Life in Air

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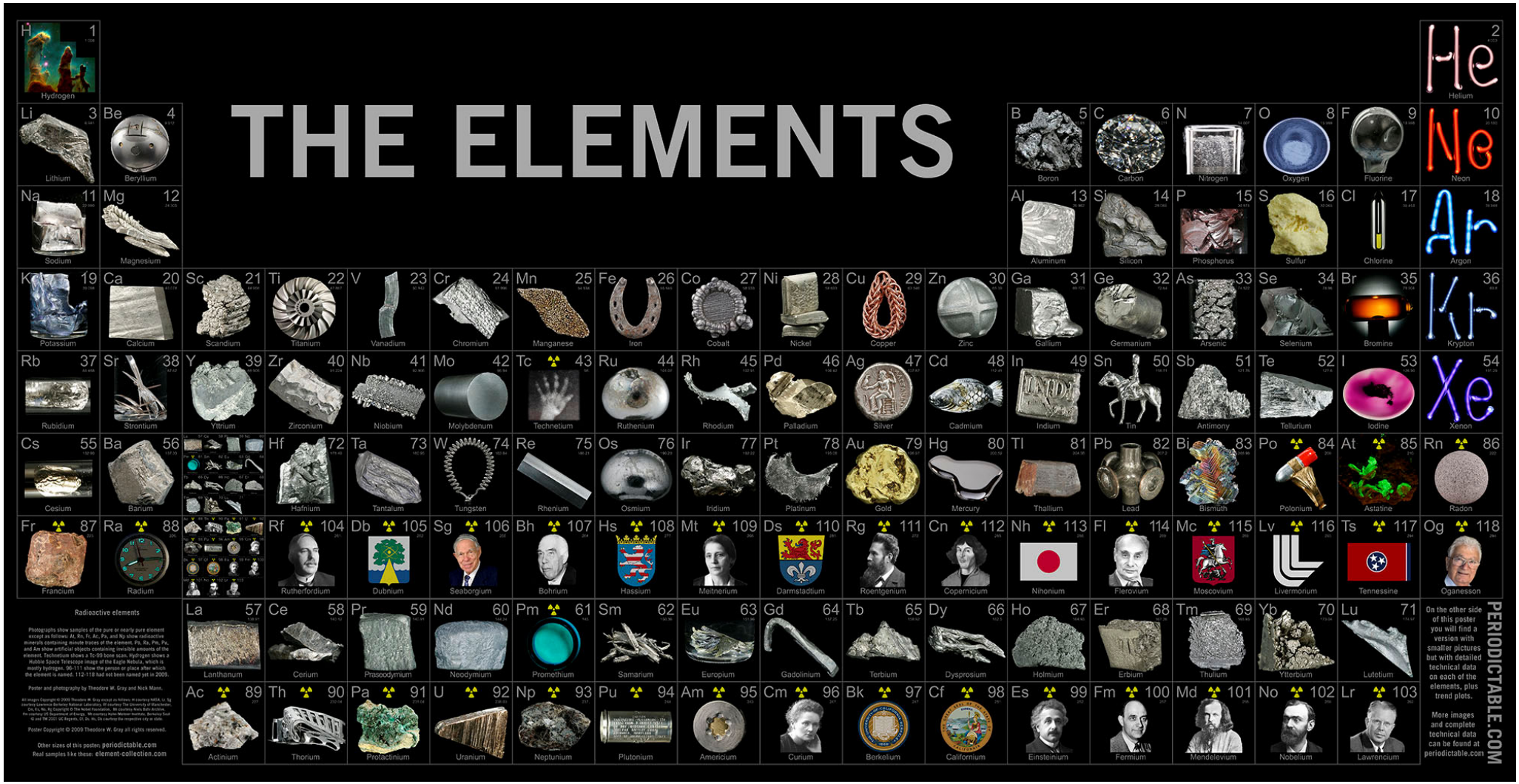
