



OXYGEN AND SILVER

Relevance to Good Delivery Bars

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LBMA Assaying and Refining Conference

PREAMBLE

What is the Oxygen problem for Silver?

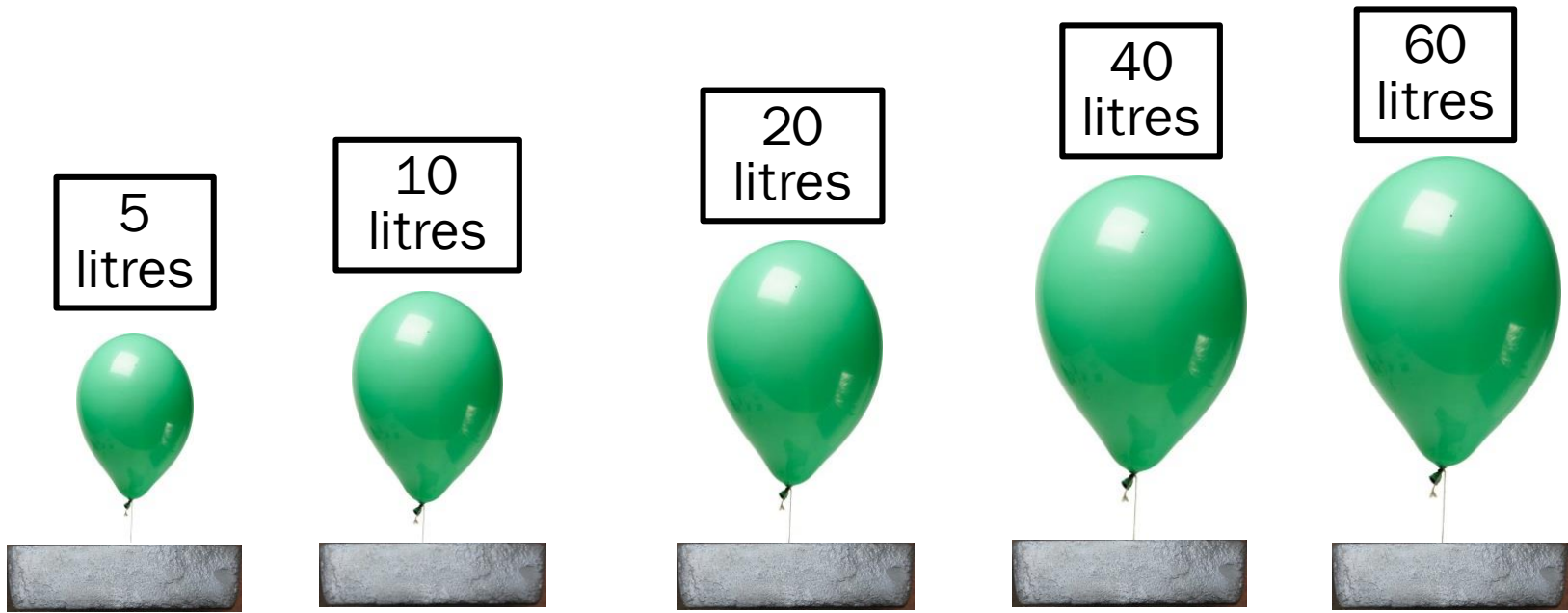
- It is not (mainly) the financial one, that oxygen counts as silver (even at a high level of 100 ppm the loss would be only ~£1 per bar)
- Instead it is that Oxygen is readily soluble in molten silver...

Starter Question

Gay-Lussac discovered in 1830 how much oxygen a bath of molten silver could contain in solution.

Question:

For a 30 kg bath of molten silver (enough for one GD Bar) how much oxygen at 1 atmosphere pressure could it hold?



