Thermochemical equations and combustion reactions
Lesson 6a

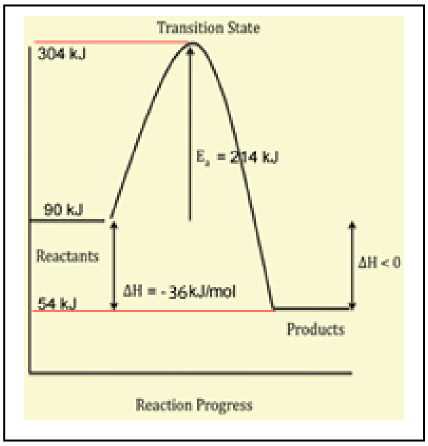
As of 2024 VCAA has modified the requirement for the expression of ΔH. It is now given in the units of kilojoules. *Eg* $3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$ $\Delta H = -93kJ$

Refer to the dot point below given in the 2024-2027 VCAA Chemistry study design.

comparison of exothermic and endothermic reactions, with reference to bond making and bond breaking, including enthalpy changes (ΔH) measured in kJ, molar enthalpy changes measured in kJ mol^{-1} and enthalpy changes for mixtures measured in kJ g^{-1}, and their representations in energy profile diagrams

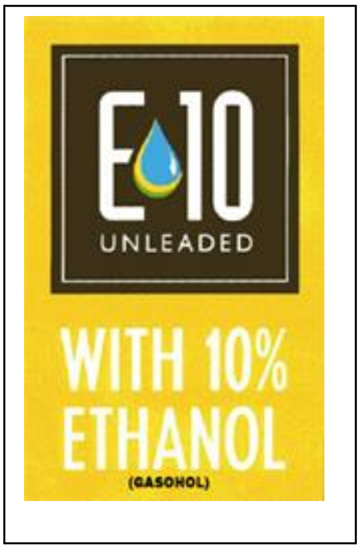
1) One mol of an unknown hydrocarbon is completely burnt in excess oxygen. During this process it was found that 214 kJ of energy was used to break the reactants' bonds and start the reaction process. As atoms then reacted and formed new bonds to create products, a total of 250 kJ of energy was then released. The total enthalpy of the reactants was 90 kJ/mol

   i. Using the experimental data shown above, draw the energy profile for the reaction on the set of axis shown on the right. Clearly indicate the:
   a) ΔH and its sign.
   b) activation energy
   c) total enthalpy of the products.



   ii. With reference to the Data Sheet, calculate the ΔH for the equation below.
   $6CO_2(g) + 8H_2O(g) \rightarrow 2C_3H_8(g) + 10O_2(g)$.
   This equation is the reverse of the combustion reaction of propane and then doubled.
   $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$ $\Delta H = -2217$ kJ
   $3CO_2(g) + 4H_2O(g) \rightarrow C_3H_8(g) + 5O_2(g)$ $\Delta H = +2217$ kJ
   $6CO_2(g) + 8H_2O(g) \rightarrow 2C_3H_8(g) + 10O_2(g)$ $\Delta H = +4434$ kJ

2) A fuel is composed of 90.0% octane and 10.0% ethanol by mass.
   With reference to the data sheet calculate:
   a) the amount of energy delivered by 50.0 grams of this fuel when it combusts completely in excess oxygen.



Substance	Mass(g)	Mol	Energy (kJ)
Octane	45.0	0.394	2158
Ethanol	5.00	0.108	147.3
Total			2305

3) What is the mass, in kg, of ethanol that burns in excess oxygen in order to deliver 40.4 MJ of heat energy.

Step 1 Write a balanced thermochemical equation for the complete combustion of ethanol using the ΔH_c found in the data booklet

$C_2H_6O(l) + 3½\ O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)\ \ \Delta H = -1364\ kJ$

Step 2 Using the stoichiometric ratio find the mol of ethanol that will generate 40.4 MJ

- ⇨ $1364kJ / 1 = 4.04 \times 10^4 kJ / n_{ethanol}$
- ⇨ $n_{ethanol} = 4.04 \times 10^4 kJ / 1364kJ = 29.6\ mol$

Step 3 Find the mass of ethanol

- ⇨ *mass = 29.6 X 46.0 = 1.36 kg*

4) What is the mass, in kg, of CO_2 that is produced when 23.2 MJ of energy is obtained from the complete combustion of liquid hexane.

