



What would be the enthalpy change when 25 g of water are produced by the reaction?

1 - Convert 25 g water to moles. Use FORMULA WEIGHT.

2 - Convert moles water to enthalpy change.

$$\textcircled{1} \text{H}_2\text{O}: \begin{array}{l} \text{H} - 2 \times 1,008 \\ \text{O} - 1 \times 16,00 \end{array}$$

$$\hline 18,016 \text{ g H}_2\text{O} = \text{mol H}_2\text{O}$$

$$\textcircled{2} 3 \text{ mol H}_2\text{O} = -1800 \text{ kJ}$$

$$25 \text{ g H}_2\text{O} \times \frac{\text{mol H}_2\text{O}}{18,016 \text{ g H}_2\text{O}} \times \frac{-1800 \text{ kJ}}{3 \text{ mol H}_2\text{O}} = \boxed{-830 \text{ kJ}}$$

Some notes:

1) Negative sign - indicates process is EXOTHERMIC. (Not surprising for a COMBUSTION)

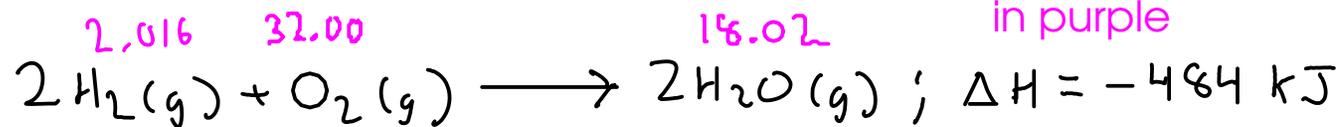
2) -830 kJ is also the HEAT (Q), provided pressure is constant.

A few more terms related to enthalpy:

- Enthalpy of vaporization / heat of vaporization: The enthalpy change on vaporizing one mole of a substance. (from liquid to vapor)

- Enthalpy of fusion / heat of fusion: The enthalpy change when a mole of liquid changes to the solid state.

 Phase changes require energy, too!



Calculate the enthalpy change for the combustion of 1.00 kg of hydrogen gas.

1 - Convert 1.00 kg hydrogen gas to moles. Use FORMULA WEIGHT.

2 - Convert moles hydrogen gas to enthalpy change. Use THERMOCHEMICAL EQUATION

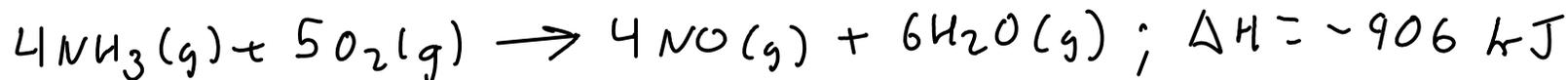
$$\textcircled{1} 2.016 \text{ g H}_2 = 1 \text{ mol H}_2 \quad \textcircled{2} 2 \text{ mol H}_2 = -484 \text{ kJ}$$

$$\text{kg} = 10^3 \text{ g}$$

$$1.00 \text{ kg H}_2 \times \frac{10^3 \text{ g}}{\text{kg}} = 1000 \text{ g H}_2$$

$$1000 \text{ g} \times \frac{\text{mol H}_2}{2.016 \text{ g H}_2} \times \frac{-484 \text{ kJ}}{2 \text{ mol H}_2} = -120000 \text{ kJ per kg H}_2$$

$\textcircled{1}$ 
 $\textcircled{2}$



What is the enthalpy change when 150. L of nitrogen monoxide are formed by this reaction at 25.0 C and 1.50 atm pressure?

1 - Convert 150. L of NO to moles. Use IDEAL GAS EQUATION.

