Accuracy and Precision in the Determination of the Density of Water

PA State Standards Addressed:

3.4.10.A	Explain concepts about the structure and properties of matter.
3.4.12.A	Apply concepts about the structure and properties of matter.
	Quantify the properties of matter by applying mathematical formulas.
3.7.10.B	Apply appropriate instruments and apparatus to examine a variety of objects and processes.
	Explain the need to estimate measurements within error of various instruments.

Introduction:

Mass and volume are extrinsic properties which depend on the quantity of a substance. Density, which is the ratio of mass to volume (D=m/V), is an intrinsic property. The density of a substance is a constant and is characteristic of the substance. Therefore, density can be used to aid in the identification of a substance. However, the density of a substance may vary with its temperature. In this lab the mass and volume of water will be measured, and the density of the water will be calculated. This value will be compared to the accepted density of water at the relevant temperature. The accuracy and precision of the measurements will also be determined. Accuracy refers to the closeness of a measurement to the true or accepted value, while the precision refers to the repeatablility of a measurement. Multiple trials of each method will be done to determine the precision.

In this experiment, two instruments will be used to measure the mass: a top loading balance, and an analytical balance. Four different instruments will be used to measure volume: a beaker, a graduated cylinder, a glass pipet, and an automatic pipet.

Guiding Questions:

1. Which combination of instruments will be the least accurate? Why?

2. Which combination of instruments will be the most accurate? Why?

3. Which combination of instruments will be the least precise? Why?

4. Which combination of instruments will be the most precise? Why?

Equipment/Materials:

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30 mL beaker	deionized water
250 mL beaker	10 mL automatic pipet
10 mL graduated cylinder	top loader balance
volumetric pipet	analytical balance
thermometer	plastic dropper

Safety:

- Goggles should be worn in the lab when using glassware.

Procedure and Data:

1. Place 150 – 200 mL of deionized water in a 250 mL beaker.

2. Measure and record the temperature of the water.

   Water Temperature: _____ ˚C

Beaker and Top Loading Balance

1. Place a clean, dry 30 mL beaker on the top loading balance. Tare.

2. Remove the beaker from the balance, and pour 10 mL of deionized water into it, using a dropper if necessary. Record the volume in the data table to the correct number of significant digits.

3. Place the beaker on the balance and record the mass of the water in the data table. **Do not round!**

4. Discard the water in the sink and repeat for trials 2 & 3. It is not necessary to dry the inside of the beaker when using a top loading balance.

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____g/mL

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Graduated Cylinder and Top Loading Balance

1. Look at the writing on the 10 mLgraduated cylinder.
    a. If it says TC, it is designed To Contain the volume of liquid that is read. If the cylinder says TC, tare it on the balance.
    b. If it says TD, it is designed To Deliver the volume of liquid that is read. If the cylinder says TD, tare the 30mL beaker on the balance.

2. Pour 10mL of deionized water in the graduated cylinder, using a dropper if necessary. Record the volume on the data table to the correct number of significant digits.

3. To determine the mass:
    a. If the cylinder says TC, put the cylinder on the balance and record the mass in the data table. Do not round!
    b. If the cylinder says TD, pour the water into the tared beaker, and place the beaker on the balance. Record the mass in the data table. **Do not round!**

4. Repeat for trials 2 & 3.

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____g/mL

Pipet and Top Loading Balance

1. Place a clean, dry 30 mL beaker on the top loading balance. Tare.

2. Using a volumetric pipet, add 10 mL of deionized water to the 30 mL beaker. Record the volume of water in the data table to the correct number of significant digits.

3. Place the beaker on the balance, and record the mass in the data table. **Do not round!**

4. Repeat for trials 2 & 3.

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____g/mL

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Automatic Pipet and Top Loading Balance

1. Place a clean, dry 30 mL beaker on the top loading balance. Tare.

2. Using the automatic pipet, add 10 mL of deionized water to the 30 mL beaker. Record the volume of water in the data table to the correct number of significant digits.

3. Place the beaker on the balance, and record the mass of the water in the data table. **Do not round!**

4. Repeat for trials 2 & 3.

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____g/mL

Repeat each of the above sets of procedures using the analytical balance in place of the top loading balance.

Beaker and Analytical Balance

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____g/mL

Graduated Cylinder and Analytical Balance

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____g/mL

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Pipet and Analytical Balance

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____ g/mL

Automatic Pipet and Analytical Balance

Trial	Vol (mL)	Mass (g)	Density (g/mL)
1			
2			
3			

Average Density _____ g/mL

Calculations:

1. Actual density of water at recorded temperature from Appendix 1 : _____ g/mL

2. Calculate the % error (accuracy) for each density average value.

    % ERROR = (│ Actual - Ave calc density │ / actual density) x 100%

	Top loading	Analytical
Beaker		
Graduated Cylinder		
Pipet		
Automatic Pipet		

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3. Calculate the precision (standard deviation) of each set of data

$$\text{standard deviation} = \sqrt{[(\sum(x - x_1)^2)/(n - 1)]}$$

where x = density for each individual trial
x_1 = average density
n = number of trials

	Top loading	Analytical
Beaker		
Graduated Cylinder		
Pipet		
Automatic Pipet		

Questions:
1. Which combination of instruments was the least accurate? How do you know?

