UNIVERSITY OF ZAMBIA
SCHOOL OF MINES
DEPARTMENT OF GEOLOGY

GGY5159 – ECONOMIC GEOLOGY OF METALLIC MINERAL DEPOSITS

ASSIGNMENT 1 – 18th MARCH 2019 - SOLUTION

(i) COPPER

Discovery

Cu was first discovered in the Middle East in 9000BC. Archaeological evidence suggests that it was the early Mesopotamians who, around 5000 to 6000 years ago, were the first to harness the ability to extract and work with copper.

Physical and Chemical Properties

Cu I native form is reddish-orange in colour (Figure 1). It has an atomic number of 29 and atomic weight of 63.546 Copper melts and boils at 1083ºC and 2567ºC respectively and has a specific gravity of 8.96. It takes a bright metallic lustre, is malleable (ability to be flattened into thin sheets by hammering or rolling), ductile (ability to undergo significant plastic deformation before rupture) and a good conductor of electricity and heat.

Figure 1 Native Copper.

Source Minerals

The main minerals from which copper is extracted include (i) copper carbonates such as malachite, azurite; (ii) copper sulphides such as chalcopyrite and bornite; and (iii) copper oxides such as cuprite.

Uses and Why

Figure 2 shows the global consumption of copper per end-use sector. Generally, copper is used in buildings construction, power generation and transmission, electronic product manufacturing, and the production of industrial machinery and transportation vehicles. Copper is an essential component in the motors, wiring, radiators, connectors, brakes, and bearings used in cars and trucks. An average car contains about 15 kg of Cu as an essential component in the functioning of the motor (good conductor of electricity), wiring (good conductor of electricity), radiator (good conductor of heat), connectors (good conductor of electricity), breaks and bearings (because of wear characteristics - not too hard, not too soft). Cu is essential for maintaining proper health of humans, animals, plants and miro-organisms. For example, without copper human brains, nervous systems and cardiovascular systems would not function normally (https://copperalliance.org.uk/benefits-copper/health/; accessed on 28-04-19). Cu is used as an alloy metal in higher- corrosion resistant Cu-Ni alloys widely used in desalination plant to support the conversion of seawater to fresh water because the alloy is not corroded by seawater. Cu has used in pipes and drainage (plumbing) systems of buildings going as far back as 3500BC because it is durable and has a high recycling rate and thus good for the environment. Cu is used in tiny amounts in solar panels because of its high thermal and electrical conductivity. It is only second to silver. Cu is a very efficient conductor of heat and electricity and as such it reduces the amount of energy needed to power appliances. It is thus used in high efficiency motors that run lifts and air conditioning systems. Cu is used in wind turbine motors as it is a good conductor of electricity. Wind turbines, depending on the technology employed, can use between 400 g and 4 tonnes of Cu. Cu is used as alloying metal in brass (Cu and Zn) and bronze (Cu and Sn) (Figure 3)

and in coinage because of malleability. For example, copper-nickel alloy is applied to the hulls of ships because it does not corrode in seawater and reduces the adhesion of marine life, such as barnacles, thereby reducing drag and increasing fuel efficiency. Brass is more malleable and has better acoustic properties than pure copper or zinc; consequently, it is used in a variety of musical instruments, including trumpets, trombones, bells, and cymbals.

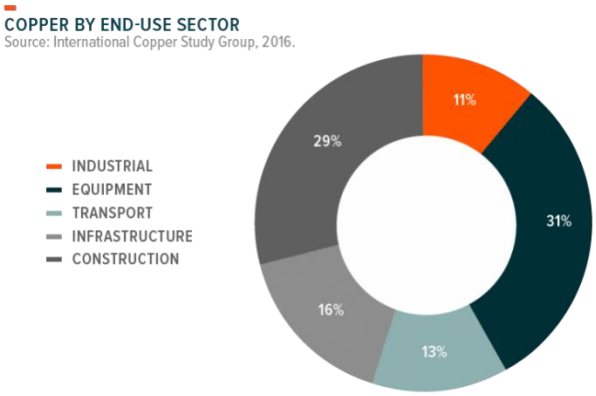

Figure 2 Global copper consumption by end-use sector.

Figure 3 Brass (alloy of Cu and Zn) (left) and bronze (alloy of Cu and Sn) (right).

Current Price

The current price of Cu at the London Metal Exchange (LME) is about US$6500/tonne.

(ii) COBALT

Discovery

It was discovered in 1735 by Georg Brant, a Swedish Chemist although Co compounds had been used for centuries to impart a rich blue color to glass, glazes and ceramics (https://en.wikipedia.org/wiki/Cobalt; accessed on 17-04-19).