2 - Convert moles NO to enthalpy change. Use THERMOCHEMICAL EQUATION

$$\textcircled{1} \quad PV = nRT \quad \left| \quad P = 1.50 \text{ atm} \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right.$$

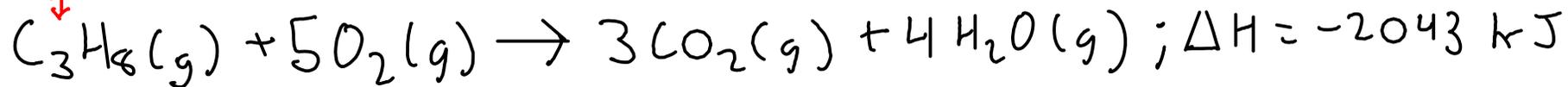
$$n = \frac{PV}{RT} \quad \left| \quad V = 150. \text{ L} \quad T = 25.0^\circ\text{C} = 298.2 \text{ K} \right.$$

$$n_{\text{NO}} = \frac{(1.50 \text{ atm})(150. \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(298.2 \text{ K})} = 9.194822849 \text{ mol NO}$$

$$\textcircled{2} \quad 4 \text{ mol NO} = -906 \text{ kJ}$$

$$9.194822849 \text{ mol NO} \times \frac{-906 \text{ kJ}}{4 \text{ mol NO}} = \boxed{-2080 \text{ kJ}}$$

propane



Calculate the volume of propane gas at 25.0 C and 1.08 atm required to provide 565 kJ of heat using the reaction above.

- 1 - Convert heat requirement (565 kJ) to mol propane. Use THERMOCHEMICAL EQUATION
- 2 - Convert moles propane to volume. Use IDEAL GAS EQUATION.

$$\textcircled{1} \text{ mol C}_3\text{H}_8 = -2043 \text{ kJ}$$

Since the calculation is from the point of view of the reaction, the reaction LOSES 565 kJ, so the number we start with will be -565 kJ

$$-565 \text{ kJ} \times \frac{\text{mol C}_3\text{H}_8}{-2043 \text{ kJ}} = 0.276554087 \text{ mol C}_3\text{H}_8$$

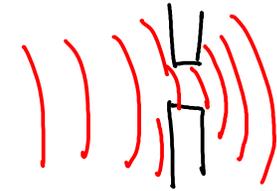
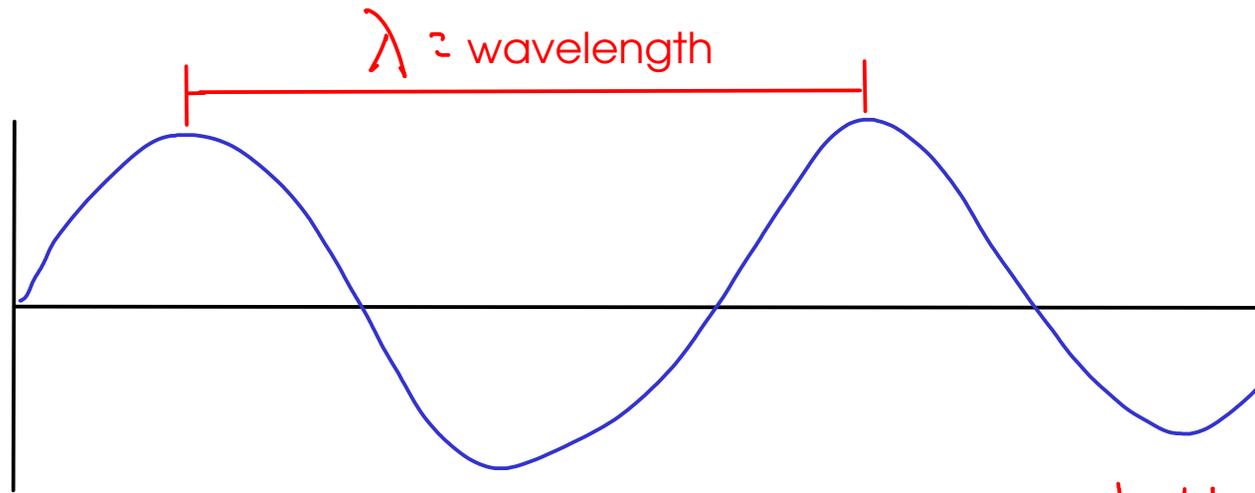
$$\textcircled{2} \begin{array}{l} PV = nRT \\ V = \frac{nRT}{P} \end{array} \quad \begin{array}{l} n = 0.276554087 \text{ mol C}_3\text{H}_8 \\ P = 1.08 \text{ atm} \\ R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \\ T = 25.0^\circ\text{C} = 298.2 \text{ K} \end{array}$$

