

O. Principles of quantum, atomic and nuclear physics - Introduction: electron volt definition, basic properties of atoms (Avogadro's constant, atomic mass constant or unit, molar mass, molar volume, excitation and deexcitation, photon production, Planck's formula and Planck's constant, wave properties of particles, de Broglie (matter) waves, wave function and its importance).

O1-1. Particle wavelength given by the de Broglie relation is:

- a) a quotient of the Planck constant and momentum of the particle
- b) a quotient of the momentum and mass of the particle
- c) a quotient of the Planck constant and mass of the particle
- d) a quotient of the mass and momentum of the particle
- e) No answer is correct.

O1-2. Particle wavelength given by the de Broglie relation is:

- a) directly proportional to the momentum of the particle
- b) inversely proportional to the velocity of the particle
- c) directly proportional to the mass of the particle
- d) directly proportional to the electric charge of the particle
- e) No answer is correct.

O1-3. The wavelength of the de Broglie waves (connected with a particle) can be represented by ratio

- a) of energy and mass of the particle.
- b) of position and mass of the particle.
- c) of Planck constant and momentum of the particle.
- d) of oscillation period and momentum of the particle.
- e) No answer is correct.

O1-4. The wavelength of de Broglie waves is

- a) inversely proportional to the electric charge of a particle.
- b) identical to the dimension of a particle.
- c) inversely proportional to the mass of a particle.
- d) directly proportional to the mass of a particle.
- e) No answer is correct.

O1-5. Which of the following particles is characterised by de Broglie wavelength shorter than the wavelength of a nucleus of deuterium (heavy hydrogen)? (All particles move with the same velocity.)

- a) electron
- b) neutrino
- c) alpha particle
- d) proton
- e) No answer is correct.

O1-6. The De Broglie wavelength always becomes shorter if we consider

- a) a particle moving with higher speed.
- b) a particle with a greater electric charge.
- c) a lighter particle.
- d) a particle with a smaller momentum.
- e) No answer is correct.

P- Principles of quantum, atomic and nuclear physics - Properties of electron shells: Main features of quantum mechanics model of the hydrogen atom, quantum numbers (incl. Pauli's exclusion principle), spectral analysis (spectral curve, spectrophotometers, emission and absorption spectrum, line spectra, band spectra and continuous spectra). We deal a little more in detail with origin of X-rays, X-ray tubes, "bremsstrahlung" (deceleration radiation), characteristic radiation. Photoelectric effect and Compton scatter.

P1-1. When fast electrons hit a metallic surface, a certain part of their energy is transformed into:

- a) gamma radiation
- b) beta radiation
- c) X-rays
- d) positrons
- e) No answer is correct.

P1-2. The photoelectric effect is the:

- a) transformation of electric energy into light

- b) liberation of photons from electrically charged atomic nuclei
- c) capture of a photon by a nuclear proton
- d) production of light by an electric discharge (arc)
- e) No answer is correct.

P1-3. X-rays are:

- a) beams of fast electrons.
- b) beams of fast ions.
- c) electromagnetic radiation with wavelength above 10 nm.
- d) electromagnetic radiation with wavelength below 10 nm.
- e) No answer is correct.

P1-4. In the photoelectric effect,

- a) the energy of photons transforms fully into the energy of secondary photons.
- b) light is emitted from the conductor carrying an electric current.
- c) the potential energy of electrons transforms into the energy of photons.
- d) the energy of electric current transforms partly into light photons.
- e) No answer is correct.

P1-5. The photons of a high-energy electromagnetic radiation are transformed in the so-called work function and kinetic energy of electrons, while the photons completely disappear. What is the name of this phenomenon?

- a) Compton scatter
- b) luminescence
- c) photoelectric effect
- d) origin of the characteristic radiation
- e) No answer is correct.

P1-6. The photoelectric phenomenon (effect) takes place in the situation of:

- a) impact of photons of high energy onto atoms of solids
- b) impact of electrons onto a semiconductor
- c) absorption of visible light by atom nucleus
- d) emission of X-rays from anode of the X-ray tube
- e) No answer is correct.

P1-7. The photoelectric phenomenon (effect) can play an important role in

- a) intense illumination of the galvanic cell.
- b) absorption of photons of X-rays in matter.
- c) impact of electrons on the surface of an X-ray tube anode.
- d) illumination of a charged photographic film.
- e) No answer is correct.

P1-8. In the photoelectric phenomenon (effect)

- a) a body emits light when carrying electric current.
- b) the photon energy is transformed into the energy of electrons.
- c) the energy of incident photons is transformed into the energy of emitted electrons and scattered photons.
- d) light is transformed into useful electric work.
- e) No answer is correct.

