Quiz 2

NAME: _____ SCORE: _____

Subject: Introduction to Nuclear and Particle Physics
Date: Tuesday 13 December 2022
Duration: 60 minutes
Credits: 20 points, Type of evaluation: Quiz

This quiz consists of closed-book concept questions. Provide answers to the following items.

1. Through which two forces can we measure the nuclear radius ?

   - Coulomb force
   - strong force

2. Describe shortly the muonic X-ray method to measure the radius of a nucleus?

   Measuring the energy difference between two isotopes, when they capture a muon on a high energy levels and the muon cascades down to a lower energy state by emitting an X-ray photon.

3. Is it possible to probe the distribution of the neutrons inside the nucleus by using low energy scattering experiments? Give a short explanation.

   No. Low energy scattering probes the charge distribution (p) only. To probe the n distribution we need high energy experiments

4. Calculate the mass defect for $^{235}_{92}U$. The measured mass of $^{235}_{92}U$ is 235.0349 u, the mass of the proton is: 1.00728 u, the mass of the neutron is 1.00867 u, and the mass of the electron can be neglected. The answer can be given in units of u.

$$\Delta = 92 \cdot m_p + 143 \cdot m_n - m_u$$
$$= 92 \cdot 1.00728\,u + 143 \cdot 1.00867\,u - 235.0349\,u$$
$$= 1.87467\,u$$

5. Calculate the mass of the deuteron (D) from the following measured mass difference:
$m(C_5D_{12})$-$m(C_6D_6)$ = (84.610626 ± 0.000090) $\times 10^{-3}$ u

$5m(C) + 12m(D) - 6m(C) - 6m(D) = 84.610626 \times 10^{-3}$ u

$6m(D) - 1m(C) = 84.61\ldots 10^{-3}$

$m(D) = (84.61 \times 10^{-3} + 12)/6$

$m(D) = 2.014101$

6. The binding energy in the semi empirical mass formula has 5 terms, 2 describing the density of the nucleon and one the coulomb term. What do the other two terms account for?

- symmetry term (small A : number of p = number of n)
- pairing term (energy difference for paired nucleons)

7. Why is the number of neutrons greater than the number of protons in stable nuclei that have an A greater than 40?

To stabilize the nucleon against the repulsive Coulomb force of the protons.

8. Why is the calculated magnetic dipole moment different from the measured magnetic moment for heavy elements?

→ deformation of nucleus → rotational modes
→ increase in magnetic moment

9. When calculating the magnetic dipole moment, we assume that the spin g-factor of the proton is 2, however, the measured value significantly differs from 2. Why is that?

g=2 assumes a point like particle. The proton is not a point like particle or an elementary particle. The proton is composed of 3 quarks.

10. Can we study the excited states of the deuteron to learn about the nuclear excited states? Shortly explain your answer.

No. The deuteron is very lightly bound and it does not have excited states.

11. What does the cross section describe in nucleon-nucleon scattering experiments?

The cross section describes the probability of scattering.

12. What does the scattering length describe in nucleon-nucleon interactions?

The scattering length describes the strength of the scattering

13. What experimental evidence do we have that the nucleon-nucleon force is spin dependent?

Scattering experiments on ortho and para hydrogen molecules.

14. What is the reason that neutron-neutron scattering experiments are difficult to carry out?

There are no free neutrons. The half life of n is ≈ 11 minute which makes experiments difficult

15. Which terms does the potential have that we can use to describe the interaction between nucleons?

1. attractive potential
2. spin depent potential
3. non central term (tensor potential)
4. charge symmetry
5. nearly charge indepent
6. repulsive at short distances
7. dependence on the relative momentum of the nuclei

16. What model can we use to explain the force between the nucleons?

The exchange force model: the force can be represented through the exchange of mesons

17. Shortly describe the key concept of the shell model?

Similar to the model of the atom: protons and neutrons occupy shells with discrete energy levels.

18. Shortly describe the key concept of the liquid drop model?

The nucleus gets treated like a drop of liquid. This can explain rotational and vibrational excitation states.

19. Do light nuclei A < 40 have rotational modes? Shortly explain your answer.

No. Rotational modes are only relevant for high A, deformed nuclei.

20. What is a meson?

A particle that consits of an equal number of quarks and anti quarks.