Sequence 12
Chemical energy

Fiche de synthèse mobilisée (collection en français) :

- Fiche n°12 : énergie chimique

Sommaire des activités ETLV:

ACTIVITY 1: Hess's Law

DOCUMENT 1: **Standard molar enthalpy of formation**

"**Standard molar enthalpy of formation** is defined as the enthalpy change when one mole of a compound is formed from its constituent elements under standard conditions (pressure: 1 bar; temperature: 298 K), with all reactants and products in their standard states."

$\Delta_fH°(CO_2\ (g)) = -394\ kJ.mol^{-1}$
$\Delta_fH°\ (H_2O(g)) = -242\ kJ.mol^{-1}$
$\Delta_fH°$ (*iso*-butane (g)) = - 134.5 $kJ.mol^{-1}$
Note that:
$\Delta_fH°(O_2\ (g)) = 0\ kJ.mol^{-1}$

DOCUMENT 2: **Standard molar enthalpy of combustion**

"**Standard molar enthalpy of combustion** is defined as the enthalpy change when one mole of a compound is completely burned in excess oxygen under standard conditions (pressure: 1 bar; temperature: 298 K), all reactants and products in their standard states."

$\Delta H°_{comb}\ (C\ (s)) = -394\ kJ.mol^{-1}$
$\Delta H°_{comb}\ (H_2(g)) = -285.8\ kJ.mol^{-1}$
$\Delta H°_{comb}$ (éthanol(l)) = - 1367 $kJ.mol^{-1}$

DOCUMENT 3: Hess' Law

Two methods can be used to determine the amount of heat involved in a chemical change: one can **measure** it experimentally, or **calculate** it from other experimentally determined enthalpy changes. This last method involves the use of Hess's law which states: *"If a process can be written as the sum of several stepwise processes, the enthalpy change of the total process equals the sum of the enthalpy changes of the various steps."*

$$\Delta H°_{reaction} = \Sigma\, b * \Delta H°_f(products) - \Sigma\, a * \Delta H°_f(reactants)$$

with *a and b* standing for the stoichiometric coefficients: a for the reactants and b for the products

DOCUMENT 4: Let's camp!

If you are camping this summer, you might need a camping stove in order to cook. Fuel camping stoves are lightweight stoves that burn liquid fuel such as butane, petrol or methylated spirits which is predominantly ethanol with additives. How can we use Hess' law to investigate the energetics of the processes involved?

Source : Wikimedia commons

1. Why is it unwise to use a camping stove inside a tent?
2. The standard molar enthalpy of formation of *iso*-butane is -134.5 $kJ.mol^{-1}$. Write a chemical equation for the reaction to which this enthalpy change applies.
3. In a camping stove, the *iso*-butane undergoes combustion. Write a chemical equation to describe the enthalpy change of combustion of *iso*-butane in excess oxygen.
4. Using **documents 1, 2** and **3**, calculate the standard enthalpy of the overall reaction of combustion for *iso*-butane: $\Delta H°_{comb}$(*iso*-butane (g)).
5. Write a chemical equation to describe the enthalpy change of combustion of ethanol in excess oxygen if ethanol is used in the camping stove instead of butane.
6. Using **documents 2** and **3**, compute the standard molar enthalpy of formation for ethanol: $\Delta_f H°$(ethanol(l)).

ACTIVITY 2: Getting us back to the moon

DOCUMENT 1: Back to the moon

With the Artemis campaign, NASA will send a piloted spacecraft to the Moon, using innovative technologies to explore more of the lunar surface than ever before. The four rocket engines of the main core stage will be powered by over 2500 m^3 of liquified hydrogen and oxygen. The engines will produce a total of 3.9×10^7 N of thrust, making it the largest rocket ever built. The reaction which takes place at the core stage is:

$$H_2(l) + \frac{1}{2} O_2(l) \longrightarrow H_2O(g) \quad (1)$$

$M(H) = 1.0\ g.mol^{-1}$
$M(O) = 16.0\ g.mol^{-1}$
Density ($H_2(l)$): $0.0709\ g.cm^{-3}$
Density ($O_2(l)$): $1.14\ g.cm^{-3}$