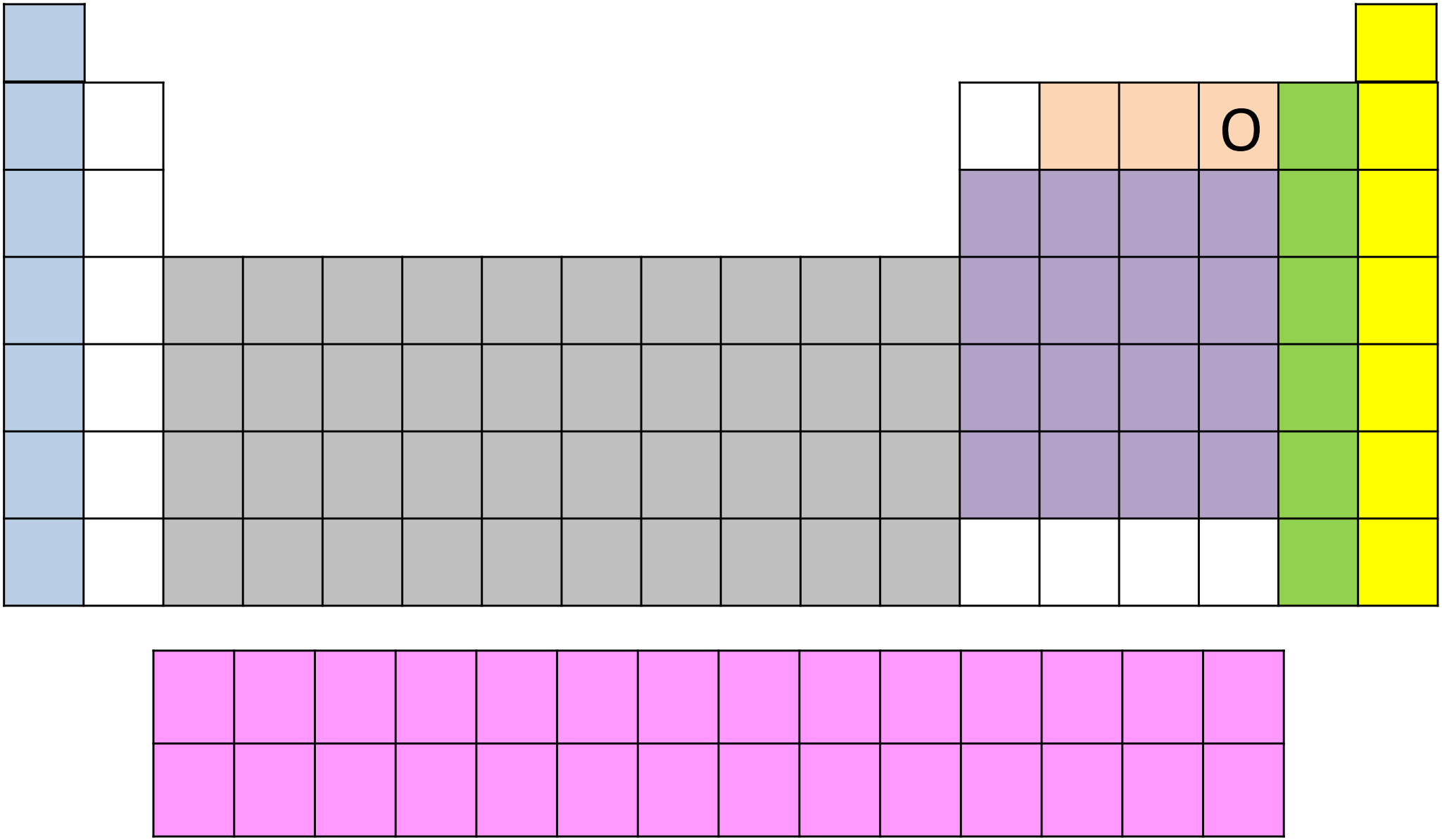
Elements: Up, close and personal