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- It is not (mainly) that oxygen counts as silver (even at a high level of 100 ppm the loss would be only ~£1 per bar)
- Oxygen is very soluble in molten silver
- but not in solid silver
- It can therefore spoil physical appearance of GD bars



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The Challenge

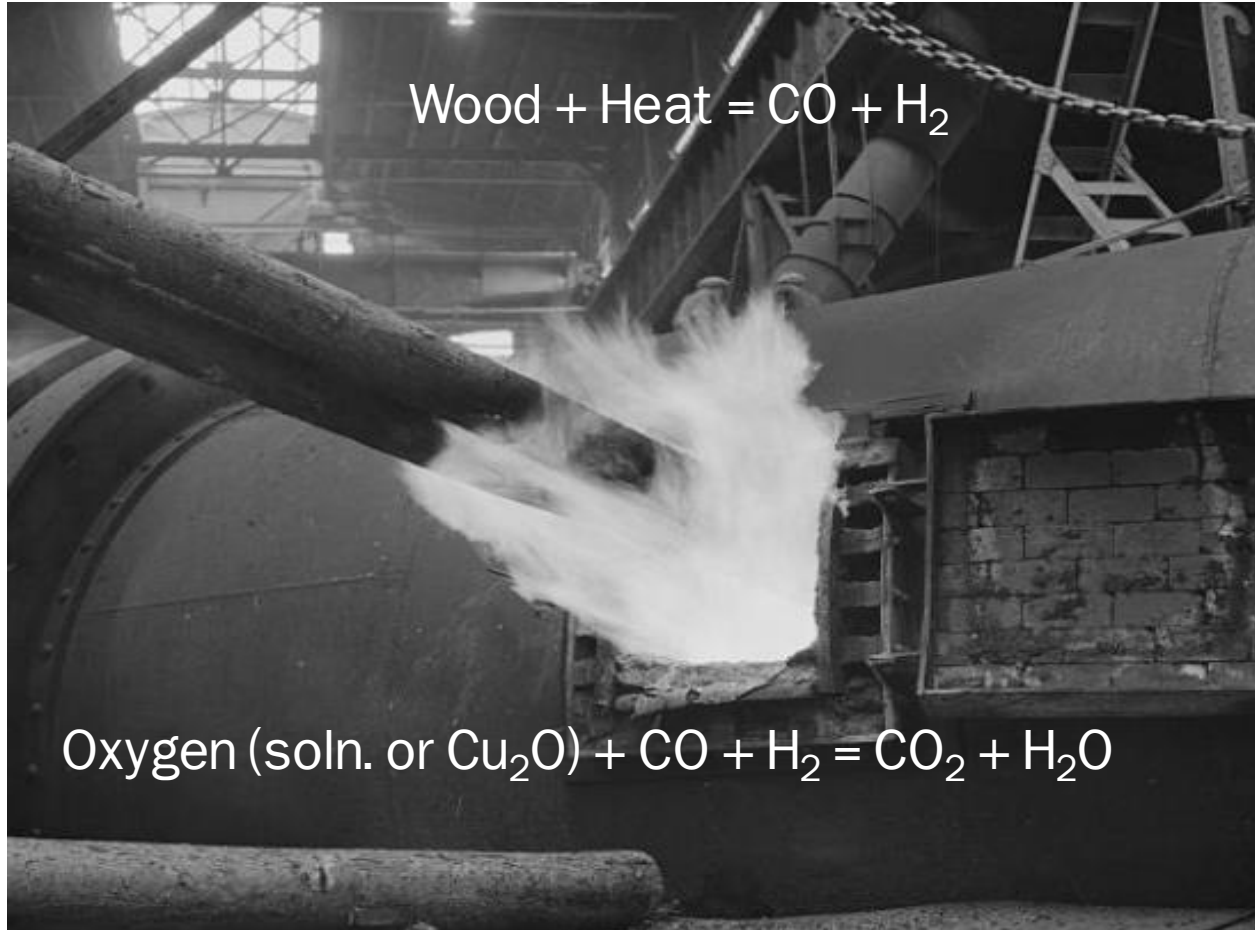
Preventing absorption by or removal of oxygen from molten silver

Lessons for Silver from Poling of Copper?



COPPER POLING

What is (was) poling and can it be used for silver?



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Attempts to find a speaker from a GD Copper Refiner

Similarities and differences between copper and silver etc



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Failed attempts! That is why I am here.



