

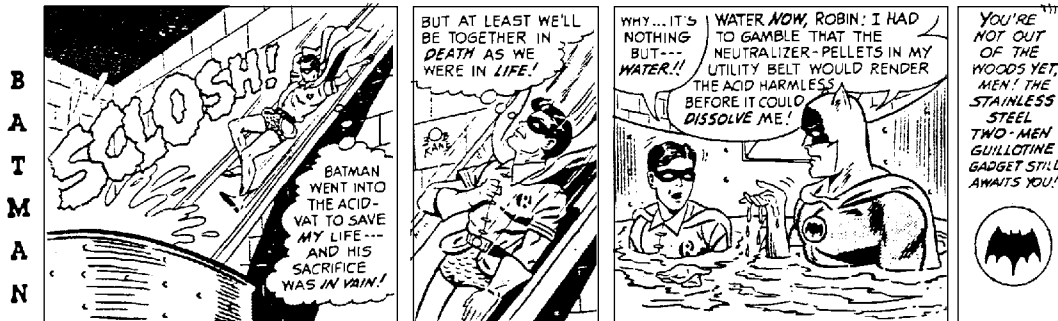
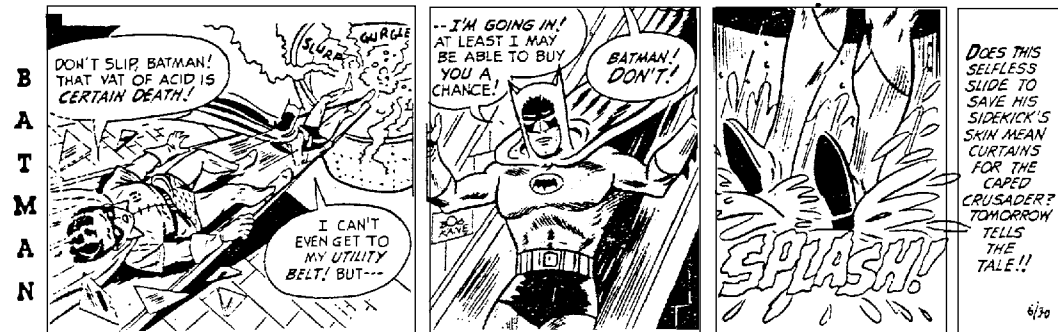
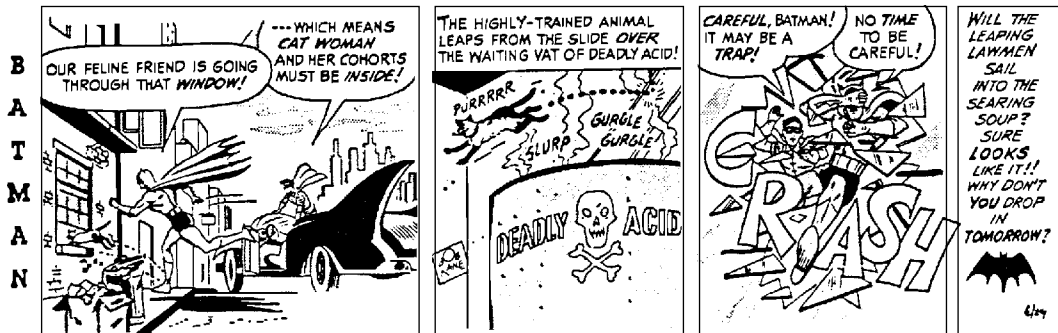
Batman and Robin in Chemistry

(Adapted from activity supplied by Larry Duberich. Used by permission of American Chemical Society. See first reference in *References* section.)

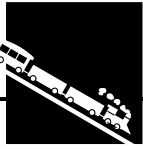
Batman uses pellets, which he does not identify, to neutralize the acid in the tank into which he falls. He does not give the size of the tank. Suppose the pellets were NaOH and the tank was 3.00 meters in diameter filled with 98% sulfuric acid by mass to a depth of 1.25 meters (see transparency).

Perform the following calculations and *show your work*.

1. Calculate the volume of acid (in cm^3) in the tank. (The volume of a cylinder is $\pi r^2 h$.)
2. Calculate the mass of acid in the tank, then find the number of moles of H_2SO_4 present. (Concentrated sulfuric acid is 98% (by mass) H_2SO_4 and has a density of 1.84 g/cm^3 .)
3. One mole H_2SO_4 produces *two* moles of H^+ ions. With this in mind, write the balanced equation for the neutralization of NaOH and H_2SO_4 . Determine the number of moles NaOH required to neutralize the acid in the tank. What *mass* of NaOH is required?
4. The heat of reaction for neutralization of a strong acid and a strong base is -57.3 kJ for each mole of H_2O formed. How much thermal energy (in kJ and J) was released in the neutralization reaction?
5. If the initial temperature of the acid bath was 20°C , how much thermal energy would be needed to raise the temperature of the mixture in the tank ($\text{NaOH} + \text{H}_2\text{SO}_4$) to 100°C ? Assume the mass of the solution is the combined masses of the H_2SO_4 and NaOH. Also, assume the heat capacity of the liquid in the tank is 4.184 J/g .
6. Was all the generated thermal energy (Question 4) used to heat the liquid in the vat to 100°C (Question 5)? After water reaches the boiling point, an additional 2260 J/g is required to vaporize it. How much water was evaporated by the heat generated in the reaction of NaOH with H_2SO_4 ?
(Ignore the boiling point elevation.)
7. In view of answers to Questions 3 and 6, how likely is it that the comic strip author passed high school chemistry?



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Cylindrical Tank

