Exploring the Chemical Reactions and Quantitative Relationships in the Production of a **Delicious Double Layer Chocolate Cake**

‘Stoichiometry and Cooking’

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# Introduction

Stoichiometry makes use of the relationships between mass and amount of the

reactants and products in a chemical reaction. The amount of products in a chemical reaction

can be predicted from the amount of reactants. Stoichiometry problems involving masses can

be solved by converting masses to amounts, using mole ratios. In this task you will relate

stoichiometry with the everyday phenomena of cooking.

# Hypothesis

The reaction of an appropriate amount of sugar, flour, cocoa powder, baking powder, baking soda, salt, espresso powder, buttermilk, canola oil, eggs, vanilla extract and water should combine to create a delicious dough for a cake. While a combination of butter, cocoa powder, milk, vanilla extract and icing sugar should create a delicious icing. When these all react and mix with each other there should be little to no excess reactants and the mass of the ingredients should equal the mass of the products or exactly 2049g.

# Materials

1. 2 cups (278 grams) of all-purpose flour
2. 2 cups (380 grams) of granulated white sugar
3. 1 ¼ cup (113 grams) of unsweetened cocoa powder
4. 2 teaspoons (12 grams) of baking powder
5. 1 ½ teaspoons (9 grams) of baking soda
6. 1 teaspoon (3 grams) of salt
7. 1 teaspoon (2 grams) espresso powder
8. 1 cup (206 grams) buttermilk
9. ½ cup (111 grams) vegetable oil
10. 2 large eggs (128 grams)
11. 3 teaspoons (10 grams) vanilla extract
12. 1 cup (189 grams) boiling water
13. ¼ cup (72 grams) butter
14. ⅓ cup (50 grams) milk
15. 4 ½ cup (486 grams) confectioners’ sugar
16. Two 9 inch diameter pans
17. 1 pair of Oven Mitts
18. 1 Oven that can reach 350oF
19. 1 electric mixer
20. 2 large bowls
21. 1 small bowl
22. 1 microwave
23. 1 butter knife
24. 1 large serrated knife
25. 1 refrigerator
26. 1 teaspoon
27. 1 measuring cup
28. 1 table spoon
29. 2 large plates
30. 1 small pot
31. 1 stove top

# Observations

Final Cake mass 1963g

# Chemical Formulas

* Flour
  + C4H8O4
* White Sugar
  + C12H22O11
* Cocoa
  + C4H8O4
* Baking Powder
  + NaHCO3
* Baking Soda
  + NaHCO3
* Salt
  + NaCl
* Espresso Powder
  + Trigonelline
    - C7H7NO2
* Buttermilk
  + Diacetyl
    - C4H6O2
* Vegetable Oil
  + C3H8O3
* Egg
  + C6H12O3N2
* Vanilla Extract
  + C8H8O3
* Water
  + H2O
* Butter
  + C9H14O6
* Milk
  + 85% H2O
  + 15% C9H14O6
* Icing sugar
  + C12H22O11

# Calculations:

Moles = mass/molar mass

n=m/M

Finding the moles for each substance

nFlour = 278/(4\*12.01+8\*1.01+4\*16.00)

=2.314

=2.31 mol of flour

nSugar=380/(12\*12.01+22\*1.01+11\*16.00)

=1.110

=1.1 mol of sugar

nCocoa=(60g+53g)/(4\*12.01+8\*1.01+4\*16.00)

=0.9407

=0.94 mol of cocoa powder

nBaking Powder=12/(22.99+1.01+12.01+16.00\*3)

=0.1428

=0.14 mol of baking powder

nBaking Soda=9/(22.99+1.01+12.01+16.00\*3)

=0.1071

=0.1 mol of baking soda

nSalt=3/(22.99+35.45)

=0.05133

=0.05 mol of salt

nEspresso powder=2/(7\*12.01+7\*1.01+14.00+2\*16.00)

=0.01458

=0.01 mol of espresso powder

nButtermilk=206/(4\*12.01+6\*1.01+2\*16.00)

=2.392

=2.39 mol of buttermilk

nVegetable Oil = 111/(3\*12.01+8\*1.01+3\*16.00)

=1.205

=1.20 mol of vegetable oil

nEgg=128/(6\*12.01+12\*1.01+3\*16.00+2\*14.00)

