METALLIC MINERAL RESOURCES

CRUSTAL ABUNDANCE AND CONCENTRATION FACTORS

- **<u>A natural resource</u>** is a useful and valuable natural material.
- **<u>Mineral resources</u>** can be metallic and non-metallic or industrial minerals.
- **<u>A mineral</u>** is a naturally occurring inorganic crystalline compound with a definite chemical composition.
- **<u>A polymorph</u>** is a mineral that has the same composition but occurs in different crystal forms.
- **<u>Reserves</u>** are the amount of a material that can be extracted at a profit using existing technology.
- **<u>Ore</u>** is the rock containing valuable metal(s) that is economic to mine as well as some low-value gangue minerals.
- **<u>An ore deposit</u>** is an accumulation of metal that may be economic to mine.
- **<u>Ore minerals</u>** a mineral containing valuable metals.
- **<u>Gangue minerals</u>** are low-value waste minerals.
- **<u>Average crustal abundance</u>** describes the amount of metal in average in the continental crust
- **<u>The concentration factor</u>** is the amount by which the metal is concentrated to make an ore deposit.

Metals are **unevenly distributed** through the Earth's crust. The concentrations of these are often too low to be economic to mine. In order to form an **ore deposit**, the metal must be **concentrated above its average crustal abundance** by geological processes such as **igneous activity or weathering and erosion**.

The **concentration factor** is the amount by which the metal has to be concentrated **above its average crustal abundance** to form an **ore deposit** (i.e. how profitable).

$$\textit{Concentration factor} = \frac{\textit{concentration of metal in the ore deposit (grade)},\%}{\textit{average crustal abundance},\%}$$

Concentration factor has no units (notice the sign % is on the top and bottom of the fraction so cancels!)

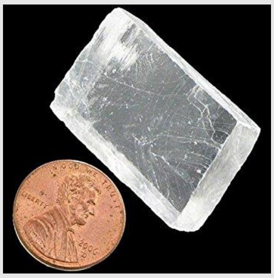
e.g. An ore deposit contains 6% copper and the average crustal abundance of copper is 0.007%. Calculate the concentration factor:
C.F. = 6 / 0.007 = 857.14 **= 857** (3 s.f.)
This means that in this ore deposit, the copper is concentrated 857 times above the average crustal abundance.

Ore deposits consist of rocks called **ores**. An ore is a mixture of **valuable ore minerals** and **low-value gangue**-minerals. Most ore minerals are compounds of either oxygen (e.g. metal oxides) or sulfur (metal sulphides).

Common gangue minerals are calcite, quartz and pyrite (fool's gold).

Note: sometimes density is referred to as specific gravity.

Quarts (SiO_2)
Hardness 7
Vitreous (glassy) lustre
Clear or white (impurities may change this)
Usually hexagonal habit



Calcite is $Ca(CO_3)$
Hardness 3
Vitreous lustre
Perfect cleavage in 3 directions not at 90^0
Reacts with HCL (effervescence)

Iron pyrite (fool's gold) = FeS_2
Hardness 6 – 6.5 unlike gold = 3
Density of ~ 5
Metallic lustre
Streak is a black
Cubic habit/form
Colour is a brassy yellow that may tarnish to darker hues

Metal	Ore mineral	Formula	Colour	Lustre	Form / Habit	Hardness	Streak	Density (g/cm^3)	Cleavage
Copper	**Chalcopyrite**	$CuFeS_2$	**Brassy**	**Metallic**	**Tetragonal**	3.5 to 4	**Green-black**	**4.2**	None
Gold	**Gold**	Au	**Yellow**	**Metallic**	**Cubic**	3	**--**	**19.3**	None
Iron	**Magnetite**	Fe_3O_4	**Black**	**Metallic**	**Cubic**	6	**Black**	**5.2**	Poor
Lead	**Galena**	PbS	**Grey**	**Metallic**	**Cubic**	2.5	**Grey**	**7.5**	**3 at 90^0**
Tin	**Cassiterite**	SnO_2	**Brown**	**Adamantine**	**Tetragonal**	6-7	**Brown**	**7.0**	Poor
Zinc	**Sphalerite**	ZnS	**Brown**	**Adamantine**	**Cubic**	3.5-4	**Brown**	**4.1**	6 at 60^0

