Math Diversion Problem 657: Stoichiometry

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People often overlook the obvious.
— Doctor Who

The problem is found at:

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Source: Chemical Principles: The Quest for Insight
Title: Kilograms to kilograms
 Presenter:  P. Atkins and L. Jones.
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1 Problem Kilograms to kilograms

This problem is taken from the chemistry textbook *Chemical Principles: The Quest for Insight* ([1], p. F82):

► What mass of aluminum is needed to reduce 10.0 kg of chromium (III) oxide to produce chromium metal? The chemical equation for the reaction is

$$2\mathrm{Al(l)} + \mathrm{Cr_2O_3(s)} \xrightarrow{\Delta} \mathrm{Al_2O_3(s)} + 2\mathrm{Cr(l)}\,. \tag{1}$$

SOLUTION:

As a note to the reader: Appendix A (found in the short articles on stoichiometry) contains a list of molar masses of various compounds for the problem in this paper, although, slight differences can occur in these molar masses depending on differences existing in various references.

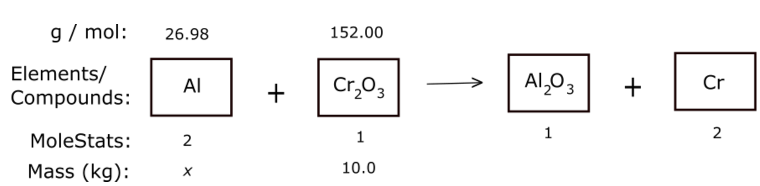

Figure 1. A kilograms-to-kilograms problem.

First, we make Fig. 1 that contains all relevant data.

Next, we formulate the fundamental (mole) proportion[1] of this problem:

$$\frac{\text{moles Al}}{\text{moles Cr}_2\text{O}_3} = \frac{2}{1}\,. \tag{2a}$$

But now we have to relate moles to kilograms, which is simple. Switching sides and expanding with the given information, yields:

$$\frac{2}{1} = \frac{\text{moles Al}}{\text{moles Cr}_2\text{O}_3} = \frac{x[\text{kg Al}]/26.98\,\text{g/mol}}{10.0\text{ kg}[\text{Cr}_2\text{O}_3]/152.00\,\text{g/mol}}\,. \tag{2b}$$

where the information in the square brackets is parenthetical.

Now, I must explain that I pulled a fast one in Eq. (2b). There is actually nothing incorrect about what I did in writing this proportion; however, your chemistry teacher may not think so. For purists, I should have written

$$\frac{2}{1} = \frac{\text{moles Al}}{\text{moles Cr}_2\text{O}_3} = \frac{x[\text{kg Al}]/26.98\times 10^{-3}\,\text{kg/mol}}{10.0\text{ kg}[\text{Cr}_2\text{O}_3]/152.00\times 10^{-3}\,\text{kg/mol}}\,. \tag{3}$$

This is the kind of subtlety with units that trips-up new students. Anyway, the reason (3) is just as good as (2b) is because we can go between them by merely multiplying both numerator and denominator by the same conversion factor. However, if we needed to know the moles of Cr_2O_3, given that we know there are 10.0 kg of it, then the correct units in the calculation would be

$$\text{moles Cr}_2\text{O}_3 = \frac{10.0\ \cancel{\text{kg}}[\text{Cr}_2\text{O}_3]}{152.00\times 10^{-3}\ \cancel{\text{kg}}/\text{mol}}\,. \tag{4}$$

Solving (2b) for x and canceling units where possible, we get

$$x = \frac{2}{1}26.98\frac{10.0\text{ kg}}{152.00} = 3.55\text{ kg}\,. \tag{5}$$

Now that we've finished our first real stoichiometry problem, what have we learned about the solution? We've learned that the solution to this problem is much the same as the solutions seen above to ordinary algebra word problems, especially those that include conversion factors and proportional reasoning.

References

[1] P. Atkins and L. Jones. *Chemical Principles: The Quest for Insight*, 3rd Ed. Freeman (2005).

[2] R. Blitzer. *Intermediate Algebra for College Students*, 3rd Ed. Prentice-Hall (2002).

[1] I refer to this proportion as involving moles, but it could just as easily refer to ratios of numbers of molecules. However, the masses of compounds are usually given in terms of molar masses, not molecular masses.

[3] M. Hein and S. Arena *Foundations of College Chemistry*, alternate 12th ed, John Wiley & Sons (2007), 421–422.

[4] H. Rolf. *Finite Mathematics*, 5th Ed. Brooks/Cole (2002), p. 57.

[5] M. S. Silberberg. *Chemistry: The Molecular Nature of Matter and Change* 4th Ed. McGraw-Hill (2006).