Name _____ Section _____

# Activity 12: Energy from Nuclear Reactions

## 12.1 A Model of the Composition of Nucleons

**1) Formation of Nucleons** Nucleons consist of quark trios.

a) Place orange or green "quarks" into the metal "nucleon" or "gluon cloud" to represent a proton. Draw a diagram showing the quarks in the proton.

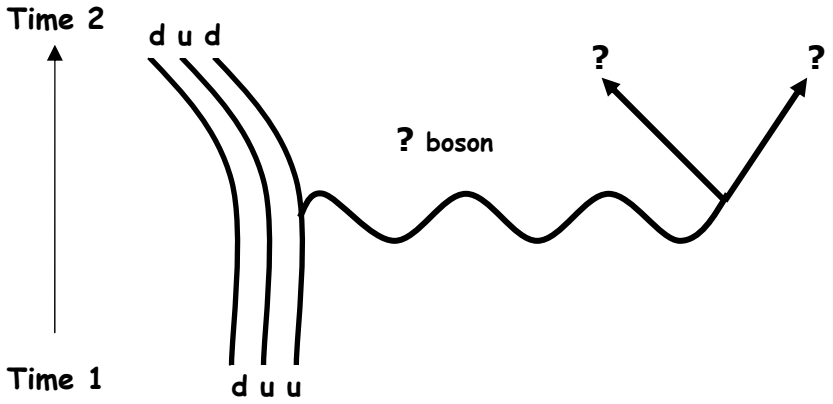
b) Flip one of the "quarks" in the metal "gluon cloud" to represent a neutron. Make sure the spin of the neutron points in the same direction as the spin of the proton. Draw a diagram showing the quarks in the neutron.

c) Which of the four fundamental forces is involved in binding quarks into nucleons?

d) The exchange of which type of gauge boson is responsible for binding quarks into nucleons?

## 12.2 A Model of Beta Decay

**2) Feynman Diagram of a Beta Decay** Beta decays, in which a neutron changes into a proton or a proton changes into a neutron, can be represented by a Feynman diagram.




a) Place the appropriate orange and green quarks into the gluon cloud to form the nucleon shown at Time 1. Which type of nucleon is this? _____

b) Flip the appropriate quark to form the nucleon at Time 2. Which type of nucleon is this? _____

c) Open the black plastic box that correctly completes this reaction. Which box is this? _____

d) Is an electron or an antielectron emitted? Why?

e) Is a neutrino or antineutrino emitted? Why?

f) Write the nuclear reaction illustrated by this Feynman diagram.

g) Which of the four fundamental forces is responsible for beta decay?

h) Which type of boson is responsible for beta plus decay? _____

i) Group Discussion Question: What changes occur in the identity of the quark trio making up the nucleus when a proton becomes a neutron? Why?

**3) Summary of beta decay** Fill in the table below to summarize the discussion of beta decay.

| Decay | Nucleon change | Quark change | Particles emitted | Force involved | Gauge boson |
|---|---|---|---|---|---|
| **beta-plus ($\beta^+$)** | | | | | |
| **beta-minus ($\beta^-$ )** | | | | | |

## 12.3 How Are Nucleons Bound into Nuclei?

**4) Pions** Your instructor will discuss pions, which consist of two quarks.

a) Which quark and antiquark can form a positive pion? Draw a diagram showing this pair and the directions of their spins.

b) Which quark and antiquark can form a negative pion? Draw a diagram showing this pair and the directions of their spins.

c) Which quark and antiquark can form a neutral pion? Draw a diagram showing this pair and the directions of their spins. (There are two combinations of a quark and an antiquark that form a neutral pion. Draw diagrams of both combinations.)

d) Which of the four fundamental forces is responsible for binding quarks and antiquarks into pions?

## 12.4 Nuclear Binding Energy

### 1) Releasing energy from nuclear decay

a) Open the plastic boxes representing beta plus decay, beta minus decay, and gamma decay. What reaction product do each of these decays have in common?

b) Name three other nuclear reactions that release energy.

