Re: How much enerygy required to evaporate one liter of H2O ?

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From: The Ghost In The Machine (*ewill_at_aurigae.athghost7038suus.net*)
Date: 07/22/04

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Date: Thu, 22 Jul 2004 05:05:39 GMT
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In sci.physics, tj Frazir
<GravityPhysics@webtv.net>
wrote
on Tue, 20 Jul 2004 15:34:31 −0400
<29894−40FD73C7−158@storefull−3212.bay.webtv.net>:
> *Boil it and you will nead 100 times the energy by placing a flame under*
> *the can than if you used that energy to run a vaccume pump .*
> *A 60 watt vaccume pump will evaporate a gallon on water in less time*
> *than a burner on the stove could boil the water dry.*
> *IF you just let the water evaporate by its self then it cost you no*
> *energy.*
> *A solar furnace boiler running a steam engine*
> *that runs a vaccume pump might or might not be better.*
> *The deck can get rid of a gallon of water in 60 seconds so surface*
> *aria will be a large factor.*
> *A tube boiler uses aurface aria per flame aria .*
> *IF its in a raidator it might take all the energy you can dump in and*
> *not boil .*
> *NOT very much;;; to,,,, all the energy you want.*
>

An interesting problem, that.

Let's see... Numbers. I need numbers.

[1] Take a liter of water (1000 cc, 1 kg) at 300 K. Vaporization
energy at STP is 2.26 * 10^6 J/kg. Presumably vaporization
energy at 300K is about the same. Atmospheric pressure is
assumed at 101350 Pascal (= N/m^2 = (kg m/s^2)/m^2 or kg/(m s^2)).

[2] Let the sun shine in! Assuming all of the energy is used to
vaporize and the water is carried away by a constant breeze,
the amount of energy needed would be, as it turns out, 2.26 * 10^6 J.

[3] The vapor pressure of water at 300K = 27.3C is about 4,000 Pascal.

[4] If one wants to boil the water, one must heat it to 373K.
It takes 1 kcal to heat 1 kg of water 1 degree; 1 kcal = 4180 J.
Therefore the amount of energy required for this step
is 4180 * 73 = 305,000 J. Total cost to put the water on
a burner and watch it boil away dry: 2.565 * 10^6 J.

This should be enough.

The first problem is computing the size of that water vapor cloud.
Guy−Lussac gives us:

V = nRT/P = (1 / 0.018) * 8.3144 * 300 / 101350 = 1.137 m^3.

The second problem is computing the amount
of air needed in that breeze. We'll need to move at least
1.137 * (101350−4000)/4000 m^3 = 27.67 m^3 of dry air across
that water surface, and then dispose of the humid air.
The mass of this dry air is computable via Rydberg's
Constant, and a mole of air weighs about 29 g.
Total mass: n = PV/(RT) = 101350 * 27.67 / (8.3144 * 300) = 1124.3 kg.

More than a ton of air?! Woof.

If we assume the water's in a cubical vessel (0.1 m deep,
0.01 m^2 in area), we'll be moving a "tape" of air across
that surface. This will probably be a fairly thick tape
for minimum energy consumption, further exacerbated by the
necessity of pushing the water bottom up as it evaporates
(a total energy of 1/2 * 1 kg * 0.1 m * 9.805 m/s/s = .49 J,
so that's not very much). We also need to consider that the
water gains energy as it moves up: E = mgh. That's probably
even less.

If we assume a tape thickness of 0.1 m (the width is of course
1 m to cover the water cube), we get a tape length of 276.7 m.
After passing over the water the tape will be sopping wet, and
the water in each section of the tape would have been raised
0.05 m on average. Total energy gained here:
0.05 * 9.805 * 1 = 0.49 J again. Woo.

We now seal the cube in a container of size 1.137 m^3
(for purposes of simplicity, the cross−section in a certain
direction is 1 m^2, yielding dimensions of 1m x 1m x 1.137
m) and start pumping. We assume the ability of a certain
filter to keep the air going to the pump absolutely dry,
and sufficient controls/heat to keep the water at 300 K.
In short, all the water will do in this experiment is transform
from liquid to gaseous.

We pump out enough air to reduce the pressure from 101350 to 4000.
That's equivalent to stretching a piston from 1.137 m

to 1.137 * 101350/4000 = 28.81 m. The pressure on one side
of this piston is 101350 * x / 28.81 (where x is the distance
from the other wall of the piston's face); the pressure on the
other side is 101350. The amount of work required is then,
by simple integration,

101350 * (log(28.81) − log(1.137)) / 1.137 − 101350 * (28.81 − 1.137)
= 288124 − 2804658 = −2.516534 * 10^6 J.

The minus sign indicates an endothermic transition; we need, basically,
to put this much work into the system.

This is more energy than simply boiling the water using a heater,
and we've not even begun to vaporize the water yet.

I'm not sure how to proceed from here. As the water vaporizes,
the pressure rises; the vacuum pump will therefore have to
expend more work. The simplest way I can think of to properly
calculate this is to assume a constant pressure on both
sides of the piston and simply move it 28.81 more meters,
for a total work of

(4000 − 101350) * (28.81) = −2.805 * 10^6 J.

Total energy cost using a vacuum pump: −5.32 * 10^6 J −− more than
double that used by a simple heater.

For a 60W vacuum pump, it would take more than a day.

Upon rereading your diatribe, you stated a gallon. Quadruple everything. :−)

However, I should note that the pump cheats. Take a
cube of hot water at 373 K, rather than 300K. The vapor
pressure of hot water is greater than cold water (indeed,
at 100C = 373K the pressure is 1 atm or 101350 Pascal),
and the work done by the vacuum pump is far less −−
until the water cools to 300 K, of course, but there's
less water by then.

However, there's no way around that vaporization J/kg figure.

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#191, ewill3@earthlink.net
It's still legal to go .sigless.
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