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Measuring the Expansion of Freezing Water at Different Precisions

Goal: To show proper lab report procedure + format

Procedure:
1. Fill bottle w/ distilled water
2. Record initial water level
3. Freeze overnight
4. Record final ice level

Data:

	Ruler #1	Ruler #2
Initial Water Level (before)	~~17.8 cm~~ 16.8 cm BB	16.67 cm
Final Ice Level (after)	17.7 cm	17.64 cm

Sample Calcs (Ruler #1)

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$$\%\ \text{change in level} = \frac{A - B}{B} \times 100\%$$

$$= \frac{17.7\,\text{cm} - 16.8\,\text{cm}}{16.8\,\text{cm}} \times 100\%$$

$$= \frac{0.9\,\text{cm}}{16.8\,\text{cm}} \times 100\%$$

$$= 5\%$$

$$\%\ \text{error} = \frac{E - R}{R} \times 100\%$$

$$= \frac{5\% - 8.4\%}{8.4\%} \times 100\%$$

$$= \frac{-3.4\%}{8.4\%} \times 100\%$$

$$= -40\%$$

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Results

	Ruler #1	Ruler #2
% Change level	5%	5.8%
% error	-40%	-31%

Discussion

The percent level change represented the volume change of the freezing water, assuming the bottle had a constant cross-sectional area. The cross-sectional area was, however, not constant. ~~It~~ The bottle had a tapered top, irregular bottom, and flexible sides.

Ruler #2 was closer than Ruler #1 to the reference value of 8.4% volume expansion. Ruler #2 was more accurate because it was more precise and could be better read. The ice level, however, was not actually level (flat). Differences in the results between the rulers could have occurred due to measurements at different locations. Both Rulers #1 and #2 produced results considerably lower than the reference value with -40% and -31% error, respectively.

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Based on the tapered top, it was expected that the level rise would be more than 8.4%. This did not occur. The negative percent errors suggest that the bottle expanded sideways, which was not measured. This could have been due to the flexible sides of the bottle. Typically, the water would have frozen from the top downward, because the open top exposed the water at the top to the cold air in the freezer. Perhaps, an ice plug formed in the top layer of water, preventing upward expansion in the tapered bottle top. This would have created a force to expand the ice and the bottle sideways.

This experiment could be redesigned with a better container to get more accurate results. A container with rigid sides and flat bottom could be filled sufficiently below any taper at the top. This would allow upward expansion without causing sideways expansion. As such, the percent level increase may be closer to representing the true expansion of freezing water.

Conclusion We measured volume expansion w/ two rulers to obtain expansions on freezing water of 5% and 5.8% with percent errors of -40% and -31%, respectively.

SCRATCH PAPER

NOT PART OF REPORT

Ruler #1

A – after
B – before

$$\%\text{ change in level} = \frac{A-B}{B} \times 100\%$$

$$= \frac{17.7-16.8}{16.8} \times 100\%$$

$$= \frac{\cancel{0.9}^{\text{1 sig fig}}}{16.8} \times 100\%$$

$$= 5.357142857\,\%$$

$$\Rightarrow \boxed{5\%}$$

Ruler #2

$$\%\text{ change} = \frac{A-B}{B} \times 100\%$$

$$= \frac{17.64-16.67}{16.67} \times 100\%$$

$$= \frac{\cancel{0.97}^{\text{2 sig fig}}}{16.67} \times 100\%$$

$$= 5.818836233\%$$

$$\Rightarrow \boxed{5.8\%}$$

E = Exp. result
R = reference / known / literature value = 8.4%

$$\%\text{ error} = \frac{E-R}{R} \times 100\%$$

$$= \frac{5-8.4}{8.4} \times 100\%$$

$$= \frac{-3.4}{8.4} \times 100\%$$

$$= \boxed{-40\%}$$

$$\%\text{ error} = \frac{E-R}{R} \times 100\%$$

$$= \frac{5.8-8.4}{8.4} \times 100\%$$

$$= \frac{-2.6}{8.4} \times 100\%$$

$$= \boxed{-31\%}$$