Step by Step Radioactive Decay and Bombardment

Radiochemistry

The "attractive" nuclear force between protons and neutrons is usually stronger than the repulsion energy of the protons. But some isotopes have too many protons and not enough neutrons, so there is too much repulsion. These atoms are unstable (radioactive).
Atoms with more than 83 protons are always unstable (atomic #'s > 83).

I. Nuclear Decay Reactions

(Atoms will decay to get to/toward a stable proton to neutron ratio, thus becoming a stable isotope.) The rate of decay is measured in half-lives. This is the time it takes for half of the starting material to decay into another atom.
If a half-life is 6 hours, in 6 hours half of the material will decay into another atom, leaving 50% of the original sample.
After another 6 hours, half of that 50 % will decay, leaving 25 % of the original sample.
After another 6 hours, half of that 25% will decay, leaving 12.5% of the original sample and so on.

In nuclear decay reactions, particles can be emitted. In emission the particle is given off, so it will go on the product side of the reaction.

Or the particles can be captured, if the particle is taken into the isotope. Then the particle will go on the reactant side of the reaction.

Or the isotope can give off **Gamma (γ) radiation (i.t. = isomeric transition)**, which is light energy (electromagnetic spectrum). Since this is light energy and not a particle, the energy carries through matter easily. Gamma rays go through more matter, than any of the other forms of radiation. They can be stopped by 60 cm of Al metal or 7cm of Pb metal.

Isotopes usually do a combination of these processes of losing particles and electromagnetic energy. Each element will have numerous isotopes, some being stable isotopes and some being radioactive. These radioactive isotopes will then decay to become stable. A table of isotopes will usually tell you which isotopes are stable and which are radioactive, usually stating the type of radioactive decay.

Alpha Decay ($_2^4He$):

An alpha (α) particle { $_2^4\mathbf{He}$ (nucleus only) } is emitted. An alpha particle barely passes through paper, since it is a helium nucleus, which is fairly large. The atoms in the paper will slow and eventually stop (if the paper is thick enough) the alpha particle as it attempts to move through the paper atoms.

Ex. 1) ^{265}Bh decays by α-emission.

The "α" tells you that an alpha particle is involved. Alpha particles are usually emitted, even if it is not stated! This means the $\mathbf{{}_{2}^{4}He}$ will go on the product side of the reaction.

${}_{107}^{265}Bh \rightarrow {}_{2}^{4}He +$? (Bh is atomic # 107 on the periodic table.)

Elements do not balance in these reactions, because the atom is actually falling apart into pieces. But the Law of Conservation of Mass still applies. The mass number (on top) must balance, so that the total mass on the reactant and product side will be equal. And the atomic number (on the bottom), telling us the number of protons, must balance, so that the total number of protons on the reactant and product side will be equal. The mass of the element will be conserved and this encompasses the number of neutrons being conserved and the number of protons being conserved.
For the mass number:

${}^{265}Bh \rightarrow {}^{4}He +$? $265 = 4 + ?$
$261 = ?$

So we will have:

${}^{265}Bh \rightarrow {}^{4}He + {}^{261}$

For the atomic number:

${}_{107}Bh \rightarrow {}_{2}He + ?$ $107 = 2 + ?$
$105 = ?$ Look at a periodic table.
Element 105 is Dubnium (Db).

So putting it all together:

$\mathbf{{}_{107}^{265}Bh \rightarrow {}_{2}^{4}He + {}_{105}^{261}Db}$

<u>Beta Decay:</u>
Traditionally a beta (β) particle is an electron. This can be distinguished by a β-, since an electron is negative (${}_{-1}^{0}e$).

A positron is a positive electron (anti-matter) and can be distinguished by a β+ (${}_{+1}^{0}e$). Beta particles are smaller than alpha particles and can go through more atoms, before they are stopped. Beta particles are stopped by 3 mm of Al metal or 10 mm of wood.

When a beta particle is emitted a neutron is transformed into a proton, which remains in the nucleus, emitting an e^- and an anti-neutrino, which is another type of particle.

****Beta decay is always emission, unless stated as electron capture <u>(e.c. or ε)</u>.**

β- ($_{-1}^{0}e$):

Ex. 2) ^{99}Mo decays by β emission (β-).

β is always emission, unless stated as electron capture. The $_{-1}^{0}\mathbf{e}$ will go on the product side.

$_{42}^{99}Mo \rightarrow {}_{-1}^{0}e + \ ?$ (Mo is atomic #42 on the periodic table.)

The Law of Conservation of Mass still applies. The mass number (on top) must balance, so that the total mass on the reactant and product side will be equal. And the atomic number (on the bottom), telling us the number of protons, must balance, so that the total number of protons on the reactant and product side will be equal. The mass of the element will be conserved and this encompasses the number of neutrons being conserved and the number of protons being conserved.

$_{42}^{99}Mo \rightarrow {}_{-1}^{0}e + \ ?$

mass # 99 = 0 + ?
99 = ?

atomic # 42 = -1 + ?
43 = ? Element 43 is Technetium (Tc).

