

# Math Diversion Problem 885

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Self-education is, I firmly believe, the only  
kind of education there is.

— Isaac Asimov

Source: <https://www.calstatela.edu/sites/default/files/dept/chem/07winter/201-1ec/201-1-4-gravimetric-analysis.pdf>

Title: A Gravimetric Analysis Problem 2

Presenter: Patrick

## 1 Problem

Definitions:

FW = Formula weight = molar mass  
ppt = precipitate

PROBLEM (p. 7):

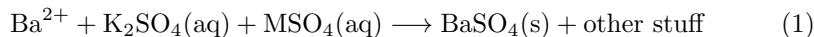
Consider a 1.0000 g sample containing 75% potassium sulfate (FW 174.25) and 25%  $\text{MSO}_4$ . The sample is dissolved and the sulfate is precipitated as  $\text{BaSO}_4$  (FW 233.39). If the  $\text{BaSO}_4$  ppt weighs 1.4900, what is the atomic weight of  $\text{M}^{2+}$  in  $\text{MSO}_4$ ?

Answer given:  $\text{Mg}^{2+}$ . (There's a problem here between what is given as the answer and what was asked for. I'll change the request to, Find the actual element that M stands for. This turns out to be Mg.)

SOLUTION: Step 1.

We clearly have yet another before-and-after process, but what should we identify as the main invariant of this process? To answer that question, we need a clearer idea of the process itself. First, we dissolve all the analyte in water. Second, we *apparently* add excess of barium ion  $\text{Ba}^{2+}$  until all the sulfate ions  $\text{SO}_4^{2-}$  in solution have precipitated out in the form of  $\text{BaSO}_4$ .

We begin with an unbalanced equation<sup>1</sup> that deals with the precipitation:



Step 2. Make a stoich diagram to help out.

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Molar Mass (g/mol):		174.25	$\bar{M} + 96.06$	278.11	
Elements/ Compounds:	<span style="border: 1px solid black; padding: 2px;">Ba<sup>2+</sup></span>	+	<span style="border: 1px solid black; padding: 2px;">K<sub>2</sub>SO<sub>4</sub></span>	+	<span style="border: 1px solid black; padding: 2px;">MSO<sub>4</sub></span>
			→	<span style="border: 1px solid black; padding: 2px;">BaSO<sub>4</sub></span>	+
Mass (g):		0.75	0.25	1.4900	
Moles:		↳ 0.0043039	↳ 0.25 / ( $\bar{M} + 96.06$ )	↳ 0.0063841	

Figure 1. We need only track what happens to the sulfate ions, which are contained in columns 2, 3, and 4. The bar over the M means to take the molar mass of the element. The molar mass of the sulfate ion is 96.06 g/mol.

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Step 3.

The masses of the two compounds in the analyte are easily calculated from the percentages each has of the original dry analyte (see the figure). Next, from the claim that *we add excess of barium ion Ba<sup>2+</sup> until all the sulfate ions SO<sub>4</sub><sup>2-</sup> in solution have precipitated out in the form of BaSO<sub>4</sub>*, we derive the conservation equation that the molar amount of SO<sub>4</sub><sup>2-</sup> ions in solution at the beginning is equal to the molar amount of SO<sub>4</sub><sup>2-</sup> ‘ions’ in the BaSO<sub>4</sub> precipitate; hence we can count them by moles in this before-and-after process:

$$\begin{aligned} & (\text{moles SO}_4^{2-} \text{ from col. \#2}) + (\text{moles SO}_4^{2-} \text{ from col. \#3}) \\ & = (\text{moles SO}_4^{2-} \text{ from col. \#4}). \end{aligned} \quad (2)$$

Now, because there is a one-to-one ratio of moles of K<sub>2</sub>SO<sub>4</sub> to moles of SO<sub>4</sub><sup>2-</sup> produced by dissolving, and a one-to-one ratio of moles of MSO<sub>4</sub> to moles of SO<sub>4</sub><sup>2-</sup> produced by dissolving, and, finally, a one-to-one ratio of moles of BaSO<sub>4</sub> to moles of SO<sub>4</sub><sup>2-</sup> taken out of solution by precipitation, then (2) becomes

$$0.0043039 \text{ mol} + \frac{0.25 \text{ g}}{(\bar{M} + 96.06) \text{ g}\cdot\text{mol}^{-1}} = 0.0063841 \text{ mol} \quad (3)$$

Solving this last equation for  $\bar{M}$ , yields

$$\bar{M} = 24.12 \text{ g}\cdot\text{mol}^{-1}. \quad (4)$$

Therefore, we conclude that Mg is the correct element corresponding to M.

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<sup>1</sup>We won’t bother to balance this equation because we won’t be requiring the use of a stoichiometric ratio.