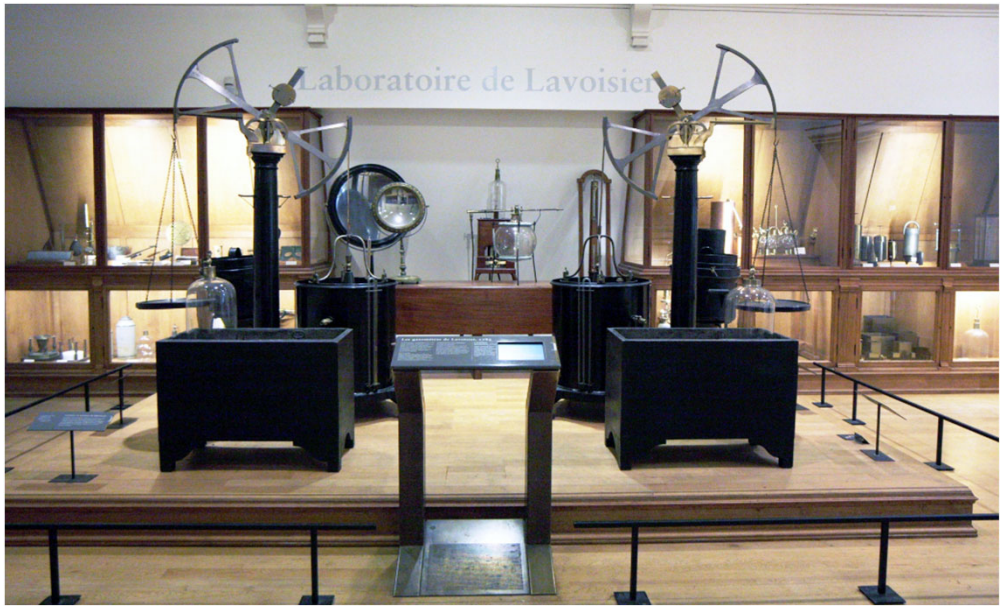


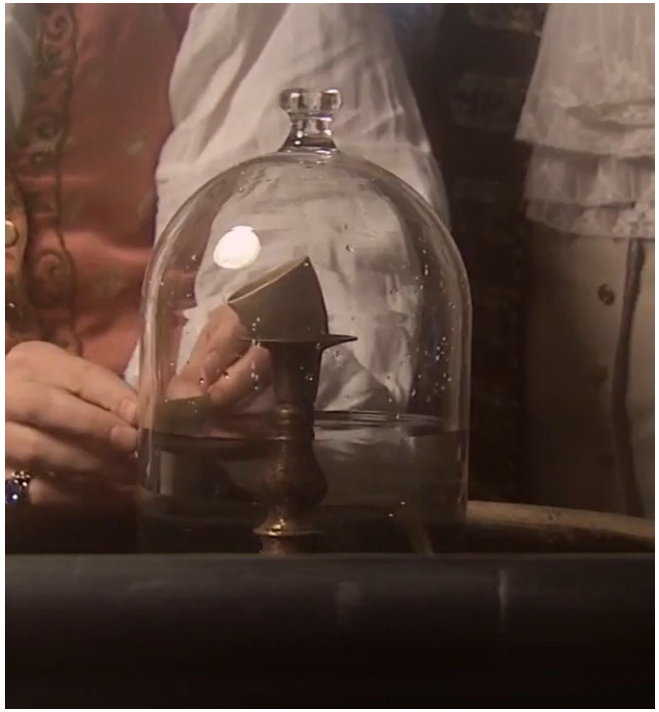
https://periodictable.com/theelements/index.html

