i **Front page**

i **Equations**

The equations are relevant for all the questions.

i **Constants**

The constants are relevant for all questions.

1 **Question 1**

[30 points]

The ground state of $^{40}_{19}K$ has nuclear spin 4 and negative parity. In 90% of the cases this nuclide decays by β^- to the ground state of ^{40}Ca, and in 10% of the cases by β^+ and/or electron capture to an excited state of ^{40}Ar, which subsequently is de-excited to the ground state by γ emission of quantum energy 1460 keV. The half-life of ^{40}K is $1.25 \cdot 10^9$ years.

a) Explain that 4^- is a possible ground state of ^{40}K.

b) The sequence of low-energy states of the shell model is
$1s_{1/2}, 1p_{3/2}, 1p_{1/2}, 1d_{5/2}, 2s_{1/2}, 1d_{3/2}, 1f_{7/2}, 2p_{3/2}, 1f_{5/2}, 2p_{1/2}$.
Classify the β^- transition to ^{40}Ca in terms of degree of forbiddenness and whether it is Fermi and/or Gamow-Teller type.

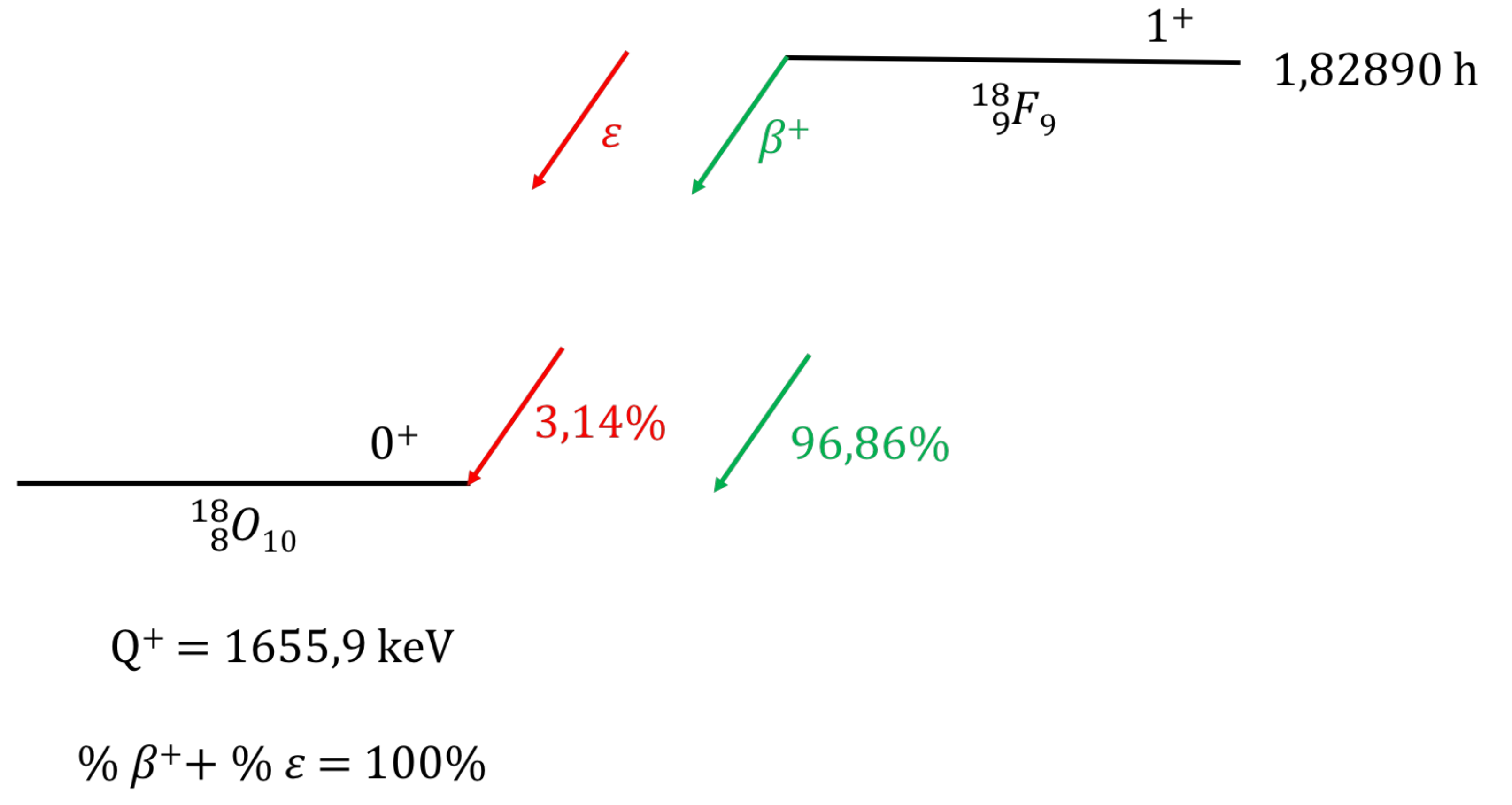
c) Write the definition of the Q value of a nuclear reaction, and derive the formula for the Q value of β^+ decay, expressed by atomic masses, and also expressed by mass excess values. Calculate the Q value of β^+ disintegration using the following mass excess values (in μu units): ^{40}Ar: -37617, ^{40}K: -36001, ^{40}Ca: -37409.

