Technical Possibilities to Support Separation of Radioactive Elements from Metallic Waste

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Content

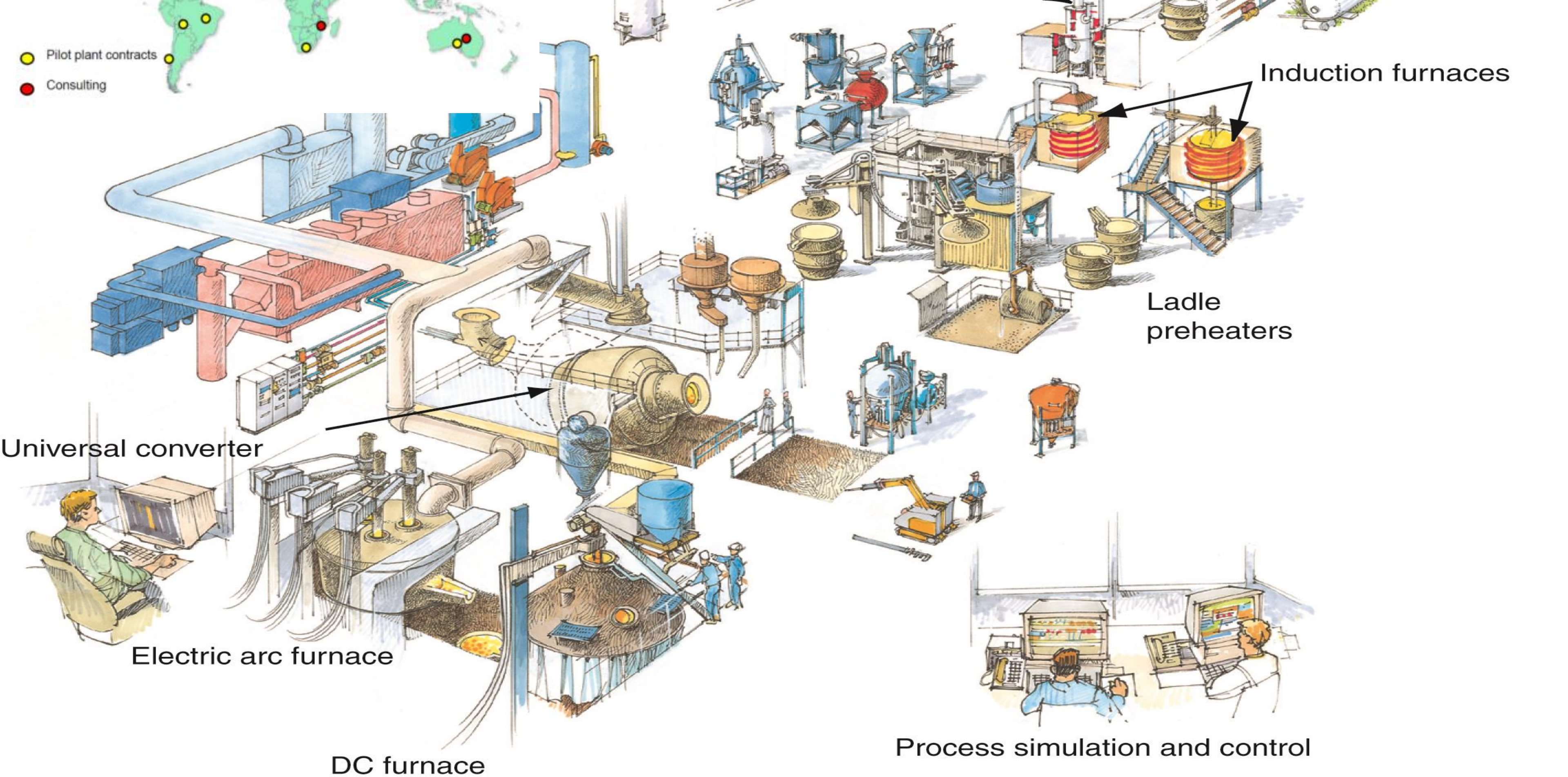
- Short about Swerea MEFOS
- Thermodynamics: what is possible and what is not possible
- Metallurgical Principle of Metal Recycling and Recovery
- EAF - The conventional steel scrap meltshop
- Tramp elements vs radioactive scrap
- Scrap cleaning projects at Swerea MEFOS

Swerea MEFOS – 50 years of exellence

- Nordic
- Associated members
- Applied research
- New technology
- Pilot testing
- Contract research

