Chemical changes

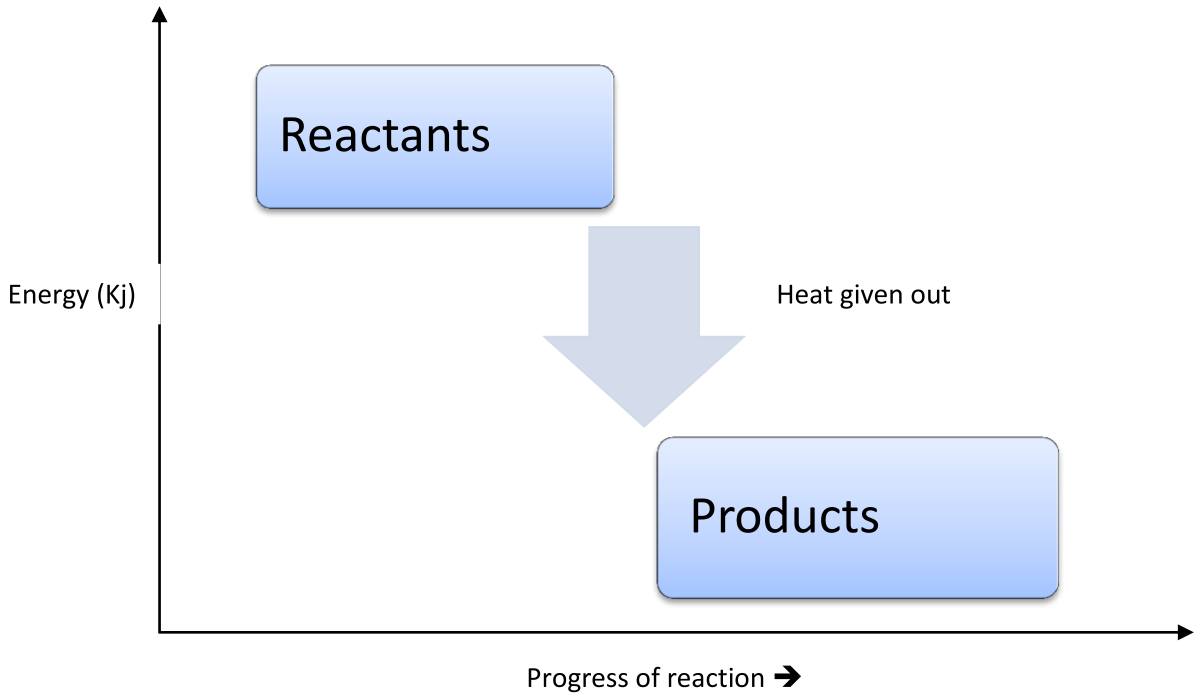
6.1 Energetics of a reaction

All chemical reactions involve an energy change. Energy is taken in or given out in the form of heat. So the reactions are divided into 2 groups – Exothermic and Endothermic.

All exothermic reactions release heat energy to the surroundings.

Reactants = Products + Heat energy

The chemical energy of the reactants is bigger than the chemical energy of the products. The difference is transferred to the surroundings in the form of heat energy.