SURVEY OF GD REFINERS

Managing Oxygen in Silver

Questions

- Raw material for melting?
- Melting method (ie furnace type and capacity)?
- Methods of minimisation of oxygen absorption?
- Use of flame polishing during casting?
- Need for physical treatment of cast bars?
- Analysis of oxygen in molten and solid silver?

Results

- Many similarities to obviating problems
- Some unique solutions



SCOPE

Cosmological Digression - Oxygen and Metals

Physical Chemistry of the Silver-Oxygen System

- Molten silver
- Solid silver

Good Delivery Issues

- Why oxygen counts as silver
- Analysis is not easy (or necessary?)
- Possible impact on bar quality

GD Refiner Strategies to avoid Oxygen Problems

- Oxygen absorption – sources and prevention
- Removal of oxygen from molten silver
- Casting Methods



Let's talk about OXYGEN

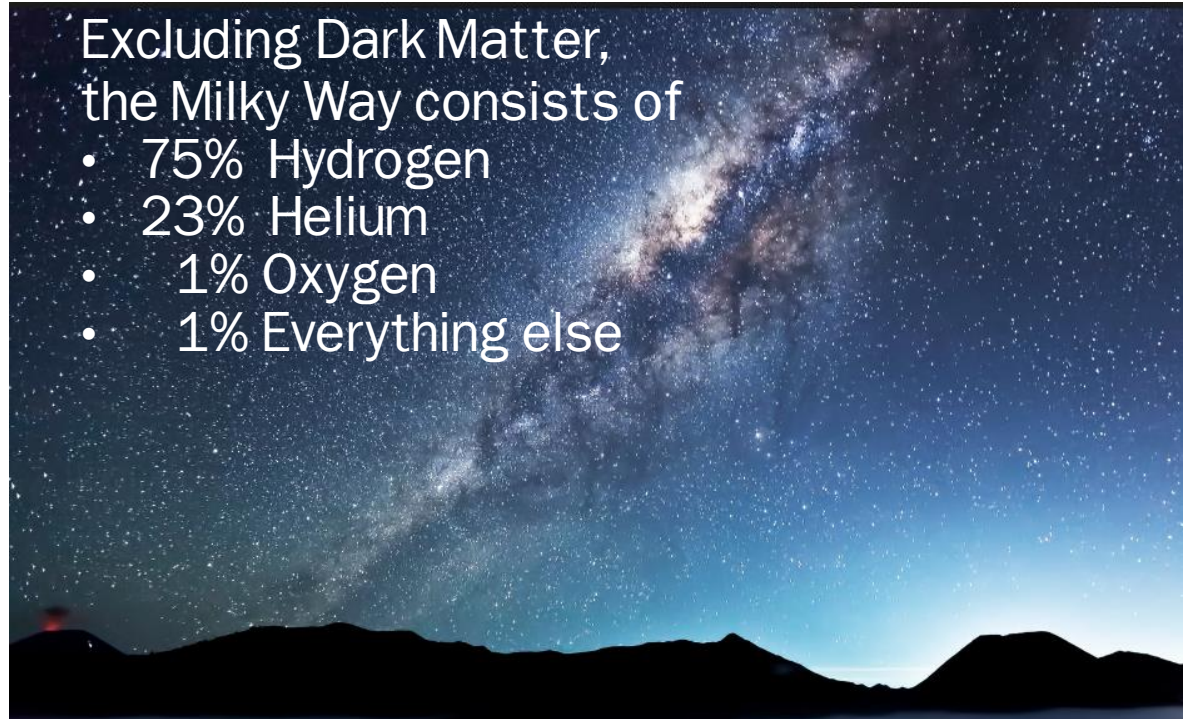
From the stellar forge to the Earthly anvil