Pilot Plant

Clients from all over the world



LKAB:s Experimental Blast Furnace

- **Owner:** LKAB
- **Aim:** Development of pellets
  Know-how of operation with pellets and sinter
- **Special project:** **ULCOS – TGR** (EU)

Spring 2012

Japanese Course 50 comes to Sweden

Decreasing the emissions of carbon dioxide from hot metal production

Thermodynamics

- Gibbs free energy, $\mathbf{\Delta G = \Delta H - \Delta ST}$
- Selectivity: Ca-O-Fe, CaO-SiO2-FeO
- Nobleness – Distribution (Fe/slag/dust)
- The Ellingham diagrams and how to apply them in your daily operation
- Activity

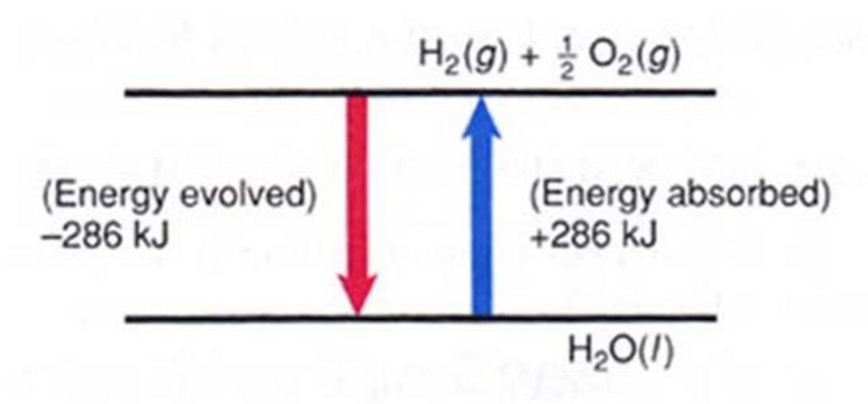
Chemical Reactions vs the Periodic System

	I	II											III	IV	V	VI	VI	0
1	1 H 1.0																	2 He 4
2	3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12	7 N 14	8 O 16	9 F 19	10 Ne 20.2
3	11 Na 23	12 Mg 24.3											13 Al 27	14 Si 28.1	15 P 31	16 S 32.1	17 Cl 35.5	18 Ar 39.9
4	19 K 39.1	20 Ca 40.1	21 Sc 45	22 Ti 47.9	23 V 50.9	24 Cr 52	25 Mn 54.9	26 Fe 55.9	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79	35 Br 79.9	36 Kr 83.8
5	37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137	57 # La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226	89 @ Ac 227	104 Unq (259)	105 Unp (260)	106 Unh (263)	107 Uns (262)	108 108 (265)	109 Une (266)									

Lanthanide # Series	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152	64 Gd 157.2	65 Tb 157.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175
Actinide @ Series	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

- Alkali Met.
- Metal
- Trans. Met.
- Noble Gas
- Chalcogens
- Lanthanide
- Non-Metal
- Halogen
- Actinide
- Metaloids

