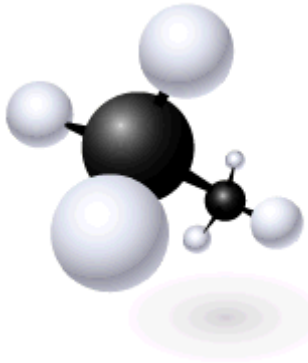
Oxidation Numbers

(Chapter 12 in the Klein text)



Definitions of Oxidation and Reduction

Looking at Carbon we think of oxidation as:

Introduction of oxygen or removal of hydrogen

Conversely, we think of reduction as:

Introduction of hydrogen or removal of oxygen

Definitions of Oxidation and Reduction...

We can also think of oxidation as:

Removal of electrons or electron density

Conversely, we think of reduction as:

Introduction of electrons (or electron density)

Electron density in organic molecules

Considering electronegativity values; in methane the **carbon** is slightly electron-rich since **H** (**2.1**) is less electronegative than **C** (**2.5**).

In **carbon dioxide** the **carbon** is electron-poor since **O** (**3.5**) is significantly higher in electronegativity than **C** (**2.5**).

Electron density in organic molecules…

Since reduction is the introduction of electrons, the **carbon** in **methane** is reduced by each of the hydrogen atoms attached.

Since oxidation is the removal of electrons, the **carbon** in **carbon dioxide** is oxidized by the oxygen atoms attached.

Assigning oxidation state numbers

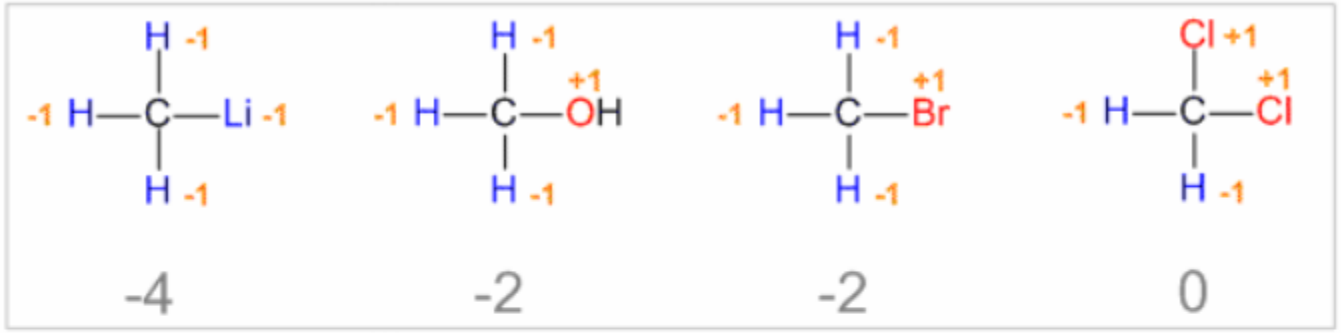
We use a numbering system for oxidation states of carbon;

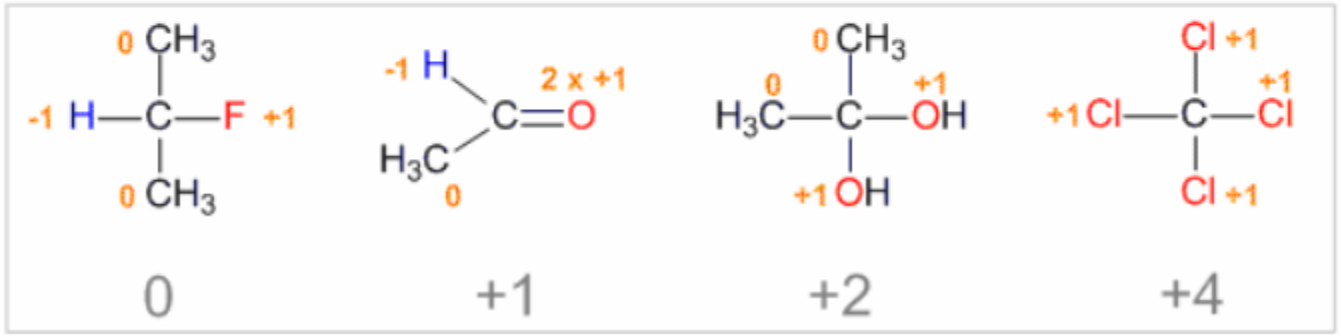
If a **less electronegative** element is attached it gets **minus 1**

