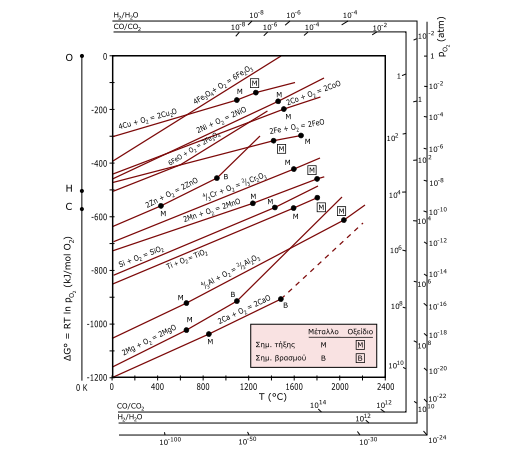
Statement: At low temperatures, metals have a high tendency to oxidise but the rate of oxidation is slow whereas the reverse is true at higher temperatures.

Answer: The statement is partially correct. In order to critically discuss this statement, mechanisms of dry oxidation for metals is going to be analysed.

Oxidation of a metal is possible in earth’s atmosphere because it contains oxygen. However, not every material react the same way to this aggression and their tendency to oxidise is function of different parameters. Considering a metal M, the process of oxide formation is an electrochemical one and can be described by the following reactions.

M+1/2O2 → MO or in other terms: Metal + Oxygen + Energy → Oxide of metal

Like in any other chemical reaction, the mechanism itself is driven by the energy actually needed for the reaction. As a consequence, as it is clear here, if the energy is negative, a metal in contact with earth’s atmosphere will oxidize and it the energy is positive it will not. As a general rule, at 273 K energies of formation of metals oxides are negative and as a consequence metals have indeed tendency to oxidise under normal circumstances. This statement is just wrong for gold which is the only metal completely resistant to oxidation at all temperature and which can therefore be found in its native form in nature.[[1]](#footnote-2)

Furthermore, this tendency to oxidise can be quantified. Indeed, in metallurgy, Ellingham diagrams are used as a source of information concerning the oxidation of a metal under particular conditions. As figure1[[2]](#footnote-3) shows, this diagram plots the energy of formation of oxides versus the temperature.

The important thing to notice on that diagram is that if any metal is considered, as the temperature goes down, its energy of oxidation becomes more negative. As a consequence, as the temperature goes down metals have a higher tendency to oxidise; and as it has been said before, this rule does not apply only for gold.

Figure 1: Ellingham Diagram

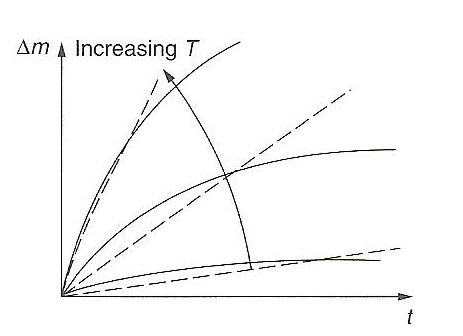
Moreover, the rate of oxidation is not driven by the energy of oxidation. For instance, Al which energy of formation equals -1045 kJ mol-1 at 0.7TM oxidise very slowly whereas W which energy of formation equals -510 kJ mol-1 at 0.7TM oxidise very fast[[3]](#footnote-4). Mechanisms are far more complex. There are in fact two types of oxidation over time:

The first one is the linear oxidation which can be described by the following equation where kL is a kinetic constant: ∆M = kLt  
The second one is the parabolic oxidation which is described by the following equation:   
 (∆M)2= kpt  
(∆M is the weigh increase, showing that oxygen atoms are added in the material and as a consequence showing that the material becomes oxidised.)

In fact, the oxidation type a metal follows strictly depends on how its oxide film behaves. For instance, as a material becomes oxidised, its oxide film grows and can sometime act like a barrier for the new atoms of oxygen. As a consequence it becomes more and more difficult for them to reach the metal and the oxidation rate goes down following a parabolic behaviour type. It also happens that the oxide film formed is too brittle and cracks quickly under stress. The metal is no longer protected and the oxidation rate remains constant over time.

But still, even if these two different behaviours exist, temperature dependency remains the same. Indeed, as it is show figure 2[[4]](#footnote-5), both kinetics constants kL and kp increase exponentially with temperature following the Arrhenius’s law:

kL = AL x e - QL/RT and kp = AP x e -QP/RT where AL, AP, QL, QP and R are constants.

  
Figure 2: Oxidation time increase with temperature according to Arrhenius’s law

Therefore, every metal which has a tendency to oxidise will have its oxidation rate increased as the temperature goes up.

As a conclusion, considering all that has been said in these two pages, the statement was indeed correct except on one tiny thing: it is not true only for gold which is the only metal resistant to oxidation.

1. Ashby, M. F., Jones D. R., (2005), *Engineering Materials 1*, Butterworth Heinemann, p. 328 [↑](#footnote-ref-2)
2. http://commons.wikimedia.org/wiki/Image:Ellingham-diagram-greek.svg, viewed 11 Nov 2008 [↑](#footnote-ref-3)
3. Ashby, M. F., Jones D. R., (2005), *Engineering Materials 1*, Butterworth Heinemann, p. 332 [↑](#footnote-ref-4)
4. Ashby, M. F., Jones D. R., (2005), *Engineering Materials 1*, Butterworth Heinemann, p. 331 [↑](#footnote-ref-5)