ΔH, reaction or formation energy



ΔS, disorder, spontaneity

Monday

Friday

ΔS>0

$\Delta G = \Delta H - \Delta S T$

- $\Delta G < 0$, possible

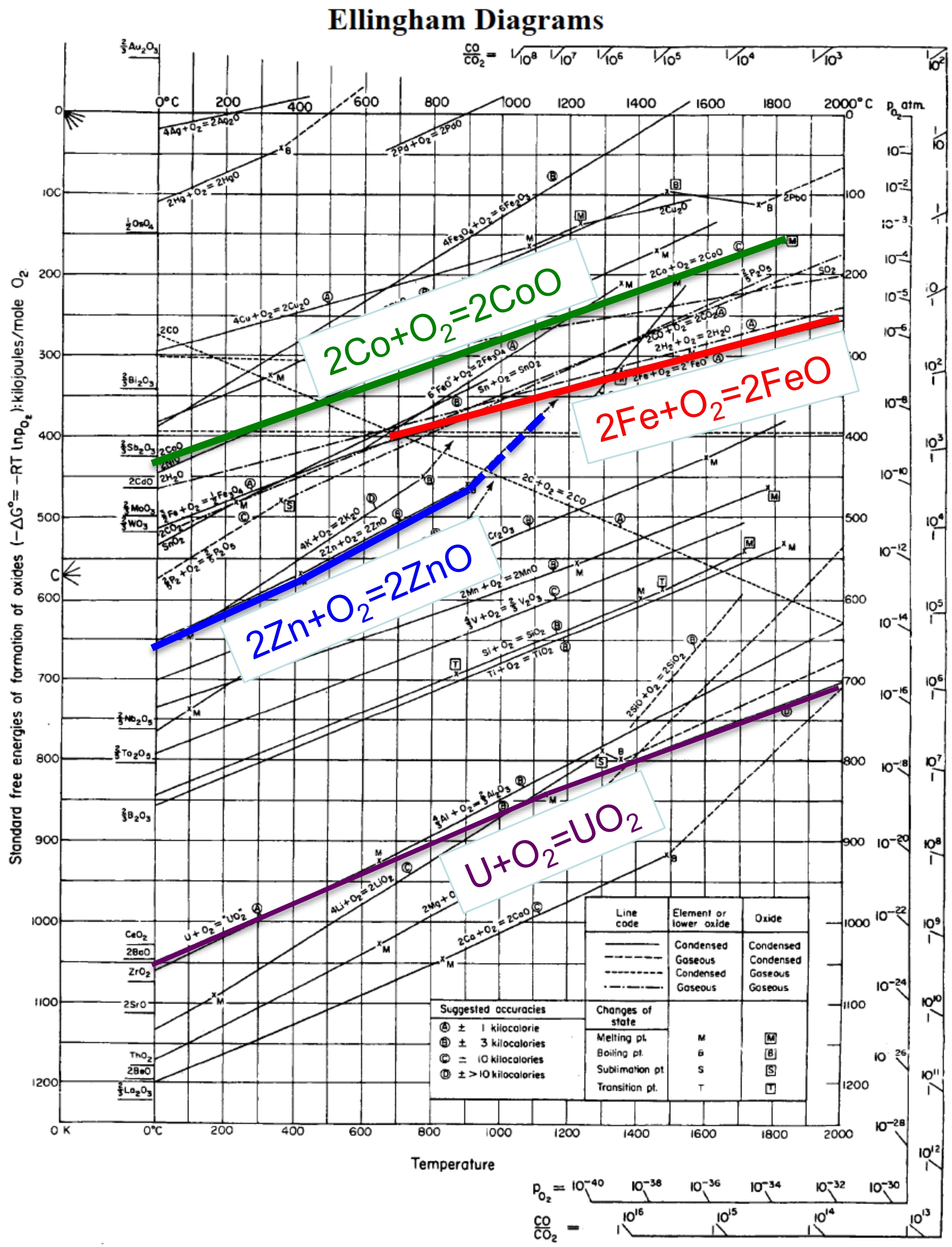
- $\Delta G > 0$, not possible

Selectivity

$$Ca + 1/2O_2 = CaO,\ \Delta G_1 < 0$$

$$Fe + 1/2O_2 = FeO,\ \Delta G_2 < 0$$

$$\Delta G_1 << \Delta G_2$$

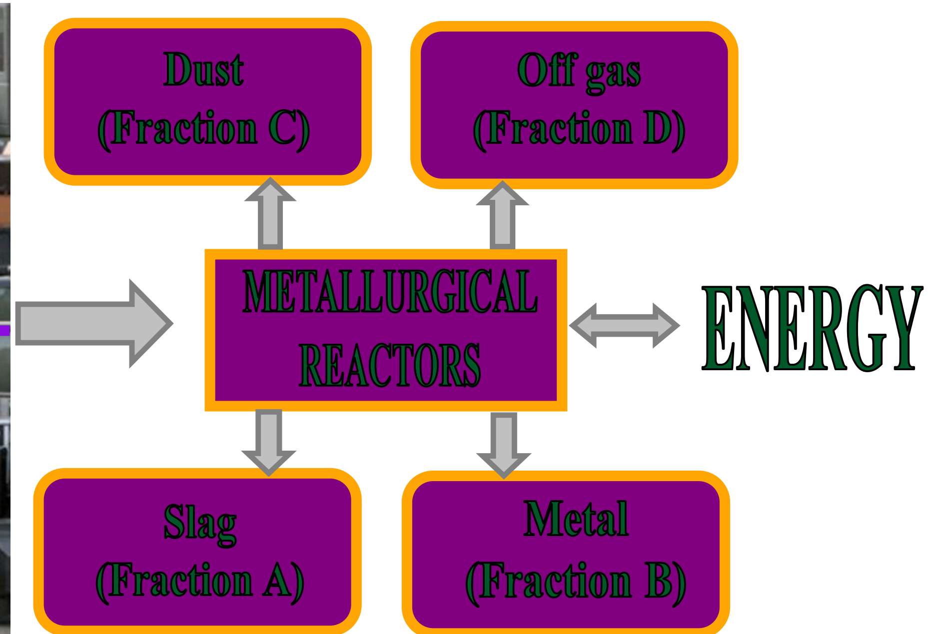


- The lower the line the more stable oxide
- The slope changes with phase change
- FeO is only stable at higher temperatures

