

Heats of Vaporization and Condensation

Ck12 Science

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[Figure 1]

How much energy is available?

Natural resources for power generation have traditionally been waterfalls or use of oil, coal, or nuclear power to generate electricity. Research is being carried out to look for other renewable sources to run the generators. Geothermal sites (such as the geyser pictured above) are being considered because of the steam they produce. Capabilities can be estimated by knowing how much steam is released in a given time at a particular site.

Heat of Vaporization and Condensation

Energy is absorbed in the process of converting a liquid at its boiling point into a gas. As with the melting of a solid, the temperature of a boiling liquid remains constant and the input of energy goes into changing the state. The **molar heat of vaporization** (ΔH_{vap}) of a substance is the heat absorbed by one mole of that substance as it is converted from a liquid to a gas. As a gas condenses to a liquid, heat is released. The **molar heat of condensation** (ΔH_{cond}) of a substance is the heat released by one mole of that substance as it is converted from a gas to a liquid. Since vaporization and condensation of a given substance are the exact opposite processes, the numerical value of the molar heat of

vaporization is the same as the numerical value of the molar heat of condensation, but opposite in sign. In other words, $\Delta H_{\text{vap}} = -\Delta H_{\text{cond}}$.

When 1 mol of **water** at 100°C and 1 atm pressure is converted to 1 mol of water vapor at 100°C, 40.7 kJ of heat are absorbed from the surroundings. When 1 mol of water vapor at 100°C condenses to liquid water at 100°C, 40.7 kJ of heat are released into the surroundings.

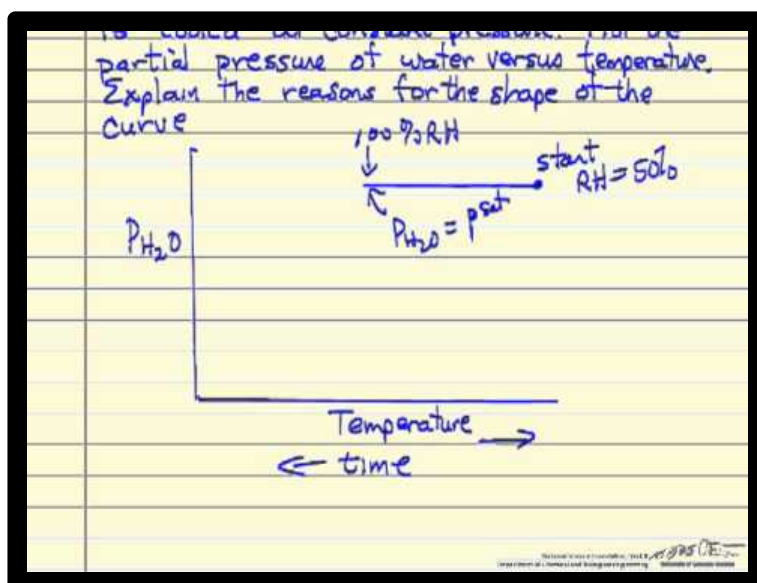


Other substances have different values for their molar heats of fusion and vaporization and these are summarized in **Table below**.

Molar Heats of Fusion and Vaporization

Substance	ΔH_{fus} (kJ/mol)	ΔH_{vap} (kJ/mol)
Ammonia (NH ₃)	5.65	23.4
Ethanol (C ₂ H ₅ OH)	4.60	43.5
Methanol (CH ₃ OH)	3.16	35.3
Oxygen (O ₂)	0.44	6.82
Water (H ₂ O)	6.01	40.7

Notice that for all substances, the heat of vaporization is substantially higher than the heat of fusion. Much more **energy** is required to change the state from a liquid to a gas than from a **solid** to a liquid. This is because of the large separation of the particles in the gas state. The values of the heats of fusion and vaporization are related to the strength of the intermolecular forces. All of the substances in **Table above**, with the exception of oxygen, are capable of **hydrogen bonding**. Consequently, the heats of fusion and vaporization of oxygen are far lower than the others.



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Sample Problem: Heat of Vaporization

What mass of methanol vapor condenses to a liquid as 20.0 kJ of heat are released?

Step 1: List the known quantities and plan the problem.

Known

- $\Delta H = 20.0 \text{ kJ}$
- $\Delta H_{\text{cond}} = -35.3 \text{ kJ/mol}$
- molar mass $\text{CH}_3\text{OH} = 32.05 \text{ g/mol}$

Unknown

- mass methanol = ? g

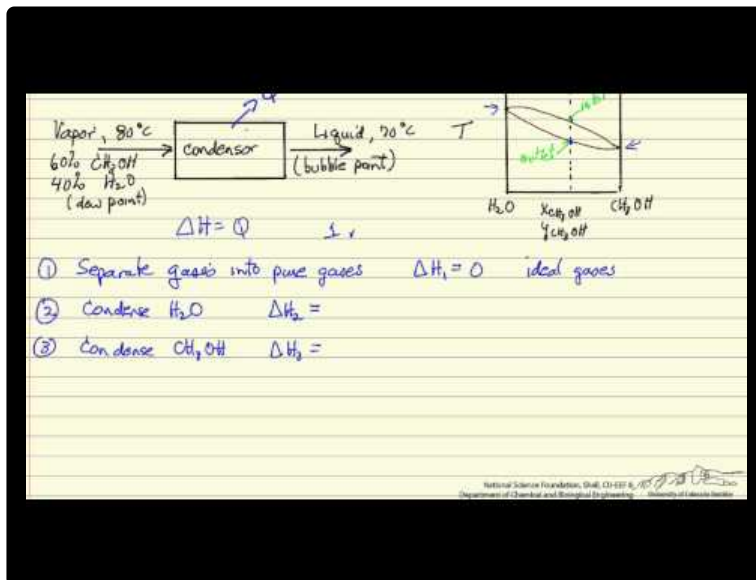
First the kJ of heat released in the condensation is multiplied by the conversion factor of $\left(\frac{1 \text{ mol}}{-35.3 \text{ kJ}} \right)$ to find the moles of methanol that condensed. Then, moles are converted to grams.

Step 2: Solve.

$$-20.0 \text{ kJ} \times \frac{1 \text{ mol CH}_3\text{OH}}{-35.3 \text{ kJ}} \times \frac{32.05 \text{ g CH}_3\text{OH}}{1 \text{ mol CH}_3\text{OH}} = 18.2 \text{ g CH}_3\text{OH}$$

Step 3: Think about your result.

Condensation is an exothermic process, so the **enthalpy** change is negative. Slightly more than one-half mole of methanol is condensed.



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Summary

- Molar heats of condensation and vaporization are defined.
- Examples of calculations involving these parameters are illustrated.

Review

1. What is common to all the substance in the table except oxygen?
2. How much heat is needed to convert 2.7 moles of ethanol at its **boiling** point from liquid to vapor?
3. How many moles of **water** will condense from vapor to liquid if 45 kJ are removed?

1.0 REFERENCES

1. Colin Faulkingham.
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