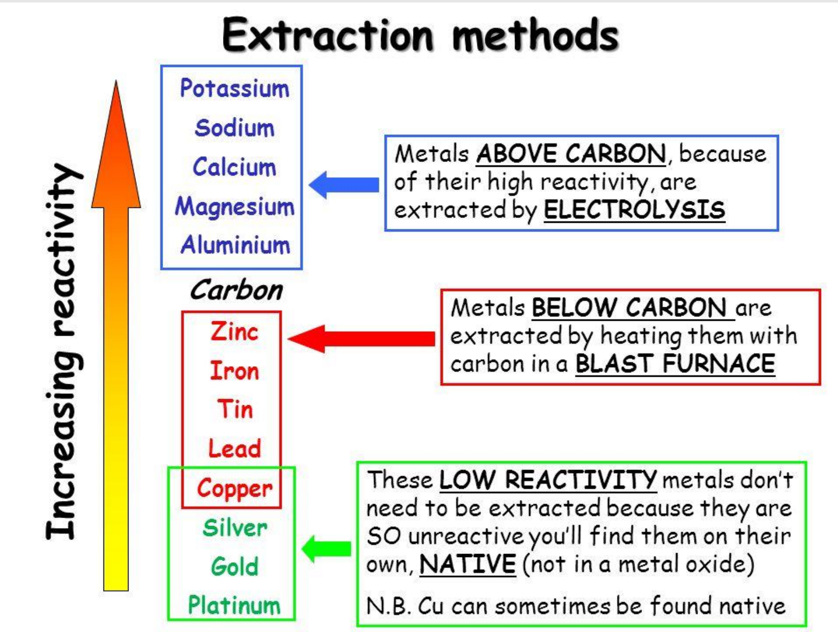
Learn this table well! Try rewriting it out a few times before the exam.

GRADE, CUT-OFF GRADES AND ORE RESERVES

- **The grade** is the amount of metal present in a mineral deposit, usually given as a percentage.
- **The cut-off grade** is the minimum grade that is economic to mine.

The grade may sometimes be quoted in grams per tonne for scarce metals. The cut-off grade for a metal is determined by:

1	**The value of the metal** – the more valuable the lower the cut-off grade.
2	**Demand** – the higher the demand for the metal, the more valuable and lower its cut-off grade will be.
3	**Abundance of a metal** – if they are useful, scarce metals will have a lower cut-off grade.
4	**The size of the ore deposit** – large deposits are economic to mine at lower-cut off grades than small deposits
5	**Costs of mining**, extraction and purification – if it is costly to mine, extract and purify then the cut-off grade will be higher.



Electrolysis is an expensive process since the compounds must allow for the flow of ions. This may involve heating the metal ore until it is molten (lots of heat energy) or using a solution, however, most metal compounds are not soluble.

In addition there are the costs of electricity.

Copper is expensive since its purification is usually done by electrolysis.

The low reactive metals are found in native states but are much rarer with their low grades and low crustal abundance.

We can find the cut-off grade be rearranging the equation for concentration factor

Cut-off grade = $Minimum\ concentration\ factorto\ be\ economic\ \ X\ average\ crustal\ abundance$ (%)

There is a fine link between **cut-off grade and reserves**. When the cut-off grade for an ore deposit raises, the reserves across the world decline because it will no longer be economic to mine lower grade deposits (even if the resource is there). If cut-off grade decreases then reserves will increase.

In the past 100 years, the cut-off grade for copper has reduced from 3% to 0.4%. This is because **higher grade deposits are declining (resources reduced)** and **new technology** has been developed that makes **mining low-grade deposits easier and cheaper.**

The following table is not required to be learnt for OCR but gives a good idea of what metals are the most economical and valuable to our culture.

Metal	Cut-off grade (%)	Average crustal abundance	Minimum concentration factor
Iron	40	5.0	8
Aluminium	35	8.1	4.32
Lead	4	0.0015	2666.67
Zinc	4	0.007	571.43
Tin	1	0.002	500
Copper	0.4	0.007	57.14
Gold	0.001	0.0000004	2500