The Many Faces of Energy

1 Joule = 10 million ergs
1 electron Volt (eV) = 1.6 x 10^{-19} Joules
1 degree (K) = 8.62 x 10^{-5} eV
1 calorie = 4.2 Joules
1 kiloWatt hour = 3.6 x 10^{6} Joules
1 eV = 1.78 x 10^{-33} grams
1 AMU = 931.5 million eV (MeV)

Energy comes in many forms, and each one can be measured in terms of its own convenient units. For example, if you were interested in creating a balanced diet, you would measure food energy by its calorie content, not by its number of Joules!

The table to the left shows a few of the equivalent units that scientists use to keep track of energy in different kinds of systems.

Problem 1 - In a chemical reaction, an energy of about 2.5 eV is required to activate the reaction to create a new compound. To form a single molecule of the compound: A) How many Joules of energy is this? B) How many calories is this?

Problem 2: A star has a surface temperature of 20,000 K. About what is the average energy per atom in electron Volts?

Problem 3: The mass of an electron is 9.11 x 10^{-28} grams. What is its equivalent mass in kiloelectron Volts (keV)?

Problem 4: A proton and a neutron are combined to form a deuterium nucleus. Their total individual masses equal 2.016490 AMU, but the mass of a deuterium nucleus is only 2.014102 AMU. If the mass difference to form the deuterium is 0.002388 AMU, how much energy does this energy difference represent in: A) million electron volts (MeV)? B) grams? (Note: this is called the binding energy of the nucleus.)

Problem 5: An astronomer detects X-ray light from a pulsar with an energy of 15 keV. About what is the temperature of the gas emitting this light?

Answer Key

Problem 1 - In a chemical reaction, an energy of about 2.5 eV is required to activate the reaction to create a new compound. To form a single molecule of the compound: A) How many Joules of energy is this? B) How many calories is this?

A) Answer: 2.5 eV x (1.6 x 10^{-19} Joules / 1 eV) = **4.0 x 10^{-19} Joules per molecule.**
B) Answer: 4.0 x 10^{-19} Joules x (1 calorie / 4.2 Joules) = **9.5 x 10^{-20} Joules per molecule.**

Problem 2: A star has a surface temperature of 20,000 K. About what is the average energy per atom in electron Volts? Answer: 20,000 K x (8.62 x 10^{-5} eV / K) **= 1.7 eV**.

Problem 3: The mass of an electron is 9.11 x 10^{-28} grams. What is its equivalent mass in kiloelectron Volts (keV)? Answer: 9.11 x 10^{-28} grams x (1 eV/1.78 x 10^{-33} grams) = 512,000 eV = **512 keV**.

Problem 4: A proton and a neutron are combined to form a deuterium nucleus. Their total individual masses equal 2.016490 AMU, but the mass of a deuterium nucleus is only 2.014102 AMU. If the mass difference to form the deuterium is 0.002388 AMU, how much energy does this energy difference represent in: A) million electron volts (MeV)? B) grams?

Answer: A) 0.002388 AMU x (931.5 MeV/1 AMU) = **2.2 MeV**.

Answer: B) 2.2 MeV x (1,000,000 eV/1 MeV) x (1.78 x 10^{-33} grams/ eV) = **3.9 x 10^{-27} grams.**

Problem 5: An astronomer detects X-ray light from a pulsar with an energy of 15 keV. About what is the temperature of the gas emitting this light? Answer; 15 keV x (1,000 eV/ 1 keV) x (1 K/8.62 x 10^{-5} eV) = **174 million degrees Kelvin**.

Problem 6: A physicist wants to create a proton with a mass of 938 MeV in his accelerator. What is the minimum energy, in Joules, that he will need to provide? Answer: 938 MeV x (1,000,000 eV/1 MeV) x (1.6 x 10^{-19} Joules/ 1 eV) = **1.5 x 10^{-10} Joules.**

Note: $E = mc^2$ is the basis for stating the mass of a particle 'm' in terms of its equivalent electron-Volt energy, E. Physicists understand that $m = E/c^2$ but drop the speed of light constant, c, as a shorthand way of stating a particle's mass..