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Inequality, Rubber, and Thermodynamics in Indonesia

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The *Washington Post* recently wrote an article concerning fumes. This particular story relates the country of Indonesia and its sulfur miners. Indonesia's Mount Ijen, though being a popular tourist attraction, is the site of a rich agglomeration of sulfur. Unfortunately, while the miners will work in Mount Ijen for the money, their health suffers as a result. Mount Ijen releases many toxic fumes, which have proven to be deleterious to people's health. This is particularly concerning when some miners spend night after night at this site. However, the volcano houses a rare substance that has high market value. The said substance has been proven to be useful in both bleach and the process that vulcanizes rubber. These fumes are released when the miners break through solid blocks of sulfur. When broken apart, gaseous sulfur is released and, as a result, inhaled by the miners. Adverse effects of sulfur fumes include an abbreviated life span as well as multiple deformities. For all their troubles, the Indonesian miners can expect to make pennies a day, nowhere near enough to sustain an individual, let alone a family.[1]

The *Washington Post* did an excellent job reporting on the Mount Ijen miners. Although this is a story far from home, it is important for all people to know of the trials that individuals in foreign countries undergo to provide resources for everyday products that citizens of core countries purchase in large quantities. Mining in the U.S., thankfully, has benefitted from advances in technology and workers' rights legislation that protect miners from the dangerous conditions that Indonesia's miners face on a daily basis. Unfortunately, the Mount Ijen miners do not have any advanced technology and must haphazardly break through slabs of sulfur to extract the substances that the market hungers for. This poignant story is a resounding reminder that unfair and unsafe conditions exist throughout the world. The chilling consequences that miners face throughout their lives are also important reminders of the dangers of toxic fumes and why it is important for them to be controlled when possible. Mount Ijen's natural toxic fumes cannot sufficiently be controlled to the point that mining on this volcano would be safe, so it truly is disheartening to learn that so many individuals literally sacrifice their lives in the pursuit of less than a living wage.[1]

Moving on from the human aspects of volcano mining, Mount Ijen and the vulcanized rubber that can be created as a result of the mining are prime examples of aspects of the chemistry concept known as entropy. To define the term, entropy is essentially a measure of the freedom of motion that particles have within a particular system. Colloquially, entropy is sometimes described as disorder due to the fact that more freedom of motion can result in high kinetics and a visually chaotic and unorderly system, but entropy is better understood as how much particles can move within their system. The different configurations of particles within systems that help visualize the freedom of motion that particles have within a system are known as microstates. Because a high entropy would be the result of a high degree of freedom of motion, gases inherently have a higher entropy than solids or liquids do.[3] Relating this back to the article, it should be recalled that the miners were suffering from the toxicity of the sulfur fumes.[1] The slabs from which the sulfur fumes emanate from are in the solid state of matter, giving them a low entropy. However, once the slabs are broken down, which allows the gaseous sulfur to sublimate into the surroundings and be inhaled by people, they are in the gas state of matter. This means that within Mount Ijen, comparatively, there is higher entropy found in the toxic fumes of sulfur than there is in the solid slabs of sulfur.[3]

Entropy is just a subtopic of a much larger field of study in chemistry known as thermodynamics. Thermodynamics is the study of all forms of energy and how these forms relate to one and other. Thermodynamics has four fundamental laws, two of which can be easily related to Mount Ijen. The First Law of Thermodynamics states that the energy of the universe is conserved. This concept can be represented by the equation:

$$\Delta E_{sys} + \Delta E_{surr} = \Delta E_{univ} = 0$$

This concept holds true always, regardless of what type of work is done unto a system, for how long that work is done, etc.[3] Now, recall the activities taking place on Mount Ijen. Miners exert physical energy on solid sulfur slabs as they work by hitting the slabs with tools. This action causes the reaction of gaseous sulfur fumes being released from the slabs, lowering the total mass of the sulfur slab.[1] However, despite all this, there is not any energy that is created, nor is there any energy that is destroyed. All of it is conserved, in accordance with the First Law of Thermodynamics. The Second Law of Thermodynamics states that the entropy of the universe always increases due to a thermodynamic process. This concept is represented by the inequality:

$$\Delta S_{univ} > 0$$

This law can also be seen at Mount Ijen. When the miners exert physical energy onto the solid sulfur slabs through the work they perform on it, gaseous sulfur fumes are released.[1] Gases have a higher entropy than solids, so there is an increase in entropy of the universe, just as the Second Law of Thermodynamics states.[3]

Finally, the process of vulcanizing rubber relates to thermodynamics, as well. Rubbers have entropy-driven elasticity, meaning that the stretchy nature of rubber results from changes in entropy. Rubber releases heat when it is stretched, which causes entropy to decrease.[2] The exothermic releasing of heat results in a negative delta H value, otherwise known as enthalpy. Enthalpy is another important measurement in thermodynamics. Essentially, it looks at the total heat content of a system. Because the process of rubber stretching outwards results in a negative enthalpy and a positive entropy, this process would be spontaneous at all temperatures. Spontaneity is defined as an action that results without an external stimulus. Because both a positive entropy (S) and a negative enthalpy (H) are both favored by thermodynamic processes, this process can be considered spontaneous at any temperature.[3]

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