Diagnosing Students’ Learning Difficulties in Stoichiometry

Multiple choice items can be set for the topic “stoichiometry.” An example is shown below:

Example 1: What is the percentage of hydrogen by mass in the compound C₂H₆?

(relative atomic mass: C = 12.0, H = 1.0)

A. B. 20% C. D.

A chemistry teacher can easily work out the correct answer and put it randomly as alternative B. But how can he/she work out the three distractors?

Most teachers arbitrarily assign values as distractors. To make them more plausible and attractive, teachers usually set the values in similar order of magnitude and number of significant figures; they may deliberately arrange the values either in descending or ascending order. Thus, the distractors may take the form below:

A. 15% B. 20% C. 27% D. 30%

Schmidt (1987) pointed out that students have two common misconceptions when they calculate the percentage of mass of an element in a compound. Students may equate the % of mass to simple mass ratio or percentage of atoms. Consequently, some students may apply these two strategies to tackle the above MC item.

\[
\text{Simple mass ratio strategy: } \frac{1 \times 6}{2 \times 12} \times 100\% = 25\%
\]

\[
\text{% of atoms strategy: } \frac{6}{2 + 6} \times 100\% = 75\%
\]

If students have used these two strategies, they may wonder why their answers do not match any of the four alternatives, and they will probably start on another different strategy to solve the MC item. Some may even make a guess. If this MC item is set in a test, examination or assignment, is it a good and effective evaluative or diagnostic instrument for chemistry teaching and learning?

Let us take a look at another example that also deals with the concept of percentage of mass but is set in a different way:
Example 2: Which one of the compounds represented by the following formulae has the highest proportion of hydrogen by mass in 1 mole?

A. H$_2$O  B. NH$_3$  C. PH$_3$  D. SiH$_4$  E. SnH$_4$

It is common to find this type of MC items in examinations and books written by teachers, but Example 2 is a poor item. Why? Schmidt (1987) explained the reasons with the aid of the following table:

<table>
<thead>
<tr>
<th></th>
<th>% of mass</th>
<th>mass-ratio</th>
<th>% of atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$O</td>
<td>11%</td>
<td>13%</td>
<td>67%</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>18%*</td>
<td>21%*</td>
<td>75%</td>
</tr>
<tr>
<td>PH$_3$</td>
<td>9%</td>
<td>10%</td>
<td>75%</td>
</tr>
<tr>
<td>SiH$_4$</td>
<td>13%</td>
<td>14%</td>
<td>80%*</td>
</tr>
<tr>
<td>SnH$_4$</td>
<td>3%</td>
<td>3%</td>
<td>80%*</td>
</tr>
</tbody>
</table>

The distractors have not been properly set because the incorrect mass-ratio strategy can also get the right answer (i.e., NH$_3$). Furthermore, students applying the % of atoms strategy will wonder why two answers are the same and this will give them an opportunity to use another strategy without revealing their errors.

Schmidt (1987) also found that some students do not recognize the particle concept in chemical formula. They assume that chemical formula represents: (a) the mass ratio of individual elements, or (b) the ratio of molar masses of elements. With the help of these two findings, can you design two plausible distractors for the following MC item? How do you know that your distractors are functional?

2 g of a compound contains 1 g of the element X, the rest is element Y. Which of the following formulae correctly represents this compound? (Relative atomic mass: X = 64.0, Y = 32.0)

A. B. XY$_2$ C. D.

Reference: