Investigating Stars Name:____Block:____________

Leftovers from Massive Stars **E4:A4**

Of all objects in the universe, neutron stars, pulsars, and black holes are some of the most intriguing and least understood. In this activity, you will model the process of how neutron stars and black holes are formed.

Modeling the Death of a Massive Star

1. Make a model of a star by blowing up a balloon and tying off the end. The balloon represents a massive star.

   The heat and gas pressure of the fusion process inside a star supports the star against the relentless pull of gravity trying to shrink it. What keeps the balloon inflated?

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2. Find the radius (R) of the balloon.
   a. Measure the diameter of the balloon in centimeters with a metric ruler in two different directions and average your two measurements.

   a. Diameter in 1st direction = ______________

   b. Diameter in 2nd direction = ______________

   c. Average of diameters = _________________

   d. Divide the diameter average by 2 to get the radius (R) of the balloon. ___________________

3. Compute the volume (V) of the balloon using the formula $V = (4)(\pi)(R^3) / (3)$. Show your steps below and circle the volume. (Don't forget to label your answer with correct units.)

4. Wrap a piece of aluminum foil around your balloon to represent the core of your balloon star.

5. Carefully take off the foil without crumpling it and use a balance or scale to find the mass of the star core in grams.

   Mass of uncompressed core = ___________________

6. Compute the density of the stellar core using the formula Density = Mass/Volume. Show your steps below and circle the density. (Don't forget to label your answer with correct units.)

   $$\text{Density} = \frac{\text{Mass}}{\text{Volume}} =$$

7. Record, in a data table, the volume and density of the foil model.

8. Gently crush the aluminum foil (not too much) into a smaller ball.

   - The new smaller ball represents how the stellar core represents (very roughly) is changing on its way to becoming a white dwarf. The force holding up the mass of the star is the repulsion of close-packed electrons, a condition called electron degeneracy. This process never happens on Earth because no machine is powerful enough to exert such enormous force.

9. You'll have to measure the new radius as you did in number 2 above. Then find the new volume, $V = (4)(\pi)(R^3) / (3)$, and finally compute density, Density = Mass/Volume, of the new stellar core and record the values in your data table. Show your steps below and circle the density. (Don't forget to label your answer with correct units.)

   Mass = ____________Radius = ____________Volume = ___________ Density =_____________

10. Use your hands and compress the aluminum into the smallest ball you can.

    - This represents the star's iron core that cannot be compressed any smaller.

11. You'll have to measure the new radius as you did in number 2 above. Then find the new volume, $V = (4)(\pi)(R^3) / (3)$, and finally compute density, Density = Mass/Volume, of the new stellar core and record the values in your data table. Show your steps below and circle the density. (Don't forget to label your answer with correct units.)

    Mass = ____________Radius = ____________Volume = ___________ Density =_____________

12. Pop your balloon—your star has just gone supernova. Bring your foil ball to your teacher, who will use a hammer to crush it down as far as possible.

    • This core model simulates (very, very roughly) the further compression of a star's core as it is crushed in a supernova to a tiny neutron star. This core is held up by the nuclear forces that attend a close-packed ball of neutrons, a condition called neutron degeneracy.

13. You'll have to measure the new radius as you did in number 2 above. Then find the new volume, $V = (4)(\pi)(R^3) / (3)$, and finally compute density, Density = Mass/Volume, of the new stellar core and record the values in your data table. Show your steps below and circle the density. (Don't forget to label your answer with correct units.)

    Mass = ____________Radius = ____________Volume = ___________ Density =_____________

14. Graph your data with volume on the y- axis and density on the x-axis.

15. Read FYI: *Nature's Most Exotic Objects— Neutron Stars and Black Holes.*