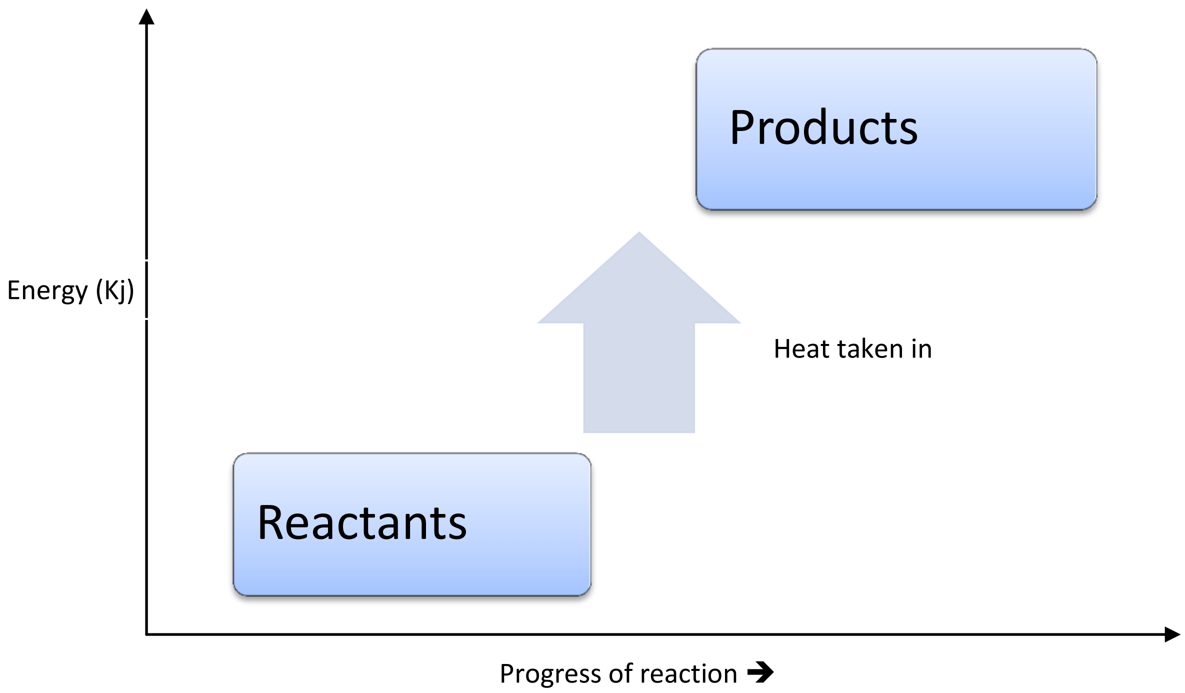


This is an energy level diagram.

An endothermic reaction absorbs energy from the surrounding.

Reactants + Heat energy = Products

The chemical energy of the reactants is smaller than the products, so this difference in energy is transferred from the surrounding to the chemicals.



An energy level diagram for an endothermic reaction.

For a reaction to be exothermic, the total energy taken in to break the bonds should be less than the energy given out when forming the bond.

For a reaction to be endothermic, the total energy taken in to break the bonds should be more than the energy given out when the bonds are formed.

So in conclusion, bond breaking is endothermic and bond forming is exothermic.

e.g. $H_2 + Cl_2 \rightarrow 2HCl$

- Bonds present:
  H-H and Cl-Cl
  These 2 bonds at first have to be broken.
  The H-H bond needs 436 kJ/mol to be broken.
  The Cl-Cl bond needs 242 kJ/mol to be broken
  So total energy need to break the bonds = 436 + 242 = 678 kJ
- Bonds to be made:
  2x H-Cl
  These bonds release 431 kJ/mol when made.
  So total energy released = 431 x 2 = 862 kJ/mol.

678-862= -184 Kj/mol

The – sign indicates that the reaction was exothermic, as energy was released.

The hydrogen and chlorine reaction is actually explosive, which obviously show that the reaction is exothermic.

e.g. 2, the decomposition of ammonia:

If ammonia is heated strongly the following reaction occurs:

$2NH_3 \rightarrow N_2 + 3H_2$

- Bonds present:
  6x N-H
  The energy needed to break these bonds = 391 kJ/mol x6 = 2346 kJ/mol

- Bonds to be made:
  3x H-H
  N≡N
  H-H bond releases 436 kJ/mol
  N≡N bond releases 946 kJ/mol
  Total = 3(436) + 946 = 2254 kJ/mol

2346 – 2254 = 92 kJ/mol

This shows that this reaction is endothermic as the energy released is less than the energy taken in.

6.2 Production of energy

- Production of heat energy by burning fuels:

  The most common way of producing heat energy is by burning of fossil fuels. Heat energy and then electrical energy is then produced from this energy in power stations.

  e.g. Methane (natural gas) being burnt:

  $CH_4 + 4O_2 \rightarrow 2CO_2 + 2H_2O$ + (ENERGY)

- Hydrogen as a fuel:
  The combustion of hydrogen is highly exothermic.
  It is used as rocket fuel, in experimental vehicles and in fuel cells.

Advantages:

- It is the most energy rich fuel. It releases more energy per kg than any other conventional fuel.
- The only product of combustion is water, no pollutants are formed.
- Oxides of nitrogen are not formed.