Oxygen Occurrence

- Milky Way

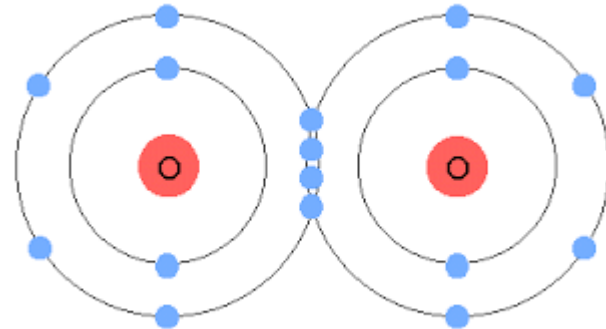
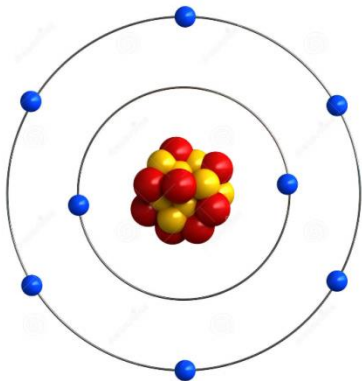
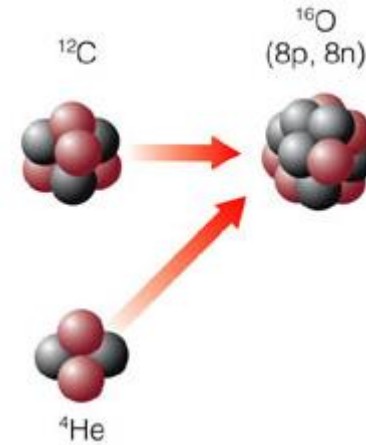
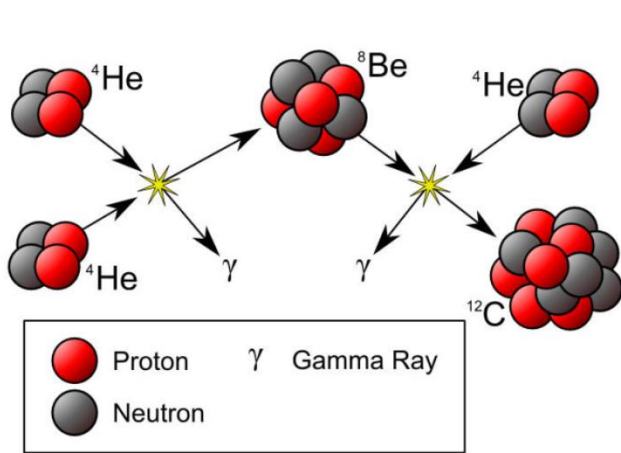
Excluding Dark Matter,
the Milky Way consists of