If a **more electronegative** element is attached in gets **plus 1**

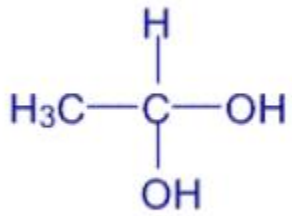
Double bonds count twice, triple bonds three times

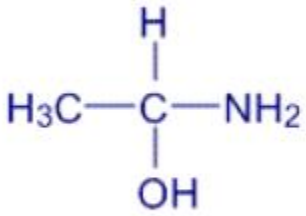
Examples

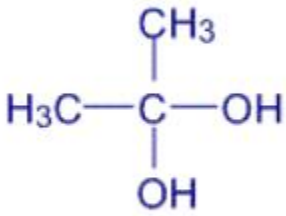


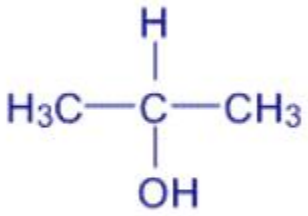


Which carbon has a +2 oxidation number?









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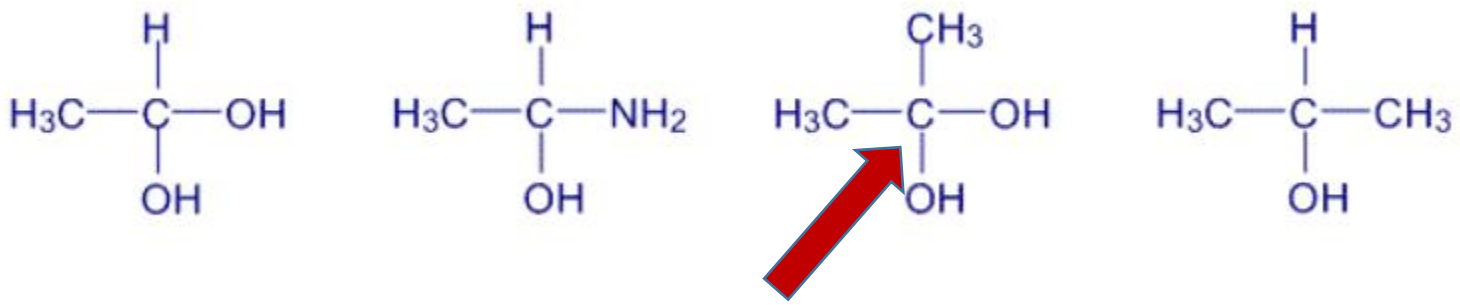
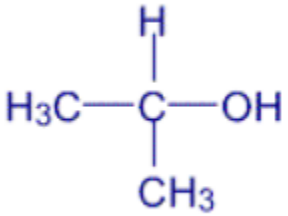
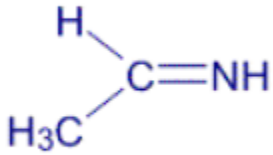
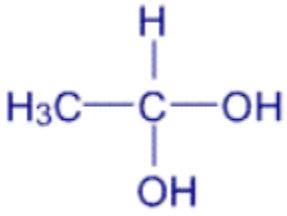
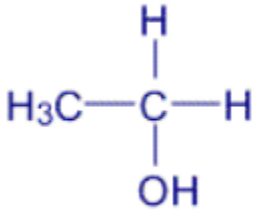


Which carbon has a -1 oxidation number?