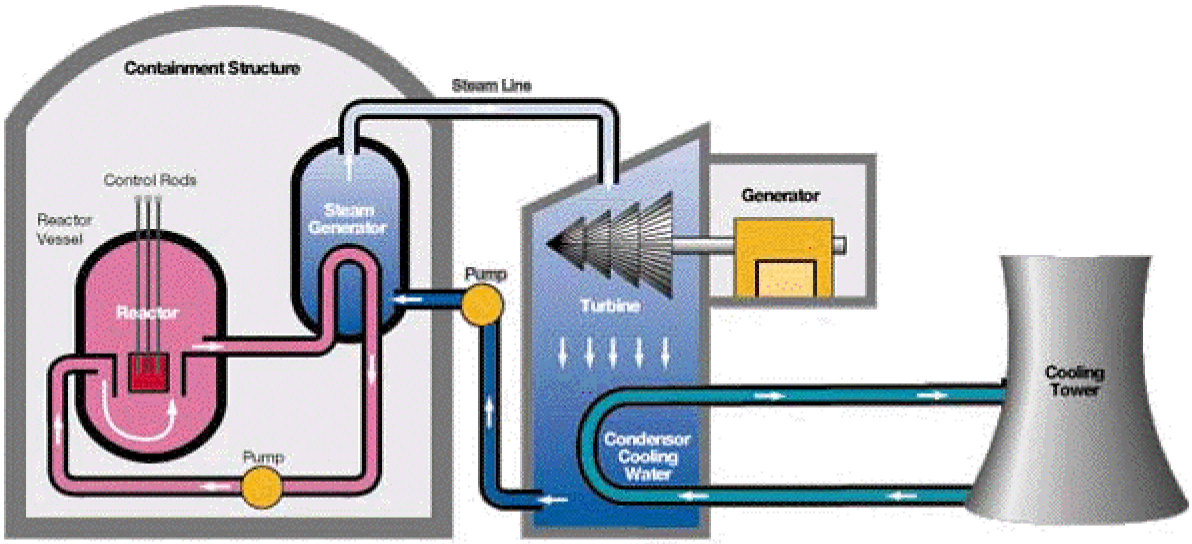
$H_2 + O_2 \rightarrow H_2O$ + (ENERGY)

- Nuclear reactions:

  Energy is released in nuclear reactions. This nuclear energy can be released in an explosive and controlled manner.

  - Fission (splitting of uranium-235)

  It was used in the atom bomb. If the nuclear energy from the fission of the U-235 is released in a safe regulated manner, it can be used to produce electrical energy in nuclear power stations.

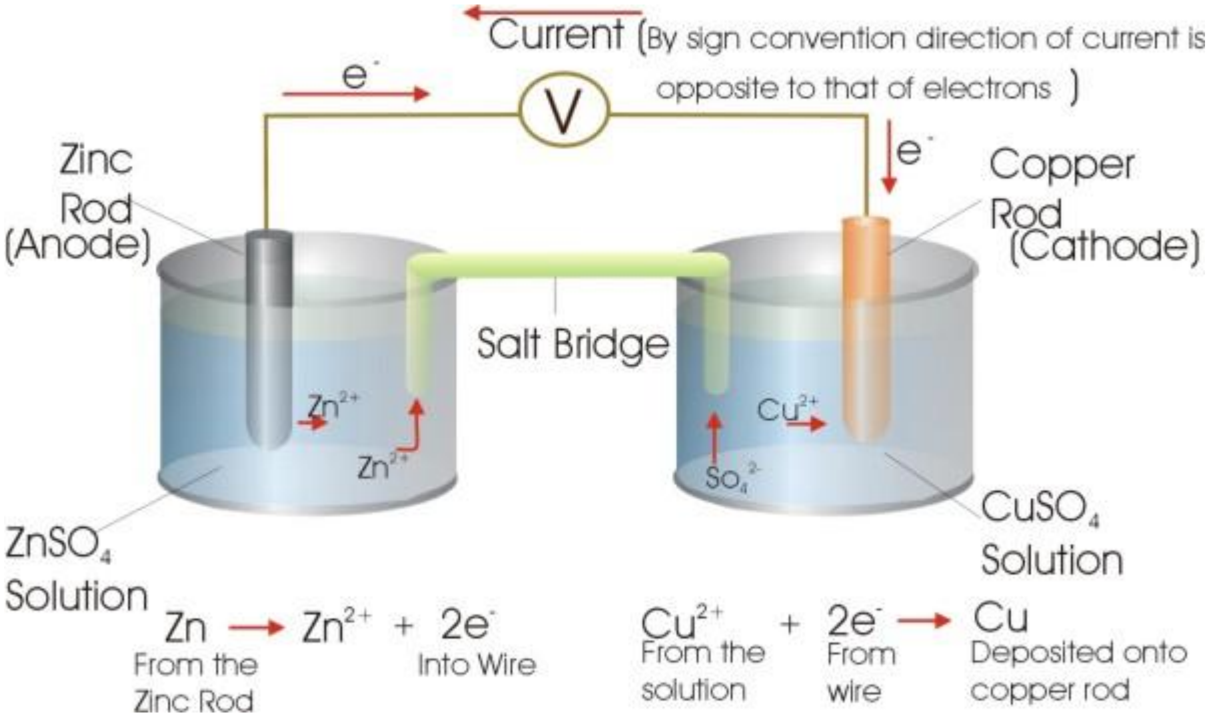


  -Fusion (joining together)

  The fusion of the hydrogen nuclei is the source of energy in the hydrogen bomb. The sun obtains its energy from the fusion of the hydrogen atoms.