DOCUMENT 2: Standard molar enthalpy of combustion and enthalpy change of vaporisation

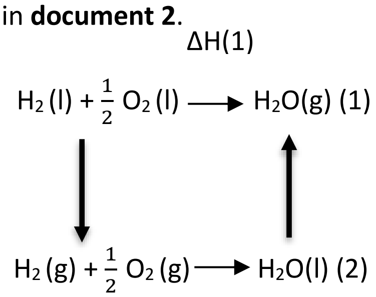
"**Standard molar enthalpy of combustion** is defined as the enthalpy change when one mole of a compound is completely burned in excess oxygen under standard conditions (pressure: 1 bar; temperature: 298 K), all reactants and products in their standard states."
"The enthalpy of vaporisation is the amount of energy needed for one mole of a liquid to become a gas**"**

$\Delta H°_{comb}(H_2(g)) = -285.8\ kJ.mol^{-1}$
Enthalpy change of vaporisation of hydrogen: $\Delta H_{vaporisation}(H_2) = 0.9\ kJ.mol^{-1}$
Enthalpy change of vaporisation of oxygen: $\Delta H_{vaporisation}(O_2) = 6.8\ kJ.mol^{-1}$
Enthalpy change of vaporisation of water: $\Delta H_{vaporisation}(H_2O) = 40.7\ kJ.mol^{-1}$

1. According to the chemical equation (1) written in **document 1**, identify the state (gas, liquid or solid) of each reactant and of water produced.

The enthalpy change of the reaction of liquid hydrogen and oxygen (**document 1**) in the core stage rocket can be estimated using Hess' Law by combining several other known enthalpy changes (**document 2**).

2. For each step in the energy cycle below, work out the formula and the numerical value of the enthalpy change using the enthalpies given in **document 2**.



Using Hess' Law, explain that the enthalpy change for the core stage fuel reaction is $\Delta H(1) =$ <u>- 241 kJ.mol⁻¹</u>.

This enthalpy change is calculated for the combustion of **1 mole** of liquid hydrogen with **0.5 mole** of liquid oxygen according to equation (1).

3. Using the following method, we aim to work out the amount of energy produced by the hydrogen/oxygen mixture in the rocket:
   a. Calculate the volume of 1 mole of liquid hydrogen.
   b. Calculate the volume of 0.5 mole of liquid oxygen.
   c. Deduce the total volume of hydrogen/oxygen mixture needed for the combustion of 1 mole of hydrogen.

   This total volume produces <u>241 kJ.</u>

   d. According to question 4.c, calculate the amount of energy produced by 2500 m^3 of the hydrogen/oxygen mixture that is used in the core stage rocket.

Activity summary

What you must remember:

- **balancing equations**
- **state symbols**
- **standard molar enthalpy of formation**
- **standard molar enthalpy of combustion**
- **enthalpy change of vaporisation**
- **Hess' law**

standard molar enthalpy of formation	enthalpie molaire standard de formation
thrust	force de poussée
core stage	étage principal

camping stove	réchaud
density	masse volumique

Skills linked to the curriculum**:**

Compétences	Capacités à maîtriser	Où dans cette séquence ?
APP	Utiliser du vocabulaire spécifique	Activités 1 et 2
	Lire et comprendre des documents scientifiques	Activité 1
ANA	Mettre en lien des documents pour émettre des hypothèses en réponse à une question scientifique	Activités 1 et 2
COM	S'exprimer à l'écrit en utilisant le vocabulaire adapté	Activités 1 et 2
REA	• enthalpie standard de formation • enthalpie standard de réaction de combustion • enthalpie de changement d'état • loi de Hess	Activités 1 et 2