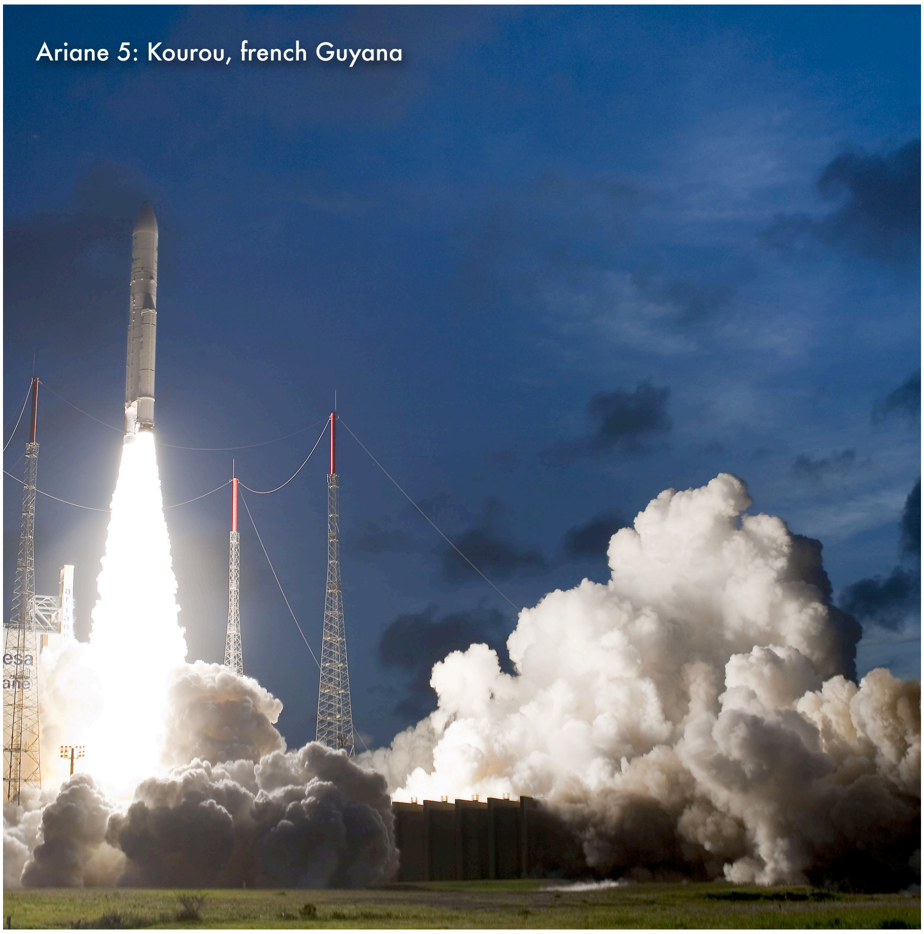
Rocket Thrusters



Ariane 5: Kourou, french Guyana

Context: Thrusters or Pushing things around

Not everything in space flight needs a huge rocket motor, sometimes we have to be far more delicate. Typical jobs involve changing the direction a satellite is pointing in (but not travelling in) or giving it a very gentle nudge when it is docking with another satellite. These low force rocket motors are usually called 'thrusters'.

Monopropellant systems

As the name implies monopropellant rockets do not carry separate fuel and oxidant supplies. Rather the propellant is a single liquid that decomposes to gases either on heating or when it is passed over a catalyst. There are two common monopropellants; hydrogen peroxide (H_2O_2) and hydrazine (N_2H_4). Hydrogen peroxide decomposes when it comes in to contact with a silver or platinum catalyst mesh (up to 98% concentration is used as a monopropellant):

$$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$$

This produces steam and oxygen at over 600 °C and produces a specific impulse of up to 165 s. Hydrogen peroxide has also been used to power devices as diverse as drag racing cars and torpedoes.

Hydrazine is a more powerful but toxic monopropellant. It decomposes in contact with platinum/iridium metal into ammonia, nitrogen and hydrogen by a number of different possible paths:

$$N_2H_4 \rightarrow N_2 + 2\ H_2$$

$$3\ N_2H_4 \rightarrow N_2 + 4\ NH_3$$

$$N_2H_4 + 4\ NH_3 \rightarrow 3\ N_2 + 8\ H_2$$

It does this at a temperature of around 800 °C and can produce a specific impulse of around 200 s.

Bi-propellant systems

These are the most powerful thrusters currently available. They are needed because many new satellites are becoming increasingly large and so need far larger forces to manoeuvre them. A commonly used bi-propellant mixture is monomethylhydrazine

($CH_3N_2H_3$) as the fuel and dinitrogen tetroxide (N_2O_4) as the oxidant. This burns very hot and so has a high specific impulse of over 300 s. Another property of this propellant mixture is that it is 'hypergolic', that is it ignites on mixing. This means that the two substances have to be handled extremely carefully but also that there is no need for a complex ignition system. It also means that the two materials cannot accidentally build up in one place, leading to an explosion the next time the thruster is fired.

$$4\ CH_3N_2H_3 + 5\ N_2O_4 \rightarrow 9\ N_2 + 12\ H_2O + 4\ CO_2$$

The monomethylhydrazine/dinitrogen tetroxide combination is also used in the space shuttle 'orbital manoeuvring system' and in the third stage of the Ariane 5, this 115 kg motor can produce 2.7 tonnes of thrust and burn 9.8 tonnes of propellant in around 1000 s, some thruster!

Problem:

Give for each oxidation-reduction equation: the oxydation, the reduction , the number of oxydation for each element in each equation, and the number of electron exchange.

1°) $N_2H_4 \rightarrow N_2 + 2\ H_2$

2°) $3\ N_2H_4 \rightarrow N_2 + 4\ NH_3$

3°) $N_2H_4 + 4\ NH_3 \rightarrow 3\ N_2 + 8\ H_2$