2. Which combination of instruments was the most accurate? How do you know?

3. Which combination of instruments was the least precise? How do you know?

4. Which combination of instruments was the most precise? How do you know?

5. Did the mass of water shown on the analytical balance tend to decrease with time? If so, why? If not, why not?

References:
Snelling, C. (2008, June 14). *Density of Water (g/mL) vs. Temperature (°C)*. Retrieved June 1, 2011, from http://www2.volstate.edu/CHEM/Density_of_Water.htm

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Appendix 1

Density of Water (g/mL) vs. Temperature (°C)

(from <u>Handbook of Chemistry and Physics</u>, 53rd Edition, p. F4)
Whole **degrees** are listed down the left hand side of the table, while **tenths of a degree** are listed across the top.
So to find the density of water at say **5.4** °C, you would first find the whole degree by searching down the left hand column until you reach '**5**'. Then you would slide across that row until you reach the column labeled '**0.4**'.
The density of water at **5.4** °C is 0.999957 g/mL.

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.999841	0.999847	0.999854	0.999860	0.999866	0.999872	0.999878	0.999884	0.999889	0.999895
1	0.999900	0.999905	0.999909	0.999914	0.999918	0.999923	0.999927	0.999930	0.999934	0.999938
2	0.999941	0.999944	0.999947	0.999950	0.999953	0.999955	0.999958	0.999960	0.999962	0.999964
3	0.999965	0.999967	0.999968	0.999969	0.999970	0.999971	0.999972	0.999972	0.999973	0.999973
4	0.999973	0.999973	0.999973	0.999972	0.999972	0.999972	0.999970	0.999969	0.999968	0.999966
5	0.999965	0.999963	0.999961	0.999959	0.999957	0.999955	0.999952	0.999950	0.999947	0.999944
6	0.999941	0.999938	0.999935	0.999931	0.999927	0.999924	0.999920	0.999916	0.999911	0.999907
7	0.999902	0.999898	0.999893	0.999888	0.999883	0.999877	0.999872	0.999866	0.999861	0.999855
8	0.999849	0.999843	0.999837	0.999830	0.999824	0.999817	0.999810	0.999803	0.999796	0.999789
9	0.999781	0.999774	0.999766	0.999758	0.999751	0.999742	0.999734	0.999726	0.999717	0.999709
10	0.999700	0.999691	0.999682	0.999673	0.999664	0.999654	0.999645	0.999635	0.999625	0.999615
11	0.999605	0.999595	0.999585	0.999574	0.999564	0.999553	0.999542	0.999531	0.999520	0.999509
12	0.999498	0.999486	0.999475	0.999463	0.999451	0.999439	0.999427	0.999415	0.999402	0.999390
13	0.999377	0.999364	0.999352	0.999339	0.999326	0.999312	0.999299	0.999285	0.999272	0.999258
14	0.999244	0.999230	0.999216	0.999202	0.999188	0.999173	0.999159	0.999144	0.999129	0.999114
15	0.999099	0.999084	0.999069	0.999054	0.999038	0.999023	0.999007	0.998991	0.998975	0.998959
16	0.998943	0.998926	0.998910	0.998893	0.998877	0.998860	0.998843	0.998826	0.998809	0.998792
17	0.998774	0.998757	0.998739	0.998722	0.998704	0.998686	0.998668	0.998650	0.998632	0.998613
18	0.998595	0.998576	0.998558	0.998539	0.998520	0.998501	0.998482	0.998463	0.998444	0.998424
19	0.998405	0.998385	0.998365	0.998345	0.998325	0.998305	0.998285	0.998265	0.998244	0.998224
20	0.998203	0.998183	0.998162	0.998141	0.998120	0.998099	0.998078	0.998056	0.998035	0.998013
21	0.997992	0.997970	0.997948	0.997926	0.997904	0.997882	0.997860	0.997837	0.997815	0.997792
22	0.997770	0.997747	0.997724	0.997701	0.997678	0.997655	0.997632	0.997608	0.997585	0.997561
23	0.997538	0.997514	0.997490	0.997466	0.997442	0.997418	0.997394	0.997369	0.997345	0.997320
24	0.997296	0.997271	0.997246	0.997221	0.997196	0.997171	0.997146	0.997120	0.997095	0.997069
25	0.997044	0.997018	0.996992	0.996967	0.996941	0.996914	0.996888	0.996862	0.996836	0.996809
26	0.996783	0.996756	0.996729	0.996703	0.996676	0.996649	0.996621	0.996594	0.996567	0.996540
27	0.996512	0.996485	0.996457	0.996429	0.996401	0.996373	0.996345	0.996317	0.996289	0.996261
28	0.996232	0.996204	0.996175	0.996147	0.996118	0.996089	0.996060	0.996031	0.996002	0.995973

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