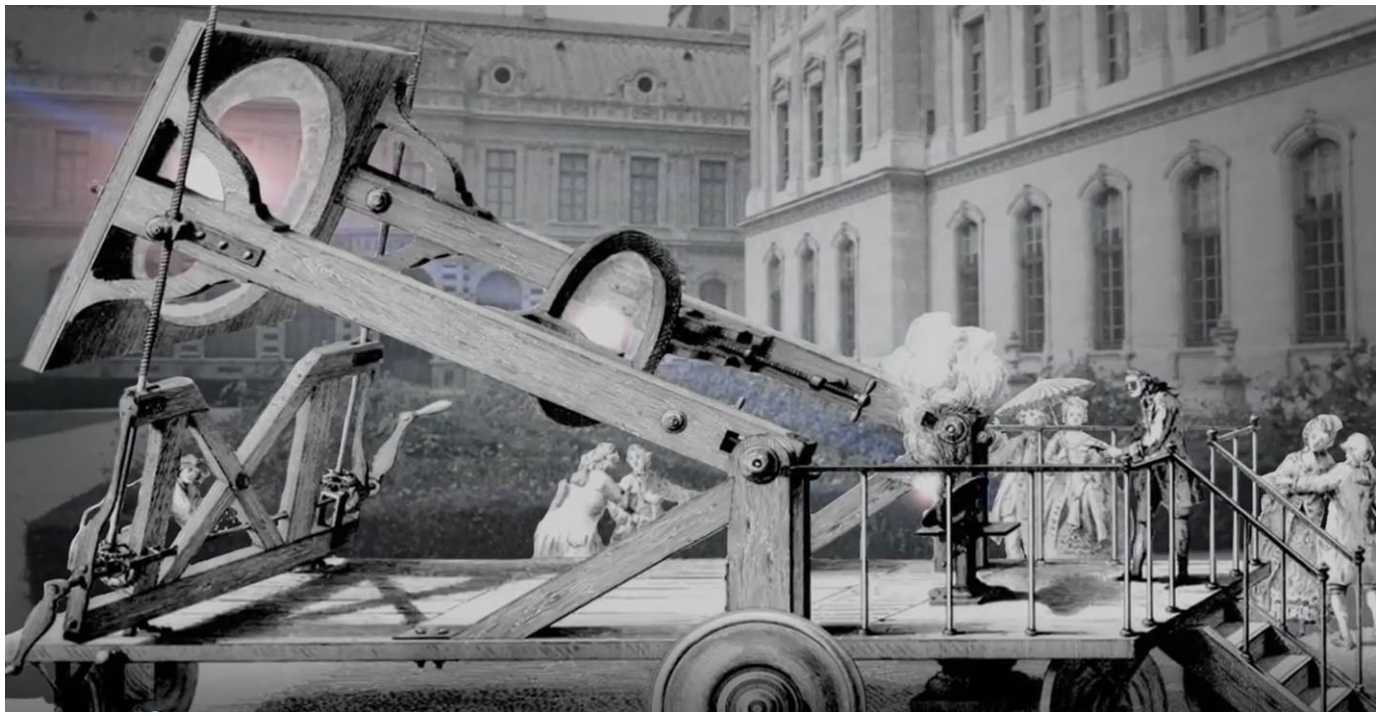

O

The Discovery of Oxygen: Antoine Lavoisier (1743 –1794)

- Born into a well-to-do Parisian family, Lavoisier had received a fine education and taken a degree in law
- Now 28, he had joined a consortium that collected taxes for King Louis the XV
- As a result, Lavoisier became a very wealthy man, but his true passion was chemistry.







Calyx of Lead + charcoal + water + intense heat

The oxide of Pb releases O_2 upon heating with C

Lavoisier’s execution

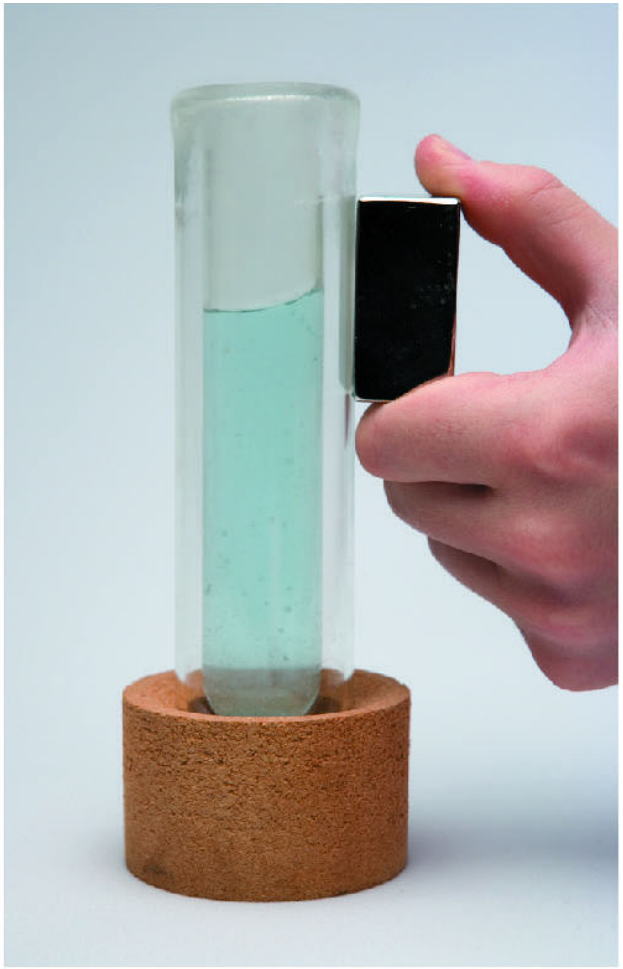
- Lavoisier was tried, convicted, and guillotined on 8 May 1794 in Paris, at the age of 50

- The appeal to spare his life so that he could continue his experiments was cut short by the judge: “The Republic has no need of scientists or chemists; the course of justice cannot be delayed.“