- 75% Hydrogen
- 23% Helium
- 1% Oxygen
- 1% Everything else



Oxygen's Nuclear and Chemical Stability

Why Oxygen is Number 3 in Cosmic Abundance

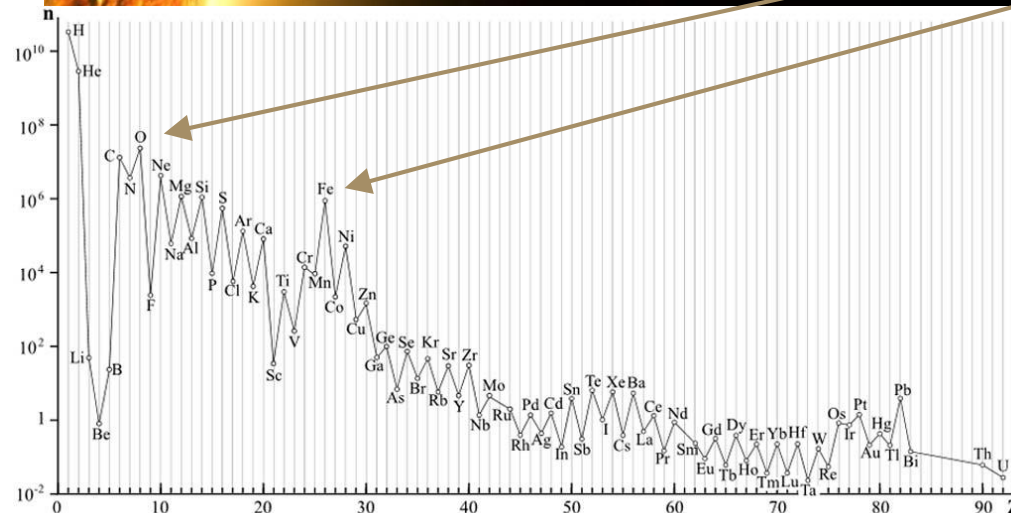
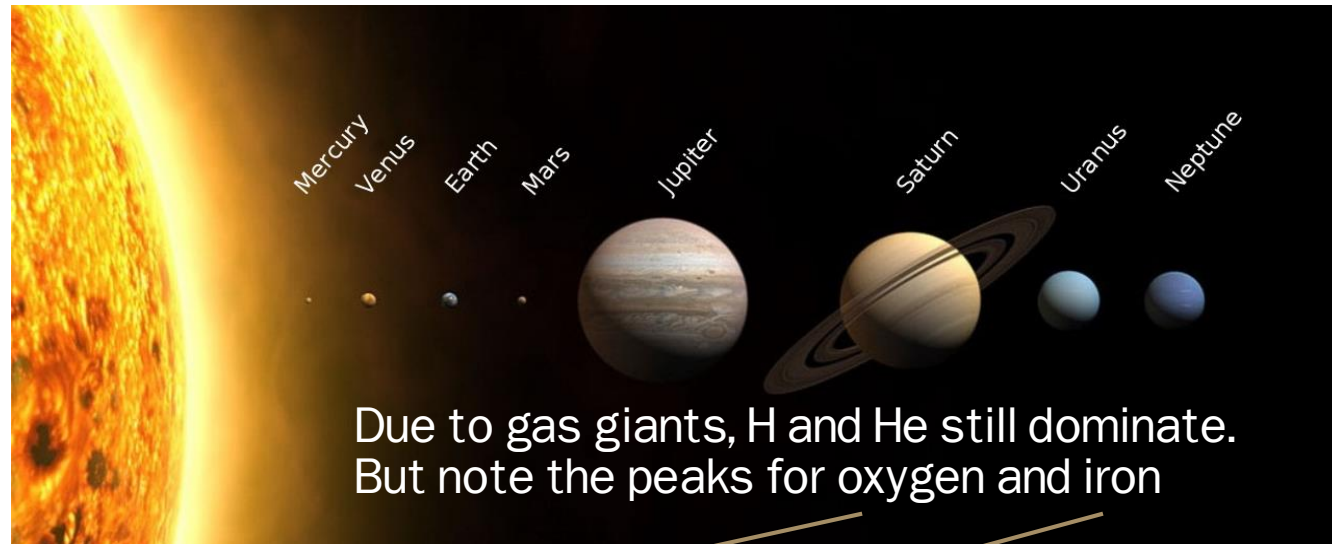