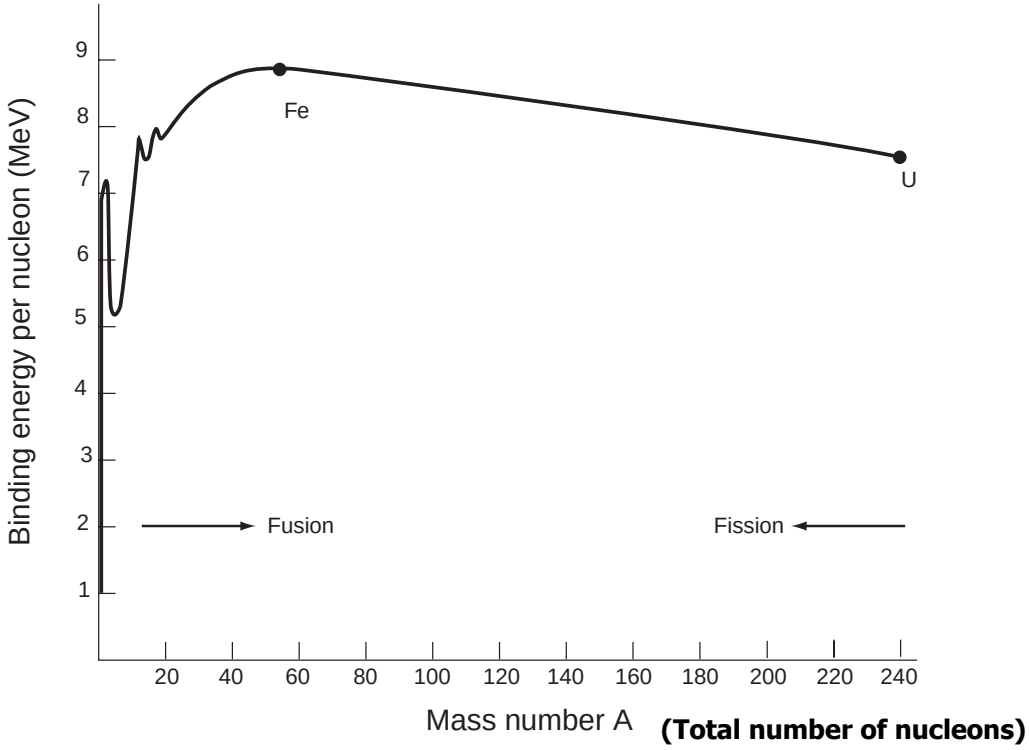
c) What is the one nucleus naturally occurring that fissions spontaneously (without the addition of activation energy)?

### 2) Releasing energy from fusing matter

a) When two protons come together, one proton can change into a neutron. The proton and neutron can then bind together to form one deuterium nucleus. For each deuterium nucleus formed, $3.52 \times 10^{-13}$ joules of energy are given off. What is this energy called?

b) What is the process of nucleons binding called? _____

c) Why would you expect the process of forming a deuterium nucleus from two protons to require a large amount of activation energy?




## 12.5 Nuclear Reactions Produced in the Laboratory

### 3) Nuclear accelerators

a) Are naturally-occurring nuclear reactions endothermic or exothermic? _____

b) How can activation energy be supplied to produce nuclear reactions?

c) In addition to providing activation energy, what other function do accelerators play in particle physics?

d) What is the advantage of a circular particle accelerator?

e) Which type of particle accelerator could provide the most energy to colliding particles: a linear accelerator, a circular accelerator, or two accelerators?

f) Group Discussion Question: Nuclear fission occurs in nuclear reactors. Why don't we have nuclear fusion reactors?

## 12.6 Nuclear Reactions in Stars

### 4) Fusion reactions in stars

a) What is the source of energy in stars such as the Sun? _____

b) Major challenges to controlling nuclear fusion reactions on Earth are providing the activation energy and containing the reactants. What force provides the activation energy and contains the reactants in fusion reactions in stars?

c) What is the proton-proton fusion chain?

d) Where does nuclear fusion occur in a star? _____

e) How does the energy from fusion reach the star's surface?

