

Life in Air



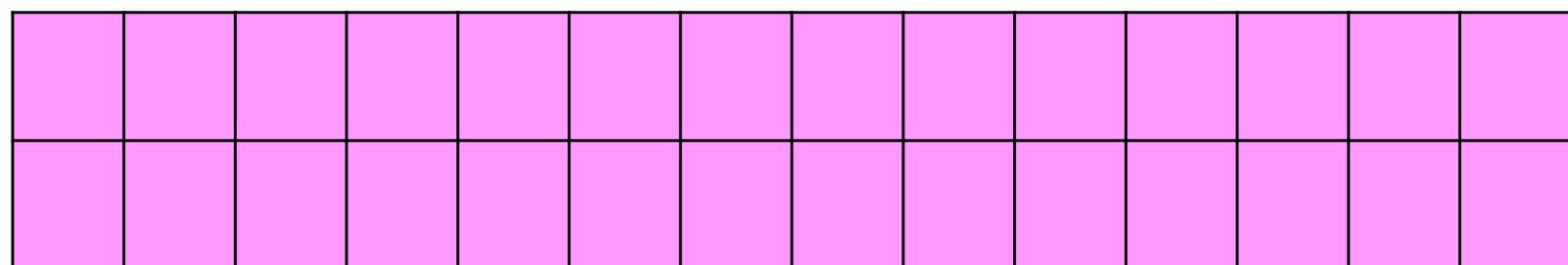
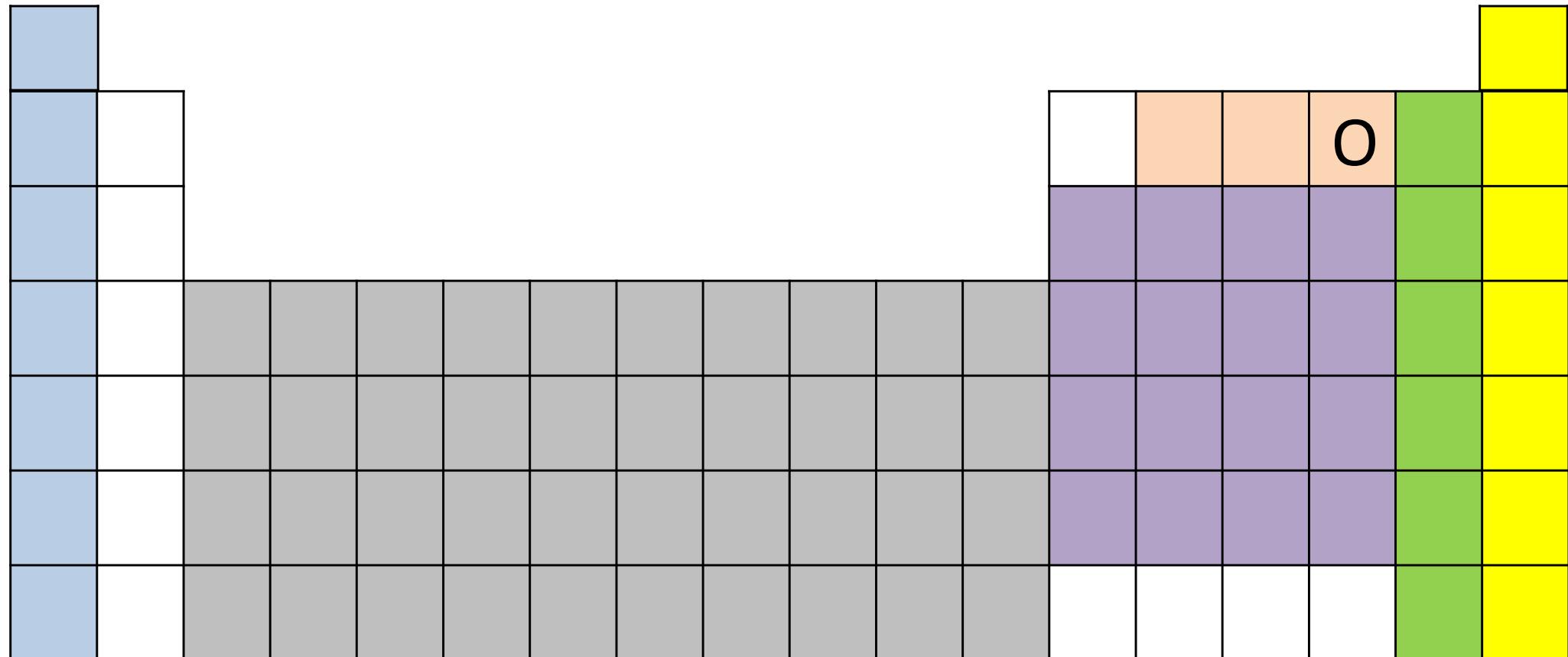
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Elements: Up, close and personal