Physical and Chemical Properties

Co has an atomic number of 27 and weight of 58.933 g/mol. It melts and boils at 1495ºC and 2927ºC respectively. It is a hard ferromagnetic, silver-white or gray (Figure 4), and brittle metal. It has a density of 8.86 g/cm^3. It is stable in air and does not react with water, can be magnetized, reacts slowly with dilute acids, moderately malleable and ductile.

Figure 4 Cobalt metal.

Source Minerals

The key minerals from which Co is extracted are cobaltite (sulphide; most common; Figure 5), erythrite (hydrated arsenate) and skutherudite (arsenic).

Figure 5 Cobaltite crystal (top left corner).

Uses and Why

Figure 6 shows the global consumption of Co by end-use. Cobalt is used in many alloys & super alloys to make parts in aircraft engines, gas turbine, high-speed steels, corrosion resistant alloys, cemented carbides. Co is used in batteries of electric vehicles. Li-Co-Ni rich batteries emit no tailpipe (exhaust pipe) pollutants when running. Co is one of the metals essential for maintaining proper health of humans, animals, plants and micro-organisms. Co is used in smartphone batteries in which it constitutes 60%.

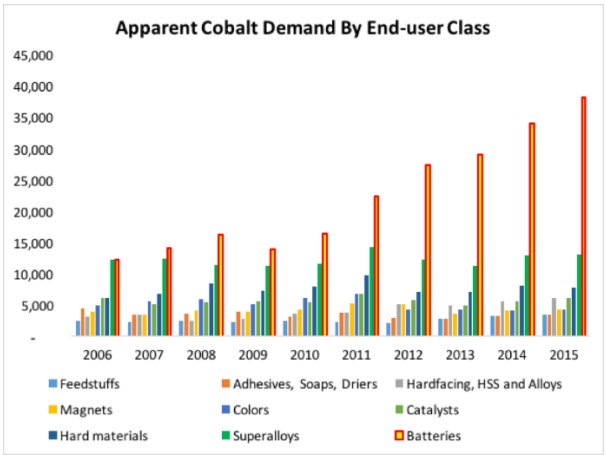

Figure 6 Global cobalt consumption by end-use sector.

Current Price

The current price of Co on the London Metal Exchange (LME) is US$35,000/tonne as at 15th April 2019 (https://www.metalradar.com/lme-prices/; accessed on 18-04-19).

(iii) IRON

Discovery

Iron has been in use for at least 5000 years and goes back to 4000BC (https://wanttoknowit.com/who-discovered-iron/; accessed on 20-04-19). In modern times it is not clearly known who discovered the metal iron.

Physical and Chemical Properties

Fe has an atomic number of 26 and weight of 55.845 g/mol. It melts and boils at 1538°C and 2862°C respectively. It is a hard and brittle. However in its pure form it is a shinny bright white metal (Figure 7), soft, malleable and ductile. It has a density of 7.847 g/cm^3. In the presence of oxygen and moisture Fe corrodes easily.

Source Minerals

The main minerals from which Fe is extracted are hematite and magnetite (Figure 8).

Figure 8 Magnetite (left) and hematite (right).

Uses and Why

Figure 9 shows the global consumption of iron through steel. Steel is used to make paper clips, skyscrapers and everything in between. Fe is used in the production of steel (an alloy of Fe and carbon) and various stainless steels (alloys of steel and metals such as Cr, Mn, Ni etc). Steel is employed in the production of vehicle frames. Fe is one of the essential for maintaining proper health of humans, animals, plants and micro-organisms. Iron helps keep plants and animals alive. Iron plays a role in the creation of chlorophyll in plants and is an essential part of hemoglobin, the substance that carries oxygen within red blood cells. Iron sulfate ($FeSO_4$) is used to treat the blood disease anemia. Stainless steel is employed in the production of products such as knives, folks and surgical materials. Steel and stainless steels are also used in the production of agricultural machinery and equipment. Fe has been used in pipes and drainage systems of buildings going as far back as 3500BC. The use of stainless steel containing Ni has revolutionized the construction of modern buildings (Figure 10). Fe, together with Nd, Bo and Dy, is used in the permanent magnet in many wind turbines.

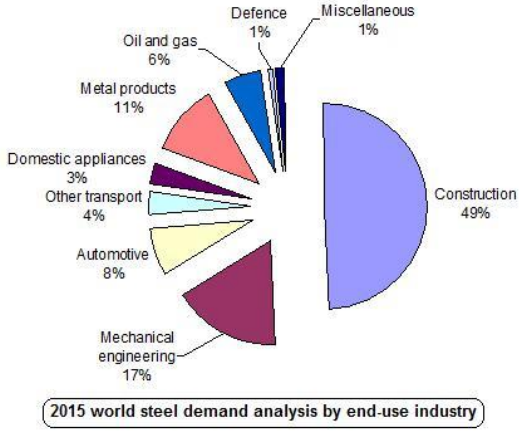

Figure 9 Steel global consumption by end-use sector.

