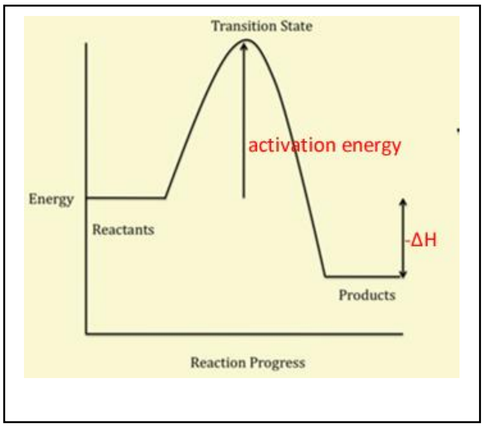
Thermochemical equations and combustion reactions
Lesson 2

1) a) Exothermic

Label the:

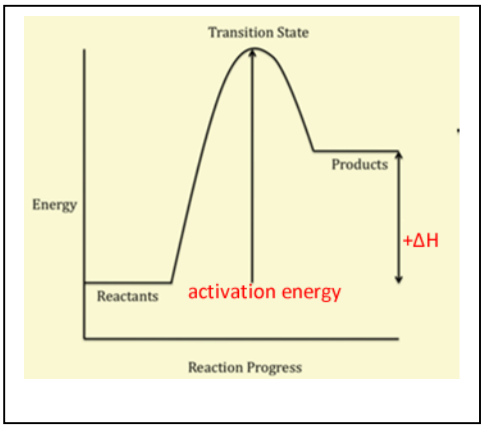
- Activation energy
- ΔH and its sign



b) Endothermic

Label the:

- Activation energy
- ΔH and its sign



c) What is activation energy?

The minimum energy required by particles to undergo successful collisions.

d) Combustion reactions are always exothermic and as such have a *negative* ΔH

e) Two types of combustion reactions exist.

i. *Complete combustion* occurs when *the reaction takes place in excess oxygen* and produce CO_2

ii. *Incomplete combustion occurs when oxygen is limited and produce CO.*

f) Combustion reactions involve fuels that are oxidised in oxygen and give of heat energy. Combustion reactions involving hydrocarbons and other carbon based molecules containing oxygen, such as alcohols, react with oxygen to produce water, and carbon dioxide. Carbon monoxide, instead of carbon dioxide, or solid carbon, are formed when oxygen is in *limited* supply.

Eg1 $C_5H_{12}(l) + 11O_2(g) \Rightarrow 5CO_2 + 6H_2O(l)$ ΔH = -ve
Eg2 $2C_5H_{10}(l) + 15O_2(g) \Rightarrow 10CO_2(g) + 10H_2O(g)$

Write balanced chemical equations for each of the following hydrocarbons undergoing complete combustion.

Eg3 $2C_{10}H_{22}(l) + 31O_2(g) \Rightarrow 20CO_2(g) + 22H_2O(l)$
Eg4 $C_9H_{20}(l) + 14O_2(g) \Rightarrow 9CO_2(g) + 10H_2O(l)$
Eg5 $2C_3H_6(g) + 9O_2(g) \Rightarrow 6CO_2(g) + 6H_2O(l)$

Write balanced chemical equations for each of the following hydrocarbons undergoing incomplete combustion, assuming all products are gases.

Eg6 $2C_{10}H_{22}(l) + 21O_2(g) \Rightarrow 20CO(g) + 22H_2O(l)$

Eg7 $2C_9H_{20}(l) + 19O_2(g) \Rightarrow 18CO(g) + 20H_2O(l)$

Eg8 $C_3H_6(g) + 3O_2(g) \Rightarrow 3CO(g) + 3H_2O(l)$

Write a balanced chemical equation for the incomplete combustion of liquid benzene if liquid water and a solid substance are formed.

$2C_6H_6(l) + 3O_2(g) \Rightarrow 12C(s) + 6H_2O(l)$

2) Ethane undergoes complete combustion in the presence of oxygen according to the equation below.