Activity

Once impurty elements are the dissolved in the metal the activity of that will be low

Metallurgical processes for recycling



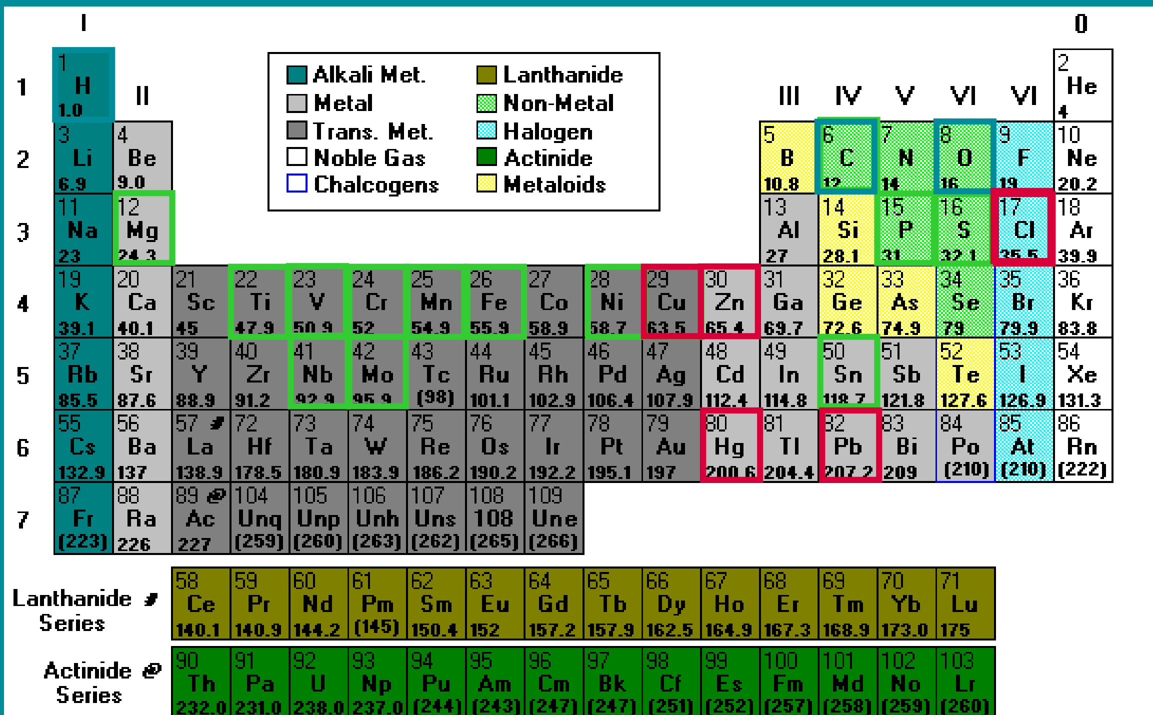
