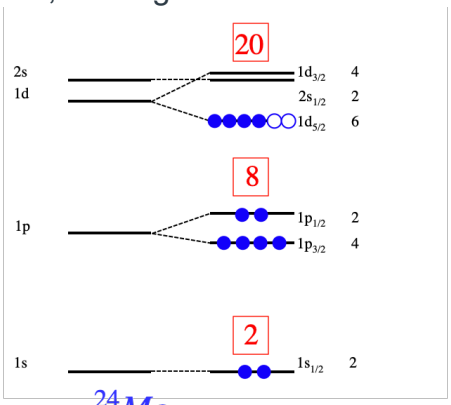
NuPEERS Rare Isotopes HOMEWORK

1) We want to study the clustering in ^{24}Mg:
   a. How many protons and neutrons does this nucleus have?
      12 protons & 12 neutrons
   b. How many alpha particles would this be?
      6 α (^{4}He) particles
   c. Show the shell structure of the protons and neutrons in ^{24}Mg with the diagram below, for its ground state. Does it have any closed shells?



$^{24}_{12}Mg_{12}$ protons

OR neutrons

The last shell is the $1d_{5/2}$ and it only has 4 nucleons out of the 6 available, so it is OPEN

2) We are performing an experiment to understand the structure of ^{12}Be, using the following reaction:

$$^{13}\text{B} + \text{d} \rightarrow {}^{3}\text{He} + {}^{12}\text{Be}$$

We are using a beam of ^{13}B at 30 MeV/u and a gas detector filled with deuterium (D_2) with density $\rho(D_2) = 0.171\ kg/m^3$ at 1 atmosphere

   a. How many protons and neutrons does our beam and product nucleus have?

$$^{13}_{5}B_8 + {}^{2}_{1}H_1 \rightarrow {}^{3}_{2}He_1 + {}^{12}_{4}Be_8$$

   d- deuterium, it is a proton and a neutron, or ^{2}H
   B- boron, 5 protons, so 8 neutrons
   Be – Beryllium, 4 protons, so 8 neutrons

   b. What are the half-lives of ^{13}B and ^{12}Be?
   From Nudat , we have:

$$t_{1/2}\ (^{13}_{5}B) = 17.16 \pm 0.18\ ms$$
$$t_{1/2}\ (^{12}_{4}Be) = 21.46 \pm 0.05\ ms$$

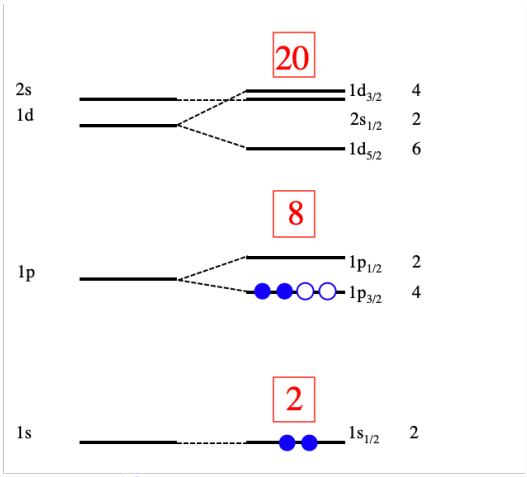
   If you have a certain number of nuclei at a certain time, after this half-time $t_{1/2}$ half of the nuclei will have decayed.

   c. How many nucleons are transferred in the reaction?

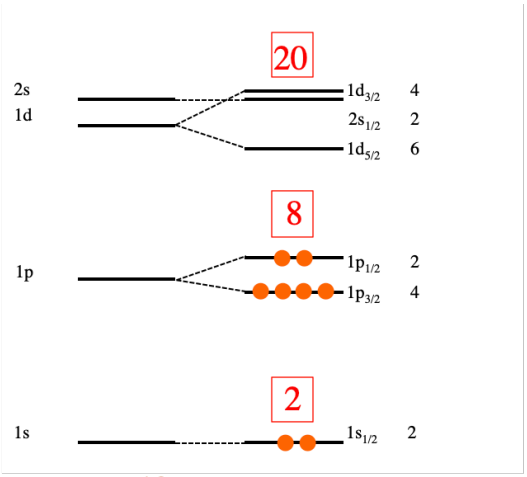
Here we concentrate on the heavier nuclei in the reaction.
We start from $^{13}_{5}B$ and go to $^{12}_{4}Be$ so we remove a **proton** from nucleus in this reaction

d. What type of nuclear reaction is this?
Since we remove one nucleon only, it could be a transfer OR a knockout reaction. However, we are given the initial energy of the reaction as 30 MeV/u, which means that we are at low energy and have a **transfer reaction**.

e. Show the shell structure of the protons and neutrons in ^{12}Be with the diagram above, for its ground state. Does it have any closed shells?



$^{12}_{4}Be_{8}$ protons



$^{12}_{4}Be_{8}$ neutrons

On the proton side, we have 4 protons. We first fill the $1s_{1/2}$ shell with two protons and fill that one, then we have two protons left in the $1p_{3/2}$ shell, but this one can have 4 protons. This means that the last proton shell is **open**.

On the neutron side, we have now 8 neutrons. This will fill the $1s_{1/2}$ shell with 2 neutrons, $1p_{3/2}$ shell with four neutrons, and then the $1p_{1/2}$ shell with the remaining two neutrons. This means that ALL shells on the neutron side are **closed**.

Remember as a rule that we are filling the shells from the lowest one and just going in order, so when we talk about a open/closed shell, we usually talk about the last shell, that is the first one that can pick up a nucleon easily if it is open, or can have a nucleon removed or excited to a higher level.