d) How can you explain the fact that ^{40}K decays by both β^- and β^+/EC processes?

Fill in your answer here

Maximum marks: 30

2 **Question 2**



[20 points]

In a positron emission tomography (PET) exam at the hospital a patient is injected with an activity of 500 MBq of ^{18}F.

a) What is the total effective dose to the patient?
If you make assumptions, please justify/explain them.
Information about the decay of ^{18}F is given in the figure. Assume uniform distribution of radiation in the body and no physiological clearance.

b) In stead of a uniform distribution of radiation in the body you can rather assume a slightly more realistic scenario where the ^{18}F activity accumulates both in the bladder (40%) and in the brain (60%).

Re-estimate the total effective dose to the patient.

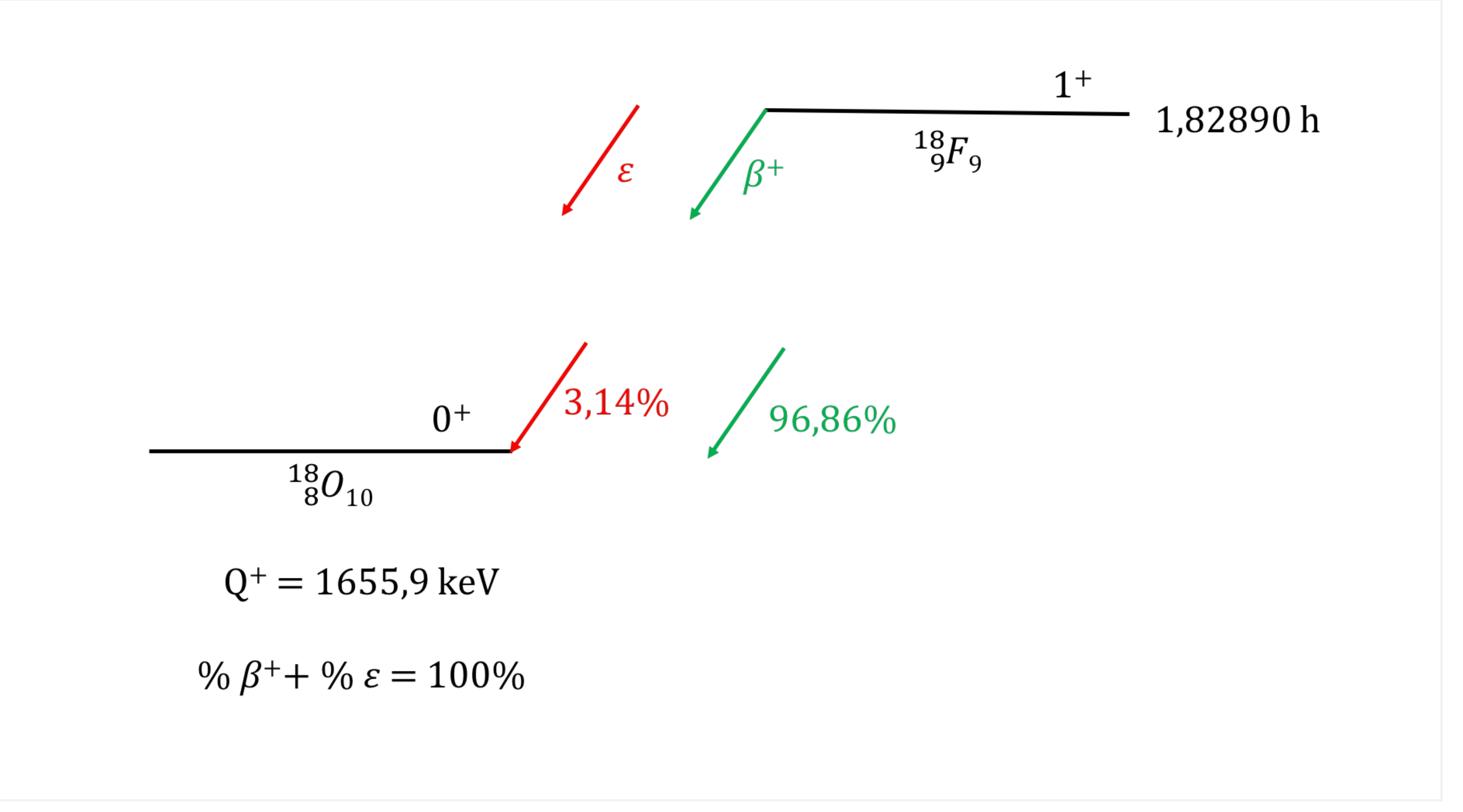
You can use 2 kg and 100 g for the brain and bladder masses, respectively, and 0.01 and 0.04 for the corresponding weighting factors.