P1-9. In the photoelectric phenomenon (effect)

- a) the light energy liberates the electrons from surfaces of metals
- b) energy of electrons is transformed into light
- c) blackening of photographic material in electric field occurs
- d) we can see a light emitting electric discharge
- e) No answer is correct.

P1-10. The Compton scatter accompanies

- a) impacts of electrons onto a hot metal surface.
- b) transmission of X-rays through matter.
- c) absorption of a photon by atom nucleus.
- d) release of electron from the cathode of an X-ray tube.
- e) No answer is correct.

P1-11. X-rays originate when

- a) neutrons are decelerated in a moderator
- b) light photons are absorbed in a medium
- c) hitting heavy atoms by fast electrons
- d) splitting helium nuclei
- e) No answer is correct.

P1-12. The properties of X-rays are very similar to the properties of

- a) ultraviolet light with very short wavelength.
- b) cathode rays.
- c) accelerated electrons.
- d) infrared radiation.
- e) No answer is correct.

P1-13. The X-rays originate mainly:

- a) in the atom nucleus
- b) due to acceleration of electrically charged particles
- c) due to sudden deceleration (stopping) of electrons in a medium
- d) by impacts of electrons onto the X-ray tube cathode
- e) No answer is correct.

P1-14. X-rays differ from visible light in their

- a) higher intensity.
- b) longer wavelength.
- c) lower frequency of oscillations.
- d) higher frequency of oscillations.
- e) No answer is correct.

P1-15. X-ray properties are very similar to the properties of

- a) gamma radiation.
- b) cathode rays.
- c) accelerated electrons.
- d) infrared radiation.
- e) No answer is correct.

P1-16. Find the radiation which is of the same character as X-rays:

- a) alpha-radiation
- b) gamma-radiation
- c) ultrasound waves
- d) beta-radiation
- e) No answer is correct.

P1-17. The frequency of X-rays is *always* higher than the frequency of

- a) gamma rays.
- b) microwaves.
- c) a radiation with a wavelength above 0.01 nm.
- d) a radiation with a wavelength below 1 pm.
- e) No answer is correct.

P1-18. The energy of the electrons in electron orbitals is given mainly by the

- a) principal quantum number n .
- b) orbital momentum quantum number l .
- c) magnetic quantum number m .
- d) Bohr's radius.
- e) No answer is correct.

Q. Principles of quantum, atomic and nuclear physics - The atomic nucleus:

Q1. Kinds of radioactive decay

Q1-1. The number of neutrons in an atomic nucleus increased by 1 without a change in total number of nucleons. It was caused by:

- a) emission of an alpha-particle
- b) emission of an electron
- c) emission of a positron
- d) emission of the gamma-particle
- e) No answer is correct.

Q1-2. The number of neutrons in an atomic nucleus decreased by 1 without change in total number of nucleons. It was caused by:

- a) emission of an alpha-particle
- b) emission of an electron
- c) emission of a positron
- d) emission of the gamma-particle
- e) No answer is correct.

Q1-3. The number of protons in an atomic nucleus decreased by 1 without change in total number of nucleons. It was caused by:

- a) emission of an alpha-particle
- b) emission of an electron
- c) emission of a positron
- d) emission of the gamma-particle
- e) No answer is correct.

Q1-4. The number of protons in an atomic nucleus decreased by one, without changing the total number of nucleons. It was caused by the:

- a) emission of a proton
- b) capture of an electron
- c) capture of a positron
- d) emission of an alpha-particle
- e) No answer is correct.

Q1-5. A β^+ -particle was emitted from atom nucleus. It resulted in:

- a) increase of neutron number of the nuclide
- b) decrease of proton number by 1
- c) decrease of nucleon number by 2
- d) decrease of neutron number by 1
- e) No answer is correct.

Q1-6. A β^- -particle was emitted from an atom nucleus. It resulted in:

- a) increase of neutron number of the nuclide
- b) decrease of proton number by 1
- c) decrease of nucleon number by 2
- d) decrease of neutron number by 1
- e) No answer is correct.

Q1-7. If the number of neutrons in a nucleus decreases by one, it is possible that only one of the following particles is emitted (neutrinos or antineutrinos are not considered):

- a) α
- b) β^+
- c) β^-
- d) gamma
- e) No answer is correct.

Q1-8. If the number of protons in a nucleus decreases by one, it is possible that only one of the following particles is emitted (neutrinos or antineutrinos are not considered):

- a) α
- b) β^+
- c) β^-
- d) gamma
- e) No answer is correct.

