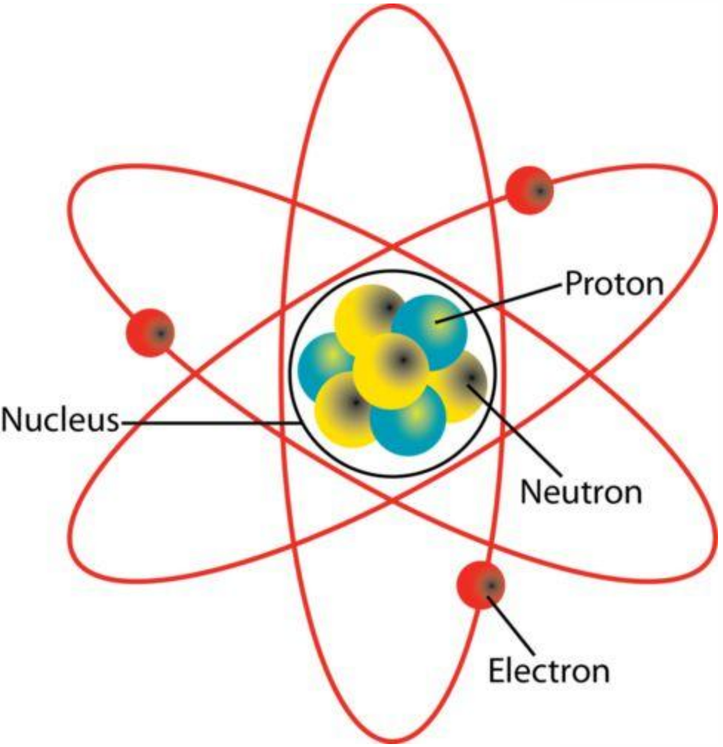
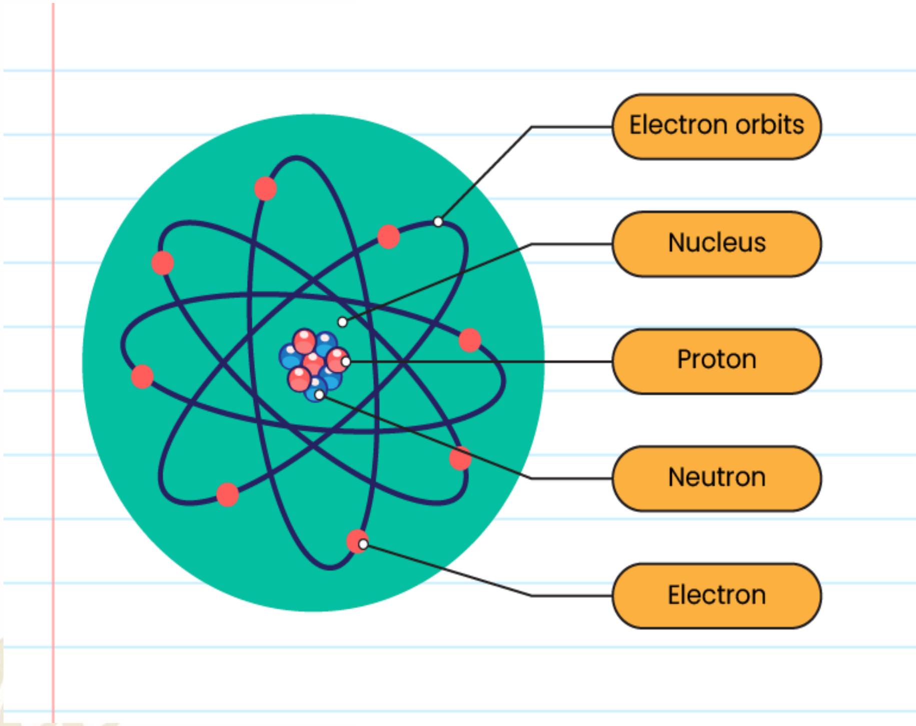
Physics Grade 12 LS/ GS