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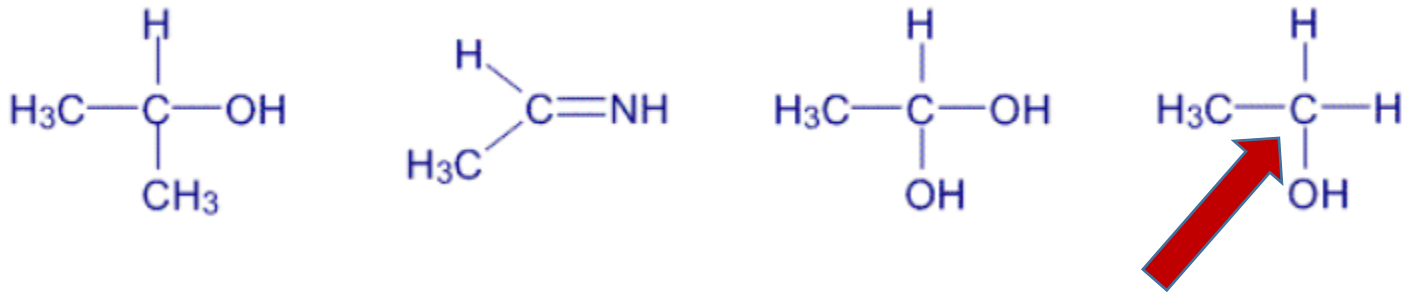
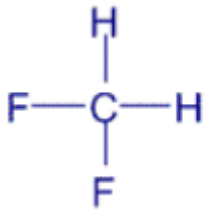
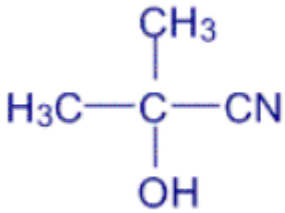
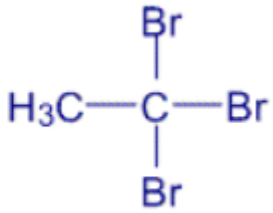


Which carbon has a 0 oxidation number?







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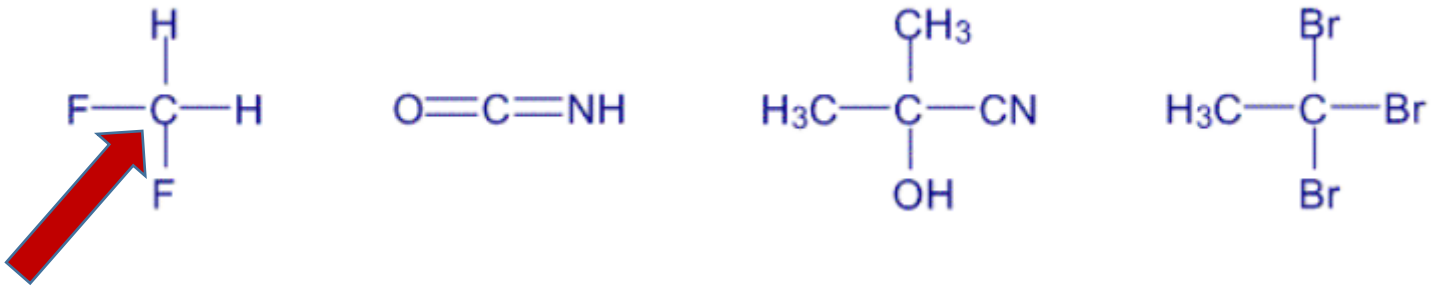


Tracking oxidation state changes

Being able to assign oxidation numbers allows us to track changes during chemical reactions.

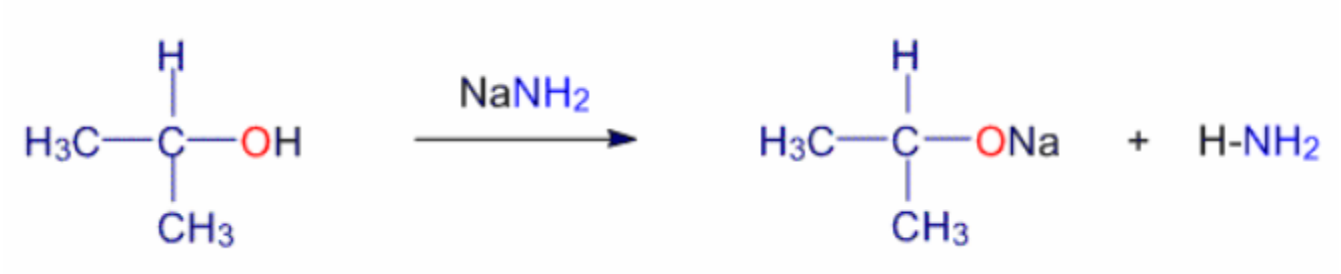
In the example above, methane is fully reduced (**minus 4**) and is converted to carbon dioxide (**plus 4**) which is fully oxidized.