  It is also how the sun gets its heat!

- Electrolytic cells



Metals and solutions of their own salts can be used to generate electricity. If the above experiment is set up, a bulb will glow showing that electricity has been produced in the zinc and copper half-cells.

Zinc is higher than copper in the reactivity series, so is the producer of electrons at THE CATHODE. The copper takes the electrons at THE ANODE.

The reactions are:

CATHODE (-) $Zn_{(s)} = Zn^{2+}_{(aq)} + 2e^-$ (OXIDATION LOSS OF ELECTRONS)

ANODE (+) $Cu^{2+}_{(aq)} + 2e^- = Cu$ (REDUCTION GAIN IN ELECTRONS)

Although zinc/copper is used here as the example, you can get electricity from any pair of metals set up in a diagram like the one shown above.

The amount of electricity produced depends on the position of the metals in the reactivity series. The rule is:

THE FURTHER APART THE METALS ARE IN THE REACTIVITY SERIES – THE MORE ELECTRICITY WILL BE PRODUCED.

- Hydrogen fuel cells

  In a fuel cell there are 2 electrodes usually containing platinum. An electrolyte of aqueous sodium hydroxide and the reactants which are continuously supplied through the electrodes supplies electrical energy continuously.

  At the negative electrode hydrogen is supplied. The molecules lose electrons and form ions in the electrolyte.

  $H_2 \rightarrow 2H^+ + 2e^-$

  The electrons move through the external circuit to the positive electrode to which O2 is supplied

  $O_2 + H_2O + 4e^- \rightarrow 4OH^-$

  The ions react to produce water

  $H^+ + OH^- \rightarrow H_2O$

  The overall reaction is $2H_2 + O_2 \rightarrow 2H_2O$

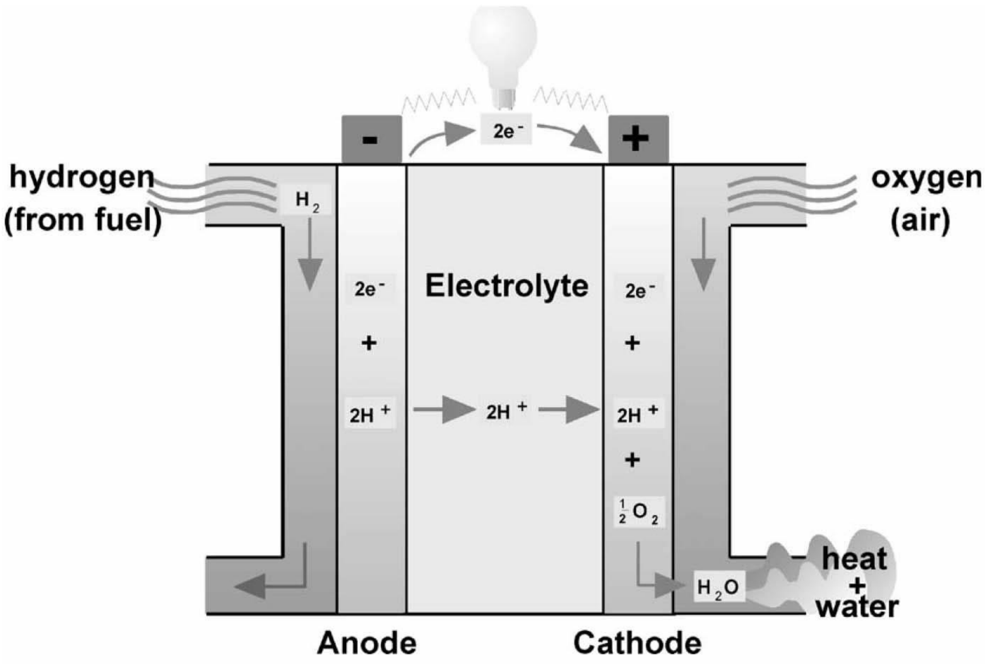


Fig. 2. Schematic of a PEM fuel cell operation. Source: World Fuel Cell Council.