Chapter 18

Atom nucleus

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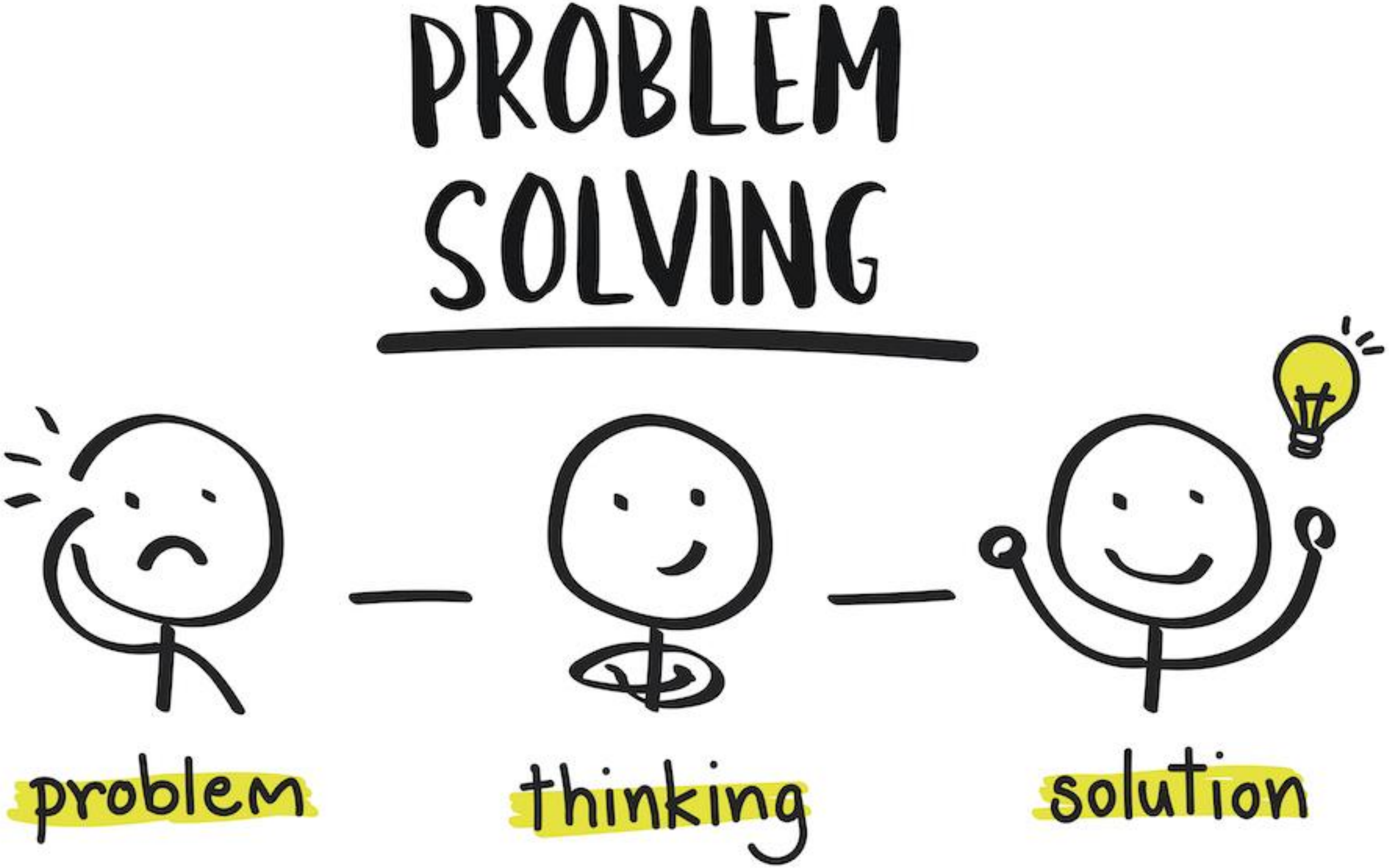
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Exercise 1 stability of atoms

The uranium nucleus $^{235}_{92}U$ has a mass of 234.9935u. Given $1u = 931.5MeV/c^2$; $r_0 = 1.2fm$; $m_p = 1.00728u$; $m_n = 1.00866u$;

1. **Indicate the constituents of this nucleus.**
2. **Calculate the radius of this nucleus.**
3. **Calculate the mass defect in u and in MeV/c^2.**
4. **Deduce in MeV the binding energy per nucleons.**
5. **The binding energy per nucleon of $^{2}_{6}C$ is 7.67957MeV. Which nucleus (uranium or carbon) is more stable**

