Problem 10 An element typical for Azerbaijan mud volcanoes expelled water

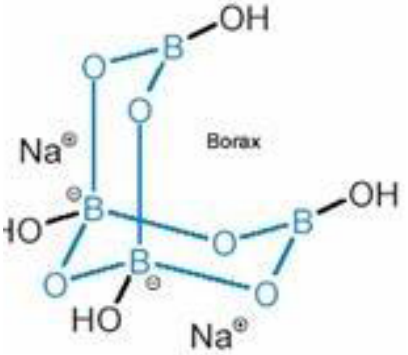
Azerbaijan is famous for mud volcanoes. About 400 active mud volcanoes are present in this region, both onshore and offshore - more than half the total throughout the world. Mud volcanoes come in a variety of shapes and sizes, but those most common in Azerbaijan have several small cones, or vents, up to about four meters in height. Mud volcanic eruptions in Azerbaijan normally last for less than a few hours, and are characterized by vigorous extrusion of mud breccias, hydrocarbon gases, and waters. Bakhar is a mud volcano with a high seep activity in the dormant period. The reservoirs formed by the volcanoes' activity contain the expelled waters. Those of Bakhar volcano have a composition with Na and Cl as dominant ions. The analyzed waters are enriched in metals and in an element X that causes flame coloration. Its' concentration in seeping water of 250 ppm represents a 55-fold enrichment in comparison to seawater. Being concentrated, the expelled water gives the white crystals, among them the compound Y, one of the main sources of X. The common oxide of X contains 31.0% of the element, whereas the compound Y – 11.3% only.
1. What are the element X and the compound Y?
2. Calculate the mass of Y that can be obtained from 1 L of expelled water.
3. Draw a possible crystal structure of Y, knowing that the mass loss under gentle heating is 37.8% and in Y two different types of X atoms are present.

Solution.

1. Let's consider the gram equivalent for element X with E_X and equivalent for Oxygen E_O. Then we can write the relation $E_X : E_O = E_X : 8 = 31 : 69$. From this proportion $E_X = 3.6$.
Taking into consideration valence = (1....5) then we find that it corresponds to valence 3, and atomic mass is $A_X = 10{,}8$ and it corresponds to BORON. The oxide is B_2O_3.
The mineral Y, main source of boron, is the borax $Na_2B_4O_7 \cdot 10\ H_2O$. We can demonstrate this as follows: molecular mass of borax is $M = 2 \cdot 23 + 4 \cdot 10.8 + 7 \cdot 16 + 10 \cdot 18 = 381.2$
The content of boron in borax is $4 \cdot 10.8 = 43$. 2. The content of boron in percentages is $43.2 \cdot 100 / 381.2 = 11.3\%$, exactly what we have to demonstrate.

2. 1 liter (we consider the density = 1) of expelled water contains 255 mg of boron. But as we know already 381.2 mg of borax contain 43.2 mg of boron. Then we find the 255 mg of boron in $255 \cdot 381.2 / 43.2 = 2250$ mg of borax, meaning 2.25 grams of borax.

3. Under gentle heating of the mineral borax we get another mineral losing a molecules of water: $Na_2B_4O_7 .(10\text{-}a)\ H_2O$ with molecular mass $M = 381.2 - 18a$. Then $18a \cdot 100 / 381.2 = 37.8$ where $a = 8$. Then the mineral name is kernite $Na_2B_4O_7 \cdot 2\ H_2O$.
We could write the borax also in this way: $[Na_2B_4O_5(OH)4].\ 8H_2O$ and kernite $[Na_2B_4O_5(OH)_4]$.
The structure for this, taking into consideration that we have anions of boron and atoms of boron:



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