Step 1 Write a balanced thermochemical equation for the complete combustion of hexane using the ΔH_c found in the data booklet

$C_6H_{14}(l) + 9½\ O_2(g) \rightarrow 6CO_2(g) + 7H_2O(g)\ \ \Delta H = -4158\ kJ$

Step 2 Using the stoichiometric ratio find the mol of carbon dioxide produced when 23.2 MJ of energy is released

- ⇨ $4158kJ / 6 = 23.2 \times 10^4 kJ / n_{hexane}$
- ⇨ $n_{hexane} = (23.2 \times 10^4 kJ / 4158\ kJ) \times 6 = 33.5\ mol$

Step 3 Find the mass of carbon dioxide

- ⇨ *mass = 33.6 X 44 = 1.50 kg 1.47 kg*

5) What is the amount of energy, in kJ, released when one <u>molecule</u> of liquid octane burns completely to produce carbon dioxide and water.

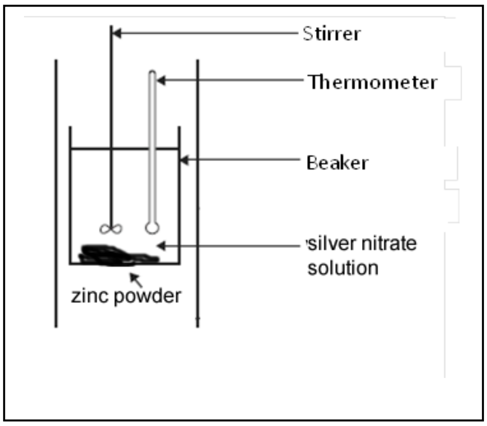
From the data sheet the ΔH_c of octane is 5464 kJ/mol. That is 5464 kJ of energy is released for every mol of octane burnt.

=> hence $5464kJ / 6.02 \times 10^{23} = 9.08 \times 10^{-21}$ kJ.

6) A 6.54 g sample of pure Zinc is placed in excess silver nitrate solution, at 21.0 °C. Zinc nitrate, $Zn(NO_3)_2$, and solid silver were formed. The final temperature of the water reached 24.2 °C.

a) Find the experimental ΔH for the reaction below if 100.0 mL of solution was used.

$2AgNO_3(aq) + Zn(s) \rightarrow Zn(NO_3)_2(aq) + 2Ag(s)$



Step 1 Find the mol of Zn

=> 6.54 / 65.4 = 0.100 mol

Step 2 Find the amount of energy that was absorbed by the water. Assume no energy loss from the system.

=> E = 4.18 X mass X ΔT

E = 4.18 X 100.0 mL X 0.997 X 3.2 °C = 1336 J

Step 3 calculate ΔH

=> ΔH = 1.336 kJ / 0.100 = - 13 kJ (2 sig figs)

b) What assumptions were made in calculating the ΔH of the reaction above?

- *No energy was lost from the system*
- *100.0 mL of water was present and that the silver nitrate solute did not contribute to the volume of the solution.*

c) What mass of silver is formed when 12.2 kJ of energy is released during the reaction?

Using the stoichiometric ratio find the mol of silver produced per kJ of energy released

$2AgNO_3(aq) + Zn(s) \rightarrow Zn(NO_3)_2(aq) + 2Ag(s)$ ΔH =- 13.4 kJ

Step 1 find the energy released per mol of silver produced

=> Energy / mol = 13.4 kJ / 2

=> So for one mol of silver 6.70 kJ of energy is released.

Step 2 Find the mol of silver produced

=> 12.2 kJ / 6.70 kJ 1,82 mol

Step 3 find the mass of silver

=> mass =1.82 X 108 =197 g