The Candle Experiment

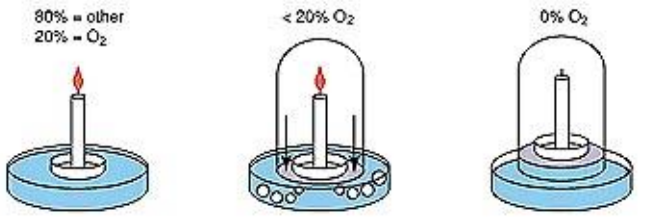
Known Phenomenon

1. A lit candle floating in water and is allowed to burn for a couple of minutes.
2. A jar is placed over the candle at an angle to expel some air. This lowers the level of water in the jar.
3. When the candle burns out, the water rises.

Why?

Explanation 1

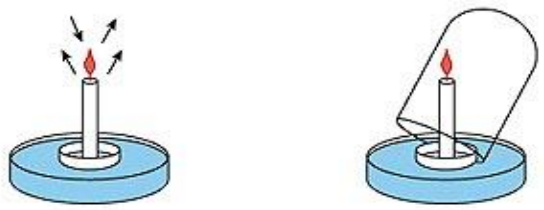
O_2 + fuel → the use of oxygen.
Since the water rose, the oxygen must have been used up.
It has risen about 1/5,showing that oxygen made up 1/5 of the original air.



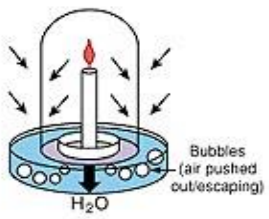
1. The air is made up of 80% other gases and 20% oxygen
2. Now that the air is enclosed, the candle is burning the O_2 in the jar. Thus, there is now < 20% O_2 .
3. The O_2 has been completely burned up and water has replaced the volume of lost O_2

Explanation 2

The equation of burning O_2 is: $C_6H_{12}O_6 + 6O_{2(g)} \rightarrow 6H_2O + 6CO_{2(g)}$.
As we can see, the oxygen is equally replaced with CO_2.
Therefore, there must be another explanation for the change in volume
The relevant equation for this phenomenon is PV = nRT (the Ideal Gas Law).

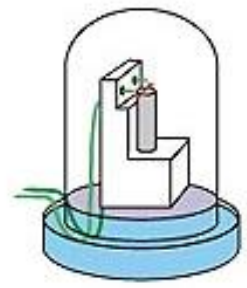


1. Normal atmospheric conditions.
2. As the cover is placed over the candle, the heat from the candle puts hot air into the cover. That decreases the amount of air molecules.

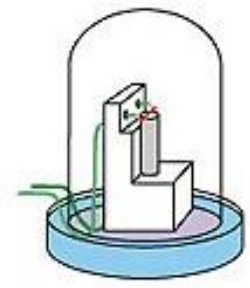


3. Heat pushes H_2O down and more air may escape but pressure inside and outside of the jar are equal.
4. When the candle burns out the air inside cools and the inside pressure decreases. The outside air pressure pushes water in until the pressures are equal.

Expect either 3a or 3b results



3a. If oxygen is used up then we expect the water level to rise about 20% of the volume.



3b. If oxygen is converted to $CO_2 + H_2O$ then we expect no loss in the number of molecules of air, and the water level to remain the same at, or be lower than, at the starting point.

Observation

Upon ingition water level lowers. When the candle goes out, the water level returns to the normal area but does not rise.

Conclusion

The observations are contrary to the predictions of Explanation 1, and consistent with the predictions of Explanation 2.

We reject Explanation 1.

Explanation 2 survives the test of experimental scrutiny.

Water level stays the same or lowers because of 1:1 gas exchange (at least) + H_2O condensation.

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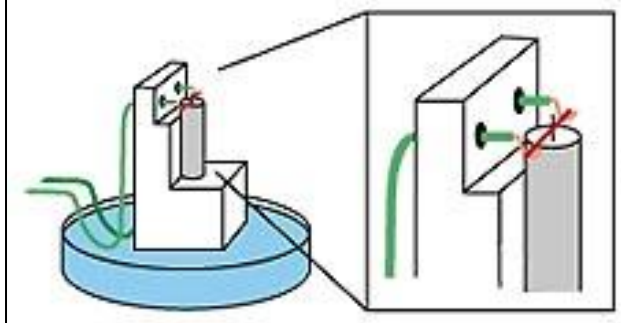
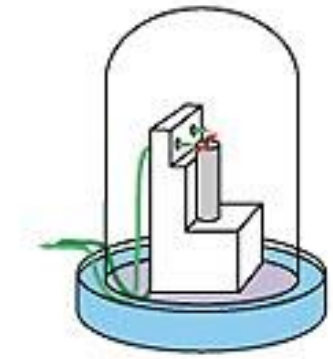
Test

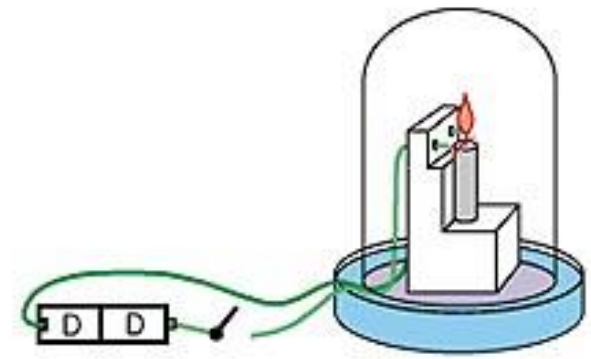
If explanation 2 is correct, let's imagine what would happen if a candle is ignited after the covering is placed over it. This would by-pass all variables introduced by placing the jar over the candle.



A fine wire filament to ignite the candle wick.



Temperature inside = Temperature outside
Pressure inside = Pressure outside
Water level inside = Water level outside



1. Once the candle is ignited, we open the switch to turn off the electricity.
2. Contained burn, no bubbles escape, temperature rises, water pushes down but air doesn't escape