On Buoyancy Correction (revised)

The formula given in Skoog and West is wrong! This is given by equation (1) below.

$$W_{corr} = W_{obs} + W_{obs}\left(\frac{d_{air}}{d_{obj}} - \frac{d_{air}}{d_{wts}}\right) \qquad (1)$$

do not use!

It assumes that $W_{\mathrm{sple}} \cong W_{\mathrm{wts}}$ which introduces also a significant error in W_{corr}.

The correct formula should be (this is also found in Harris's *Analytical Chemistry* book):

$$W_{true\_sample} = \frac{W_{obs}\left(1 - \frac{\rho_{air}}{\rho_{wts}}\right)}{\left(1 - \frac{\rho_{air}}{\rho_{sple}}\right)} \qquad (2)$$

correct!

The buoyancy effect here is the difference in the buoyant force on the sample being weighed and the counterweight (or standard weights) because of a difference in density. When these two have a large difference in their densities, then the error is significant.

This equation may be derived as follows. Think of a double pan balance, the sample is being weighed on the left, and the counterweights (standard weights) are placed on the right. The observed weight of the sample is the exact total of the standard weights placed on the right pan when the balance is 'balanced'. This is the observed weight, which is actually an apparent weight because each side of the balance experiences a buoyant force.

$$W_{\text{left pan}} = W_{\text{right pan}} \qquad (2)$$

$$W_{true\_sample} - W_{buoy\_sample} = W_{wts} - W_{buoy\_wts} \qquad (3)$$

Here, the weight observed on the left pan (also the right) is the buoyed weight. Thus, the true weight of the sample is greater by an amount equal to the buoyancy effect. According to Archimedes's principle, the apparent weight of the object is less by an amount equal to the weight of displaced fluid (in our case, air). The weight of displaced fluid is just the volume of the sample times the density of the fluid (we are using mass as synonymous to weight here—anyway, just multiply everything by acceleration due to gravity).

$$W_{true\_sample} - V_{sple}\rho_{air} = W_{wts} - V_{wts}\rho_{air} \qquad (4)$$

$$W_{true\_sample} - \frac{W_{sple}}{\rho_{sple}}\rho_{air} = W_{wts} - \frac{W_{wts}}{\rho_{wts}}\rho_{air} \qquad (5)$$

$$W_{true\_sample}\left(1-\frac{\rho_{air}}{\rho_{sple}}\right)=W_{wts}\left(1-\frac{\rho_{air}}{\rho_{wts}}\right) \qquad (6)$$

$$W_{true\_sample}=\frac{W_{wts}\left(1-\frac{\rho_{air}}{\rho_{wts}}\right)}{\left(1-\frac{\rho_{air}}{\rho_{sple}}\right)} \qquad (7)$$

Equation (7) is also Equation (2).

This formula corrects for the difference in the density of the standard weights of the balance and the sample being weighed. It is applied only on the actual sample being weighed, or in other words, on every WEIGHING READING.

In our experiment, the weight of air was measured this way:

$$W_{\text{air-filled bulb}} - W_{\text{evacuated bulb}} = W_{\text{air}} \qquad (8)$$

The ones that need correction using Equation (7) is $W_{\text{air-filled bulb}}$ and $W_{\text{evacuated bulb}}$ and not W_{air} directly. Note that since the weight is mostly due to the bulb, and the density of the bulb >> air, then the correction is small. Also, the corrections will tend to cancel each other out. Note also that since air displaced ‘vacuum’ in Equation (8), then there is really a negligible correction since Equation (7) becomes:

$$W_{true\_sample}=W_{wts}\left(1-\rho_{air}/\rho_{wts}\right)/\left(1-0/\rho_{sple}\right) \qquad (9)$$

$$W_{true\_sample}=W_{wts}\left(1-\rho_{air}/\rho_{wts}\right) \qquad (10)$$

and the density of air relative to the standard weights (usually brass) is small.

A DIFFERENT EXPERIMENTAL SCENARIO

Let’s say you do not have a means to evacuate the bulb thus, your data consists only of the following:

W_{bulb} (filled with air) / g	106.3923
W_{bulb} (filled with O_2) /g	106.4177
V_{bulb} / L	3.11 x 10^{-3}
ρ_{air} /g L^{-1}	1.11×10^{-3}
ρ_{oxygen} /g L^{-1}	1.16×10^{-3}
T /K	302.0

What is the correct weight of O_2 in the bulb?

We can ignore the correction due to the standard weights as discussed above. Here, the measured weight of O_2 is buoyed by the air that it displaced in the bulb!

Thus,

$W_{\text{oxygen apparent}} = 106.4177\text{ g} - 106.3923\text{ g} = 0.0254\text{ g}$

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\begin{aligned}
W_{\text{oxygen corrected}} &= W_{\text{oxygen apparent}} + W_{\text{buoyancy correction}} \\
&= \mathrm{W}_{\text{oxygen apparent}} + W_{\text{oxygen apparent}}\,(\rho_{\text{air}}/\rho_{\text{oxygen}}) \\
&= 0.0254\,(1 + 1.11/1.16) \\
&= 0.0497\text{ g}
\end{aligned}
$$

Note that here, the correction is from the fact that oxygen displaced air inside the bulb. And since the sample being weighed is not too dense, then a buoyancy correction is important. This case is different altogether compared to our experiment which measured the weight of evacuated bulb.

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