A: CaO, SiO2, Al2O3, MgO

B: NiO, FeO, MnO, V2O3, Cr2O3, P2O5,Cu, Co, Mo

C: ZnO, PbO, Na, K, Cl, Cd, Hg

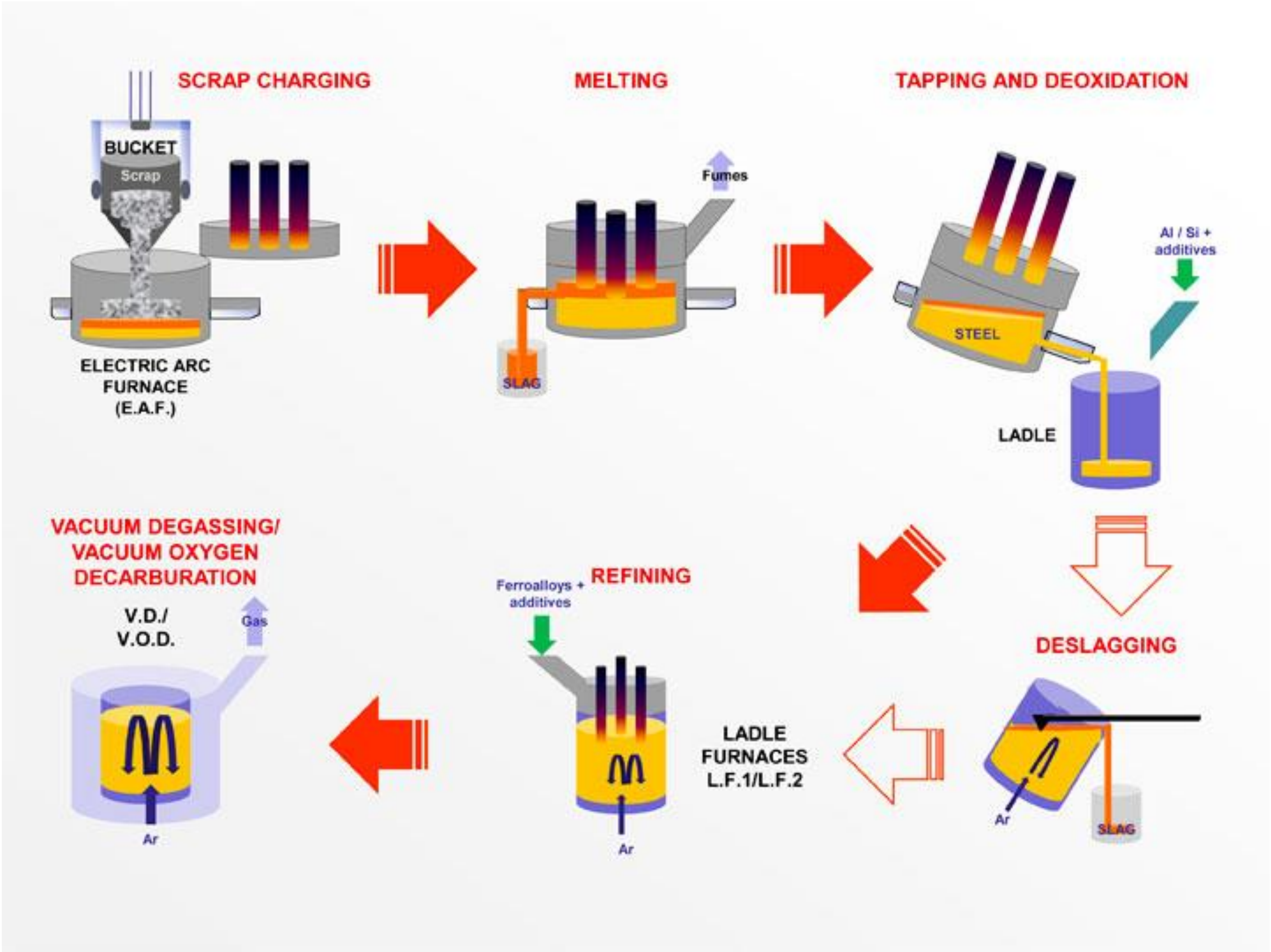
D: C-H-O, plastics/textile/fluff

What is scrap?