THE ELEMENTS

H	1	Hydrogen												He	2																						
Li	3	Be	4	Lithium	Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon																											
Na	11	Mg	12	Sodium	Magnesium	Silicon	Phosphorus	Sulfur	Chlorine	Argon																											
K	19	Ca	20	Sc	21	Ti	22	V	23	Cr	24	Mn	25	Fe	26	Co	27	Ni	28	Cu	29	Zn	30	Ga	31	Ge	32	As	33	Se	34	Br	35	Kr	36	Xe	37
Potassium		Calcium		Scandium		Titanium		Vanadium		Chromium		Manganese		Iron		Cobalt		Nickel		Copper		Zinc		Gallium		Germanium		Arsenic		Selenium		Bromine		Iodine		Radon	
Rb	37	Sr	38	Y	39	Zr	40	Nb	41	Mo	42	Tc	43	Ru	44	Rh	45	Pd	46	Ag	47	Cd	48	In	49	Sn	50	Sb	51	Te	52	I	53	Kr	54	Xe	55
Rubidium		Strontium		Yttrium		Zirconium		Niobium		Molybdenum		Technetium		Ruthenium		Rhodium		Palladium		Silver		Cadmium		Indium		Tin		Antimony		Tellurium		Iodine		Krypton		Xenon	
Cs	55	Ba	56	Hf	72	Ta	73	W	74	Re	75	Os	76	Ir	77	Pt	78	Au	79	Hg	80	Tl	81	Pb	82	Bi	83	Po	84	At	85	Rn	86				
Cesium		Barium		Hafnium		Tantalum		Tungsten		Rhenium		Osmium		Iridium		Platinum		Au		Gold		Mercury		Thallium		Lead		Bismuth		Polonium		Astatine		Radon			
Fr	87	Ra	88	Rf	104	Db	105	Sg	106	Bh	107	Hs	108	Mt	109	Ds	110	Rg	111	Cn	112	Nh	113	Fl	114	Mc	115	Lv	116	Ts	117	Og	118				
Franium		Radium		Rutherfordium		Dubnium		Seaborgium		Bohrium		Hassium		Meltnerium		Darmstadtium		Röntgenium		Copernicum		Nihonium		Flerovium		Moscovium		Livermorium		Tennessee		Oganesson					
Radioactive elements															On the other side of this poster you will find a version with smaller pictures but with detailed technical data on each of the elements, plus trend plots.															PERIODICTABLE.COM							
La	57	Ce	58	Pr	59	Nd	60	Pm	61	Sm	62	Eu	63	Gd	64	Tb	65	Dy	66	Ho	67	Er	68	Tm	69	Yb	70	Lu	71								
Lanthanum		Cerium		Praseodymium		Neodymium		Promethium		Samarium		Europium		Gadolinium		Terbium		Dysprosium		Holmium		Erbium		Thulium		Ytterbium		Lutetium									
Ac	89	Th	90	Pa	91	U	92	Np	93	Pu	94	Am	95	Cm	96	Bk	97	Cf	98	Es	99	Fm	100	Md	101	No	102	Lr	103								
Actinium		Thorium		Protactinium		Uranium		Neptunium		Plutonium		Americium		Curium		Berkelium		Californium		Einsteinium		Fermium		Mendelevium		Nobelium		Lawrencium									