0.7991

0.799 mol of egg

nvanilla=(7g+3g)/(8\*12.01+8\*1.01+3\*16.00)

=0.0657

=0.07 mol of vanilla extract

nWater=189/(2\*1.01+16.00)

=10.48

=10.5 mol of water

nButter = 72g/(9 \* 12.01 + 14 \* 1.01 + 6 \* 16.00)

=0.3299

=0.33 mol of butter

nMilk = nH2O + nC9H14O6

nH2O =(50\*0.85)/(2\*1.01+16.00)

=2.358 mol

nC9H14O6 = (50\*0.15)/(9\*12.01+14\*1.01+6\*16.00)

=0.03436 mol

=2.358+0.03436

=2.392

=2.4 mol of milk

nIcing Sugar= 486g/(12\*12.01+22\*1.01+11\*16.00)

=1.4196

=1.42 mol of icing sugar

Formula for the cake

C4H8O4 + C12H22O11 + C4H8O4 + NaHCO3 + NaHCO3 + NaCl + C7H7NO2 + C4H6O2 + C6H12O3N2 + C8H8O3 + C3H8O3 + H2O-> Cake

Formula for the Icing

C9H14O6 + (C4H8O4+ H2O) + C9H14O6 + C8H8O3  + C12H22O11 -> Icing

Combined Formula

2.31C4H8O4 + 1.1C12H22O11 + 0.94C4H8O4 + 0.14NaHCO3 + 0.1NaHCO3 + 0.05NaCl + 0.01C7H7NO2 + 2.39C4H6O2 + 0.799C6H12O3N2 + 0.07C8H8O3 + 1.20C3H8O3 + 10.5H2O + 2.358C9H14O6 + 0.03436H2O+ 1.42C12H22O11 -> Iced Cake

Adding the common coefficients up

3.25C4H8O4 +2.52C12H22O11 + 0.24NaHCO3 + 0.05NaCl + 0.01C7H7NO2 + 2.39C4H6O2 + 0.799C6H12O3N2 + 0.07C8H8O3 + 1.20C3H8O3 + 10.5H2O + 2.358C9H14O6 -> Iced Cake

Converting the mols to coefficients for the final balanced equation

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| C4H8O4 | C12H22O11 | NaHCO3 | NaCl | C7H7NO2 | C4H6O2 | C6H12O3N2 | C8H8O3 | C3H8O3 | H2O | C9H14O6 |
| 3.25mol | 2.52mol | 0.24mol | 0.05mol | 0.01mol | 3.066mol | 0.799mol | 0.07mol | 1.20mol | 10.5mol | 2.358mol |
| Divide | Divide | Divide | Divide | Divide | Divide | Divide | Divide | Divide | Divide | Divide |
| 0.01mol | 0.01mol | 0.01mol | 0.01mol | 0.01mol | 0.01mol | 0.01mol | 0.01mol | 0.01mol | 0.01mol | 0.01mol |
| Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals |
| 325mol | 252mol | 24mol | 5mol | 1mol | 306.6mol | 79.9mol | 7mol | 120mol | 105mol | 236 mol |
| Multiply | Multiply | Multiply | Multiply | Multiply | Multiply | Multiply | Multiply | Multiply | Multiply | Multiply |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals | Equals |
| 975mol | 756mol | 72mol | 15mol | 3mol | 920mol | 240mol | 21mol | 360mol | 315mol | 708mol |

# Equation

975C4H8O4 + 756C12H22O11 + 72NaHCO3 + 15NaCl + 3C7H7NO2 + 920C4H6O2 + 240C6H12O3N2 + 21C8H8O3 + 360C3H8O3 + 315H2O + 708C9H14O6 🡪 Iced Cake