$2C_2H_6(g) + 7O_2(g) \Rightarrow 4CO_2(g) + 6H_2O(l)\ \Delta H = ?\ kJ/mol$

a) Given the molar heat of combustion (ΔH_c), which is the energy released when one mol of the substance undergoes complete combustion, of ethane as 1560 kJ mol^- calculate the ΔH for the equation above.

$2C_2H_6(g) + 7O_2(g) \Rightarrow 4CO_2(g) + 6H_2O(l)\ \Delta H = -3120\ kJ/mol$

Since two moles of ethane are represented in the equation above the ΔH_c for ethane must be doubled.

b) What amount of energy in kJ is produced when 9.00 grams of ethane burns completely in oxygen gas?

Step 1 find the mol of ethane.

=> 9.00 / 30.1 = 0.299 mol

Step 2 apply the ratios as per the balanced thermochemical equation.

The amount of energy given out per mol of ethane consumed will always be the same.

=> energy/mol of ethane = energy/ mol of ethane

=> 3120 / 2 = energy / 0.299

=> 466 kJ = energy released

c) What mass of carbon dioxide is produced if 1060 kJ of energy is released?

Step 1 apply the ratios as per the balanced thermochemical equation.

The amount of energy given out per mol of CO_2 released will always be the same.

=> energy/mol of CO_2 = energy/ mol of CO_2

=> according to the equation below

$2C_2H_6(g) + 7O_2(g) \Rightarrow 4CO_2(g) + 6H_2O(l)\ \Delta H = -3120\ kJ/mol$

3120 kj of energy is released for every 4 mol of CO_2 released.

=> 3120 / 4 = 1060 / mol of CO_2

=> 1.36 mol of CO_2

Step 2 find the mass of CO_2

=> mass = mol X molar mass

=> mass(g) = 1.36 X 44.01 = 59.8g

3) Propane undergoes complete combustion in the presence of oxygen according to the equation below.

$C_3H_8(g) + 5O_2(g) => 3CO_2(g) + 4H_2O(l)$ ΔH = ?kJ/mol

a) Given the molar heat of combustion (ΔH_c), which is the energy released when one mol of the substance undergoes complete combustion, of propane as 2220 kJ mol$^-$ calculate the ΔH for the equation above.

Since one mole of propane is represented in the equation above the ΔH for reaction is. $C_3H_8(g) + 5O_2(g) => 3CO_2(g) + 4H_2O(l)$ ΔH = -2220kJ/mol

b) What amount of energy in kJ is produced when 88.0 grams of propane burns completely in oxygen gas?

Step 1 find the mol of propane.

=>88.0 / 44.1 = 2.00 mol

Step 2 apply the ratios as per the balanced thermochemical equation.

The amount of energy given out per mol of propane consumed will always be the same.

=> energy/mol of propane = energy/ mol of propane

=> 2220 / 1 = energy / 2.00

=> 4440 kJ = energy released

c) What mass of oxygen is needed to produce 66.6 kJ of energy?

Step 1 apply the ratios as per the balanced thermochemical equation.

The amount of energy given out per mol of oxygen consumed will always be the same.

=> energy/mol of oxygen = energy/ mol of oxygen

=> according to the equation below

$C_3H_8(g) + 5O_2(g) => 3CO_2(g) + 4H_2O(l)$ ΔH = -2220kJ/mol

2220 kj of energy is released for every 5 mol of oxygen consumed.

=> 2220 / 5 = 66.6 / mol of oxygen

=> 0.150 mol of oxygen

Step 2 find the mass of oxygen

=> mass = mol X molar mass

=> mass(g) = 0.150 X 32.0 = 4.80g

4) Ethanol undergoes complete combustion in the presence of oxygen according to the equation below.

$C_2H_6O(g) + 3O_2(g) => 2CO_2(g) + 3H_2O(l)$ ΔH = ? kJ/mol

a) Given the molar heat of combustion (ΔH_c), which is the energy released when one mol of the substance undergoes complete combustion, of ethanol as 1367 kJ mol$^-$ calculate the ΔH.

