Module 1 – Fusion basics

FuseNet educational materials for secondary school

Additional exercises v.1.0

This document contains additional exercises to accompany Module 1: Fusion basics of the FuseNet educational materials for secondary schools.

Legend:

*: introductory exercise: short exercise, requires little to no calculation.

**: intermediate exercise, could require some calculation or some more advanced thinking.

***: challenging exercise, might require advanced calculation or derivation.

Chapter 1: Energy and its role in our world:

Exercise A.1.

When we speak of energy, the most commonly used unit remains the Joule (*J*). To put everything in perspective it is important to get a bit of a feeling for what a Joule is:

a. Look up what a Joule is in SI units. What does this mean? Compare this with the units of velocity (*m/s*) and acceleration (m/s^2).
b. [Multiple choice] Which of the following answers represents approximately 1 Joule of energy?
    A. The kinetic energy of a tennis ball moving at 22 km/h,
    B. The energy needed to lift an apple 1 meter from the ground,
    C. The energy required to light a 1 Watt light bulb for 1 second,
    D. All of the above,
    E. None of the above, a Joule cannot be represented like this, it is too abstract as a concept.
c. How much do you expect the total energy consumption of the world to be? Look up the total energy consumption of the world in Joules and compare it with your estimate. Was your estimate close?

*Exercise A.2

Look up the **energy mix** (what energy sources produce which percentage of the total energy supply) of your country. Pay attention to the units and what type of energy is given.

a. Where did you find the data? How do you know whether the data you found can be trusted? Explain why you trust this information.
b. What units are used in the data?

The most common unit for energy is the **Joule** (*J*), which is equal to a Newton meter (*Nm*, in SI-units: $kg\ m^2\ s^{-2}$). Energy can be expressed in many different units. In the energy sector often **kilowatt-hours** (*kWh*) or **tonnes of oil equivalent** (*toe*) are used because of the large amounts of energy. Suffixes are added to indicate larger (or smaller) quantities, e.g. *MWh, GWh*, *Mtoe* (megawatt-hours, gigawatt-hours, million tonnes of oil equivalent).

c. Compare the units of Joule (*J*), kilowatt-hours (*kWh*) and tonnes of oil equivalent (*toe*). How many *Joules* is one *kWh*? How many *Joules* is one *toe*? How many *Joules* is one *Mtoe*?

Most often, **primary energy** is used for this type of data regarding energy.

d. What does primary energy mean?

e. In most countries, the so-called **fossil fuels** dominate the energy supply. Compare different countries and percentages, what is the contribution by renewable sources such as solar and wind energy?

f. Is a large portion of the energy mix derived from sustainable sources? What about renewable sources?

<u>*Exercise A.3</u>

a. Make an estimated guess of the used energy in Joules of a household, a city, a country and the world.
b. Make an estimated guess of the total used energy in industry and the total energy used by individuals on this planet

Try to find a source for questions a and b above.

c. Which sources did you use?
d. Does it match with your given answers?
e. What do you notice?

Chapter 2: The energy of the stars:

<u>*Exercise A.4</u>

a. What type of atom is displayed in figure 4 of the student reader? Look up what this isotope is used for.

b. Make a schematic drawing similar to figure 4 of a hydrogen atom.

c. Make a schematic drawing similar to figure 4 of a deuterium atom.

d. Make a schematic drawing similar to figure 4 of a tritium atom.

<u>*Exercise A.5</u>

Energy scales: compare the energy of a mars bar with the following energy sources: gasoline, coal, fission and fusion. Hint; first find the factors between Calories, Kcal and Joule.

<u>**Exercise A.6</u>

Fusion and fission are two physical processes which both produce enormous amounts of energy through nuclear reactions. This energy comes from the mass defect that occurs with nuclear reactions.

Whether a nucleus can produce energy through fission or fusion depends on the binding energy of the nucleus. Additionally, nuclei with a high binding energy are more stable and heavier atoms are more unstable.

a. Find the meaning of 'fusion' and 'fission' in the oxford dictionary and describe the difference between fusion and fission at the level of an atom.
b. Try to describe in terms of binding energy why heavier nuclei are more unstable.
c. From the graph: what would be the point of change from fusion to fission? Can you explain why?
d. Based on this graph, what material do you expect to be present in large quantities in very old stars?