Let's talk about OXYGEN

From the stellar forge to the Earthly anvil

Occurrence

- Milky Way
- Solar System

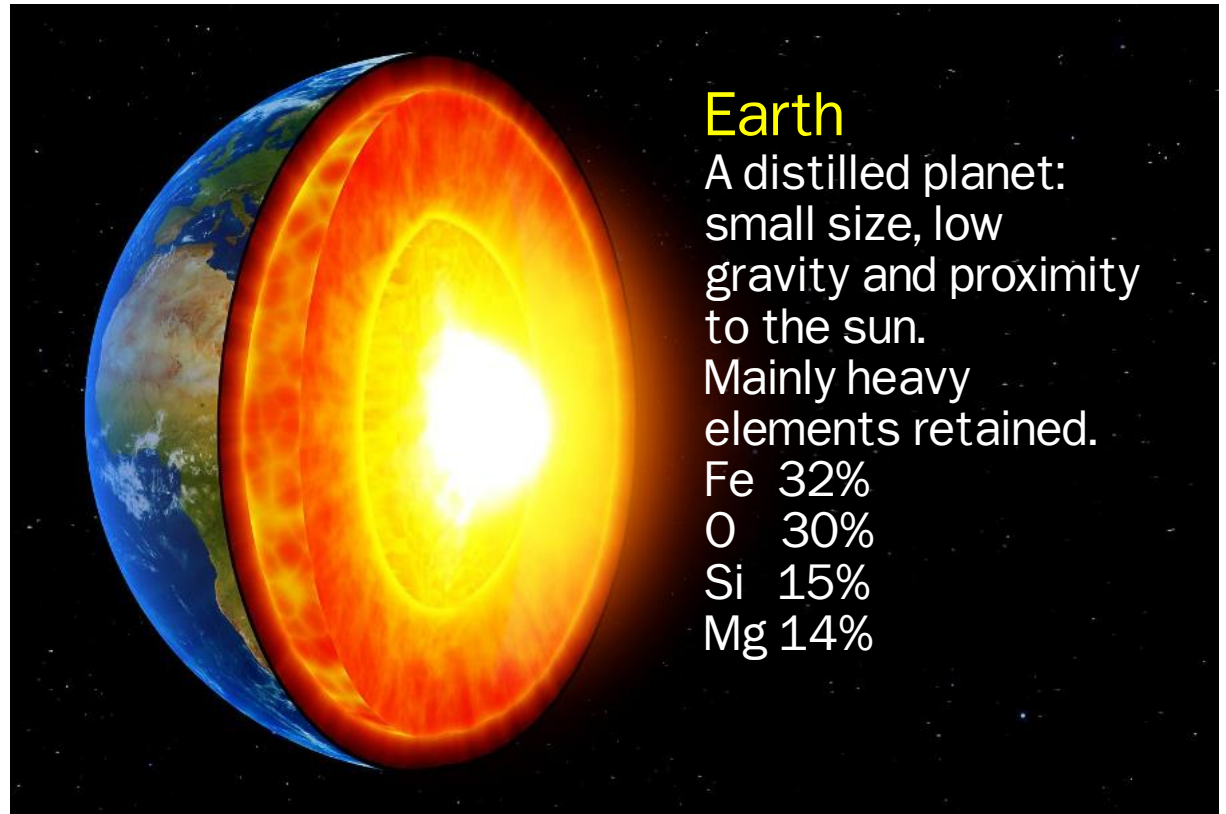


Let's talk about OXYGEN

From the stellar forge to the Earthly anvil

Occurrence

- Milky Way
- Solar System
- Earth

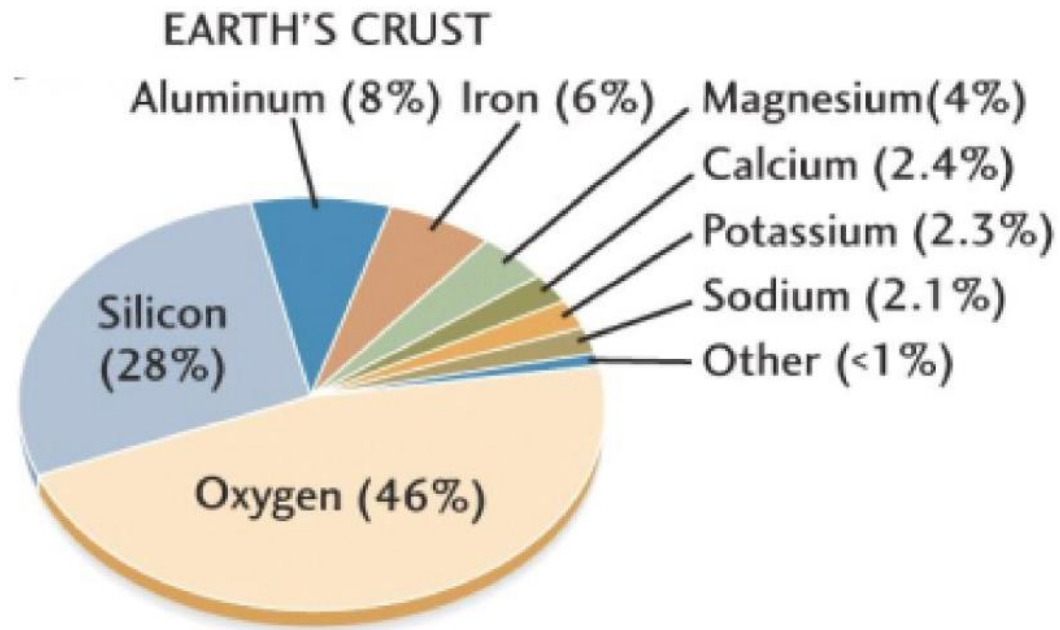


Let's talk about OXYGEN

From the stellar forge to the Earthly anvil

Occurrence

- Milky Way
- Solar System
- Earth
- Earth's Crust (the slag layer)

