Reactants, Products and Energy Change – Notes

Exothermic reactions:

- **More energy is released in forming bonds** than is required to break initial bonds.
- **Enthalpy of products is less than reactants**.
- Reactants have a higher chemical energy than the products.
- ΔH is **negative**.
- Enthalpy **decreases for the system** and **increases for the surroundings**.
- The **products have stronger bonds**.

Examples of exothermic reactions:

- Combustion.
- Reactions involving single atoms bonding together. e.g., $2I \rightarrow I_2 + 214$ kJ
- Reactions in which a positive ion gains an electron. e.g., $Na^+ + e^- \rightarrow Na$
- Condensation and solidification phase changes.
- Respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$.
- Heat packs.
- Crystallisation.

In general, **chemical processes involve greater enthalpy changes than physical processes**. This is because the **intermolecular forces are usually weaker** than the intramolecular forces.

Endothermic reactions:

- **More energy is required in breaking the initial bonds** than is released in forming.
- **Enthalpy of products is greater than reactants**.
- Reactants have a lower chemical energy than the products.
- ΔH is **positive**.

- Enthalpy **increases for the system** and **decreases for the surroundings**.
- The **reactants have stronger bonds**.

Examples of endothermic processes:

- Reactions involving a **molecule break-up**. e.g., F_2 + 158 kJ → 2F
- Reactions in which an atom or ion **loses an electron**. e.g., K → K^+ + e^-
- **Vaporisation and liquefaction** phase changes.
- **Photosynthesis**: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.
- Cold packs.

Molecular formula = $\frac{Molecular\ mass}{Empirical\ formula\ mass}$ **x empirical formula**

Avogadro's number = 6.022 x 10^{23} particles per mole

n = $\frac{m}{M}$

n = n_k x u/k

n = $\frac{Number\ of\ particles}{6.022\, x\, 10^{23}}$

n = Concentration (mol L^{-1}) x volume (L)

Fuel/heating value (MJ kg^{-1}) = $\frac{\Delta Hc}{M}$ **ΔHc = Standard heat of combustion for 1 mol of fuel.**

CO_2 emission value (g(CO_2)MJ^{-1}) = $\frac{m(CO2)}{Energy}$

The energy within chemical bonds contributes to the enthalpy of a substance. During a chemical reaction, chemical bonds **within the reactants are broken** and new chemical bonds are **formed within the products**.

In an exothermic reaction, the **products have less energy than the reactants** so there's a **negative** ΔH. **More energy was released in bond-forming** than was absorbed in bond-breaking so **temperature increases**.

In an endothermic reaction, the **products have more energy than the reactants** so there's a **positive** ΔH. **More energy was absorbed in bond-breaking** than was released in bond-forming so **temperature decreases**.

A temperature rise occurs when enthalpy decreases, and the reaction **releases an equivalent amount of heat to the surroundings**. Thus, the reaction is exothermic.

A temperature fall occurs when enthalpy increases, and the reaction **absorbs an equivalent amount of heat from the surroundings**. Thus, the reaction is endothermic.

A reaction container holds 5.77 g of P_4 and 5.77 g of O_2.The following reaction occurs:

$P_4 + O_2$ ~~P_4O_6.~~ $\longrightarrow$

If enough oxygen is available, then the P_4O_6 reacts further: $P_4O_6 + O_2 \longrightarrow P_4O_{10}$

[a] What is the limiting reagent for the formation of P_4O_{10}?

Final equation: $P_4O_{10} + 5O_2 \longrightarrow P_4O_{10}$

$n(P_4O_{10}) = \frac{5.77}{123.88} = 0.0466$ mol

$n(O_2) = \frac{5.77}{32} / 5 = 0.0361$ mol

O_2 is the limiting reagent as it produces less P_4O_{10}

[b] What mass of P_4O_{10} is produced?

$m(P_4O_{10}) = 0.0361 \times 283.88 = 10.24$

[c] What mass of excess reactant is left in the reaction container?

$m(P_4 \text{ used}) = n(\text{limiting reagent}) \times M(P_4) = 0.0361 \times 123.88 = 4.467$

$m(P_4 \text{ left}) = 5.77 – 4.467 = 1.30g$

When finding the excess reagent:

1. **Find the limiting reagent** by dividing the number of moles by the coefficients and finding which is smaller.
2. **Find the amount of the excess reagent that reacted with the limiting reagent** using n(limiting reagent) x M(excess reagent).
3. **Subtract the mass of the calculated value from the original mass** in the question.

Inside a blast furnace for the extraction of iron from iron ore, many different reactions take place. One important series of reactions for the extraction of iron is shown here.

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

$C_{(s)} + CO_{2(g)} \longrightarrow 2CO_{(g)}$

$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2(g)}$

[a] Write an overall equation showing the formation of Fe from Fe_2O_3

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ Needs to have $3CO_2 \rightarrow$ x3

$C_{(s)} + CO_{2(g)} \longrightarrow 2CO_{(g)}$ Needs to have 6CO $\rightarrow$ x3

$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2(g)}$ Needs to have 6CO $\rightarrow$ x2

$3C + 3O_2 + 3C + 3CO_2 + 2Fe_2O_3 + 6CO \longrightarrow 3CO_2 + 6CO + 4Fe + 6CO_2$

$6C_{(s)} + 3O_{2(g)} + 2Fe_2O_3 \longrightarrow 6CO_{2(g)} + 4Fe_{(l)}$

[b] Assuming no other reactions are involved, determine the minimum mass of carbon needed for every tonne of iron ore if the ore contains 97% Fe_2O_3 by mass.

$m(Fe_2O_3) = 0.97 \times 1000000 = 970000g$

$n(Fe_2O_3) = \frac{970000}{159.7} = 6073.89$ mol

$n(2Fe_2O_3) = \frac{6073.89}{2} = 3036.94$ mol

$n(C) = 3036.94 \times 6 = 18221.67$ mol

/ 6.022×10^{23}

$m(C) = 18221.67 \times 12.01 = 2.2 \times 10^5$ tonnes

X 6.022×10^{23}

Molecules / formula units

Molecules / formula units

Atoms / Ions

Atoms / Ions

Comparing Fossil Fuels: Emissions and Fuel Values

Fuel values (sometimes called heating values) compare the **energy from the complete combustion of equal masses or volumes of different fuels**. The greater the value the greater the energy available from a given mass.

Units in $kJ\ g^{-1}$, $MJ\ kg^{-1}$, $MJ\ L^{-1}$

Fuel/heating value ($MJ\ kg^{-1}$) = $\frac{\Delta Hc}{M}$ **ΔHc = Standard heat of combustion for 1 mol of fuel**

CO_2 emission value ($g(CO_2)MJ^{-1}$) = $\frac{n(CO_2) x M(CO_2)}{Energy}$

Carbon emissions: Combustion of fuels release carbon dioxide, which is a known greenhouse gas, into the atmosphere.

Carbon emission values: Compare the mass of carbon dioxide a given fuel produces with the amount of energy released. Units in $g\ MJ^{-1}$.

Biofuels

Biofuels are fuels that are produced from biodegradable materials such as crops rather than from fossil fuels. Examples of biofuels include bioethanol, biogas and biodiesel.

Advantages of biofuels are that they: Are made from a renewable resource, they have lower carbon emissions and they have extremely low sulphur content meaning there is no SO_2 formation that can lead to acid rain.

Bioethanol is produced from the fermentation of plant sugars (such as in wheat and sugar cane) to ethanol by yeast.

Biodiesel is produced by the transesterification of oilseed crops.