Since one mole of ethanol is represented in the equation above the ΔH for reaction is. $C_2H_6O(g) + 3O_2(g) => 2CO_2(g) + 3H_2O(l)$ ΔH = -1367 kJ/mol

b) What amount of energy in kJ is produced when 9.20 grams of ethanol burns completely in oxygen gas?

Step 1 find the mol of ethanol.

=>9.20 / 46.1 = 0.200 mol

Step 2 apply the ratios as per the balanced thermochemical equation.

$C_2H_6O(g) + 3O_2(g) => 2CO_2(g) + 3H_2O(l)\ \Delta H = -1367\ kJ/mol$

The amount of energy given out per mol of ethanol consumed will always be the same.

=> energy/mol of ethanol = energy/ mol of ethanol

=> 1367 / 1 = energy / 0.200

=> 273 kJ energy released

c) What mass of carbon dioxide is produced when 27.0 kJ of energy is released?

Step 1 apply the ratios as per the balanced thermochemical equation.

The amount of energy given out per mol of CO_2 *produced will always be the same.*

=> energy/mol of CO_2 *= energy/ mol of* CO_2

=> according to the equation below

$C_2H_6O(g) + 3O_2(g) => 2CO_2(g) + 3H_2O(l)\ \Delta H = -1367\ kJ/mol$

1367kj of energy is released for every 2 mol of CO_2 *produced.*

=> 1367/ 2 = 27.0 / mol of CO_2

=> 0.0395 mol of CO_2

Step 2 find the mass of CO_2

=> mass = mol X molar mass

=> mass(g) = 0.0395X 44.0 = 1.74g

5) Methanol undergoes complete combustion in the presence of oxygen according to the equation below.

$\_\_\_CH_4O(g) + \_\_\_O_2(g) => \_\_\_CO_2(g) + \_\_\_H_2O(l)\ \Delta H = ?\ kJ/mol$

a) Balance the equation above.

$2CH_4O(g) + 3O_2(g) =>2CO_2(g) + 4H_2O(l)\ \Delta H = ?\ kJ/mol$

b) Given the molar heat of combustion (ΔH_c), which is the energy released when one mol of the substance undergoes complete combustion, of methanol as 725 kJ mol^- calculate the ΔH.

Since 2 mole of methanol is represented in the equation above the ΔH for reaction is. $2CH_4O(g) + 3O_2(g) =>2CO_2(g) + 4H_2O(l)\ \Delta H = -1450\ kJ/mol$

c) What amount of energy in kJ is produced when 9.20 grams of methanol burns completely in oxygen gas?

Step 1 find the mol of methanol.

=> 9.20 / 32.0 = 0.290 mol

Step 2 apply the ratios as per the balanced thermochemical equation.

$2CH_4O(g) + 3O_2(g) \Rightarrow 2CO_2(g) + 4H_2O(l)$ $\Delta H = -1450$ kJ/mol

For every 2 mol of methanol consumed 1450 kJ of energy is released.

The amount of energy given out per mol of methanol consumed will always be the same.

=> energy/mol of methanol = energy/ mol of methanol

=> 1450 / 2 = energy / 0.290

=> 2.10×10^2 *kJ (3 sig figs) energy released*

d) What mass of carbon dioxide is produced when 27.0 kJ of energy is released?

Step 1 apply the ratios as per the balanced thermochemical equation.

The amount of energy given out per mol of CO_2 *produced will always be the same.*

=> energy/mol of CO_2 *= energy/ mol of* CO_2

=> according to the equation below

$2CH_4O(g) + 3O_2(g) \Rightarrow 2CO_2(g) + 4H_2O(l)$ $\Delta H = -1450$ kJ/mol

1450 kJ of energy is released for every 2 mol of CO_2 *produced.*

=> 1450/ 2 = 27.0 / mol of CO_2

=> 0.0372 mol of CO_2

Step 2 find the mass of CO_2

=> mass = mol X molar mass

=> mass(g) = 0.0372 X 44.0 = 1.64g (3 sig figs)