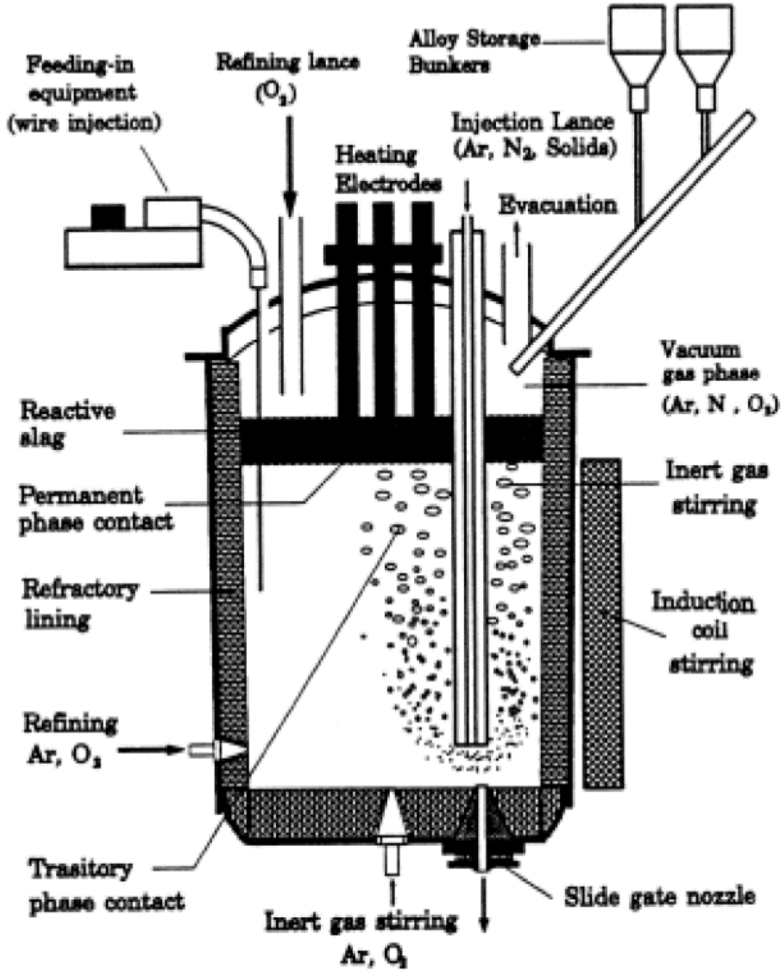


- **Scrap**
- Used steel products, i.e. Fe with alloys
- Shredded scrap is a complex material containing
  - switches, cables
  - coatings, e.g. organic or metallic
- **Coatings may result in hazardous and problematic compounds in exhaust gas**

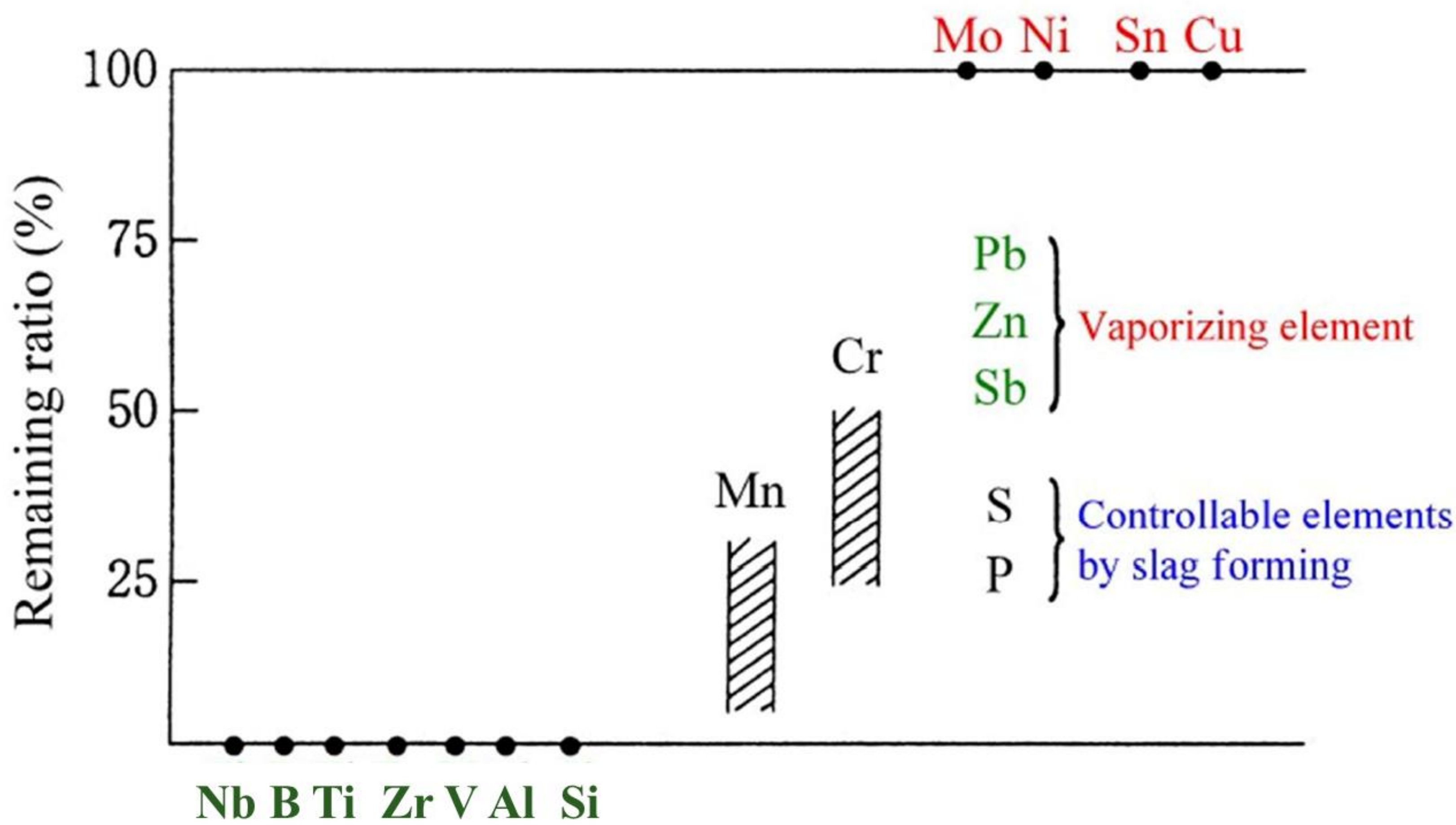
Conventional EAF smelting of steel scrap



