ANALYSIS OF BAKING SODA AND VINEGAR DEMONSTRATION

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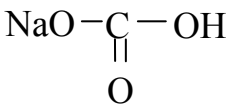
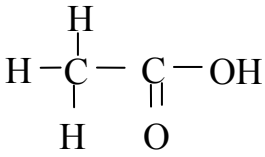
Q #1. How much vinegar does it take to react fully with a teaspoon (5 cm^3) of baking soda?
Q #2. What volume of CO_2 gas is evolved?

1. Baking soda is sodium bicarbonate*, $NaCO_2OH$: (Try to spot the hidden CO_2.)



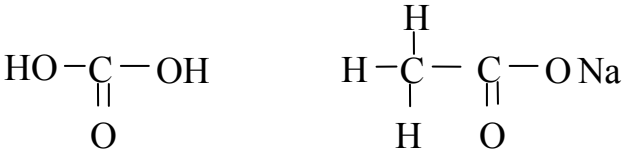
It has a molar mass of: M = 12 + 3×16 + 23 + 1 = 84 g/mole, from C + 3×O + Na + H.

2. Vinegar is acetic acid, CH_3COOH:



It has a molar mass of: M = 2×12 + 2×16 + 4 = 60 g/mole.

3. In water, these molecules trade Na for H, becoming:



The carbonic acid molecule (on the left) falls apart when one of the OH's steals an H from the other, forming H_2O that floats away, and leaving CO_2, which is a gas at room temperature and pressure. The other molecule is sodium acetate. It stays in solution.

4. I measured that my new box of Arm & Hammer baking soda contains a volume of about 9×4×8 cm^3 = 288 cm^3 of powder, and the box says it contains 450 g. 450 g corresponds to: 450g / 84 g/mole = 5.4 moles. Thus, baking soda has a molar density: 5.4 moles/288 cm^3 = 0.019 mole/cm^3. The 5 cm^3 of baking soda that I put into the baggie corresponds to: 5 cm^3 × 0.019 mole/cm^3 = 0.093 moles.

5. My bottle of Heinz vinegar says that it is 5% acetic acid by weight. I used 100 cm^3 in the demo. 100 cm^3 of vinegar is about 100 g, assuming the same density as pure water. Of that 100 g, only 5 g (5%) is acetic acid, which corresponds to: 5 g/ 60 g/mole = 0.083 moles. Thus, 110 cm^3 of acetic acid are needed to fully react with 5 cm^3 of baking soda.

6.Reacting of 5 cm^3 of baking soda with 100 cm^3 of vinegar should produce 0.083 moles of CO_2 gas, 0.083 moles of sodium acetate, and leave 0.01 moles of sodium bicarbonate unreacted. At STP, the volume of CO_2 gas would be: V = 0.083RT/P = 0.083×8.314 J/mole K × 298 K / 10^5 N/m^2 = 2.1 ℓ, just about what we observed.

*The "bi" in bicarbonate means that "half" of the H's have been replaced by Na.