Exercise 1 stability of atoms

1. **Indicate the constituents of this nucleus.**

In neutral atom no of protons=no of electrons=Z=92

Mass number: A=235

Number of neutrons: N=A-Z=235-92=143

2. **Calculate the radius of this nucleus.**

$$r = r_0 \times A^{\frac{1}{3}}$$

$$r = 1.2 \times 10^{-15}(235)^{\frac{1}{3}}$$

$$r = 7.405 \times 10^{-15} m$$

Exercise 1 stability of atoms

3. Calculate the mass defect in u and in $5 MeV/c^2$

$$\Delta m = \left[Zm_p + (A - Z)m_n\right] - m_X$$

$$\Delta m = [92 \times 1.00728 + 143 \times 1.00866] - 234.9935\text{u}$$

$$\Delta m = [92.66976 + 144.23838] - 234.9935\text{u}$$

$$\Delta m = 236.90814\text{u} - 234.9935\text{u}$$

$$\Delta m = 1.91464\text{u}$$

$$\Delta m = 1.91464\text{u} \times 931.5$$

$$\Delta m = 1783.487\text{MeV}/c^2$$

4. Deduce in MeV the binding energy per nucleons.

$$B.E = \Delta mc^2$$

$$B.E = 1783.487\,\frac{MeV}{c^2} \times c^2$$

$$B.E = 1783.487MeV$$

$$\frac{B.E}{A} = \frac{1783.487MeV}{235}$$

$$\frac{B.E}{A} = 7.589MeV$$

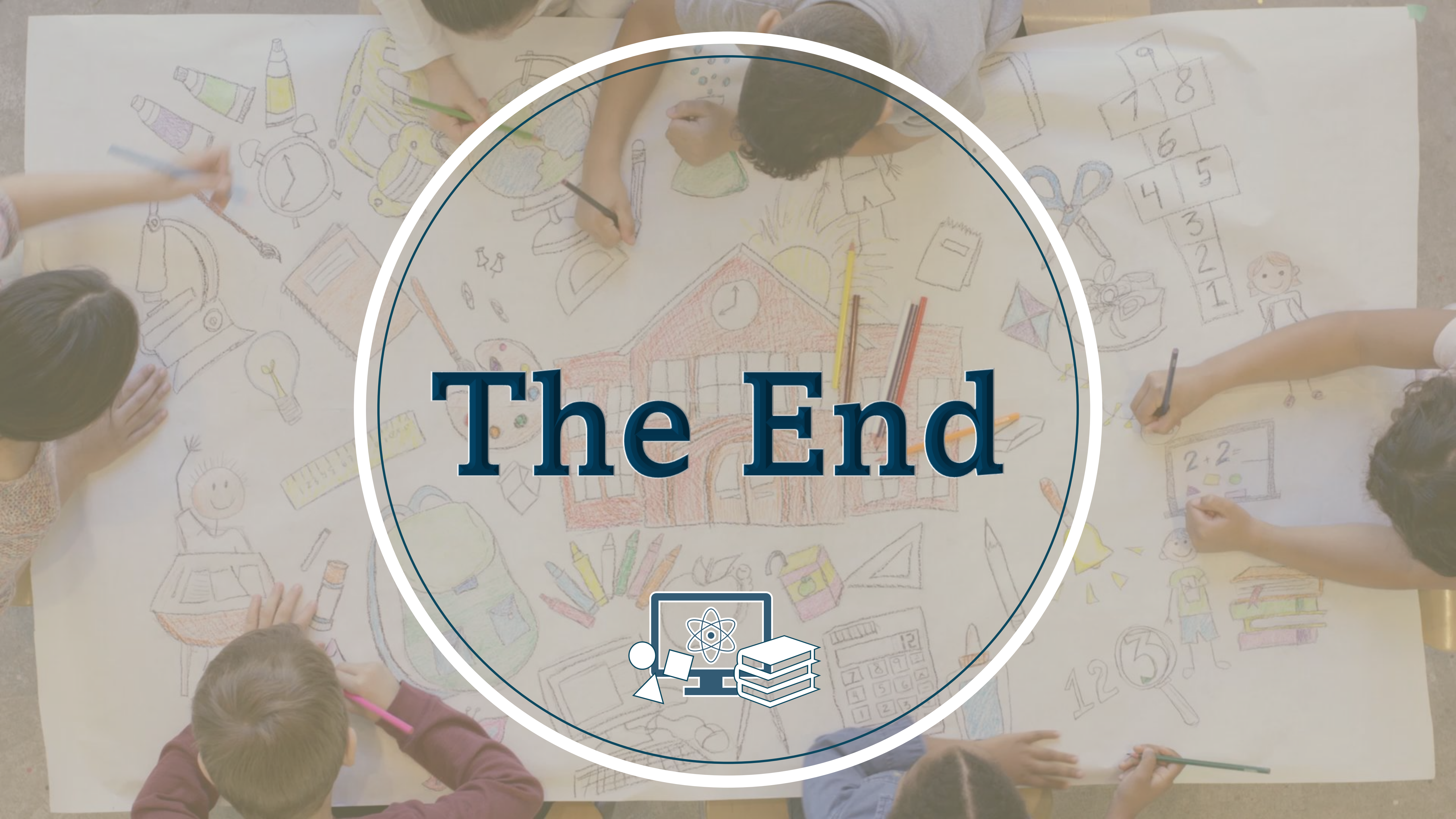
5. The binding energy per nucleon of ${}^{2}_{6}C$ is 7.67957MeV. Which nucleus (uranium or carbon) is more stable.