Do you think the estimation is correct? If no, why?

Fill in your answer here

Maximum marks: 20

3 **Question 3**



[10 points]

You have been lucky and gotten a job at the new cyclotron facility at the hospital. Your responsibility is production of ^{18}F and your boss expects you to deliver 90% of the maximum ^{18}F activity at 07:30 in the morning.

When do you have to be at work and start ^{18}F production?

You can assume that the number of target nuclei are constant.

Fill in your answer here

Maximum marks: 10

4 Question 4

[10 points]

In the second project, two of the posters were about radioactive dating.

Describe the principle of radioactive dating, what instruments / equipments can be used for the measurements and explain the physics behind how the age is calculated.

What are the main drawbacks / uncertainties in radioactive dating?

Fill in your answer here

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Words: 0

Maximum marks: 10

5 # Question 5

[15 points]

A neutron source produces a flux of neutrons of intensity Φ_{inc} and energy E. In order to protect a worker in front of the source, a wall of thickness L has to be built. This wall can be modelled with a potential barrier $V > E$. To monitor the health of the worker, the worker wears a detector that measure the neutron flux.

a) Sketch a simple drawing showing how you model this problem (assume that we live in a 1D world!). Show in the sketch the characteristics of the wavefunction describing the neutron.

b) Assume a simple model for the tunneling, in the limit where the tunneling probability is small. What is the (approximate) expression for the flux of neutrons measured by the detector?

Fill in your answer here

Maximum marks: 15

6 # Question 6

[15 points]

Pandemonium is used as a gamma source. However, it decays by alpha decay to bolocsium (Bs).

a) How can you achieve pure gamma radiation using this source? Answer with one sentence.

A Geiger-Müller tube has a cross-sectional area of 1.5 x 10^{-4} m^2. When the source is in its box, the counter records a count rate of 35 counts per minute. It is then placed 10 cm from the pandemonium source. The counter shows a count rate of 1350 counts per minute.

b) Calculate the corrected count rate in Bq.

c) Calculate the gamma activity of the pandemonium source.

d) The Geiger-Müller tube is now moved to a distance of 45 cm from the soure. Calculate the number of counts per minute that is shown by the counter.

Fill in your answer here

Maximum marks: 15