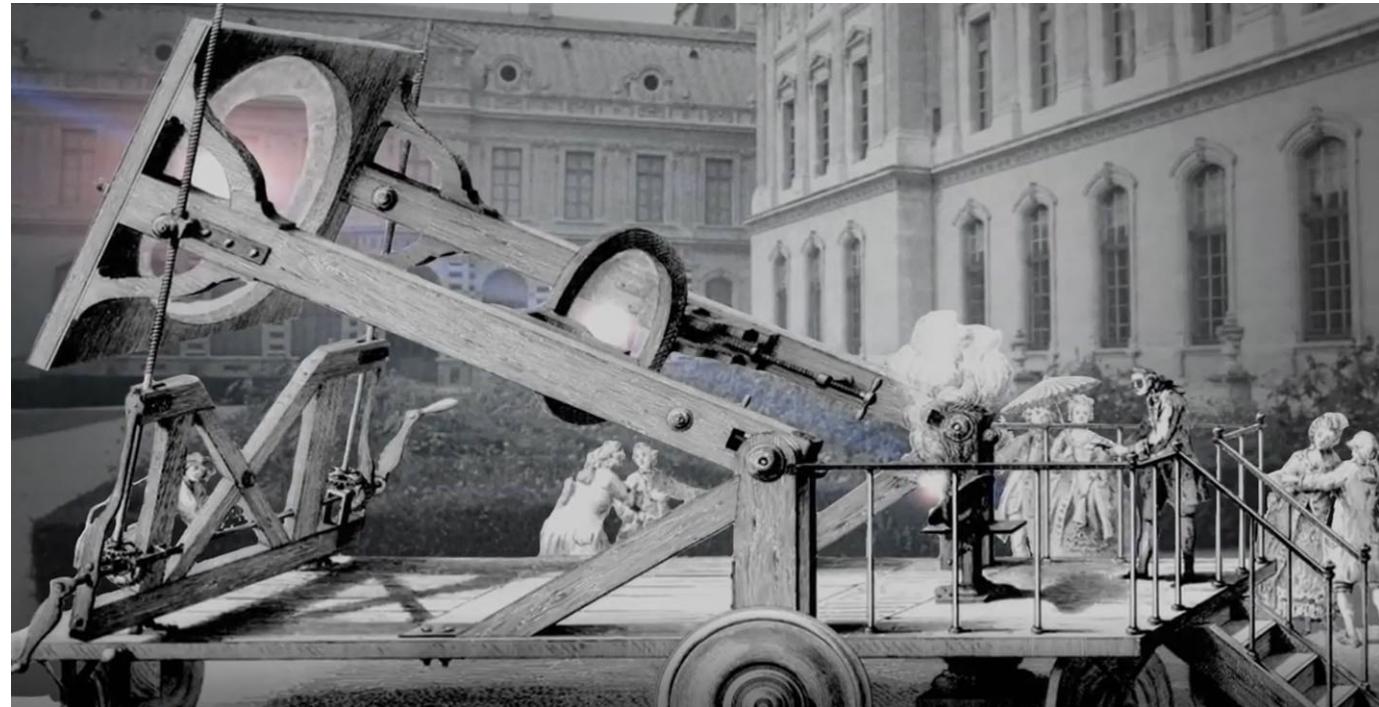
<https://periodictable.com/theelements/index.html>



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.





