

ECONOMICS OF A CHEMICAL PRODUCT

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INTRODUCTION

Have you ever wondered how the price you pay for a product in the store is determined? Have you considered prices of products to be outrageously high in comparison to the cost of the materials from which the products were made? Why does a gallon of gasoline cost over one dollar when the 42 gallons in a barrel of crude oil, from which gasoline is made, sells for approximately 30 dollars or less? Have you recently bought aspirin to alleviate aches and pains for approximately six cents for a 325 milligram tablet, when you can buy 2.5 kilograms for approximately \$57.00 (less than 0.75 cent per tablet) from a chemical supply house? Have you thought about the reason why an ice chest made from expanded polystyrene costs \$4.95 when the raw polystyrene costs only a few pennies?

Consumers and the news media tend to compare the retail cost of a product with the cost of the raw materials, but do not consider the many costs associated with the conversion of the raw materials to products (labor costs, costs for energy, machinery, buildings, local taxes, state taxes, federal taxes, costs of environmentally acceptable waste disposal, costs for transporting the products to the markets, costs for advertising, and fair profits). Industry depends upon mass production and efficient machinery to keep the cost per item low. Most chemical industries are either very high volume operations or spread the costs of production among many products.

This investigation will provide you with an appreciation for the many "hidden" costs of a product. Because you will not be able to take advantage of the economy of large scale production or diversification, don't be surprised if the cost of your product turns out to be outrageously high.

BACKGROUND INFORMATION

In this investigation you will become the operator of a chemical pilot plant (on a laboratory scale) that converts Epsom Salt, magnesium sulfate heptahydrate, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, to magnesium sulfate monohydrate, $\text{MgSO}_4 \cdot \text{H}_2\text{O}$, which can be useful as a drying agent.

The Epsom Salt, your raw material, will be purchased in a grocery store or drug store. You will set up the equipment in the laboratory to heat the raw material and drive off the water. To do this, you will need "expert" advice on how to run the process efficiently; you will need to have your operation inspected to make sure your plant is in compliance with local, state, and federal regulations; you will have to package your product, advertise it, and keep track of all your expenses. Once you have completed all the tasks, you will calculate a price for your product that allows for a profit.

Magnesium sulfate heptahydrate, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, occurs naturally as the mineral epsomite. Magnesium sulfate heptahydrate is a compound known as a *hydrate*, that is, the compound retains water as part of its crystal structure and the prefix *hepta-* means seven water molecules. The dot in the formula indicates that the two substances are not chemically combined, and that they maintain their own unique identities. The magnesium sulfate heptahydrate loses its water of hydration in steps. The heptahydrate, which consists of transparent crystals, may lose one molecule of water at room temperature, when the air has low humidity, forming the hexahydrate (6 water molecules), which has the appearance of dull, white, powdery crystals. The hexahydrate is converted to the monohydrate (one water molecule) by heating to approximately 150°C. At 200°C the monohydrate loses its water forming anhydrous magnesium sulfate. At much higher temperatures decomposition to magnesium oxide and sulfur trioxide occurs. Therefore, the conversion of the heptahydrate to the monohydrate must be carried out at a temperature above 150°C, but below 200°C.

MATERIALS NEEDED

- 250-mL beaker
- stirring rod
- beaker tongs
- Bunsen burner, ring stand support with rings and wire gauze OR hot plate

Plastic weighing dish, medium size
Epsom Salt (magnesium sulfate heptahydrate), $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
Insulated ceramic fiber board

SAFETY PRECAUTIONS

Wear approved eye protection at all times in the laboratory.

Hold and handle the hot beaker using beaker tongs. Do not set the hot beaker on a cold bench top, place it on an insulated board.

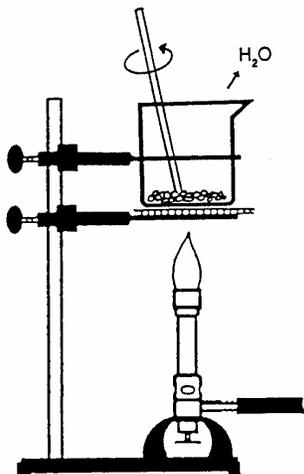
Hotplates or Bunsen burners and ring supports will become hot during the heating process. Allow all apparatus sufficient time to cool before handling and storage.

PROCEDURE

Prior to the laboratory period, someone in your lab section (or lab personnel, or your instructor) will go to a store and purchase a one-pound carton of Epsom Salt ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$). A sales receipt showing this purchase must be kept as a record and brought to the laboratory along with the time it took for the individual to travel to the store, make the purchase, and return.

