

IS IT IRONMAN? NO, IT'S ALLOYMAN!

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(1) Ironman is a Marvel comic superhero who fights villains and protects humanity while flying in a red and gold painted suit of iron. At least that's what you would think based on his superhero name, however, his suit isn't made of iron at all, it is made of Nitinol which is a nickel-titanium alloy composed of half nickel and half titanium.

(2) Alloys are mixtures of two or more metals or mixtures of metals with non-metals. When these elements are combined to form an alloy, the alloy can have desirable properties that are different from the properties of the individual elements.

(3) Alloys are made in the following way. A metal is melted down and is used as the hot liquid base within which other elements can be melted and dissolved. The first metal is called the primary metal or base metal. When the liquid mixture is cooled it will produce a solid alloy. For example, 24 karat gold is pure 100% gold metal but 18 karat gold is an alloy. 18 karat gold is made by taking 75% melted gold and dissolving 25% of another metal like copper, silver or platinum into the gold. Though 24 karat gold is more valuable than 18 karat gold, pure gold is very soft. Adding the other metal to the gold makes it much harder which is ideal for making jewellery that won't bend or break easily.

(4) Iron is a relatively strong metal but it turns into rust (iron oxide) when exposed to the oxygen in the air. Pure iron is also compressible making it bend when under pressure. If you take pure iron and add a little bit of carbon to it, even less than 2%, it forms an extremely useful alloy called steel. Steel is much stronger than iron and less compressible so it does not bend as easily. Modern skyscrapers wouldn't be possible without steel to build the strong frames needed to hold up the weight of the building. Rebar is a rod of steel that is embedded into concrete to create reinforced concrete. This type of concrete is able to bear more weight than concrete alone. The Burj Khalifa in Dubai is the tallest building in the world. It stands at 2717ft / 828m tall with 163 floors. The building's foundation alone contains 31,400 metric tons of rebar, which if connected end to end, would be able to stretch



Nitinol Wires, Credit: Peter Maerki

over more than a quarter of the Earth's surface.

(5) If you take steel and add chromium to it (at least 10%) you create a different alloy called stainless steel. Unlike iron or steel, stainless steel is very rust resistant making it ideal for tools and devices that need to resist corrosion. Rust resistance is made possible when chromium atoms in the stainless steel react with the oxygen atoms in the air to create a compound called chromium oxide. Once formed, the chromium oxide covers and seals the entire surface of the stainless steel so that the iron atoms within do not come into contact with oxygen. This prevents the formation of iron oxide (rust). If the stainless steel surface is scratched, the chromium on the newly exposed surface reacts very quickly with oxygen to reform the protective coating. Stainless steel can be found everywhere. It's in appliances, cutlery, knife blades, surgical instruments and many more objects. Besides steel and stainless steel, other common alloys are: brass (made from a mixture of copper and zinc), bronze (made from a mixture of copper and tin) and amalgam (made from a mixture of mercury and another metals).

(6) Though Ironman is fictional, the alloy that makes up his suit, Nitinol (nickel-titanium alloy), is not. Nitinol is a very special alloy with unique properties. It is a shape memory alloy (SMA) which means that it has the ability to "remember" its original shape and reform this shape even after it has been severely bent or deformed. Nitinol is also superelastic which makes it useful for many applications. It has been used to make eyeglass frames that can't

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warp or break, flexible underwires for bras and watch springs for clocks.

(7) Nitinol is also biocompatible, meaning that it can safely be put inside of the human body. An example is the use of Nitinol wires to make dental braces for teeth. Thin Nitinol wires are formed at high temperatures to create a specific shape and length. When the wires are at room temperature they cool down and expand which lengthens the wires. Lengthened Nitinol wires are then shaped around the teeth to make braces. When the patient closes their mouth, body heat will warm the Nitinol wires causing them to contract back into their

shorter original shape. This tightens the braces which puts tension on the teeth to reposition them over time. Nitinol's biocompatibility also makes it useful for reattaching tendons to bones and for knee replacement surgery. Nitinol is also used to make stents which are tubular devices inserted into damaged blood vessels to prevent them from collapsing.

(8) Though the nickel in the Nitinol can have negative effects on health, the titanium in the Nitinol reacts with oxygen in the air to quickly form a titanium oxide coating over the Nitinol. This seals the nickel inside the Nitinol and prevents it from leaking into the body.

Article Questions

1) What is an alloy?

2) How is 24 karat gold different from 18 karat gold?

3) What is steel made of?

4) Besides composition, what is the main difference between iron and steel?

5) What is rebar and why is it needed to make tall buildings?

6) What are the three elements found in stainless steel alloy?

7) Why doesn't stainless steel rust?

8) What is Nitinol composed of and give three unique properties of Nitinol.