For uranium: $\frac{\mathrm{B.E}}{A} = 7.589\mathrm{MeV}$

For carbon: $\frac{\mathrm{B.E}}{A} = 7.679\mathrm{MeV}$

Then B.E/A of carbon> B.E/A of uranium then:

The carbon nucleus is more stable than uranium nucleus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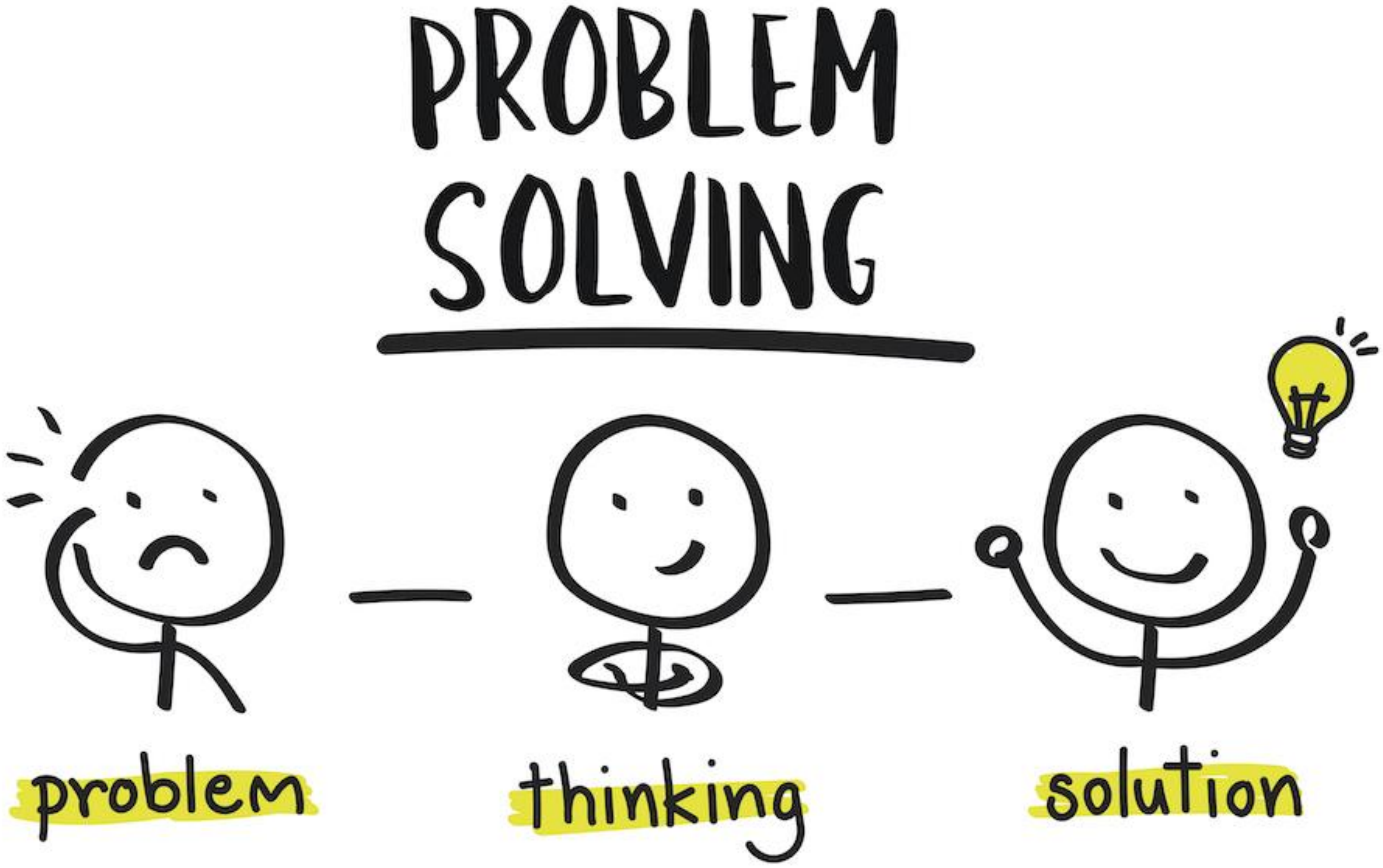
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Exercise 2 Nuclei and stability

In nature, unstable nuclei decay to produce more stable nuclei.

Part A: the more stable nucleus:

Consider the two nuclides $^{23}_{11}Na$ and $^{23}_{12}Mg$ of respective masses 22.989u and 22.994u.