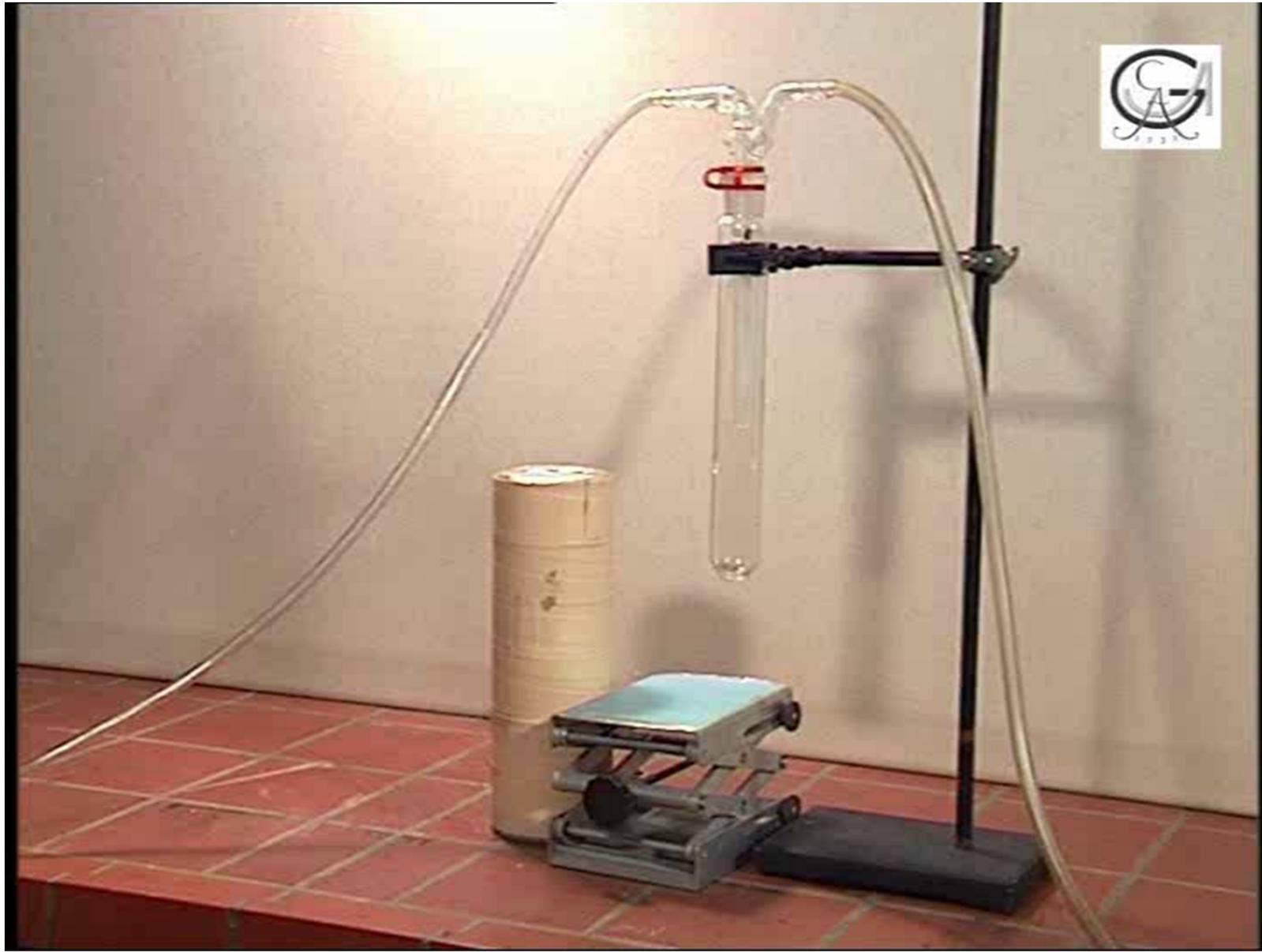
Calyx of Lead + charcoal + water + intense heat

The oxide of Pb releases O₂ upon heating with C

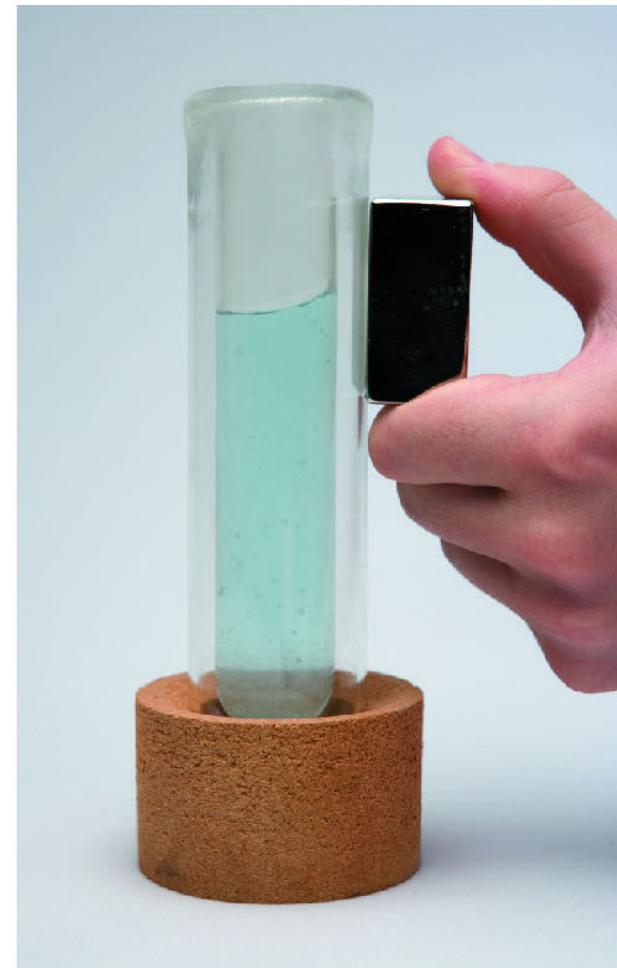
Lavoisier's execution

- 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."