Q1-9. An α -particle was emitted from an atom nucleus. It resulted in:

- a) increase of neutron number of the nuclide
- b) decrease of proton number by 1
- c) decrease of nucleon number by 2
- d) decrease of nucleon number by 4
- e) No answer is correct.

Q1-10. The alpha decay causes

- a) a decrease of the nuclear neutron number by two.
- b) a decrease of the nuclear proton number by four.
- c) a decrease of the nucleon number by two.
- d) a decrease of the nucleon number by three.
- e) No answer is correct.

Q1-11. Find the radiation which can originate in electron shell of an atom:

- a) alpha-radiation
- b) beta-radiation
- c) ultraviolet light
- d) gamma-radiation
- e) No answer is correct.

Q1-12. Find the radiation which can originate in atomic nucleus:

- a) ultraviolet light
- b) radiation of Compton scattering
- c) gamma-radiation
- d) X-rays
- e) No answer is correct.

Q1-13. Find the radiation which cannot originate in atomic nucleus:

- a) γ -radiation
- b) fast neutrons
- c) X-rays
- d) positrons
- e) No answer is correct.

Q1-14. What is the substantial difference between β - and α -particles?

- a) they are of different energy
- b) they are of different mass
- c) the first ones are without any electric charge
- d) only the β -particles are of electromagnetic character (they are similar to the photons)
- e) No answer is correct.

Q2. Law of radioactive decay

Q2-1. What is the true meaning of the symbol N_t in the Law of radioactive decay, $N_t = N_0 \cdot e^{-\lambda t}$.

- a) number of atoms decayed during time t
- b) number of particles emitted during time t
- c) it should be I (i.e. intensity of radiation)
- d) number of nucleons in the atom nucleus at the end of decay
- e) No answer is correct.

Q2-2. What is the true meaning of the symbol λ in the Law of radioactive decay, $N_t = N_0 \cdot e^{-\lambda t}$.

- a) wavelength of radiation emitted
- b) decay (disintegration) constant
- c) half-life time of decaying nuclei
- d) the respective symbol is not in the right place of the formula
- e) No answer is correct.

Q2-3. In the equation expressing the radioactive decay law $N = N_0 \cdot e^{-\lambda \cdot t}$ the letter " t " means

- a) temperature.
- b) half-life of a radionuclide.
- c) thermal constant.
- d) time elapsed from the beginning of counting decays in a sample.
- e) No answer is correct.

Q2-4. What is the correct form of equation of the Law of radioactive decay?

- a) $N_t = N_0 \cdot e^{\lambda t}$
- b) $I = I_0 \cdot e^{-\lambda t}$
- c) $N_t = N_0 + e^{-\lambda t}$
- d) $N_t = N_0 \cdot e^{-\lambda t}$
- e) No answer is correct.

Q2-5. The half-life of a radionuclide is 4 days. After 16 days, its activity will decrease to

- a) one fourth of original value
- b) one eighth of original value
- c) one sixteenth of original value
- d) zero
- e) No answer is correct.

Q2-6. The activity of a radioactive source is

- a) identical with the radioactive decay constant
- b) the number of decaying nuclei of the source in one second
- c) the amount of source nuclei which can still decay
- d) identical with the half-life time
- e) No answer is correct.

Q2-7. The half-life of a radionuclide is 4 days. The number of its nuclei decreased to one eighth of original value. What was time necessary for that?

- a) 8 days
- b) 16 days
- c) 32 days
- d) 12 days
- e) No answer is correct.

Q2-7. What is the half-life of a radionuclide if the original number of the nuclei in its sample decreased to one sixteenth after 120 years? (Help: Consider the definition of the half-life!)

- a) 120/16 years
- b) 20 years
- c) 30 years
- d) 60 years
- e) No answer is correct.

Q2-8. A radionuclide has a half-life time of 4 hours. After 16 hours its activity will decrease to

- a) one fourth of the initial value.
- b) one eighth of the initial value.
- c) one sixteenth of the initial value.
- d) zero.
- e) No answer is correct.

Q2-9. The radionuclide (iodine-131) half-life time is 8 days. Its initial activity is 1 MBq. What is the time necessary for lowering its activity to a value below 10 kBq?

- a) more than 100 years. b) more than 5 years. c) 16 days.
d) less than 2 months. e) No answer is correct.

Q2-10. After five half-lives there remained 10^6 atoms of a radioactive nuclide (isotope) in a sample. What was the original number of nuclei in the sample at the beginning of measurement?

- a) $1.6 \cdot 10^7$ b) $16 \cdot 10^6$ c) $3.2 \cdot 10^6$ d) $3.2 \cdot 10^7$ e) No answer is correct.