1. **Determine the radius of each nucleus, and calculate the density of each.**
2. **Determine the binding energy per nucleon of each nuclide.**
3. **Which nuclide decays to produce the other? Explain.**

Exercise 2 Nuclei and stability

$e = 1.6 \times 10^{-19} C$	$m_n = 1.00866u$	$m_P = 1.00727u$
$1eV = 1.6 \times 10^{-19} J$	$1u = 1.66 \times 10^{-27} kg$	$c = 3 \times 10^{8} m/s$
$N_A = 6.022 \times 10^{23} /mole$	$r_0 = 1.2 \times 10^{-15} m$	

1. Determine the radius of each nucleus.

$$r_{Na} = r_0 A^{1/3}$$

$$r_{Na} = 1.2 \times 10^{-15} (23)^{\frac{1}{3}}$$

$$r_{Na} = 3.41 \times 10^{-15} m$$

$$r_{Mg} = r_0 A^{1/3}$$

$$r_{Mg} = 1.2 \times 10^{-15} (23)^{\frac{1}{3}}$$

$$r_{Mg} = 3.41 \times 10^{-15} m$$

2. Calculate the density of each.

$$\rho_{Na} = \frac{\text{mass}}{\text{volume}} = \frac{m_P \times A}{\frac{4}{3}\pi r^3} = \frac{m_P \times A}{\frac{4}{3}\pi r_0 A}$$

$$\rho_{Na} = \frac{m_P}{\frac{4}{3}\pi r_0}$$

$$\rho_{Na} = \frac{1.00727 \times 1.6 \times 10^{-27}}{\frac{4}{3} \times 3.14 \times 1.2 \times 10^{-15}}$$

$$\rho_{Na} = 2.3 \times 10^{-17} kg/m^3$$

Exercise 2 Nuclei and stability

$$\rho_{Mg} = \frac{\text{mass}}{\text{volume}} = \frac{m_P \times A}{\frac{4}{3}\pi r^3} = \frac{m_P \times A}{\frac{4}{3}\pi r_0 A}$$

$$\rho_{Mg} = \frac{m_P}{\frac{4}{3}\pi r_0}$$

$$\rho_{Mg} = \frac{1.00727 \times 1.6 \times 10^{-27}}{\frac{4}{3} \times 3.14 \times 1.2 \times 10^{-15}}$$

$$\rho_{Mg} = 2.3 \times 10^{-17} kg/m^3$$

3. Determine the binding energy per nucleon of each nuclide.

$$\Delta m = \left(\left[Zm_p + (A - Z)m_n\right] - m_{Na}\right)$$

$$\Delta m = ([(11 \times 1.00728 + (23 - 11)1.00866] - 22.982)$$

$$\Delta m = ([11.08008 + 12.10392] - 22.982)$$

$$\Delta m = (23.184 - 22.982)$$

$$\Delta m = 0.202u$$

Exercise 2 Nuclei and stability

$$\frac{E_{Na}}{A} = \frac{\Delta m.c^2}{A} \times 931.5Mev/c^2$$

$$\frac{E_{Na}}{A} = \frac{0.202.c^2}{23} \times 931.5Mev/c^2$$

$$\frac{E_{Na}}{A} = 8.181MeV/nucleon$$

Exercise 2 Nuclei and stability

$$\Delta m(Mg) = \left(\left[Zm_p + (A - Z)m_n\right] - m_{Na}\right)$$

$$\Delta m = ([(12 \times 1.00728 + (23 - 12)1.00866] - 22.994)$$

$$\Delta m = ([12.08736 + 11.09526] - 22.994)$$

$$\Delta m = (23.18262 - 22.994)$$

$$\Delta m = 0.18862u$$

$$\frac{E_{Mg}}{A} = \frac{\Delta m.c^2}{A} \times 931.5Mev/c^2$$

$$\frac{E_{Mg}}{A} = \frac{0.18862.c^2}{23} \times 931.5Mev/c^2$$

$$\frac{E_{Mg}}{A} = 7.639MeV/nucleon$$

4. Which nuclide decays to produce the other? Explain.

Since the $\frac{E_{Na}}{A} = 8.181MeV/nucleon > \frac{E_{Mg}}{A} = 7.639MeV/nucleon$

Then Na is stable and Mg is non stable.

Therefore Mg will decays to produce the more stable nucleus Na

Part B: isotopes of carbon

Carbon has several isotopes. A 100g sample of carbon contains 98.89% of ${}^{12}_{6}C$ and 1.11% of ${}^{13}_{6}C$.

1. Define the term isotopes.

Isotopes are atoms of same element having the same atomic number (Z) but different mass number (A).