$$V = \frac{(0.276554087 \text{ mol C}_3\text{H}_8)(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}})(298.2 \text{ K})}{1.08 \text{ atm}}$$

$$= 6.27 \text{ L of C}_3\text{H}_8 @ 25.0^\circ\text{C}, 1.08 \text{ atm}$$

## END OF CHAPTER 6

## LIGHT



Diffraction

$$\text{frequency} = \text{wavelengths} / \text{time} = \nu \quad \text{s}^{-1} : \text{Hertz } \approx \text{ Hz}$$

- Light has properties of WAVES such as DIFFRACTION (it bends around small obstructions).
- Einstein noted that viewing light as a particle that carried an energy proportional to the FREQUENCY could explain the PHOTOELECTRIC EFFECT!

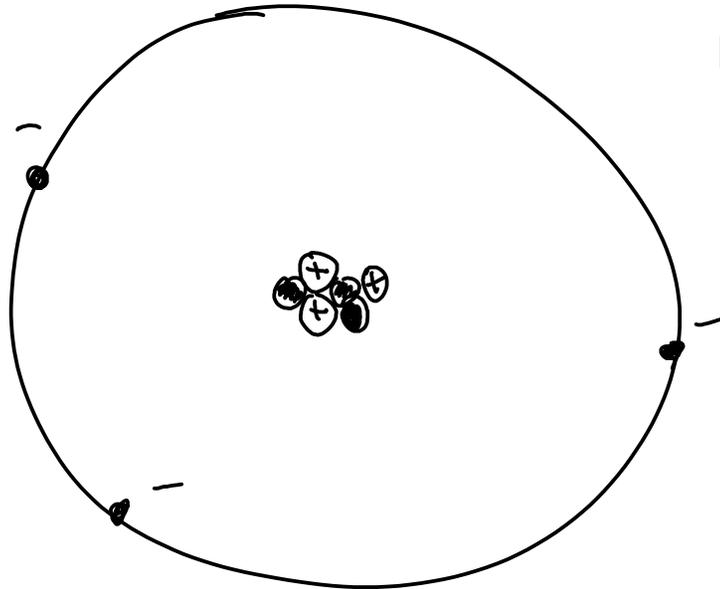
$$E_{\text{photon}} = h \nu$$

Planck's constant:  $6.63 \times 10^{-34} \text{ J}\cdot\text{s}$

photon = particle or packet of light

(The photoelectric effect is the emission of electrons from a metal caused by exposure to light. Einstein discovered that if the light were not of the correct FREQUENCY, increasing the INTENSITY of the light would not cause electron emission. He concluded that individual photons must have enough energy to excite an electron - i.e. they must have the appropriate frequency.)

The photoelectric effect and Einstein's ideas about the energy content of light led us to discover a new model for the atom! How? Let's start with the nuclear model:



Nuclear model:

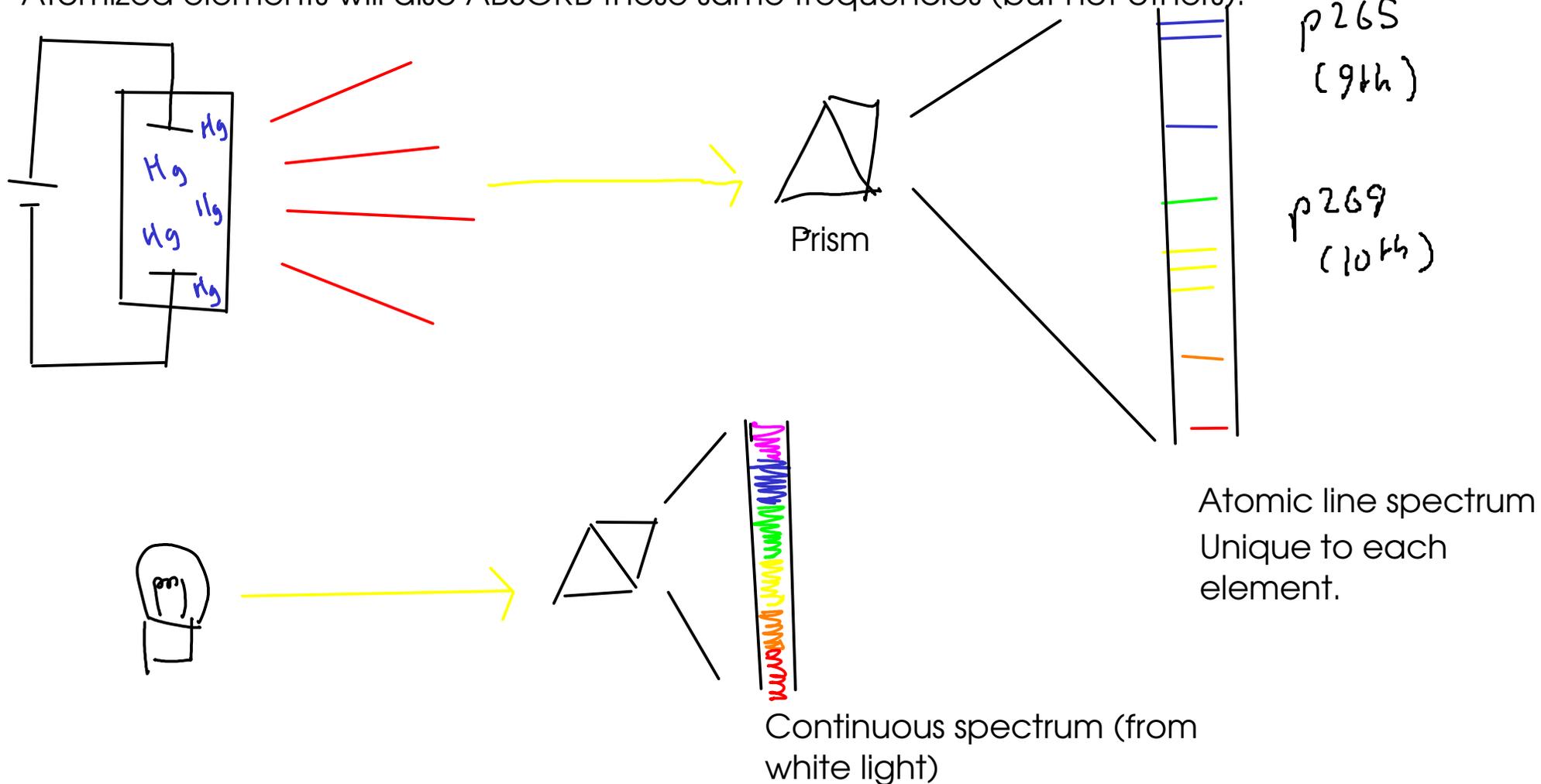
- Protons and neutrons in a dense NUCLEUS at center of atom
- Electrons in a diffuse (mostly empty) ELECTRON CLOUD surrounding NUCLEUS.

... so what's wrong with the nuclear model? Among other things, it doesn't explain ...

## ATOMIC LINE SPECTRA

- if you take element and ATOMIZE it, if excited by energy it will emit light at unique frequencies. The set of emitted frequencies is called an ATOMIC LINE SPECTRUM.