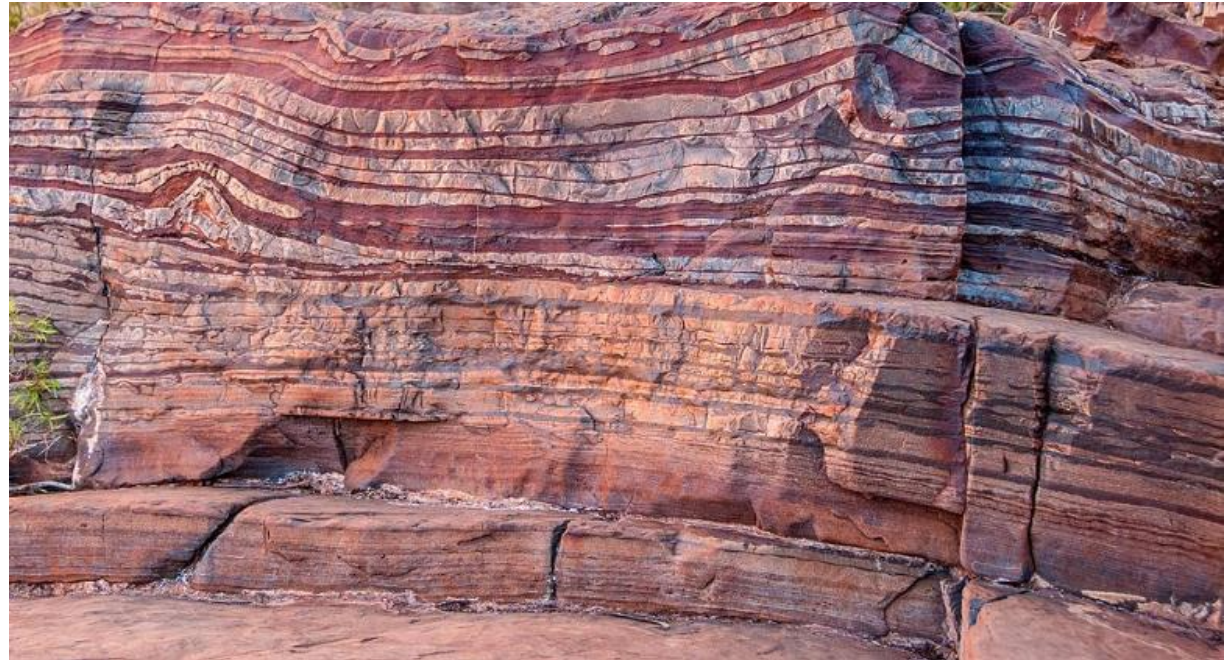


Let's talk about OXYGEN

From the stellar forge to the Earthly anvil

Occurrence

- Milky Way
- Solar System
- Earth
- Earth's Crust
- Fire, water, iron and cyanobacteria
- The Iron Ore Age ends
- The Air Age begins