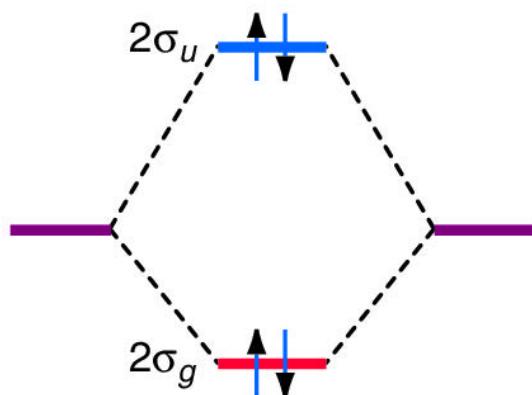
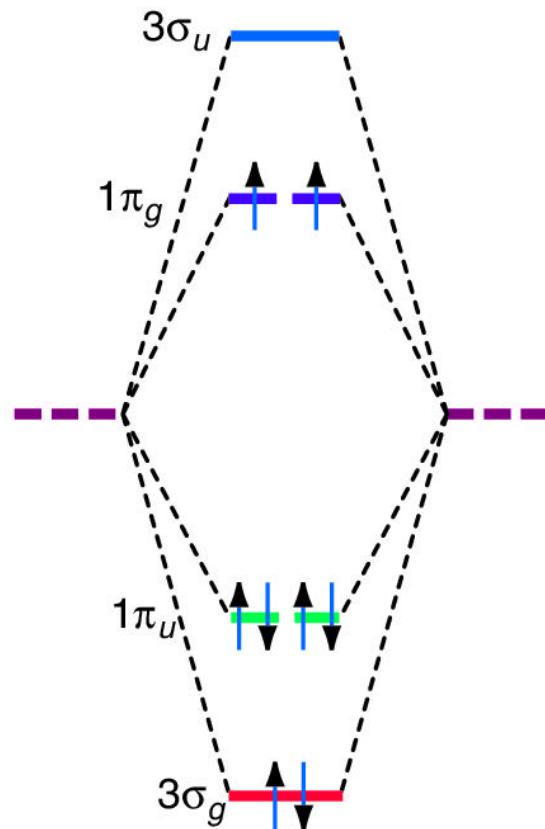
Liquid Oxygen: Video



Paramagnetism of O₂



MO Interaction Diagram of O₂



Appreciating O₂

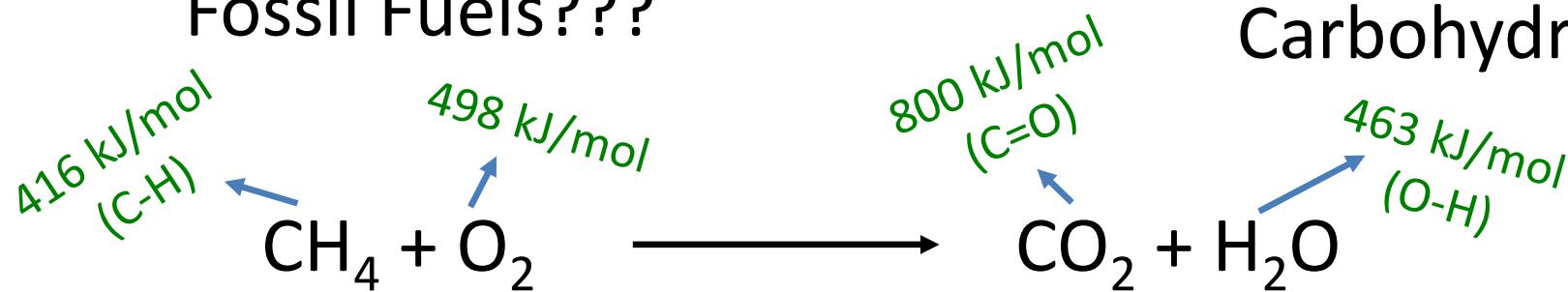
- Oxygen is a diradical held by weak bonds (BDE = 498 kJ/mol)
- The formation of water by the combination of O₂ and H₂ is exothermic
- Reverse the formation of O₂ from water is endothermic
- Energy is required for all activities – ecological and industrial – **and also Chandrayan 3**

Energy is critical to Human well-being

Sources of Energy

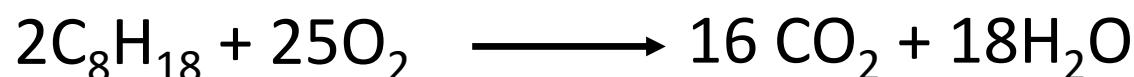
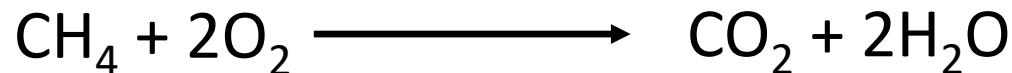


Fossil Fuels???



