**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 🡪 I2 + 214 kJ
* Reactions in which a positive ion gains an electron. e.g., Na+ + e**-** 🡪 Na
* Condensation and solidification phase changes.
* Respiration: C6H12O6 + 6O2 🡪 6CO2 + 6H2O.
* 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., F2 + 158 kJ 🡪 2F
* Reactions in which an atom or ion **loses an electron**. e.g., K 🡪 K+ + e**-**
* **Vaporisation and liquefaction** phase changes.
* **Photosynthesis**: 6CO2 + 6H2O 🡪 C6H12O6 + 6O2.
* Cold packs.

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

**Avogadro’s number = 6.022 x 1023 particles per mole**

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

**n = nk 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) =** $\frac{ΔHc}{M}$ **ΔHc = Standard heat of combustion for 1 mol of fuel.**

**CO2 emission value (g(CO2)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 P4 and 5.77 g of O2.The following reaction occurs:**

**P4 + O2  P4O6.**

**If enough oxygen is available, then the P4O6 reacts further: P4O6 + O2  P4O10**

**[a] What is the limiting reagent for the formation of P4O10?**

Final equation: P4O10 + 5O2 P4O10

n(P4O10) = $\frac{5.77}{123.88}$ = 0.0466 mol

n(O2) = $\frac{5.77}{32}$ / 5 = 0.0361 mol

O2 is the limiting reagent as it produces less P4O10

**[b] What mass of P4O10 is produced?**

m(P4O10) = 0.0361 x 283.88 = 10.24

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

m(P4 used) = n(limiting reagent) x M(P4) = 0.0361 x 123.88 = 4.467

m(P4 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) + O2(g) CO2(g)**

**C(s) + CO2(g) 2CO(g)**

**Fe2O3(s) + 3CO(g) 2Fe(l) + 3CO2(g)**

**[a] Write an overall equation showing the formation of Fe from Fe2O3**

C(s) + O2(g) CO2(g) Needs to have 3CO2 🡪 x3

C(s) + CO2(g) 2CO(g) Needs to have 6CO 🡪 x3

Fe2O3(s) + 3CO(g) 2Fe(l) + 3CO2(g) Needs to have 6CO 🡪 x2

3C + 3O2 + 3C + 3CO2 + 2Fe2O3 + 6CO 3CO2 + 6CO + 4Fe + 6CO2

6C(s) + 3O2(g) + 2Fe2O3 6CO2(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% Fe2O3 by mass.**

/ 6.022 x 1023

X 6.022 x 1023

# Atoms / Ions

# Atoms / ions

# Molecules / formula units

# Molecules / formula units

m(Fe2O3) = 0.97 x 1000000 = 970000g

n(Fe2O3) = $\frac{970000}{159.7}$ = 6073.89 mol

n(2Fe2O3) = $\frac{6073.89}{2}$ = 3036.94 mol

n(C) = 3036.94 x 6 = 18221.67 mol

m(C) = 18221.67 x 12.01 = 2.2 x 105 tonnes

**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) =** $\frac{ΔHc}{M}$ **ΔHc = Standard heat of combustion for 1 mol of fuel**

**CO2 emission value (g(CO2)MJ-1) =** $\frac{n\left(CO\_{2}\right) x M(CO\_{2})}{Energy}$

**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 SO2 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.