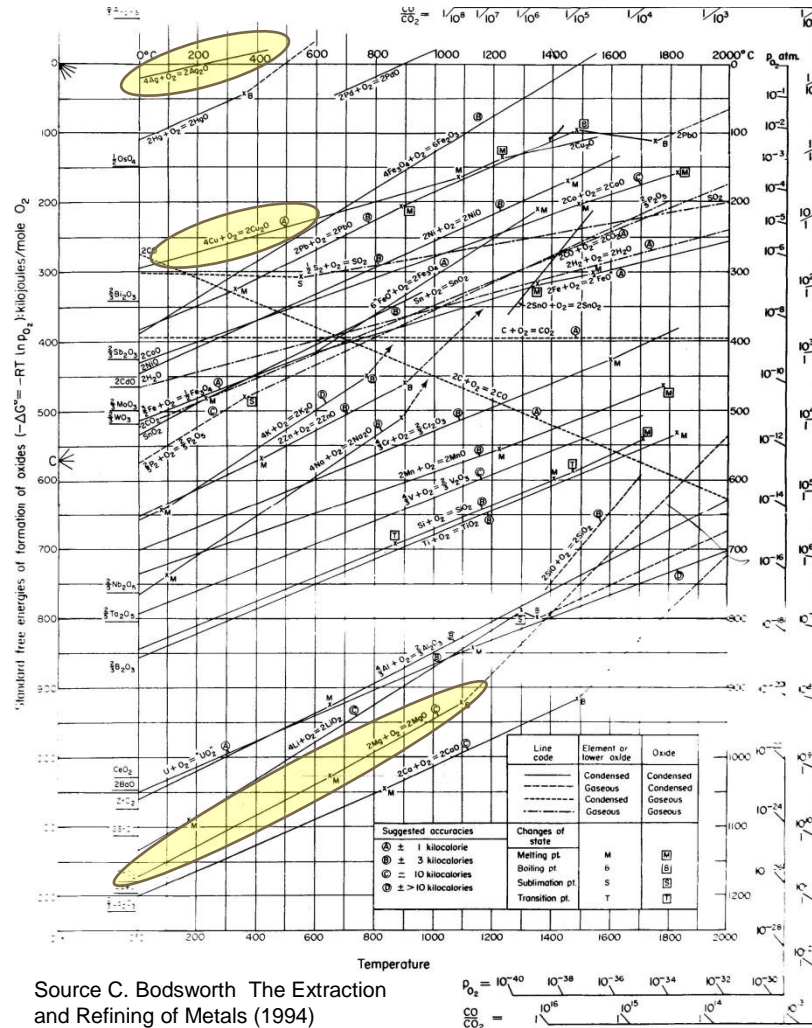
Source Graeme Churchard

OXYGEN AND METALS

Message from Metals:
Who wants my excess electrons?

Answer from Oxygen:
I do!

- Free Energy Diagram
- Ag_2O vs Cu_2O vs MgO



Source C. Bodsworth The Extraction and Refining of Metals (1994)



OXYGEN SOLUBILITY IN SILVER

Effect of pressure - Sievert's Law

$$N_{\text{Ag}} = K p_{\text{O}_2}^{1/2}$$

Solubility in molten silver

Solubility in solid silver

Supersaturation?

Oxygen Solubility in Silver At Pressure of 1 atmosphere O ₂	
Temperature (°C)	Solubility (ppm)
300	0.3
900	61.4
973	3,050
1024	2,950

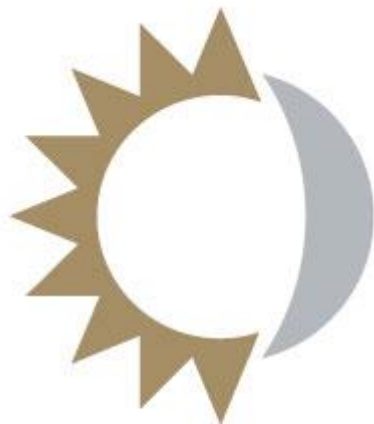
SUMMARY OF SURVEY RESULTS

Responses: 18 GD Silver Refiners from 12 countries – Thanks!

Raw material for furnace	Crystals (17); grain (2); scrap (2); bars (1) unrefined bullion (1)
Melting furnace type	Induction (13); Gas fired crucible (3); Resistance (1); Reverberatory (1)
Limiting O ₂ absorption during melting	Carbon* cover (11); Reducing flame (3); Carbon & Flame (1); Carbon rod “poling” (2); Nitrogen purge (1)
Analysis of oxygen in molten silver	4 answered “yes” – mostly occasionally finding ~20-40 ppm
Use of flame polishing for casting	Yes (12); No (6); Graphite block covers on mould (2)
Need for physical treatment of bars	Yes (13) not all related to needle removal; No (5)
Physical treatment of cast bars	Hammering (4); Hand Grinding (5); Wire brushing (4) milling (2) Polishing or buffing (2) (incl some combinations)
Analysis of oxygen in cast bars	5 answered “yes” – but not routinely, finding variously from 20-235 ppm

* Carbon included graphite blocks, activated charcoal, briquettes and lump coal





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