**Chem 1984 Marathon problem #4**

**Mystery Compound**

**Due Wednesday 9 October 2013 by 4 PM**

**(no electronic submissions will be accepted)**

**7 points**

 **Answers**

I am a compound composed of two elements. I can’t be burned. If introduced into your body I eviscerate its blood cells. One of my elements is from group 7A. The other is from group 5A. A collection of 200 molecules of me weighs 5.645 x 10-8  pg. One molecule of me contains 6 atoms. When 2 molecules of me decompose together, 5 molecules of a toxic yellow, green homonuclear diatomic gas form along with a shiny grey solid at room temperature.

1. Who am I ? (Show work or you receive no credit.)
2. What is the balanced reaction that forms the toxic green gas and shiny grey solid ?

Note: some trial and error and `out of the box’ reasoning is needed here.


**Balanced Reaction:**

**2AsF5 🡪 2As(s) + 5F2(g)**

**HOW WE KNOW THE MYSTERY COMPOUND IS AsF5**

Its molecular weight is easily calculated since:

MW = grams/moles = 5.645\*10-8\*10-12 g

(200 molecules /6.022\*1023 molecules/mole)

**=169.97 g/mol**

To figure out the two elements involved and their stoichiometry, several alternative approaches can be used.

 **Method 1: using a combination of chemical facts and trial and error**

You note that only N2 forms a gas in column 5, and N2 is colorless.

This means the homonuclear diatomic gas must be either F2 or Cl2 since Br2 gas is red and I2 is a solid at room temperature. Both F2 and Cl2 are also yellow-green in color.

 Either F or Cl make up 5 out of the 6 atoms in the mystery compound, because two molecules of the mystery compound yielded :

(2 atoms /diatomic molecule) \*5 diatomic molecules = 10 atoms of halogen (F or Cl).

However, Cl can’t be the right choice since 5 Cl weighs 5\*35.45 = 177.25 g/mol which is larger than the molecular mass of the mystery compound. This leaves F and the mystery compound must be XF5.

Substituting in the atomic masses for N, P, As for X in XF5 we compute the following molecular weights (Bi is omitted since its atomic mass exceeds the mystery compound’s molecular weight)

**5A element =X XF5 Molecular weight (g/mol)**

N 109

P 126

**As 169.9 => AsF5 = mystery compound**

Sb 216.8

 Target molecular weight:169.97

 **Method 2: Alternative approach using chemical facts and trial/error**

The shiny grey solid cannot rise from column 7A since none of those elements (from F🡪I) form anything grey. That means the grey material must be one of the elements in column 5A.

Since N is a gas and P is a white or red solid at room temperature, we’re left with As or Sb. These are both grey but are too heavy be present in the mystery molecule except as a single atom since doubling As means even the lightest group 7A (F) can be present as just a single atom with As. Doubling Sb exceeds the mystery compound’s mass.

Thus, the mystery compound must be AsY5 or SbY5, Y= F, Cl,Br,I.

Sb is quickly eliminated since SbF5 weighs 216.8 and is already too heavy to be the mystery compound. Thus, As must be the metal.

You can then quickly ascertain that AsY5 = AsF5, since 5 Cl weighs 177.3 which exceeds the mass of the mystery compound.

 **Method 3: Brute force trial and error without using chemical facts**

Since the mystery compound = a 6 atom molecule, you can systematically cycle through the molecular weight values for all possible combinations of:

 AnB6-n n=1,2,3,4,5

 A= one of the group 5 elements N,P,As or Sb

 B= one of the group 7 elements F,Cl,Br, I

For any assumed A and B, there are 5 molecular weights possible.

There are also 16 possible pairings of A,B, e.g,

N with F, Cl, Br, I (4)

Note:

Bi and At are not considered since their individual masses exceed the target compound mass.

P with F, Cl, Br , I (4)

As with F, Cl, Br, I (4)

Sb with F, Cl, Br, I (4)

 16

In principle, this means you need to compute 16\*5=80 possibilities.

However, examination of the Sb case quickly reveals that SbF5, the lightest possible combination with Sb weighs 216.8 which is greater than the target weight. The element A can’t be Sb. Thus, only 64 possibilities are left.

Similar argument can be made with I since even with just 1 iodine=B in

AnB6-n, even the lightest A element, N would require a molecular mass for

N5I1 =197 g/mol which again exceeds the target compound’s molecular mass. We are now down to:

N with F, Cl, Br (3) x 5 (n=1,2,3,4,5)

P with F, Cl, Br (3) x 5

As with F, Cl, Br (3) x 5

 45 possibilities

Repetitive calculations should thus allow you to home in on the right combo with no recourse to chemical facts. Shortcuts can be applied. For example, for As, n=1,2 only since As3 weighs more than the mystery compound. This brings the total down to 39 possibilities

Similarly, for Br, n=5 only since even 2 Br weighs 160 g/mol and thus eliminates any possibility for including even 1 group 5 element. This eliminates another 12 choices (An=1,2,3,4Br5,4,3,2) (4) x (3..As,P,N) leaving only 39-12= 27 trial calculations.

FYI…brute force is not the preferred approach. Chemists always try to use some finesse and basic chemical knowledge to arrive at an answer.