Spitzer Explores a Dying Star

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NASA's Spitzer Space Telescope finds a delicate flower in the Ring Nebula, as shown in this image. The outer shell of this planetary nebula looks surprisingly similar to the delicate petals of a camellia blossom. A planetary nebula is a shell of material ejected from a dying star. Located about 2,000 light years from Earth in the constellation Lyra, the Ring Nebula is also known as Messier-57 or NGC 6720. The ring is about 6,000 to 8,000 years old based on the speed of its expansion. The Infrared power equals 9.6 times the sun, and the dust temperature is about 64 K.

Problem 1 - A single dust grain is about 0.2 microns in diameter, and has a density of about 3 grams/cm^3. What is the total mass, in grams, of this dust grain if it has a spherical shape?

Problem 2 - What is the total power produced by this infrared source if the power from the sun is 3.8 x 10^{33} ergs/sec?

Problem 3 - A single dust grain, 0.2 microns in diameter, at a temperature of 64 K, emits about 3.75 x 10^{-10} ergs/sec of power. How many dust grains are needed to produce the infrared power observed from the dust drains in the ring of M-57?

Problem 4 - From your answer to Problem 1 and 3, what is the total mass of dust grains involved in producing the infrared light from M-57; A) in grams? B) In units of the sun's mass which is 1.9 x 10^{33} grams?

Problem 5 - By mass, the interstellar medium consist of 99% gas and 1% dust grains. If the gas within the planetary nebula has the same composition, what is the estimated total mass of the nebular medium inside M-57 in solar masses?

Problem 6: The mass of the white dwarf star left behind is about 1.4 solar masses. What percentage of the mass of the star was lost during its planetary nebula phase?

Answer Key:

Problem 1 - A single dust grain is about 0.2 microns in diameter, and has a density of about 3 grams/cm^3. What is the total mass, in grams, of this dust grain if it has a spherical shape?
Answer;
V = 4/3 (3.14) (0.1 x 10^{-4})^3 = 4.2 x 10^{-15} cm^3.
M = 4.2 x 10^{-15} cm^3 x 3 grams/cm^3.

= 1.3 x 10^{-14} grams per dust grain.

Problem 2 - What is the total power produced by this infrared source if the power from the sun is 3.8 x 10^{33} ergs/sec?
Answer: 9.6 times the sun x 3.8 x 10^{33} ergs/sec = 3.7 x 10^{34} ergs/sec

Problem 3 - A single dust grain, 0.2 microns in diameter, at a temperature of 64 K, emits about 3.75 x 10^{-10} ergs/sec of power. How many dust grains are needed to produce the infrared power observed from the dust drains in the ring of M-57?
Answer: (3.7 x 10^{34} ergs/sec) / (3.75 x 10^{-10} ergs/sec) = 9.7 x 10^{43} dust grains.

Problem 4 - From your answer to Problem 1 and 3, what is the total mass of dust grains involved in producing the infrared light from M-57; A) in grams? B) In units of the sun's mass which is 1.9 x 10^{33} grams?
Answer: A) 1.38 x 10^{-14} grams per dust grain x 9.7 x 10^{43} dust grains = 1.3 x 10^{30} grams
B) 1.3 x 10^{30} grams / 1.9 x 10^{33} grams = 0.0007 solar masses.

Problem 5 - By mass, the interstellar medium consist of 99% gas and 1% dust grains. If the gas within the planetary nebula has the same composition, what is the estimated total mass of the nebular medium inside M-57 in solar masses?
Answer: About 100 x 0.0007 solar masses = 0.07 solar masses.

Problem 6: The mass of the white dwarf star left behind is about 1.4 solar masses. What percentage of the mass of the star was lost during its planetary nebula phase?
Answer: About 100% x 0.07/1.4 = only 5%.