Tracking oxidation state changes.

This reaction is therefore an **oxidation** in the forward direction and **reduction** in the reverse direction.

We therefore need **oxidizing** conditions to convert methane into carbon dioxide and **reducing** conditions to go from carbon dioxide to methane.

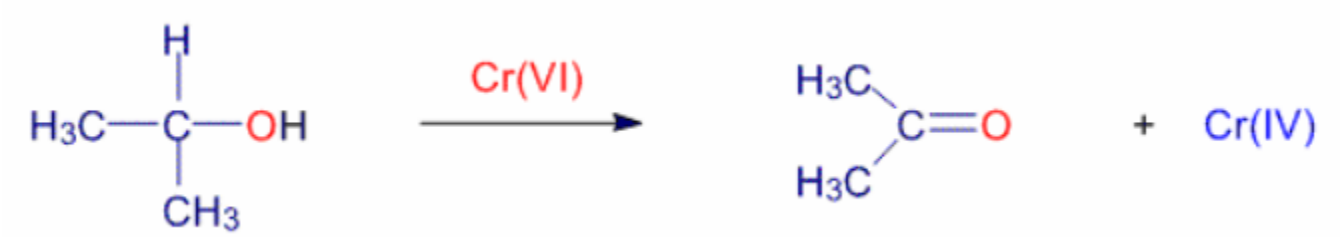
Tracking oxidation state changes..



In this acid-base reaction the carbon atoms do not change their oxidation states from starting material to product.

This reaction therefore cannot be classified as an oxidation-reduction event.

Tracking oxidation state changes...



In this conversion the secondary carbon in the starting material is **zero** while the corresponding carbon in the product is **plus 2**.

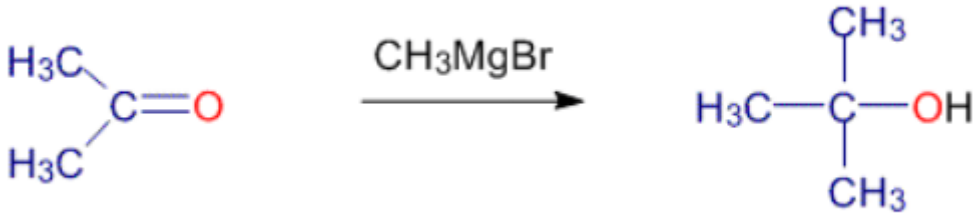
This reaction is therefore an **oxidation** at carbon that will require an oxidizing reagent such as Cr (VI) to work.

Tracking oxidation state changes....

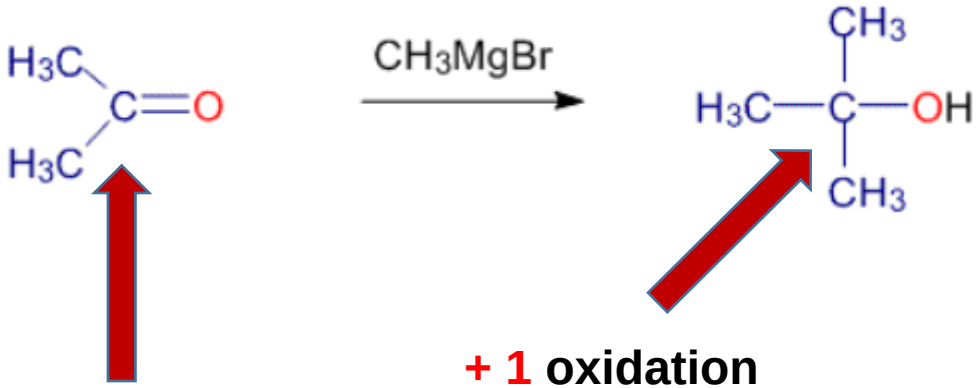
In this example the two sp^2 carbon atoms in the starting alkene are **zero** while the corresponding carbon atoms in the product are **minus 1**.

This reaction is therefore a **reduction** at carbon and will require a reducing agent such as **hydrogen gas** to work.

Is this an oxidation, reduction or neither for carbon?



Is this an oxidation, reduction or neither for carbon.?