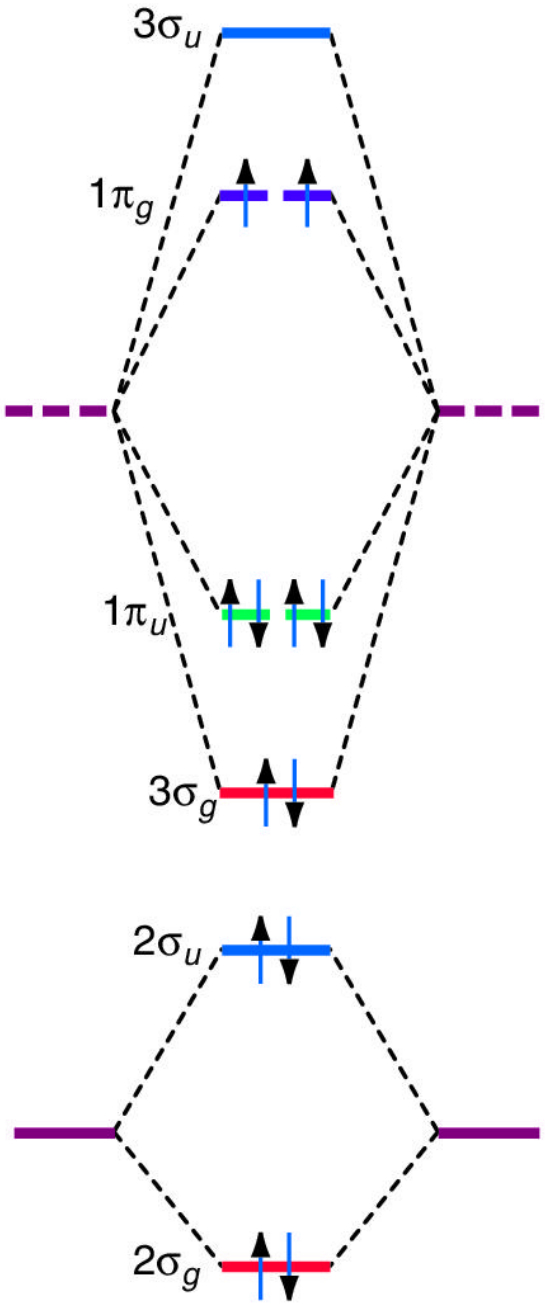
- Lavoisier's importance to science was expressed by Lagrange who lamented the beheading by saying: "It took them only an instant to cut off this head, and one hundred years might not suffice to reproduce its like."

Liquid Oxygen: Video

Paramagnetism of O_2



MO Interaction Diagram of O_2



Appreciating O_2

- Oxygen is a diradical held by weak bonds (BDE = 498 kJ/mol)
- The formation of water by the combination of O_2 and H_2 is exothermic
- Reverse the formation of O_2 from water in endothermic

- Energy is required for all activities – ecological and industrial – and also Chandrayan 3

Energy is critical to Human well-being

Sources of Energy

Fossil Fuels???

Carbohydrates???

416 kJ/mol (C-H)

498 kJ/mol

800 kJ/mol (C=O)

463 kJ/mol (O-H)

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O$$

$$H_2 + O_2 \longrightarrow H_2O$$

$\Delta H = -460$ kJ/mol

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$2C_8H_{18} + 25O_2 \longrightarrow 16\ CO_2 + 18H_2O$$

	ΔH (exp) (kJ/mol)	Moles of O_2	ΔH (calc) (kJ/mol)
CH_4	-890	2	-920
C_8H_{18}	-5452	12.5	-5750
C_2H_5OH	-1380	3	-1367
Sucrose	-5520	12	-5644

- Combustion of any "fuel" is very favorable due to the exothermic nature of the reaction (~460 kJ/mol of O_2) leading to the formation of water

Table 1. Enthalpy Calculated from the Amount of Oxygen Used

Compound	Moles of O_2	$\Delta H°/(kJ\ mol^{-1})$		Error (%)
		Calc	Exp	
Methane	2.0	–920	–890	3.4
Octane	12.5	–5750	–5452	5.5
Methanol	1.5	–690	–726	5.0
Ethanol	3.0	–1380	–1367	1.0
Benzoic Acid	7.5	–3450	–3227	6.9
Sucrose	12.0	–5520	–5644	2.2
Thiophene	6.0	–2760	–2805	1.6

NOTE: The experimental data is from ref 2.

