The Reaction of Copper Metal with Elemental Sulfur

Beginning question: does the empirical formula of the product depend on the mass of copper metal used?

Procedure:

1. Heat a crucible and its lid to constant weight. Find the mass of the lid separately in case it falls off and breaks.
2. Measure a piece of copper wire to a length of 15-25 cm.
3. Pass the Cu wire through a fold of fine grit sandpaper to take away any surface coating and to prepare a fresh surface for reaction.
4. Coil the Cu wire around a pencil, compress the sample so the coils are not touching, put in empty crucible and find mass.
5. Completely cover the Cu coil with powdered S.
6. With the lid completely on the crucible, heat until visible signs of reaction cease.
7. Repeat the process of adding more sulfur to cover the coil and heat again to constant mass.
8. Find the mass of the product.

Observations:

1. The copper metal sample is shiny, flexible, red-brown metal.
2. The sulfur powder is yellow and has the consistency of flour or cornstarch.
3. When the crucible gets hot, purple flames and a white vapor escape. The vapor is irritating in the nose/throat.

4. Some sulfur melts and drips out.
5. The product is a thick, gray-black coil (thicker than the copper wire). It is brittle. When broken apart, it is clear that there is no more pure Cu wire inside — it has all been converted to the black product.

data:

experimental (class)

team	mass Cu	moles Cu	mass S	moles S	mole ratio Cu : S
M + C	0.4393	0.006913	0.1271	0.003963	1.744:1
M + J	0.4707	0.007407	0.1309	0.004082	1.815:1
K + N	0.9318	0.01466	0.2687	0.008379	1.750:1
T + G	0.8982	0.01413	0.2532	0.007895	1.790:1
* M + R	0.6473	0.01019	0.2535	0.007905	1.289:1
M + K	0.5111	0.008042	0.1604	0.005002	1.608:1
* J + J	0.8150	0.01282	0.3203	0.009988	1.294:1
D + M	0.5953	0.009367	0.1881	0.005865	1.597:1

class avg. 1.611 mole Cu : 1.000 mole S

* = anomalous data

Calculations:

mole Cu: $\frac{0.9318\,g\,Cu \;|\; 1\,mole\,Cu}{63.55\,g\,Cu} = 0.01466\,mole\,Cu$

mole S: $\frac{0.2687\,g\,S \;|\; 1\,mole\,S}{32.07\,g\,S} = 0.008379\,mole\,S$

mole ratio: $\frac{mole\,Cu}{mole\,S} = \frac{0.01466\,mole\,Cu}{0.008379\,mole\,S} = \frac{1.750\,mole\,Cu}{1.000\,mole\,S} \approx 2:1$

claim and evidence: The empirical formula for the copper-sulfur compound is Cu_2S. Experimentally, it was found that 0.9318 g Cu (0.01466 mole Cu) combined with 0.2687 g S (0.008379 mole S) in a ratio of 1.750 mole Cu to 1.000 mole S or in a 2:1 ratio. This is supported by the overall class average of 1.611 mole Cu to 1.000 mole S, also a 2:1 ratio.

reading/reflection: Although each group used a different length of Cu wire (to "cover" the range from 15 - 25 cm of wire), it was found that the mole ratio of Cu to S remained relatively constant, 1.611 : 1. There were two anomalies.* The appearance of the final product was "rusty". It could be possible that some type of side reaction occurred creating a product that was not copper (I) sulfide. We learned from reading about copper-sulfur compounds that copper (II) sulfide melts at a temperature of 103°C, so our product could not have been CuS. No matter how much sulfur was used, copper was the limiting reactant (text, p.110) and combined with S according to the law of constant composition (definite (text, p. 44) proportions) in a ratio of two moles of copper to one mole of sulfur, according to

$$2Cu + S \rightarrow Cu_2S.$$

This empirical formula Cu_2S has the smallest whole number ratio of moles of Cu to moles of S (text, p.64). Copper is in the "plus one" oxidation state (text, p.148) in this compound.

ref.: "text": Silberberg, M.S. 2003. Chemistry: The Molecular Nature of Matter and Change. 3rd ed. Dubuque, IA: McGraw Hill.