You have made a capital investment in plant and equipment (your laboratory fee) that gives you access to the laboratory and a standard collection of equipment.

You are the "personnel" (chemist, engineer, shop foreman, worker, executive, marketing expert, salesman). You must keep a record of the time spent on your trips to the store and your laboratory working time to the nearest one-quarter hour. Pay yourself and any additional personnel \$7.50 per hour (minimum wage).



As the engineer, you must design your experiment. The process of heating the $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ will be carried out in a 250-mL beaker. The beaker is of appropriate size, is less expensive than other reaction vessels, and can withstand the required elevated temperatures. Because the beaker is made from glass, extra precautions must be taken to prevent breakage and injury to the operator.

If you are using a Bunsen burner to heat the beaker, then a ring stand and two iron rings are needed to secure the beaker above the burner. A wire gauze will have to be placed between the beaker and the lower iron ring so that the beaker is not in direct contact with the hot iron ring. The higher iron ring is used as a safety device to prevent the beaker from falling off the support. (The upper ring should not be in direct contact with the beaker.)

If you are using a hotplate to heat the beaker, then it can be placed directly on the top surface of the hotplate.

When the material in the beaker is stirred during the heating process, the beaker will move and could be knocked off its support and break. To prevent such a destructive event and the associated loss of time and material, the beaker is held with beaker tongs.

You are now the chemist and operator. Charge your beaker with approximately 20 g of Epsom Salt (permissible range 19-21 g). Place the 250-mL beaker on the top-loading electronic balance, tare the mass to zero, and carefully add Epsom Salt until the mass is approximately 20 g. Record the mass of your sample to 0.01 g (or the precision of your balance).

Inspect the Epsom Salt crystals. They must be transparent, or translucent. If the crystals are opaque and white, you will be starting with $\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$.

Place the beaker containing Epsom Salt on the hotplate or ring stand and ascertain that the beaker is secure and all the equipment is ready. Call your instructor, who acts as the government safety inspector, to inspect your plant for compliance with all regulations. If you are found to be without eye protection, to have left the balances without having cleaned up any spillages, or caught practicing other unsafe laboratory practices, your instructor may levy fines (point deductions) or in case of drastic violations "close down your plant."

After your plant has passed inspection, begin to gently heat the beaker with the crystals. Record the time you lit the burner or started the hotplate. Stir the crystals to allow the water to escape. If you heat too strongly and do not stir the crystals sufficiently, too much water is released too quickly. This water might dissolve some of the crystals and will cause your material to cake. Your final product will not be an attractive white powdery substance. In addition, the equipment will be difficult to clean. The yield will be low because some of the material will stick to the walls and will not be recoverable but make sure that your product does not begin to melt. Too much heat will cause the product to decompose, taking on an unattractive gray coloration and expelling sulfur trioxide, an air pollutant, from your reaction mixture. Your plant will be shut down and you will be fined if it pollutes the air.

After the dehydration is complete, allow the product to cool. Note the time you turned off the burner. Place a plastic weighing dish on the top-loading electronic balance and tare it to zero. Carefully transfer your product onto plastic dish and record the mass of your product to 0.01 g. Calculate the percent yield you achieved.

$$\text{Percent yield} = \frac{\text{Mass of your product}}{\text{Mass of Epsom Salt used}} \times 100$$

Your operation may generate by-products and "pollute" the environment. In order for the next generation (the students using the laboratory after you) to enjoy an unpolluted environment, clean all the glassware you used and clean your work area and around the balances. Have the Environmental Inspector (your instructor) sign the environmental impact form. Any pollution incidence will draw a fine in terms of point deductions from your grade.

Submit to your instructor your satisfactorily packaged product. The package must be labeled to show the mass of your product to the nearest 0.01 g and the yield.

You will need to market your product to your Board of Directors (your instructor - for grade points, not money). To do so, you will need to design a package and label and devise an advertisement you designed on a separate sheet of paper for submission to the Board. Some Board of Directors will require a prototype package with a label, while other Boards may only require drawings of both. Please consult with the Board about the package requirements. The advertisement should mention the positive properties and quality of your product. You may wish to point out that your product is a valuable laboratory (or household) drying agent.

Calculate a price for one gram of your product based on raw material costs, equipment costs, labor costs, energy costs, and a fair profit. Use the list in the Report Form as a guide for this calculation.