### 5) Formation of chemical elements in stars

a) What is the origin of most of the hydrogen, helium, and lithium in the Universe?

b) What is the origin of carbon?

c) How are heavier elements through iron formed?

d) How are elements heavier than iron formed?

e) Group Discussion Question: What is the origin of the heavy elements on the Earth?

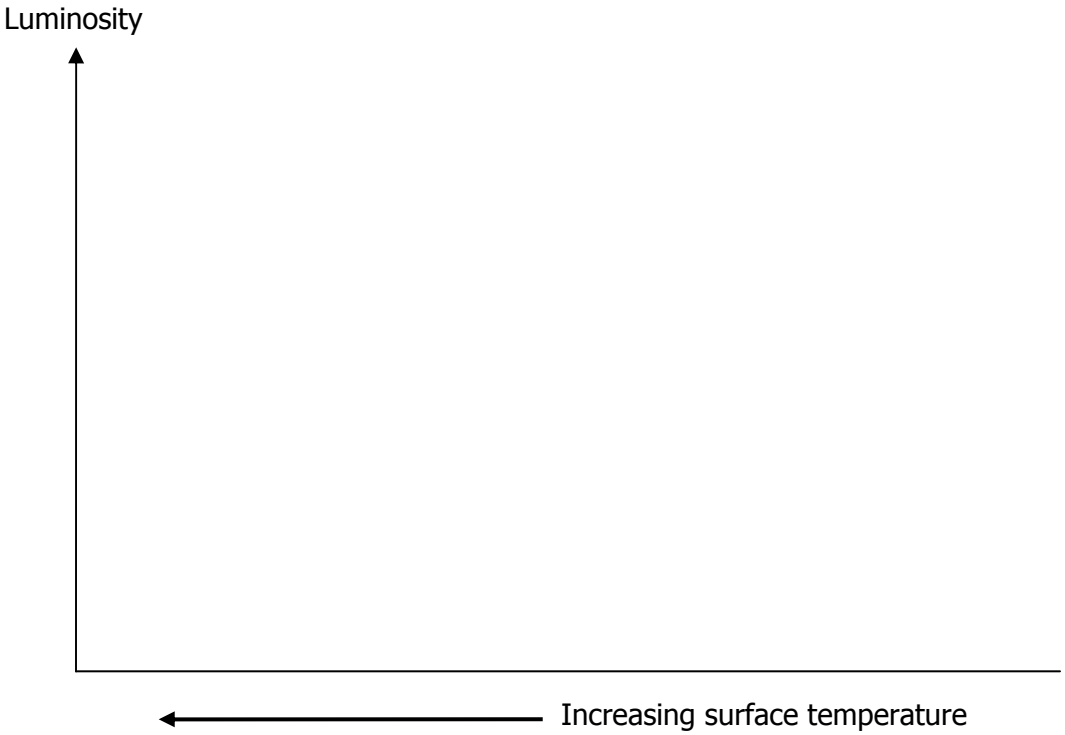
## 12.5 Types of Stars

### 6) The Hertzsprung Russell (H-R) diagram of stars

a) Place each metal disk, which represents a star, on the appropriate point of the grid of the H-R diagram that corresponds to the star's temperature and luminosity (brightness).

Note that the temperature on the horizontal axis increases as one moves to the left. The axes are logarithmic scales, therefore the spacing between temperatures on the horizontal scale is not linear.

b) Indicate on the diagram below approximately where you have placed the disks. Include information on the color of the disk and its size.




c) Explain the change in color of the stars in the main sequence.

d) Sirius is one of the brightest stars in the northern hemisphere's sky. What color is Sirius? How does its temperature compare to the temperature of the Sun?

e) What are the small stars in the lower left corner of the diagram?

f) What are the large red stars in the upper right corner of the diagram?

g) Group Discussion Question: Are any white dwarf stars visible from Earth? Are any red giant stars visible from earth?