Math Diversion Problem 781

P. Reany

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> The wicked walk on every side, when
> the vilest men are exulted.
> — Psalm 12:8

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Source:  Chemical Principles: The Quest for Insight
Title:  Solving for mystery element X
 Presenters:  P. Atkins and L. Jones
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1 Problem: Solving for Mystery Element X

This problem is taken from *Chemical Principles: The Quest for Insight* ([1], Problem L21, p. F87).

PROBLEM:

The compound $XCl_2(NH_3)_2$ can be formed by reacting XCl_4 with NH_3. Suppose that 3.571 g of XCl_4 reacts with excess NH_3 to give 3.180 g of $XCl_2(NH_3)_2$. What is element X?

SOLUTION:

We begin with a balanced equation for the reaction. I include a presumptive chlorine term on the product side to make this feasible.

$$XCl_4 + 2NH_3 \longrightarrow XCl_2(NH_3)_2 + Cl_2\,. \tag{1}$$

One thing in our favor toward solving this problem is that, by inspection of the elements in the periodic table, the atomic masses are unique. Thus, if we can find the atomic mass of element X (in $g{\cdot}mol^{-1}$), we should be able to quickly identify the element in the table. Therefore, we let x represent the atomic mass of element X. If we can solve for x, we should be able to identify element X.

Now, since the molecular mass of Cl is 35.45 $g{\cdot}mol^{-1}$, and that of NH_3 is 17.03 $g{\cdot}mol^{-1}$, then the molecular mass of XCl_4 is $x + 4(35.45) = x + 141.8$, and for $XCl_2(NH_3)_2$ we get a molecular mass of $x + 2(35.45) + 2(17.03) = x + 104.96$.

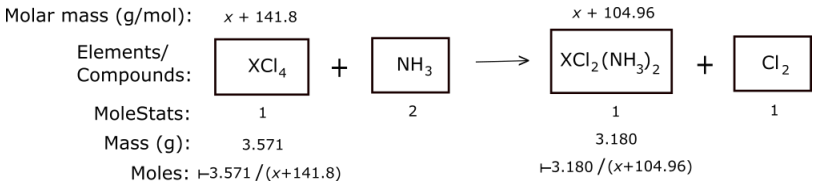

Figure 21. This graphic displays a logically 'extra' Cl_2 term.

Next, we write down our mole proportion between columns 1 and 3:

$$\frac{1}{1} = \frac{\text{moles } XCl_4}{\text{moles } XCl_2(NH_3)_2} = \frac{3.571/(x+141.8)}{3.181/(x+104.96)}\,. \tag{2}$$

Wolframalpha gives the solution for x as

$$x = 195.52\,\text{g}\,. \tag{3}$$

The element in the periodic table whose atomic mass is closet to x is platinum.

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).

[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).