Carbohydrates???





	ΔH (exp) (kJ/mol)	Moles of O_2	ΔH (calc) (kJ/mol)
CH_4	-890	2	-920
C_8H_{18}	-5452	12.5	-5750
$\text{C}_2\text{H}_5\text{OH}$	-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	$\Delta H^\circ / (\text{kJ mol}^{-1})$		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.

Thermodynamics of O_2

Standard reduction potentials for dioxygen species in water.⁸

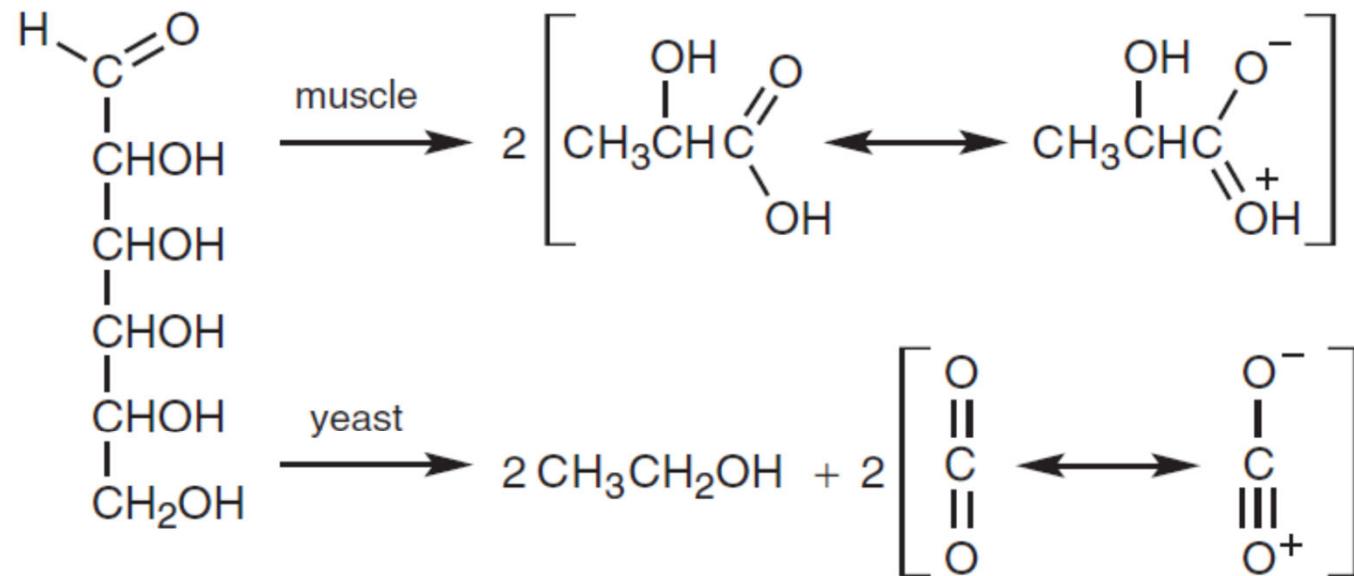
Reaction	E° , V vs. NHE, pH 7, 25°C
$O_2 + e^- \rightarrow O_2^-$	-0.33 ^a
$O_2^- + e^- + 2H^+ \rightarrow H_2O_2$	+0.89
$H_2O_2 + e^- + H^+ \rightarrow H_2O + OH$	+0.38
$OH + e^- + H^+ \rightarrow H_2O$	+2.31
$O_2 + 2e^- + 2H^+ \rightarrow H_2O_2$	+0.281 ^a
$H_2O_2 + 2e^- + 2H^+ \rightarrow 2H_2O$	+1.349
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+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 O₂ as the energy source in biological systems

Aerobic metabolism: glucose to CO₂ generates 38 ATP

Aerobic 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