$\mathbf{{}_{42}^{99}Mo \rightarrow {}_{-1}^{0}e + {}_{43}^{99}Tc}$

Positron or β+ ($_{+1}^{0}e$) :

Ex. 3) ^{207}Bi decays by positron emission (β+).

β is always emission, unless stated as electron capture. The $_{+1}^{0}\mathbf{e}$ will go on the product side.

$_{83}^{207}Bi \rightarrow {}_{+1}^{0}e + \ ?$ (Bi is element #83 on the periodic table.)

The Law of Conservation of Mass still applies. The mass number (on top) must balance, so that the total mass on the reactant and product side will be equal. And the atomic number (on the bottom), telling us the number of protons, must balance, so that the total number of protons on the reactant and product side will be equal. The mass of the element will be conserved and this encompasses the number of neutrons being conserved and the number of protons being conserved.

$_{83}^{207}Bi \rightarrow {}_{+1}^{0}e + ?$

mass # 207 = 0 + ?
207 = ?

atomic # $83 = +1 + ?$

$82 = ?$ Element #82 is Lead (Pb).

$\mathbf{{}_{83}^{207}Bi \rightarrow {}_{+1}^{0}e + {}_{82}^{207}Pb}$

<u>Electron Capture (e.c. or ε) or β- capture:</u>

Ex. 4) ^{102}Rh decays by electron capture (e.c. or ε).

Electron Capture or e.c. tells us that the electron or β- will go on the reactant side, since it is captured and taken into the atom.

${}_{45}^{102}Rh + {}_{-1}^{0}e \rightarrow ?$ (Rh is element #45 on the periodic table.)

The Law of Conservation of Mass still applies. The mass number (on top) must balance, so that the total mass on the reactant and product side will be equal. And the atomic number (on the bottom), telling us the number of protons, must balance, so that the total number of protons on the reactant and product side will be equal. The mass of the element will be conserved and this encompasses the number of neutrons being conserved and the number of protons being conserved.

${}_{45}^{102}Rh + {}_{-1}^{0}e \rightarrow ?$ mass # $102 + 0 = ?$

$102 = ?$

atomic # $45 + (-1) = ?$

$44 = ?$ Element #44 is Ruthenium (Ru).

$\mathbf{{}_{45}^{102}Rh + {}_{-1}^{0}e \rightarrow {}_{44}^{102}Ru}$

<u>II. Bombardments</u>

-linear or cyclotron particle accelerators can be used to combine smaller atoms into larger atoms or to break up large atoms into smaller atoms.

Often other particles are involved, such as neutrons (${}_{0}^{1}n$) and protons (${}_{1}^{1}p$).

Ex. 1) ^{249}Bk is bombarded by ^{22}Ne to make a new heavier element and 4 neutrons (${}_{0}^{1}n$). Write the reaction.

If Bk and Ne are bombarded, they are collided together, so they will both be on the reactant side of the reaction.

$_{97}^{249}Bk + _{10}^{22}Ne \rightarrow$?

Bk is element #97 on the periodic table.
Ne is element #10 on the periodic table.

The question states that 4 neutrons ($_{0}^{1}n$) are <u>produced</u>, so they will go on the <u>product</u> side.

$$_{97}^{249}Bk + _{10}^{22}Ne \rightarrow 4\ _{0}^{1}n + ?$$

The Law of Conservation of Mass still applies. The mass number (on top) must balance, so that the total mass on the reactant and product side will be equal. And the atomic number (on the bottom), telling us the number of protons, must balance, so that the total number of protons on the reactant and product side will be equal. The mass of the element will be conserved and this encompasses the number of neutrons being conserved and the number of protons being conserved.

$$_{97}^{249}Bk + _{10}^{22}Ne \rightarrow 4\ _{0}^{1}n + ?$$

$249 + 22 = 4\ (1) + ?$ (mass #)
$271 = 4 + ?$
$267 = ?$

$97 + 10 = 4\ (0) + ?$ (atomic #)
$107 = 0 + ?$
$107 = ?$

$$\mathbf{_{97}^{249}Bk + _{10}^{22}Ne \rightarrow 4\ _{0}^{1}n + _{107}^{267}Bh}$$

<u>**If you have to go backwards and you get to a point like this:</u>

$$_{97}^{249}Bk + _{10}^{22}Ne \rightarrow _{107}^{267}Bh + ?$$

$249 + 22 = 267 + ?$ (mass #)
$271 = 267 + ?$
$4 = ?$

$97 + 10 = 107 + ?$ (atomic #)
$107 = 107 + ?$
$0 = ?$

Then, we have a particle which should be $_{0}^{4}$

Your particle choices are

$_{-1}^{0}e$ for electrons (0 for mass, negative atomic)
$_{0}^{1}n$ for neutrons (positive mass, 0 for atomic)
$_{1}^{1}p$ for protons (positive mass, positive atomic)

The only choice for ${}_{0}^{4}$ would be (positive mass and 0 for atomic), which is a neutron. Now how many neutrons would equal ${}_{0}^{4}$, that would be $4({}_{0}^{1}n) = {}_{0}^{4}$.

$$\mathbf{{}_{97}^{249}Bk + {}_{10}^{22}Ne \rightarrow 4\ {}_{0}^{1}n + {}_{107}^{267}Bh}$$