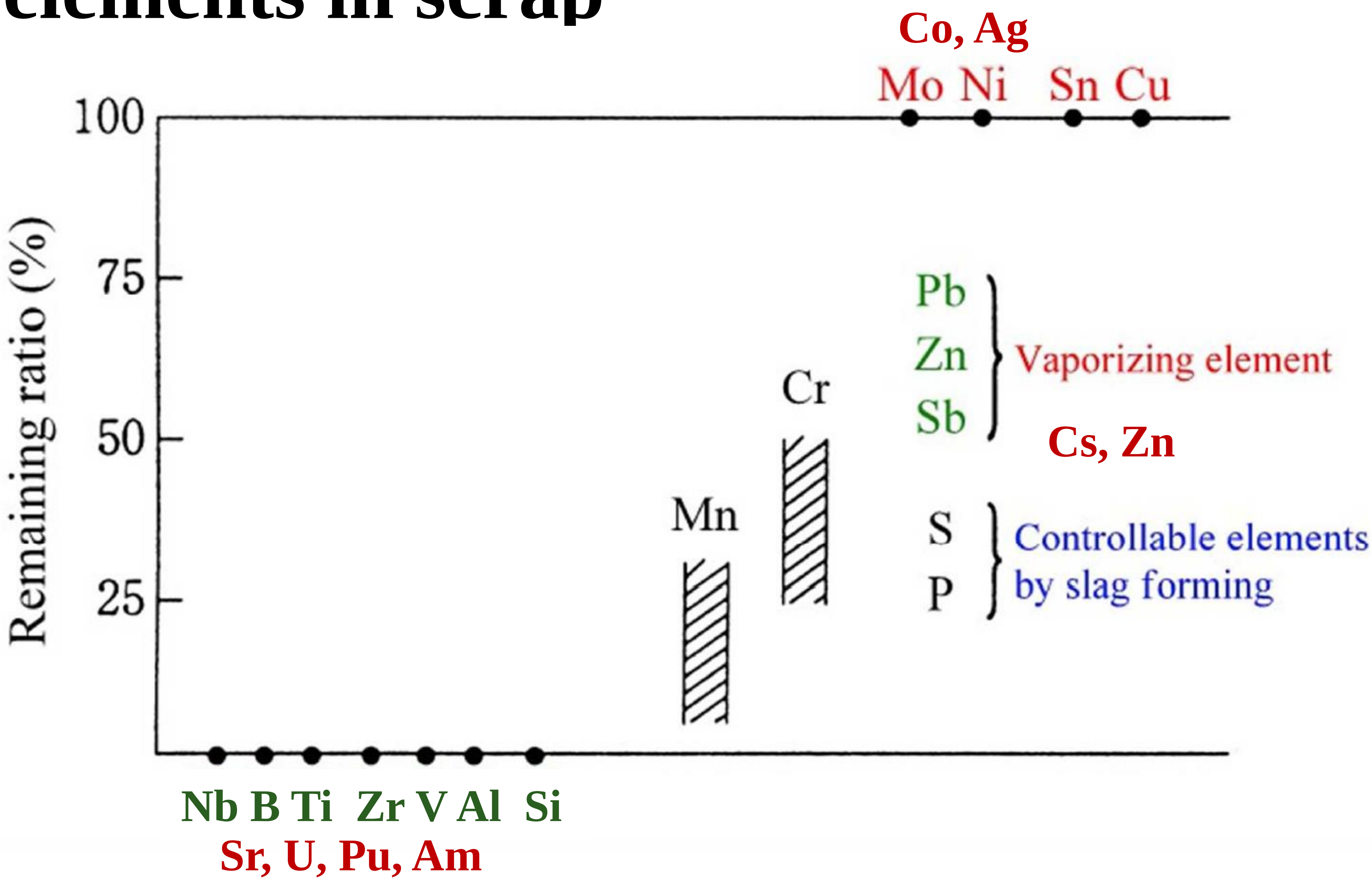
Scrap-based process metallurgy



Recyclability of tramp elements in scrap



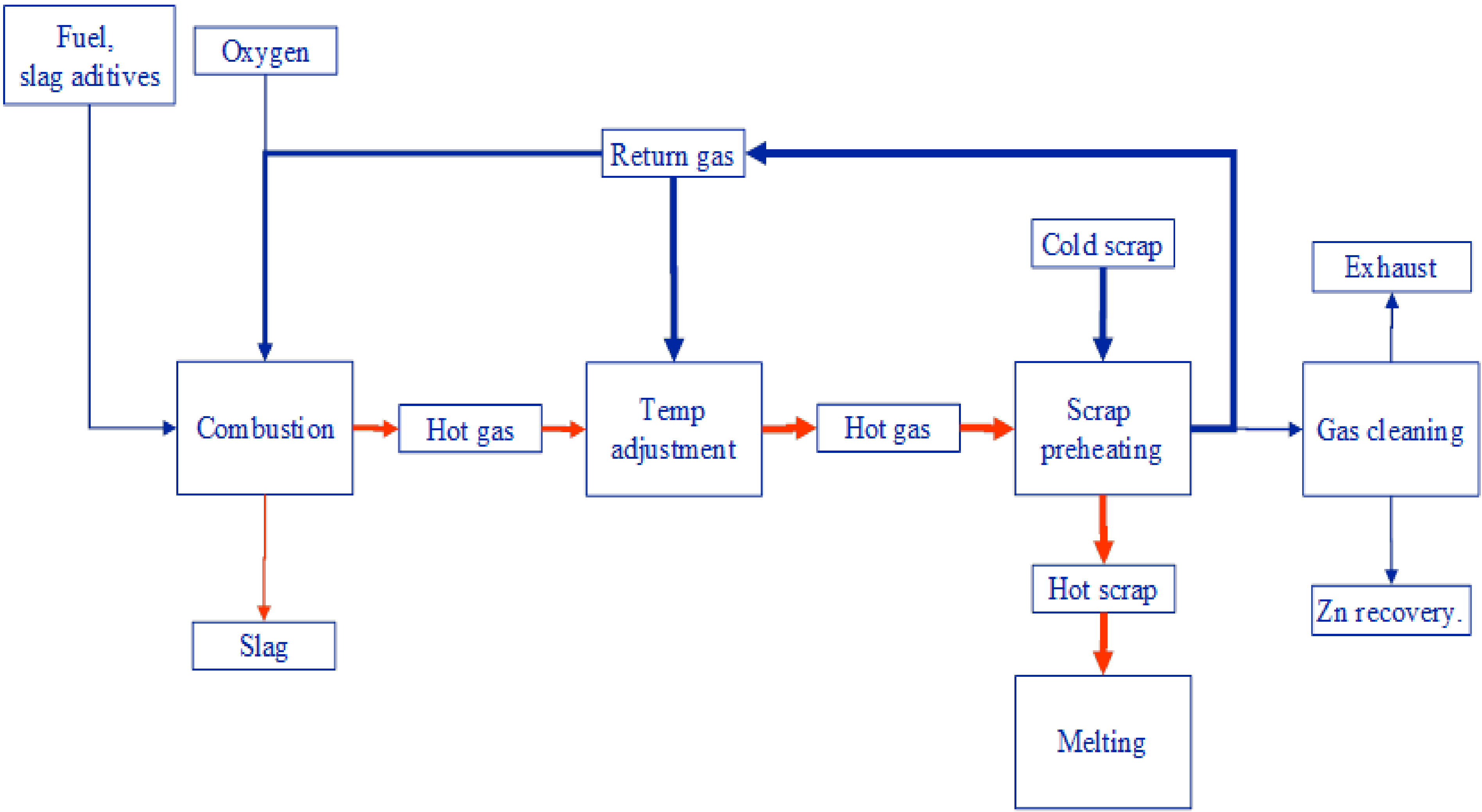
Expected distribution of the radioactive elements in scrap



Nuclide distribution from steel scrape

Nuclide	Steel (%)	Slag (%)	Dust (%)	Other (%)
Mn-54	24-100	1-75	0-5	0
Co-60	20-100	0-1	0-80	0
Zn-65	0-20	0-1	80-100	0
Sr-90	0-20	95-100	0-10	0
Ag-108m	75-100	0-1	0-25	1 (bottom)
Sb-125	60-100	0-20	10-40	0
Cs-137	0	0-5	95-100	0
U	0-1	95-100	0-5	0
Pu	0-1	95-100	0-5	0
Am-241	0-1	95-100	0-5	0

Scrap preheating and surface cleaning



Conclusions

- Thermodynamics applied for the conventional steel scrap can also be applied for cleaning, smelting and refining of radioactive scrap
- The operational results confirm the validity of the thermodynamic principle. Agreement between observation of nuclide distribution and thermodynamic data.
  - Am, U, Pu will go to the slag phase
  - Zn will evaporate
  - Co-60, and all other radioactive cobalt isotopes, will stay in the molten metal when melted under standard conditions in air

We should use thermodynamic principle to guide our future innovation in this field

Thank you and questions?