# Procedure

1. Gather Materials
2. Preheat oven to 350oF.
3. Grease two 9 inch diameter pans with less then 1 tbsp of butter and less then 1 tbsp of flour
4. Pour 2 cups of Flour, 2 cups of white sugar, ¾ cup of cocoa powder, 2 teaspoons of Baking Powder, 1 ½ teaspoons of Baking Soda, 1 teaspoon of Salt and 1 teaspoon of Espresso Powder into a large bowl
5. Mix the ingredients with the electric mixer on medium until the ingredients appear uniform
6. Pour 1 cup of Buttermilk, ½ cup of Vegetable Oil, 2 large Eggs and 2 teaspoons of Vanilla Extract into the mixture of solid ingredients
7. Mix the large bowl in the electric mixer with the mixer on low
8. Boil 1 cup of water on the stove top while wearing oven mitts
9. Slowly add 1 cup of boiling water while mixing on low.
10. Remove the mixture from the electric mixer
11. Evenly distribute the resulting mixture into the two 9 inch pans.
12. Place the two pans in the oven while wearing oven mitts and cook for 35 minutes
13. Remove the two pans from the oven while wearing oven mitts after 35 minutes and leave to cool for 15 minutes
14. Remove the cakes from the pans after 15 minutes and place on two large plates
15. Put ¼ cup of butter into a small bowl
16. Put the bowl of butter into the microwave for 30 seconds or until melted
17. In a large, clean bowl pour ¼ cup of melted butter and ½ cup of cocoa powder
18. Put the bowl in the electric mixer and mix on medium until uniform
19. Pour 1/3 cup of milk and 1 teaspoon of vanilla extract into the mixture.
20. Mix on medium until uniform
21. Continue to mix on low while slowly adding 4 ½ cups of icing sugar
22. Mix on medium until the icing sugar is properly mixed
23. Refrigerate the icing for 30 minutes
24. Take the two solid cakes and cut off the top of one of them with a large serrated knife
25. Spread the icing from the bowl onto the cake with the cut top using a butter knife,
26. Placed the second cake from the other pan onto the iced one
27. Apply the remaining icing on the entire cake using a butter knife
28. Refrigerate cake for 25 minutes
29. Dispose of materials and clean work station
30. Serve cake.

# Pictures of Cooking Process



Figure 2 Bowl full of Batter

Figure Remaining Cake batter

# Analysis

The results were as expected, when the proper procedure was followed, a delicious cake was produced that met much of the hypothesis’s requirements. There were no visible excess reactants, all of the ingredients were able to mix properly and fully into the cake. This establishes that the equation “975C4H8O4 + 756C12H22O11 + 72NaHCO3 + 15NaCl + 3C7H7NO2 + 920C4H6O2 + 240C6H12O3N2 + 21C8H8O3 + 360C3H8O3 + 315H2O + 708C9H14O6 🡪 Iced Cake” is the ideal equation where there are no excess reactants. The lack of any identifiable excess reactants is most likely due to the baking process itself. When the cake batter is placed in the oven it most likely has excess reactants as the bowl may not have been fully mixed. The baking process removes these potential impurities, for some excess reactants they are evaporated or they turn into a gas and escape the cake while for others they fuse into the cake. Some of the excess reactants may have simply been baked with the cake and thus got put into the cake while in the batter it was not fully mixed in.

There was however an anomaly, when the cake was finally massed it was found to be 1923 grams, not the 2049 grams as predicted and as is followed by the law of conservation of mass. That is a 126 grams of ingredients, how can this be accounted for? There are many possible reasons that so much mass could be lost in a cake. The first and most probable answer is due to the nature of baking, when an object undergoes baking it is subject to high temperatures and the temperate that the batter was baked at was 350oF or 177oC which is above the boiling point of water. This would mean that while the batter is baking and turning into a solid object, some of the liquid is evaporating and boiling up. This would explain a part of the loss in mass but that cannot be the only reason, another very possible reason is due to what is visible in Figure 1, a large amount of the batter is still inside the bowl, and this was the same case for the icing. The remaining batter could not be removed as the batter was fairly viscous and would tend to stick to the sides of the bowl. Finally there is another possible source of error and that is visible in Figure 2. In Figure 2. It can be seen that there is flour residue on the side of the bowl this is due to the whisking of the ingredients using the electric mixer which caused some ingredients to fly out this means some mass was lost as it never entered the mixture it like the flour was shot outwards. Another though rare possibility however is the idea that the ingredients would bond with the other elements. Especially with the more common elements it does not become an impossible idea that potentially some of the ingredients bonded with external forces such as oxygen, nitrogen or carbon dioxide.

# Applications of Stoichiometry

One application of stoichiometry is in the pharmauceutical business

# Conclusion

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