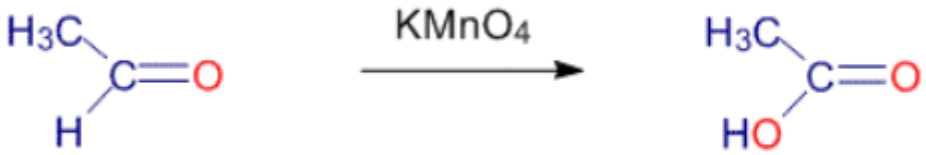


+ 2 oxidation number

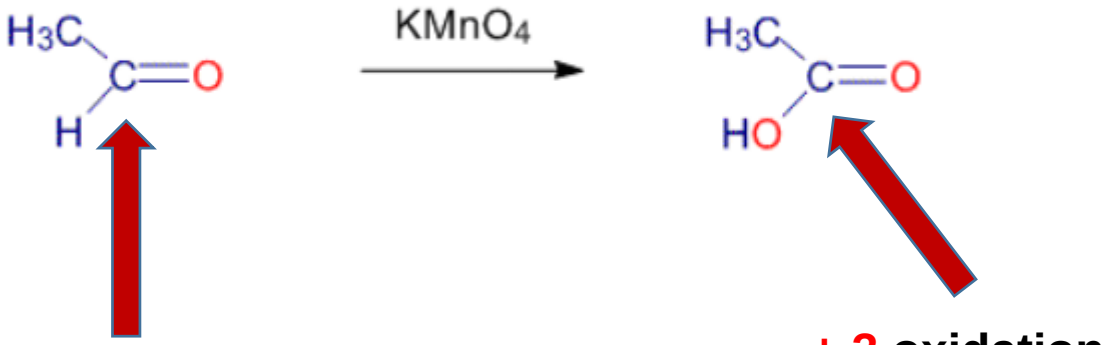
+ 1 oxidation number

The oxidation number became less positive so this is a **reduction**.

Is this an oxidation, reduction or neither for C?



Is this an oxidation, reduction or neither for C.?



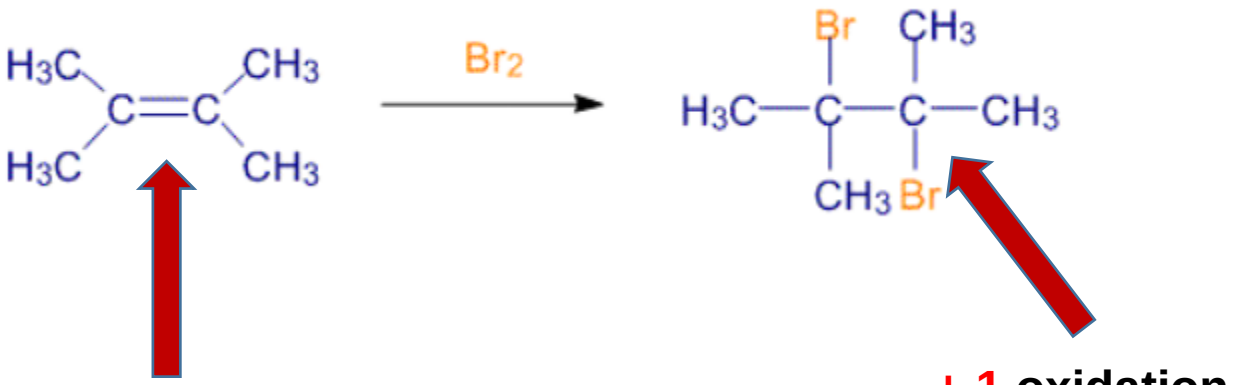
+ 1 oxidation number

+ 3 oxidation number

The oxidation number became more positive so this is an **oxidation**.

Is this oxidation, reduction or neither for C?

Is this oxidation, reduction or neither for C.?



+0 oxidation number

+ 1 oxidation number

Both carbons go from **zero** to **plus 1** so this is an **oxidation**.

To summarize…

Elements **more electronegative** than carbon get a **plus 1** designation and are said to **oxidize** the attached carbon since they make carbon more **electron-poor**.

Elements **less electronegative** than carbon get a **minus 1** designation and are said to **reduce** the attached carbon since they make carbon more **electron-rich**.