Q2-11. The radioactive isotope (caesium-137) half-life is about 30 years. Its amount will decrease to one hundredth of the original value after (approximately):

- a) an almost infinite period b) 60 years c) more than 180 years
d) at least 3000 years e) No answer is correct.

Q2-12. What is the half-life of a radionuclide, which amount decreased due to disintegration (decay) to one eighth in 10 hours?

- a) 40 hours b) 2.5 hours c) 3 hours and 20 min. d) 1 hour and 15 min.
e) No answer is correct.

Q3. Properties of nuclei and elementary particles

Q3-1. The hydrogen isotopes H-1, H-2 and H-3 differ in:

- a) number of electrons in the electron shells b) number of protons in nucleus
c) chemical properties d) number of neutrons e) No answer is correct.

Q3-2. Which of the following particles changes its trajectory when it passes through a magnetic field?

- a) neutrino b) neutron c) photon d) proton
e) No answer is correct.

Q3-3. Which of the following particles changes its trajectory due to the action of electric fields (effects connected with the spin of particles are neglected)?

- a) proton b) neutrino c) photon d) hydrogen atom
e) No answer is correct.

Q3-4. Which of the following particles easily change their trajectory when it passes through an electric field?

- a) electron, proton, alpha-particle b) proton, electron, photon
c) electron, photon, meson d) neutron, proton, electron e) No answer is correct.

Q3-5. Let us have particles with the same initial velocity. Which of these particles has the least curved trajectory after entering a homogeneous electric field?

- a) proton b) β -particle c) α -particle d) O^{2-} ion e) No answer is correct.

Q3-6. Which of the following particles starts to travel along the most curved trajectory when reaching a homogenous electric field?

- a) ion of oxygen b) neutron c) α -particle d) proton e) No answer is correct.

Q3-7. Which of the particles is *not* deflected from its original trajectory by a magnetic field? (We do not consider spin of the particle.)

- a) hydrogen atom b) β^+ -particle c) proton d) α -particle
e) No answer is correct.

Q3-8. Which of the following particles does *not* change their trajectory when they pass through an electric field?

- a) electron, proton, alpha-particle
- b) proton, neutron, photon
- c) electron, photon, meson
- d) neutron, neutrino, photon
- e) No answer is correct.

Q3-9. Find the particles whose trajectory cannot be changed by magnetic field:

- a) electrons
- b) photons
- c) protons
- d) α -particles
- e) No answer is correct.

Q3-10. What is the substantial difference between the electron and positron?

- a) the particles are of different mass
- b) the particles are of opposite electric charge
- c) electrons are particles, and the positrons are electromagnetic waves
- d) the particles are of different energy
- e) No answer is correct.

Q3-11. What is the main difference between the X-rays and γ -radiation?

- a) these radiations originate in different way
- b) the particles forming these radiations are of different rest mass
- c) X-rays are visible, the γ -radiation not
- d) the X-rays are accelerated electrons, the γ -radiation not
- e) No answer is correct.

Q3-12. Estimate what kind of particles is only little influenced by gravitational field:

- a) alpha
- b) beta
- c) protons
- d) gamma- photons
- e) No answer is correct.

Q3-13. In a cyclotron, the electrically charged particles are accelerated by means of

- a) very fast rotation of a tube containing a suitable radionuclide
- b) an alternating magnetic field
- c) an alternating electric field
- d) intense bundles of light rays
- e) No answer is correct.

Q3-15. We can get energy by synthesis of helium nuclei from heavy hydrogen and lithium because

- a) the nuclei of helium have smaller mass difference per one nucleon than the original nuclei.
- b) the nuclei of helium have smaller mass difference per one nucleon than the original nuclei.
- c) the produced helium is radioactive.
- d) high energy particles are produced in this process.
- e) No answer is correct.

Q3-16. It is possible to obtain energy from fission of plutonium-239 because

- a) the mass defect per one nucleon in daughter nuclides is smaller than in plutonium
- b) the mass defect per one nucleon in daughter nuclides is bigger than in plutonium
- c) it easily reacts with uranium-235
- d) it is radioactive
- e) No answer is correct.

Q3-18. For detection or measurement of nuclear radiation, we can use

- a) refractometer
- b) bubble chamber
- c) transformer
- d) cyclotron
- e) No answer is correct.

Q3-19. What is the substantial difference between atoms of C-12 and C-14?

- a) these atoms have different chemical properties
- b) their proton number is different
- c) their neutron number is different
- d) C-14 contains some radionuclides
- e) No answer is correct