[TP] Atom X that has an orange emission line (650 nm) with photon energy $E_{orange} = hc/(650\text{ nm})$ and a green emission line (510 nm) with photon energy $E_{green} = hc/(510\text{ nm})$. Which of the following statements are true about a single emission process of atom X?

20% 1. An atom of X can emit light with any amount of energy.
20% 2. An atom of X can emit light with energy between E_{orange} and E_{green}.
20% 3. An atom of X can emit light in multiples of E_{orange} or E_{green}.
20% 4. An atom of X can emit light only of E_{orange} or E_{green}.
20% 5. None of the above.

Lecture 28 CH101 A1 (MWF 9 am)
Monday, November 14, 2016

- Complete: Using $\Delta_b H$'s to estimate $\Delta_r H$
- If some substances are not gases, using $\Delta_b H$'s works poorly

Begin ch 8: Modeling atoms and their electrons
- Review: What light is and how it interacts with matter
- Natural frequencies of atoms

Next lecture: Light and matter exchange energy smoothly and slowly; Light energy is exchanged in tiny amounts called photons

Using $\Delta_b H$'s to *estimate* $\Delta_r H$

$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$

How much enthalpy change to break reactants apart into atoms?

How much enthalpy change to combine reactant atoms into products?

What is the total enthalpy change?

Using $\Delta_b H$'s to *estimate* $\Delta_r H$

The key feature of standard bond dissociation energies is that, the enthalpy change of any reaction, $\Delta_r H$, can be estimated using them, as …

$\Delta_r H =$ Sum[energy spent breaking bonds] –

Sum[energy evolved forming bonds]

$= \text{Sum}[\Delta_b H(\text{reactants})] - \text{Sum}[\Delta_b H(\text{products})]$

If some substances are not gases, using $\Delta_b H$'s works poorly

$\Delta_f H^o$'s versus $\Delta_b H$'s to compute $\Delta_r H$

$$C_2H_5OH(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$$

Using standard enthalpies of formation:

$$\Delta_r H = +\ 2\ \Delta H_f(CO_2, g) + 3\ \Delta H_f(H_2O, g) - \Delta H_f(C_2H_5OH, g) = -\ 1{,}277.38\text{ kJ}$$

Using bond enthalpies:

$$\Delta_r H = +\ \Delta H_{break}(C_2H_5OH) + 3\ \Delta H_{break}(O_2) - 2\ \Delta H_{make}(CO_2) - 3\ \Delta H_{make}(H_2O) = -\ 1{,}232\text{ kJ}$$

$\Delta_f H^\circ$'s versus $\Delta_b H$'s to compute $\Delta_r H$

$$C(s, gr) + 2\ H_2O(g) \rightarrow CH_4(g) + O_2(g)$$

Using standard enthalpies of formation:

$$\Delta_r H = +\ \Delta H_f(CH_4, g) -\ 2\ \Delta H_f(H_2O, g)$$
$$= -\ 74.81 - 2(-\ 241.82) = +\ 408.83\text{ kJ } (actual)$$

Using bond enthalpies:

$$\Delta_r H = +\ 2\ \Delta H_{break}(H_2O) - \Delta H_{make}(CH_4) - \Delta H_{make}(O_2)$$
$$= +\ 4\ (O\text{-}H) - 4(C\text{-}H) - (O{=}O)$$
$$= 4(460) - 4(414) - 498.7 = -\ 315\text{ kJ } (approximate)$$

Big error!

$\Delta_f H^\circ$'s versus $\Delta_b H$'s to compute $\Delta_r H$

$$C(s, gr) + 2\ H_2O(g) \rightarrow CH_4(g) + O_2(g)$$

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$$= -\ 74.81 - 2(-\ 241.82) = +\ 408.83\text{ kJ } (actual)$$

Using bond enthalpies:

$$C(s, gr) \rightarrow C(g),\ \Delta H_f(C, g)$$
$$\Delta_r H = \Delta H_f(C, g) + 2\ \Delta H_{break}(H_2O) - \Delta H_{make}(CH_4) - \Delta H_{make}(O_2)$$
$$= \Delta H_f(C, g) + 4\ (O\text{-}H) - 4(C\text{-}H) - (O{=}O)$$
$$= 716.7 + 4(460) - 4(414) - 498.7 = +\ 402\text{ kJ } (approximate)$$

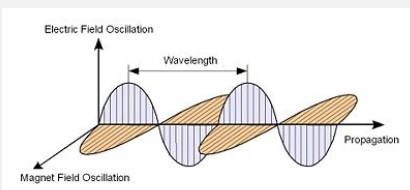
Much better!

[Quiz] "In my lecture I was told that change in enthalpy is products minus reactants, but my discussion leader told me that it is reactants minus products. I've also looked in another chemistry book and it say products minus reactants. Which is right?"

25% 1. products minus reactants
25% 2. reactants minus products
25% 3. both
25% 4. neither

Review: What light is and how it interacts with matter

Matter experiences light as an oscillating electric field



The electric field strength changes direction at frequency ν_{light}.

(The effect of the magnetic field is relatively negligible.)

The changing electric field of light tugs on matter …

Matter can respond to tugs only at "natural" frequencies of "motion" in matter

$$\nu_{\text{light}} = \nu_{\text{matter}}$$

Matter responds only at its "natural" frequencies

C-O stretch ~1000 $\text{cm}^{-1} = 3 \times 10^{13}/\text{s}$

ν_{stretch} = relative motion of atoms

$\nu_{\text{light}} = \nu_{\text{stretch}}$

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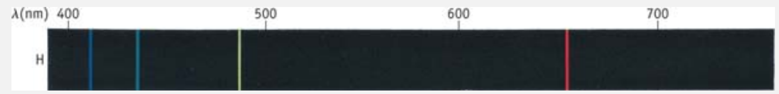
What are natural frequencies of atoms?

H atom emission spectrum



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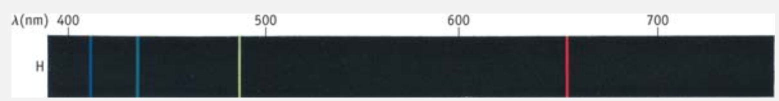

What could account for natural frequencies of atoms?

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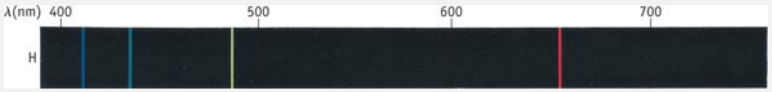
What are natural frequencies of atoms?

H atom emission spectrum



What is the frequency (in Hz) of the lowest-energy line in the H atom emission spectrum?

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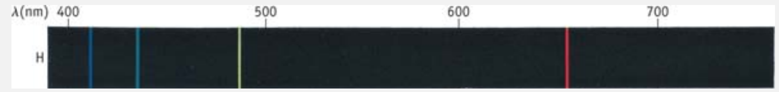
What are natural frequencies of atoms?

H atom emission spectrum



The red light emitted has frequency 4×10^{14} Hz. IR light, due to the oscillation of protons and neutrons (nuclei), has a frequency of $\sim 1 \times 10^{13}$ Hz.

Estimate the ratio of the mass of the object oscillating in H atom that leads to the emission of visible light, relative to the mass of a proton.