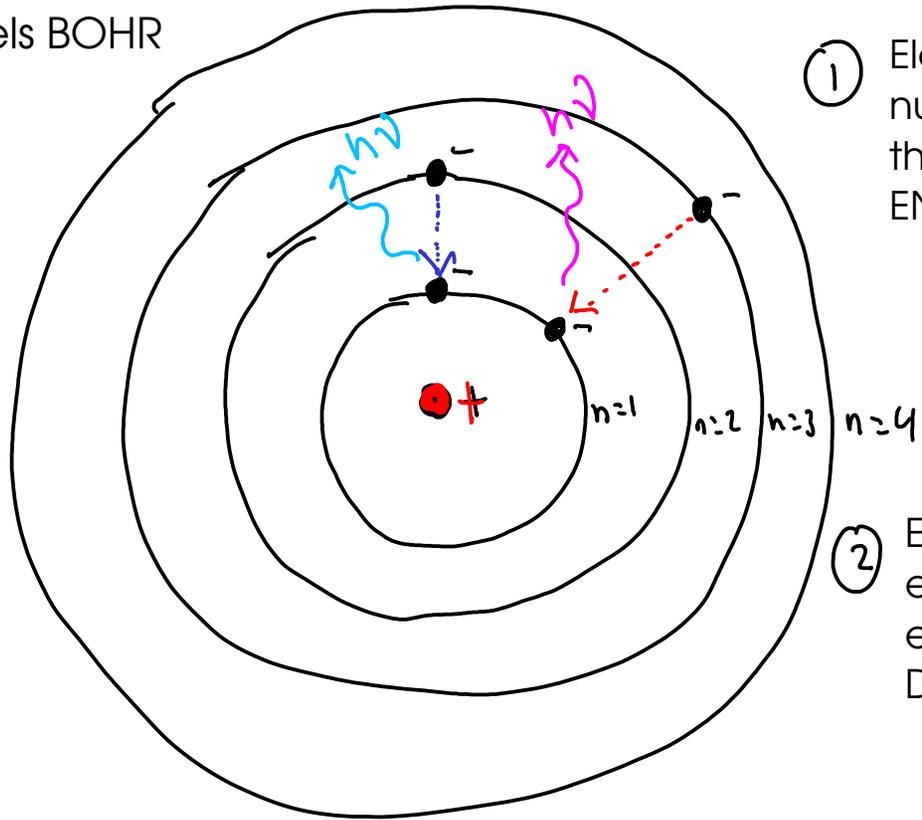
- Atomized elements will also ABSORB these same frequencies (but not others)!



... so, why don't atoms by themselves emit continuous spectra like a flashlight would?

- The regular patterns of emission and absorption of light by atoms suggest that the electron cloud has some sort of regular structure. The specific frequencies of light emitted and absorbed relate to specific values of ENERGY in the electron cloud.

Niels BOHR

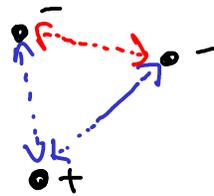


① Electrons can't be just ANYWHERE around a nucleus. They can exist only at certain distances from the nucleus. These distances correspond to certain ENERGIES and are called ENERGY LEVELS!

② Electrons CAN move (transition) between different energy levels by gaining or losing exactly enough energy to get into the new energy level. This was a DIRECT transition .

Bohr's model was the first proposal that predicted the existence of atomic line spectra, and it exactly predicted the spectra of hydrogen and "hydrogen-like" (i.e. one-electron) species.

The spectra were "off" for multi-electron atoms.



Multi-electron atoms have interactions between electrons, not just interactions between electrons and nucleus!

- The additional interactions in multi-electron atoms introduced added complexity to the model of the atom! Bohr's model was too simple.

- Improvements in Bohr's model came from treating electrons as WAVES.

de Broglie relationship

$$\lambda = \frac{h}{m \times v}$$

Planck's constant

velocity (m/s)

mass

wavelength

Calculates the WAVELENGTH of ... matter?

... for very large particles, the wavelength is very small.

## Quantum mechanics treats the electrons as waves and models THAT behavior!

- To describe the electrons, we use WAVEFUNCTIONs - which are mathematical descriptions of the behavior of electrons.
- The wavefunction describes the probability of finding an electron in a given space
- For larger objects, the wave behavior isn't very important .... and quantum mechanics becomes traditional Newtonian physics.

When we talk about describing electrons ... we will talk about the PARAMETERS that go into this WAVEFUNCTION ... without doing the actual math.

- There are FOUR of these parameters. (the Bohr model had only one!)
- The parameters are called "quantum numbers"
  - ① Principal quantum number
  - ② Angular momentum quantum number
  - ③ Magnetic quantum number
  - ④ Spin quantum number