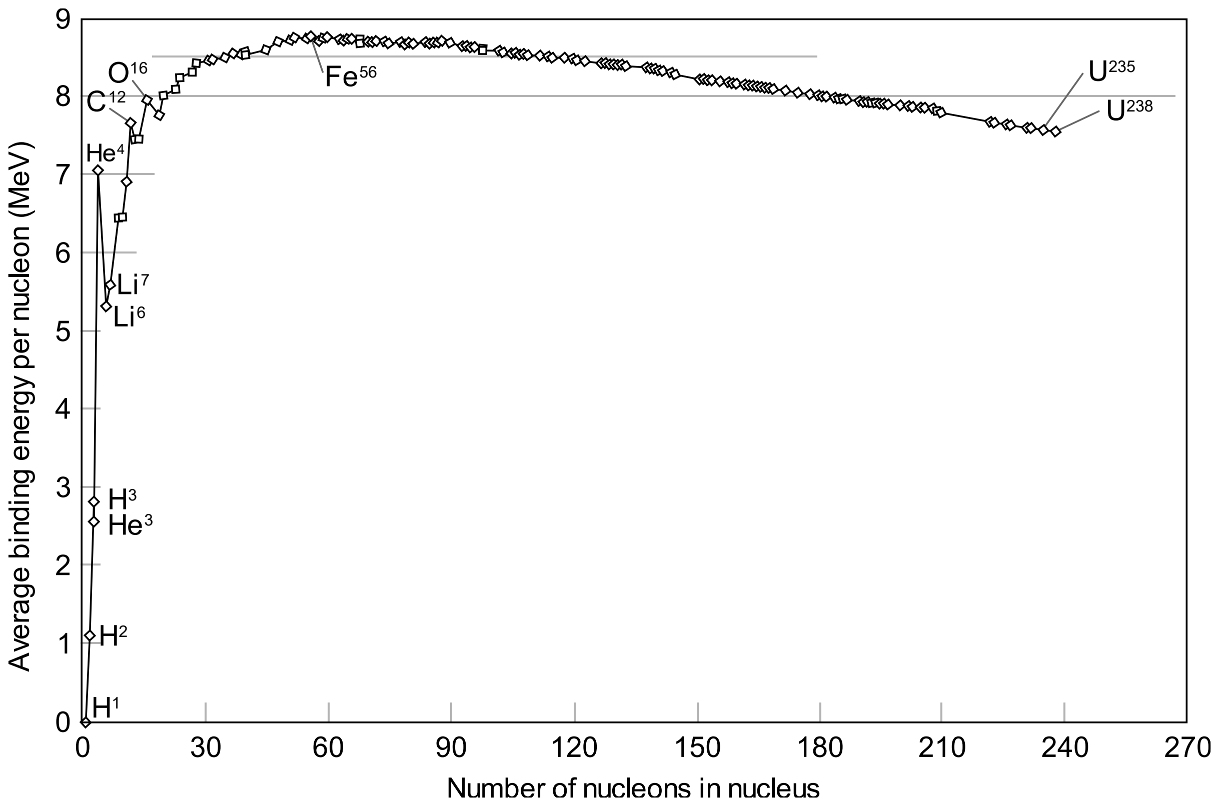

Figure: Average binding energy per nucleon. Source: Wikimedia commons

<u>**Exercise A.7</u>

a. Calculate the energy released through mass defect, with Einstein's formula, for a D-T fusion reaction.
b. Calculate the Energy released through mass defect, with Einstein's formula, for a nuclear fission reaction of Uranium-235.

*** Exercise A.8

If you compare the temperature at the core of the sun, the temperature at the surface of the sun and the density of sun with the temperature and density in fusion reactor on Earth: then why is the needed temperature in a fusion reactor on Earth much higher?

Chapter 3: plasma, the fourth state of matter

*Exercise A.9

A well-known example of a real life application of plasmas is a plasma tv or plasma display. How do these 'plasma' objects relate to a physical plasma as described in chapter 3? Try to find out, using the internet, how plasma tv's work and what the difference is between a physical plasma and plasma tv's or plasma displays.

**Exercise A.10

a. Plasmas can usually be observed to glow. But why do plasma's glow? Explain.
b. When a plasma is fully ionized, will it still be glowing? Explain your answer

Chapter 4: Building a Fusion Device

*Exercise A.11

Let us have a look at how a toroidal magnetic field, together with a poloidal magnetic field, combines into a helical magnetic field. Follow the following steps:

a. Draw an arrow (or a vector) in a random direction.
b. Draw another arrow (or vector) starting at the end of the first, in a different direction.
c. Draw a third arrow starting at the initial point of the first arrow and ending at the final point of the second arrow.

Now the third arrow is the result of (vector) addition of the first two arrows.

If we now do the same for a poloidal arrow (or vector) and a toroidal arrow (or vector), what is the result?