***Group Activity: Average Atomic Mass***

**Introduction**

The atomic mass values given in the periodic table are average atomic masses. They are calculated using the exact masses and natural abundances of the stable isotopes of an element.

As you know, atoms of an element come in different varieties called isotopes. For example, the common isotopes of nitrogen include$\begin{matrix}15\\7\end{matrix}$N and$\begin{matrix}14\\7\end{matrix}$N. Isotopes are atoms of the same element that have different mass numbers due to the fact that they have different numbers of neutrons. The isotopes of an element are not all equally common. Of all the nitrogen atoms on Earth 99.63% of them are147N. Only 0.37% of all nitrogen atoms are157N. That is why the average atomic mass of N as given in the Periodic Table is closer to 14 amu than to 15 amu.

**Percent Abundances**

The percentages given above for the isotopes of nitrogen are called **percent abundances**. The percent abundance of an isotope tells you the fraction of all atoms of an element that are a particular isotope of that element. Think of it this way: if you have 10,000 nitrogen atoms then 9,963 of them are147N and 37 of them are157N. Percentages are just a way to write fractions so that they all have the same denominator: 100. So the percentage 99.63% means 99.63/100 and 0.37% means 0.37/100. Percentages need to be written as decimals in order to use them in calculations. Therefore 99.63% (99.63/100) is 0.9963 and 0.37% (0.37/100) is 0.0037. Just move the decimal point two places to the left.

**Weighted Averages**

Average atomic masses are computed using a method called **weighted averages**. Weighted averages are used when the importance of the numbers to be averaged are different. For example, at Scarborough High School a student’s semester average is computed based on three grades. The First Term grade (T1), the Second Term grade (T2), and the Midterm Exam grade (R1). Both term grades are weighted at 40% (WT1 = WT2 = 0.40) of the semester average and the exam is weighted at 20% (WR1 = 0.20).

Say a Chemistry student named Lyle has a T1 grade of 85, a T2 grade of 80 and a R1 grade of 87. What is Lyle’s semester 1 grade? Set up the calculation this way:

 T1·WT1 + T2·WT2 + R1·WR1 = S1

 (85)·0.40 + (80)·0.40 + (87)·0.20 = 83.4

**Average Atomic Masses**

Average atomic masses are calculated in just the same way. Each isotope’s exact mass (determined using a mass spectrometer) is multiplied by the decimal equivalent of its percent abundance and all the results are added together.

**Potassium (K)**

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
| 3919K | 39 | 38.963707 | 93.2581 |
| 4019K | 40 | 39.963998 | 0.0117 |
| 4119K | 41 | 40.961826 | 6.7302 |

Here is how to calculate the average atomic mass of potassium:

 38.963707 · 0.932581

 39.963998 · 0.000117

 + 40.961826 · 0.067302

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 39.098301 amu

What if you know the percent abundance of the isotopes of an element but not all of the exact masses? Use algebra to find the missing exact mass. Take a look at the potassium data and imagine that the exact mass of 4119K is unknown. Use the average mass of the element, the known exact masses, and the percent abundances to find the missing exact mass data.

38.963707 · 0.932581 + 39.963998 · 0.000117 + x · 0.067302 = 39.098301

x · 0.067302 = 39.09830144 - 36.34148863

x · 0.067302 = 2.756812809

x = 2.756812809/0.067302 = 40.961826

Since we made up this problem we can check the answer against the exact mass given in the table: it matches perfectly. The exact mass of4119K is 40.961826 amu.

One thing that is important to getting the calculations of this kind exactly correct is to use your calculator to hold all the digits for you while you work. Set up your math so that you can type the numbers and operations into your calculator in one long calculation without having to stop, write down an answer and re-enter it. This prevents rounding errors which will cause your answers to be wrong.

**Problems**

Show your work for all the following calculations. The masses are atomic masses expressed in atomic mass units (amu). Write the symbol for each isotope. Pay attention to significant figures: do not report any more numbers after the decimal point than are reported in the data you are given.