2. Calculate the number of ${}^{13}_{6}C$ atoms found in this sample. (Neglect the mass of the electrons.)

The number of ${}^{13}_{6}C$ atoms founded in this sample is:

$$N_C = \frac{m}{M} \times N_{Av}$$

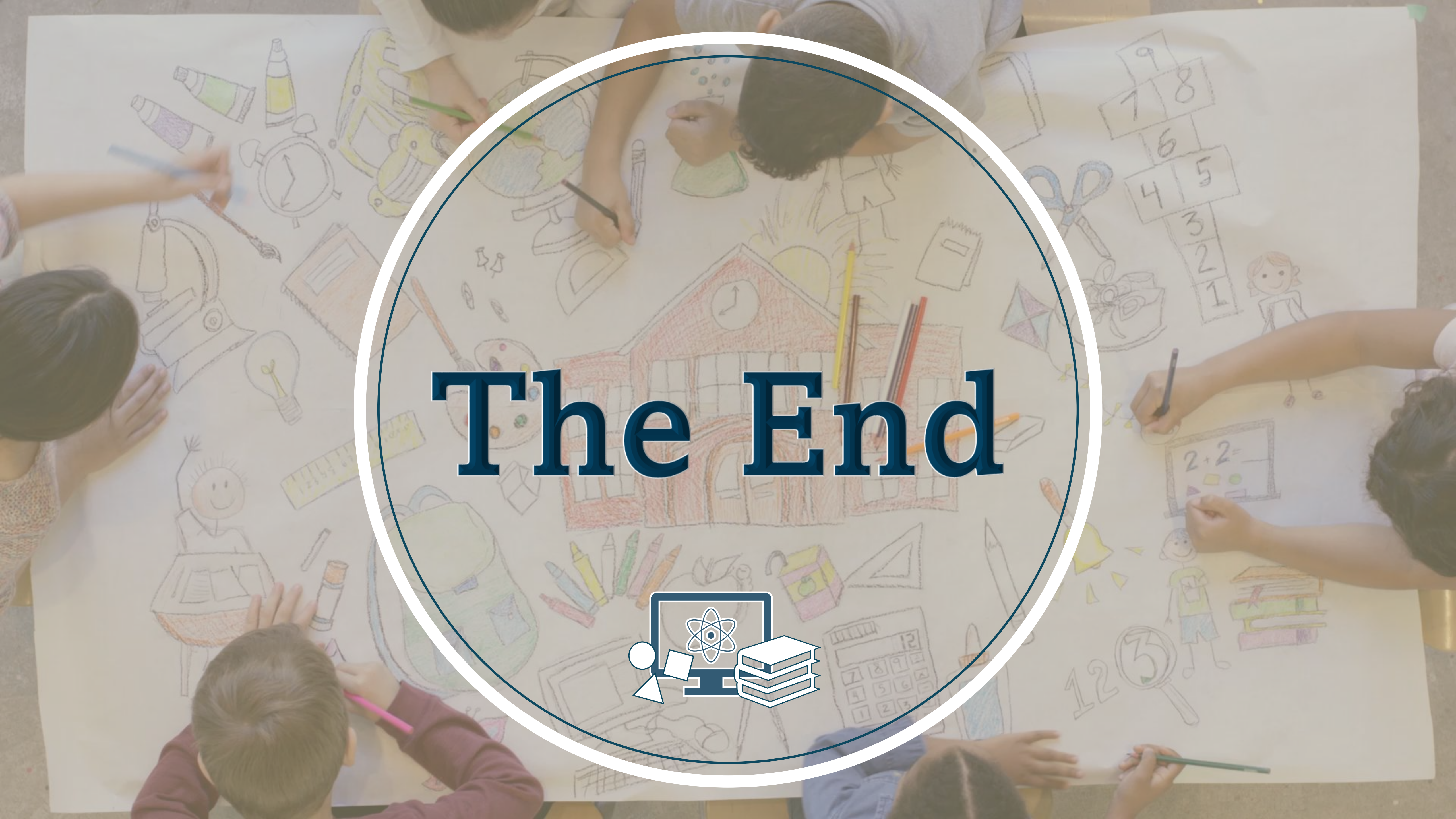
But the percentage by mass ${}^{13}_{6}C$ is 1.11%

