring by winding it change the mass of the spring?

a) Find the weight of the free play radio.

b) Calculate the mass of the radio.

c) While the radio is still hanging, carefully turn the crank one turn to wind up the radio’s spring. Did the weight of the radio change? Did the mass of the radio change?

d) Using the small newton scale, find the force needed to turn the radio’s handle at a constant speed.

e) Find the distance in meters that the end of the handle travels in when it is turned one revolution.

f) Calculate the amount of work done to turn the handle one revolution.

g) The work done to turn the radio handle equals the energy added to the radio’s spring. Use your result from part f) and Einstein’s equation to find the additional mass of the radio as a result of winding its spring.

h) Group Discussion Question: Why did the scale register no change in weight when the spring was wound?

2) Einstein’s Equation applied to physical changes: phase changes

a) Fill a beaker with 100 ml of water. What is the mass of this water?

b) Measure the temperature of the water in Celsius degrees.

c) Suppose that the water was placed in the refrigerator and cooled to 0°C without any of the water freezing. Calculate how much energy the water has lost once it has cooled to 0°C. (The specific heat of water is 1.0 J/gram °C)

d) How much mass has the water lost as a result of this cooling?
e) What if the water at 0 °C is changed into ice at 0 °C? How much energy has the water lost during the phase change from liquid to solid? (The latent heat of freezing water is 335 J/gram.)

f) How much mass has the water lost as a result of this phase change?

g) How much total mass has the water lost after the cooling and freezing processes described above?

h) What percent is this mass loss of the total mass of the water at room temperature?

3) Einstein's Equation applied to chemical changes

a) Measure the mass of a light stick ______________

b) Break the light stick's vial. What type of energy is given off? ________
   Do you detect any infrared radiation? ________

c) Examine a night light. What type of energy is given off? ________
   Do you detect any infrared radiation? ________

d) Since the light stick and the night light give off similar radiation, we compare the brightness of the light stick to the brightness of two night lights. If the light stick's brightness is 10 times greater than the two night lights, what is the wattage of the light stick? (Hint: the wattage of the night lights is given on their back cover.) ______________

e) If the light stick radiates energy at the rate of 0.6 watts for one hour, how many joules of energy have been emitted?

f) Calculate the mass loss due to this emitted energy.

  ______________

g) What is the percent change in the mass of the light stick after it has been radiating for one hour?

  ______________

h) Measure the mass of the radiating light stick. ____________ Is there a noticeable change in mass? _____ _____ Note: we will measure the mass of the light stick again at the end of this period after it has radiated for a longer time.
4) **The limits of mass measurement**

Watch the video clip of the mass of a pencil dot.

a) What was the mass of the paper before the “i” was dotted? 

b) What was the mass of the added dot? 

c) What was the percent change in the mass of the paper after the dot was added? 

d) What was the change in mass in units of energy? 

e) Group Discussion Question: If the scale used in the video could measure one part in one million, would such a scale be helpful in measuring any change in mass of your light stick? Why or why not?

8.2 **What are Nuclear Processes?**

5) **Difference between atomic and nuclear processes**

a) What determines which element an atom is?

b) How can an atom of one element change into an atom of a different element?

c) Is this process a physical, chemical, or nuclear change? 

d) What is the difference between a physical change, a chemical reaction, and a nuclear reaction?

6) **Photon Emission**  Watch the flash bulb/glow-in-the-dark stickers demonstration

a) Are glow-in-the-dark stickers radioactive? 

b) What makes them glow?

c) How are glow-in-the-dark stickers different from radium glow-in-the-dark clocks manufactured years ago?
8.3 What Holds Nuclei Together?
7) The force binding nuclei
   a) What holds electrons in orbit around the nucleus of an atom? ________________
   b) What is a nucleon? __________________________________________
   c) What is a nucleus?
   d) What holds nucleons together in the nucleus of an atom? ________________
   e) The tennis ball model simulates the forces between two protons. What force do
      the springy wires represent? __________________________
      What force do the magnets represent? ______________________
   f) How would the model have to be modified to make it represent a neutron and a
      proton?
   g) How would the model have to be modified to make it represent two neutrons?

8.4 Which Nuclei are Stable?
8) Isotopes
   a) What is an isotope?
   b) How many protons are contained in one atom of Cobalt-60 (\(^{60}_{27}\)Co)? ______
   c) How many neutrons are contained in one atom of \(^{60}_{27}\)Co? ______________
9) Nuclei stability
   a) What determines whether an element with 20 or fewer protons is stable?
   b) What determines whether an element with many more than 20 protons is stable?
   c) What can happen to nuclei with more than 82 protons?
   d) What can happen to a nuclei with \(Z < 82\) protons that has too many neutrons?
   e) What can happen to a nuclei with \(Z < 82\) protons that has too few neutrons?
   f) Why do the stability of small nuclei and the stability of large nuclei follow different
      rules?
10) **Graph of Stable Nuclei**

The graph below shows the number of neutrons versus the number of protons for stable elements.

a) Find the slope of the straight line.

b) What does the straight line represent?

c) What does the curved line show?

**Graph of neutron number N vs proton number Z for stable nuclei**

![Graph of neutron number N vs proton number Z for stable nuclei]
11) Enlarged graph of Stable Nuclei
   The grid on the next page represents an enlargement of a portion of the graph shown in part 9).
   
a) The stable isotopes of calcium are Calcium-40 (\(^{40}_{20}\) Ca), Calcium-42 (\(^{42}_{20}\) Ca), Calcium-43 (\(^{43}_{20}\) Ca), Calcium-44 (\(^{44}_{20}\) Ca), Calcium-46 (\(^{46}_{20}\) Ca), and Calcium-48 (\(^{48}_{20}\) Ca). Darken the squares on the grid that represent these stable isotopes.

b) Mark an X in the square that represents the nucleus of Silicon-40 (\(^{40}_{14}\) Si).

c) Silicon-40 nuclei last only a few seconds. Why is this nucleus unstable?

d) How would this nucleus change as it becomes more stable?

e) How many neutrons must change into protons for this nucleus to become the stable nucleus Calcium-40 (\(^{40}_{20}\) Ca)?

f) Draw a dotted line showing how the box representing Silicon-40 would move as the nucleus turns into a stable nucleus.

12) Mass of the Light Stick
   Now that the light stick used in part 3) has been radiating energy for approximately an hour, measure the mass of the stick again. Is it possible to measure a change in the mass of the stick with this scale? ________________