1. Ryan’s grades for the first semester are T1: 76, T2: 84, R1: 80. What is his semester grade?
2. Marcus would like to earn a 93 for the semester. If his T1 grade is 90 and his T2 grade is 93 what grade does he need on the semester exam?
3. Leslie’s first quarter grade was 82. She wants to know what grades she needs for T2 and R1 to earn a 90 for the semester. Assume that she will earn the same grade for T2 and R1.
4. Find the average atomic mass of carbon (C ).

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
|   | 12 | 12.000000 | 98.90 |
|   | 13 | 13.003355 | 1.10 |

1. Find the average atomic mass of chlorine (Cl).

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
|   | 35 | 34.968852 | 75.77 |
|   | 37 | 36.965903 | 24.23 |

1. Find the average atomic mass of nitrogen (N).

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
|   | 14 | 14.003074 | 99.63 |
|   | 15 | 15.000108 | 0.37 |

1. Find the average atomic mass of silicon (Si).

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
|   | 28 | 27.976927 | 92.23 |
|   | 29 | 28.976495 | 4.67 |
|   | 30 | 29.973770 | 3.10 |

1. Find the average atomic mass of magnesium (Mg).

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
|   | 24 | 23.985042 | 78.99 |
|   | 25 | 24.985837 | 10.00 |
|   | 26 | 25.982593 | 11.01 |

1. Find the average atomic mass of chromium (Cr).

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
|   | 50 | 49.946049 | 4.345 |
|   | 52 | 51.940511 | 83.789 |
|   | 53 | 52.940653 | 9.501 |
|   | 54 | 53.938884 | 2.365 |

1. Find the average atomic mass of molybdenum (Mo).

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
|   | 92 | 91.906808 | 14.84 |
|   | 94 | 93.905085 | 9.25 |
|   | 95 | 94.905840 | 15.92 |
|   | 96 | 95.904678 | 16.68 |
|   | 97 | 96.906020 | 9.55 |
|   | 98 | 97.905406 | 24.13 |
|   | 100 | 99.907477 | 9.63 |

1. There is an easy way to check whether your answers are correct when you calculate the average atomic mass for the naturally occurring isotopes of an element. Explain this easy way to check your answers.
2. An element “X” has five major isotopes, which are listed below along with their abundances. Calculate the average atomic mass. What is the element?

|  |  |  |
| --- | --- | --- |
| Symbol | Exact mass | Percent abundance |
| 46X | 45.952630 | 8.25 |
| 47X | 46.951764 | 7.44 |
| 48X | 47.947947 | 73.72 |
| 49X | 48.947871 | 5.41 |
| 50X | 49.944792 | 5.18 |

1. An element consists of 1.4% of an isotope with mass 203.973 amu, 24.1% of an isotope with mass 205.9744 amu, 22.1% of an isotope with mass 206.9759 amu, and 52.4% of an isotope with mass 207.9766 amu. Calculate the average atomic mass and identify the element.
2. The element rhenium (Re) has two naturally occurring isotopes, 185Re and 187Re, with an average atomic mass of 186.207 amu. Rhenium is 62.60% 187Re, and the atomic mass of 187Re is 186.956 amu. Calculate the mass of 185Re.
3. The isotopes of oxygen are16 8O,17 8O, and18 8O. Oxygen-18 is particularly important because of its use in medicine as a precursor for fluorine-18 (used in Positron Emission Tomography, PET) and as a marker of temperature in studies of earlier climates on the Earth. Find the exact mass of this isotope using the following information:

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | Mass number | Exact mass | Percent abundance |
| 16 8O | 16 | 15.994915 | 99.762 |
| 17 8O | 17 | 16.999132 | 0.038 |
| 18 8O | 18 |   | 0.200 |

<http://kaffee.50webs.com/Science/activities/Chem/Activity.Average.Atomic.Mass.htm>