Figure 10 Steel frame for a multi-storey building.

Current Price

The price of Fe sold as iron ore on 18th April 2019 was US$92.91/tonne (https://markets.businessinsider.com/commodities/iron-ore-price; accessed on 22-04-19).

(iv) MANGANESE

Discovery
Discovered in 1774 by Johan Gottlieb Gahn, a Swedish Chemist and Mineralogist although Mn had been used in France 30,000 years before.

Physical and Chemical Properties
Manganese (Mn) atomic number is 25 while its atomic weight is 54.938. Its melting and boiling points are 1246^{o}C and 2061^{o}C respectively. Density of Mn is 7.43 g/cm^{3}. Mn is a hard, brittle and silvery metal (Figure 11).

Figure 11 Electrolytic manganese metal flakes.

Source Minerals
The key ore minerals of Mn are pyrolusite and romanechite (Figure 12).

Figure 12 Romanechite (left) and pyrolusite (right).

Uses and Why
Manganese is too brittle to be of much use as a pure metal. It is mainly used in alloys, such as steel. Steel contains about 1% manganese, to increase the strength and also improve workability and resistance to wear. Manganese steel contains about 13% manganese. This is extremely strong and is used for railway tracks, safes, rifle barrels and prison bars. Drinks cans are made of an alloy of aluminium with 1.5% manganese, to improve resistance to corrosion. With aluminium, antimony and copper it forms highly magnetic alloys. Manganese is an essential element in all known living organisms. Many types of enzymes contain manganese. For example, the enzyme responsible for converting water molecules to oxygen during photosynthesis contains four atoms of manganese. The average human body contains about 12 milligrams of manganese. Without it, bones grow spongier and break more easily.

Current Price
In the year 2018 the price of Mn was US$2,060/tonne.

(v) GOLD

Discovery
Au has a long history as a valuable metal and its history goes as far back as 40,000 BC (https://bebusinessed.com/history/the-history-of-gold/; accessed on 23-04-19).

Physical and Chemical Properties
Gold has an atomic number of 79 and atomic mass of 196.9666. In its purest form, gold is a bright, slightly reddish yellow (Figure 13), dense, soft, malleable, and ductile metal. Gold is one of the least reactive chemical elements,

solid under standard and resistant to most acids. Gold has a density of 19.32 g/cm^3 and a good conductor of heat and electricity (https://en.wikipedia.org/wiki/Gold; accessed on 23-04-19).

Figure 13 Gold metal.

Source Minerals

The main minerals from which gold is extracted are native gold and sulphides to which gold may be attached on negatively charged surfaces.

Uses and Why

Gold has been widely used throughout the world as money for efficient indirect exchange, and to store wealth in hoards. For exchange purposes, mints produce standardized gold bullion coins, bars and other units of fixed weight and purity. Au together with Ag, Cu and W is used for electrical connections within a smart phone as it is a good conductor and never tarnishes. Au is also used as a jewelry metal as it never tarnishes. Because of the softness of pure (24k) gold, it is usually alloyed with base metals for use in jewelry, altering its hardness and ductility, melting point, color and other properties. Only 10% of the world consumption of new gold produced goes to industry,[8] but by far the most important industrial use for new gold is in fabrication of corrosion-free electrical connectors in computers and other electrical devices. Metallic and gold compounds have long been used for medical purposes especially in dentistry where human teeth can be replaced with gold teeth because of it chemical inertness.

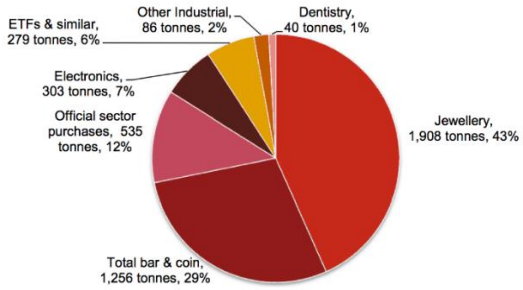

Figure 14 Gold global consumption by end-use.

Current Price

The current price of gold at the LME is US$1,351/Troy ounce on 18th April 2019. A Troy ounce = 1.09714286 ounces = 31.1034768 g. An ounce = 28.3495231 g.

References

All are web-based and are given within the text.