$$m_C = \frac{1.11}{100} \times 100\text{g} = 1.11\text{g}$$

$$N_C = \frac{m}{M} \times N_{Av}$$

$$N_C = \frac{1.11}{13} \times 6.02 \times 10^{23}$$

$$N_C = 0.514 \times 10^{23} nuclides$$



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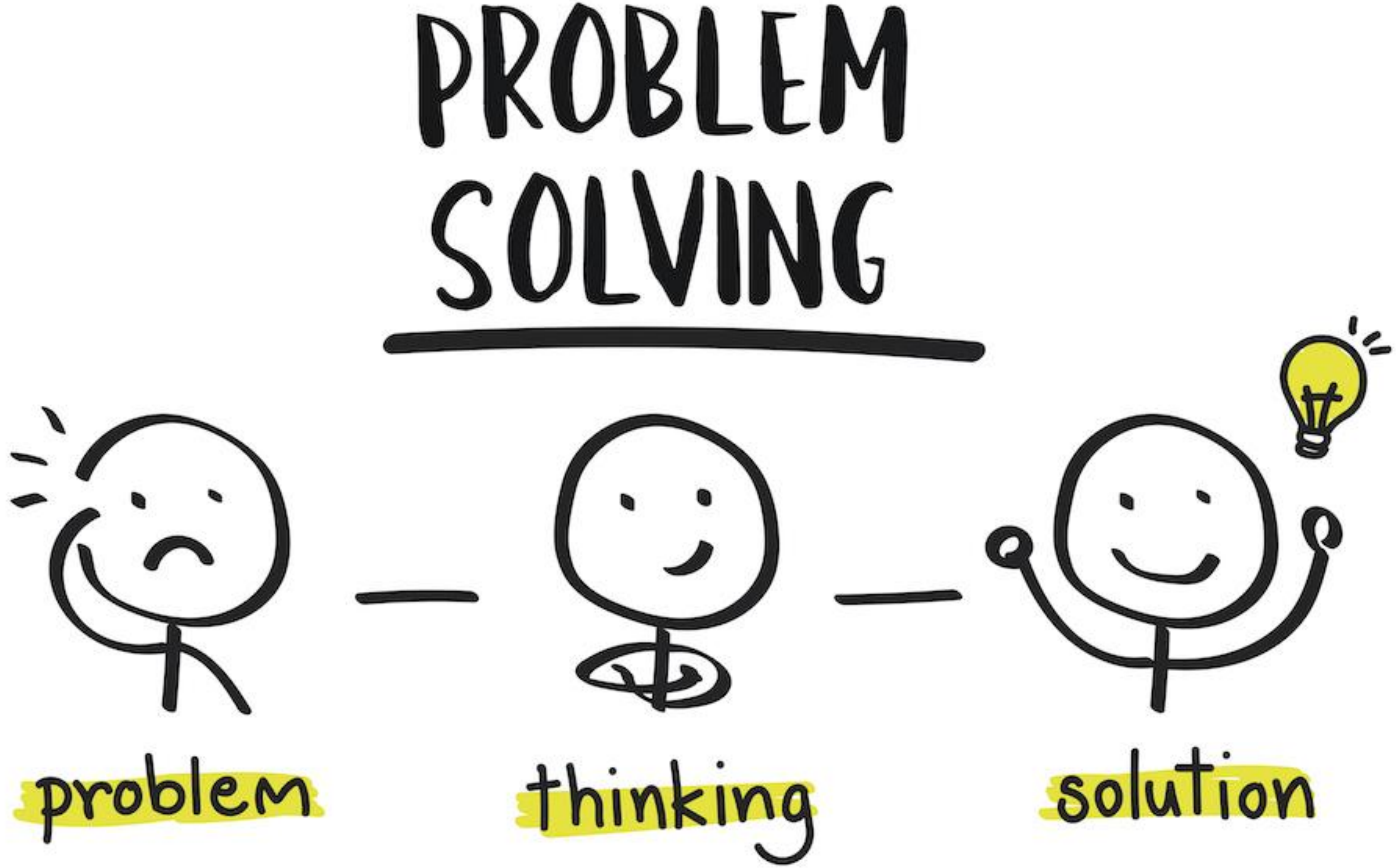
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Exercise 3 density of oxygen

Consider the following isotopes $^{14}_{8}O$; $^{15}_{8}O$and $^{16}_{8}O$.

1) **Define the term isotopes and justify why those atoms are isotopes.**
2) **Calculate the radius of the $^{16}_{8}O$ nucleus. Given $r_0 = 1.2 fm$.**
3) **Calculate the volume of the nucleus of this isotope.**
4) **Deduce the density of $^{16}_{8}O$ nucleus, knowing that the mass of a nucleon is $m_0 = 1.67 \times 10^{-27} kg$**

Exercise 3 density of oxygen

$^{14}_{8}O$; $^{15}_{8}O$ and $^{16}_{8}O$;

1) **Define the term isotopes and justify why those atoms are isotopes.**

Isotopes of an element are nuclei having the same charge number (Z) but different mass numbers (A).

$^{14}_{8}O$; $^{15}_{8}O$ and $^{16}_{8}O$ are isotopes since they are element are nuclei having the same charge number (Z=8) but different mass numbers (A=14; A=15 and A=16).

Exercise 3 density of oxygen

${}^{14}_{8}O$; ${}^{15}_{8}O$ and ${}^{16}_{8}O$;

2) Calculate the radius of the ${}^{16}_{8}O$ nucleus. Given $r_0 = 1.2 fm$

$$r = r_0 \times A^{\frac{1}{3}}$$

$$r = 1.2 \times 10^{-15} (16)^{\frac{1}{3}}$$

$$r = 3.023 \times 10^{-15} m$$

Exercise 3 density of oxygen

3)Determine the volume of the nucleus of this isotope.