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Thermodynamics of O_2

Standard reduction potentials for dioxygen species in water.[8]

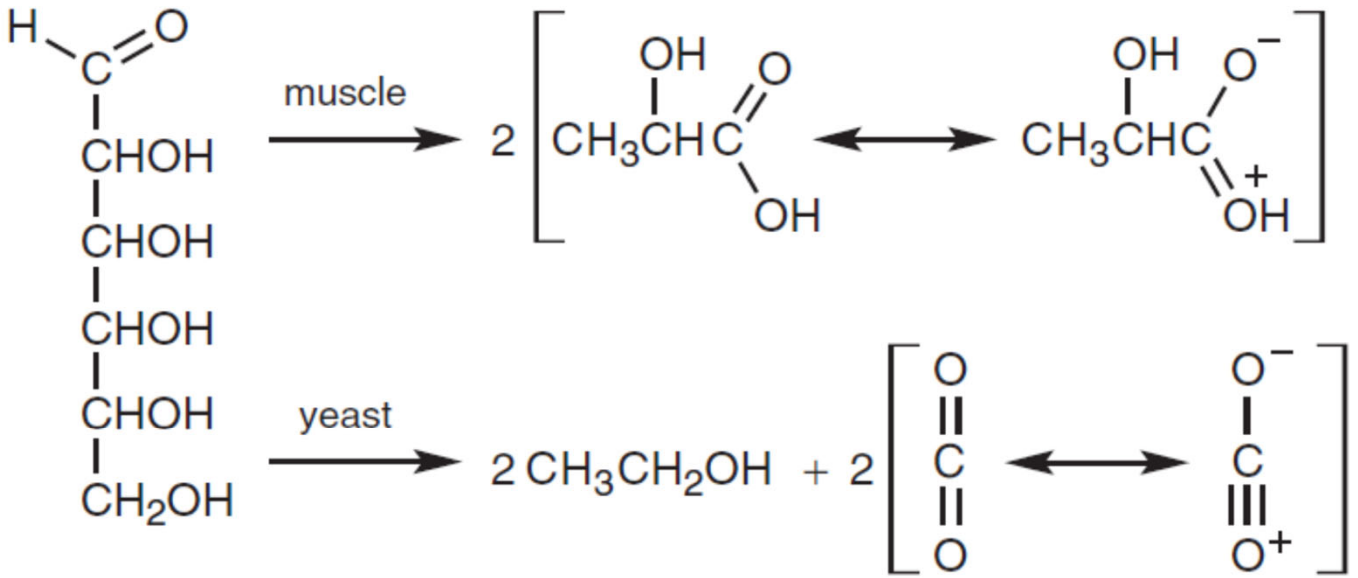
Reaction	E°, V vs. NHE, pH 7, 25°C
$O_2 + e^- \rightarrow O_2^-$	-0.33[a]
$O_2^- + e^- + 2H^+ \rightarrow H_2O_2$	$+0.89$
$H_2O_2 + e^- + H^+ \rightarrow H_2O + OH$	$+0.38$
$OH + e^- + H^+ \rightarrow H_2O$	$+2.31$
$O_2 + 2e^- + 2H^+ \rightarrow H_2O_2$	$+0.281$[a]
$H_2O_2 + 2e^- + 2H^+ \rightarrow 2H_2O$	$+1.349$
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	$+0.815$[a]

[a] The standard state used here is unit pressure. If unit activity is used for the standard state of O_2, the redox potentials for reactions of that species must be adjusted by $+0.17$ V.[8,9]

Role of O_2 as the energy source in biological systems

Aerobic metabolism: glucose to CO_2 generates 38 ATP

Anerobic metabolism: glucose generates 2 ATP



Scheme I. Balanced equations of the anaerobic metabolism of glucose.

Cryogenic Fuels

(1) the cryogenic *oxygen–hydrogen propellant system*, used in upper stages and sometimes booster stages of space launch vehicles, giving the highest specific impulse nontoxic propellant combination and one that is best for high vehicle velocity missions

(2) the *liquid oxygen–hydrocarbon propellant combination*, used for booster stages (and a few second stages) of space launch vehicles

One of the fuels used in Chandrayan launchers is cryogenic oxygen and hydrogen