REPORT FORM

ECONOMICS OF A CHEMICAL PRODUCT

Name: _____ Course/Section: _____

Partner's Name (if applicable): _____ Date: _____

Chemical Data

Mass of raw material (Epsom Salt): _____ g

Mass of product: _____ g

Percent yield: _____ % (show calculation in the space below)

Government/Safety Inspection (instructor's evaluation – please leave this section blank):

In compliance with all rules and regulations

Not in compliance. Penalty for infringement = _____ (number of points deducted)

Inspector's signature or initials: _____

Costs

Raw material

Cost of package of Epsom Salt: \$ _____

Mass of Epsom Salt package: _____ g

Cost of Epsom Salt used: \$ _____

Energy

Time burner lit or hot plate started: _____

Time burner or hot plate turned off: _____

Minutes of energy use: _____ min.

Cost of energy: \$ _____

For gas: (minutes x \$0.01/min)

For hotplate: $\left(\frac{\text{minutes} \times \text{volts} \times \text{amps} \times \$ 0.08}{60 \times 1000} \right)$

Hotplate information: volts = _____ amps = _____

OR watts = _____

Note 1: See label on hotplate for volts and amps.

Note 2: If the hotplate label gives a value in watts, substitute watts for “volts x amps” in the equation above.

Note 3: The factors of 60 x 1000 in the equation above are conversion factors from “minutes x watts” to “kilowatt hours”

Note 4: The \$ 0.08 is a cost of electricity per kilowatt hour.

Capital investment:

10% of laboratory fee paid \$ _____ (minimum \$ 5.00)

Personnel (round time to nearest 1/4 hour; minimum time 1/4 hour):

Trucker (trip to store): _____ hr x \$7.50/hr = \$ _____

Engineer (building of set up): _____ hr x \$7.50/hr = \$ _____

Chemist (development of process*): _____ hr x \$7.50/hr = \$ _____

Worker (performing reaction, clean up): _____ hr x \$7.50/hr = \$ _____

Consultant (help by instructor): _____ hr x \$7.50/hr = \$ _____

Sales promotion (designing package and advertisement): _____ hr x \$7.50/hr = \$ _____

Total Personnel Expenses: (add the above items) \$ _____

* Use the time you spent for preparation before coming to the laboratory.

SUMMARY (use values from above sections):

Raw material: \$ _____

Energy: \$ _____

Capital Investment: \$ _____

Personnel: \$ _____

Total Costs (add above 4 items): \$ _____

Profit before taxes (50% of Total Costs from above): \$ _____

Sales Price of product (Total Costs + Profit): \$ _____

Price of 1.0 g of product ($\frac{\text{Sales price}}{\text{Mass of product}}$): \$ _____

Percent profit after taxes: _____ %

Percent profit after taxes = $100 \times \frac{(\text{Profit before taxes}) - (.30 \times \text{profit before taxes})^{**}}{\text{Sales price of product}}$

**Note: We are assuming a tax rate of approximately 30% on profits.

Environmental Impact Inspection (instructor's evaluation – please leave this section blank):

In compliance with all environmental rules and regulations

Not in compliance. Penalty for infringement = _____ (number of points deducted)

Inspector's signature or initials: _____

Instructor's Evaluation of Product

Purity of product (instructor's evaluation – please leave this section blank):

Reagent grade Pure Technical grade Poor Unsatisfactory

MARKETING

Packaging

You will either submit a prototype package with a label with your laboratory report OR you will be required to complete the following. Please consult with your Board of Directors (your instructor) for the requirements.

1. How would you package this material for the marketplace (examples: packet, box, tub, etc.)? Give a reason for your choice.

2. On a separate sheet of paper, draw a diagram of the package for your product.

3. On a separate sheet of paper, draw a label for your product's package. (You may design the label in black and white or color.)

Advertising

1. On a separate sheet of paper, design an advertisement for your product. The advertisement may be in black and white or in color. The advertisement should mention the positive properties and quality of your product. (Note: Truth in advertising laws means that you must be able to substantiate all claims about the product.)

QUESTIONS (attach a separate page if necessary)

1. Which of your costs influence the sales price of your product most?
2. If your competition sells a similar product at a lower price, where would you attempt to economize?
3. In which areas would cost-cutting not be successful?
4. Identify several other costs that would accrue in an industrial setting but were not considered in this experiment.
5. How could you determine if all of the heptahydrate has been converted to the monohydrate?