$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3}\pi \times (3.023 \times 10^{-15})^3$$

$$V = 1.15 \times 10^{-43} m^3$$

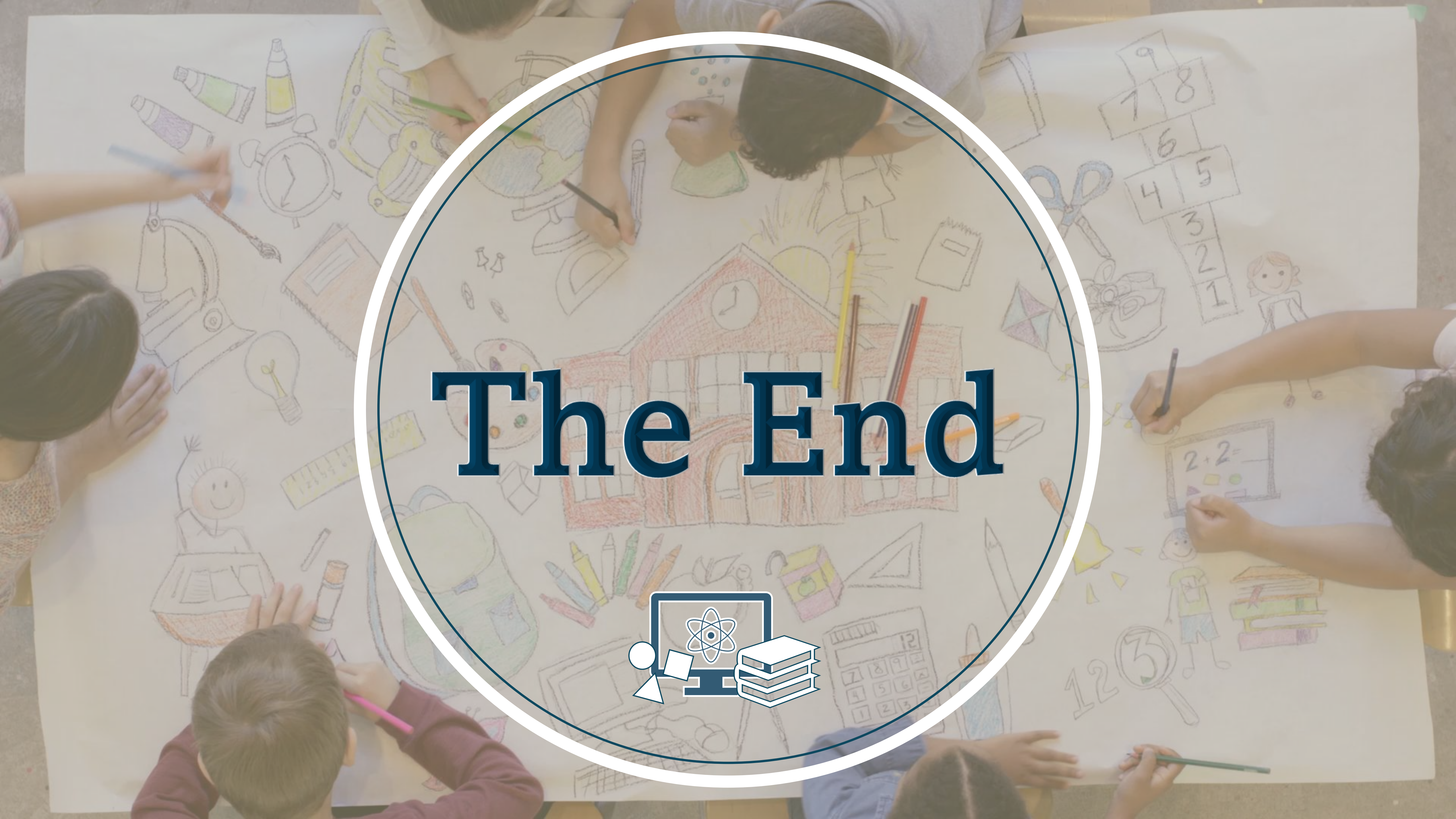
Exercise 3 **density of oxygen**

4) Deduce the density of ${}^{16}_{8}O$ nucleus, knowing that the mass of a nucleon is $m_0 = 1.67 \times 10^{-27} kg$

$$\rho = \frac{m}{V} \Rightarrow \rho = \frac{A \times m_0}{V}$$

$$\rho = \frac{16 \times 1.67 \times 10^{-27} kg}{1.15 \times 10^{-43} m^3}$$

$$\rho = 2.3 \times 10^{-27} kg/m^3$$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