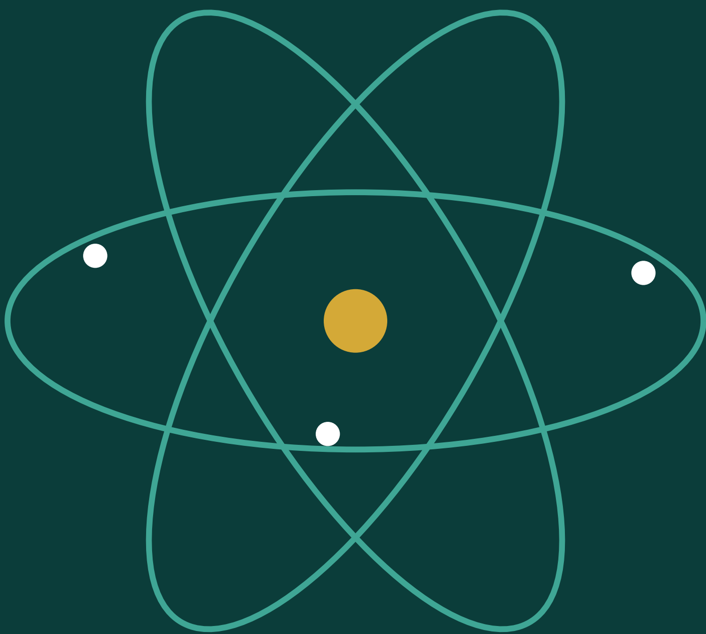
9TH GRADE • CHEMISTRY • CHAPTER 2



Atomic Structure

Complete Exercise — Step-by-Step Solutions

MCQs • Short Answers • Constructed Response • Descriptive • Investigative

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Chapter 2: Atomic Structure — Complete Exercise Solutions

Every question from the Chapter 2 exercise, answered step by step with clear explanations — perfect for quick revision and exam preparation.

1 Tick (✓) the correct answer

(i) How many electrons can be accommodated at the most in the third shell of the elements?

(a) 8

✓ **(b) 18**

(c) 10

(d) 32

Explanation

To find the maximum number of electrons in any shell, we use the formula $2n^2$, where 'n' is the shell number. For the third shell, n = 3. Plugging it in: $2 \times (3)^2 = 2 \times 9 = 18$ electrons. Option (a) 8 is the maximum for the second shell (n=2), and (d) 32 is for the fourth shell (n=4).

(ii) What information was obtained from discharge tube experiments?

(a) Structure of atom was discovered.

(b) Neutrons and protons were discovered.

✓ **(c) Electrons and protons were discovered.**

(d) Presence of nucleus in an atom was discovered.

Explanation

When high voltage is passed through a discharge tube containing gas at low pressure, cathode rays (electrons) are produced, which was discovered by J.J. Thomson. Later, Goldstein discovered canal rays (protons) using the same discharge tube setup. Neutrons (b) and the nucleus (d) were discovered through different experiments (Goldstein/Chadwick and Rutherford respectively).

(iii) Why have isotopes not been shown in the periodic table?

(a) Periodic table cannot accommodate a large number of isotopes of different elements.

(b) Some of the isotopes are unstable and they give rise to different elements

✓ **(c) All the isotopes have same atomic number; so there is no need to give them separate places.**

(d) Isotopes do not show periodic behavior.

Explanation

The modern periodic table arranges elements based on their atomic number (number of protons). Since isotopes of an element have the exact same number of protons but different neutrons, they have the same atomic number. Therefore, they all fit into the exact same slot in the periodic table.

(iv) Which particle is present in different number in the isotopes?

(a) Electron

✓ **(b) Neutron**

(c) Proton

(d) Both neutron and electron

Explanation

Isotopes are defined as atoms of the same element that have the same number of protons (c) and electrons (a), but different numbers of neutrons. Changing the number of neutrons changes the mass number but keeps the chemical properties (mostly) the same.

(v) In which isotope of oxygen there are the equal number of protons, electrons and neutrons?

(a) ^{17}O

✓ **(b) ^{16}O**

(c) ^{18}O

(d) None of these

Explanation

Oxygen's atomic number is 8, meaning it has 8 protons and 8 electrons in its neutral state. For an isotope to have an equal number of protons and neutrons, the number of neutrons must also be 8. In the notation ^{16}O, the mass number is 16. Neutrons = Mass Number – Atomic Number = 16 – 8 = 8. Thus, ^{16}O has 8p, 8e, and 8n. ^{17}O has 9 neutrons, and ^{18}O has 10 neutrons.

(vi) What will be the relative atomic mass of nitrogen given the abundances of its two isotopes, ^{14}N and ^{15}N are 99.64 and 0.35 respectively.

(a) 14.0210

✓ **(b) 14.0021**

(c) 14.2100

(d) 14.1200

Explanation

To find the relative atomic mass, we multiply each isotope's mass by its relative abundance, add them together, and divide by 100. Calculation: [(14 × 99.64) + (15 × 0.35)] / 100 = [1394.96 + 5.25] / 100 = 1400.21 / 100 = 14.0021.

(vii) How is radiocarbon dating useful for archaeologists?

✓ **(a) It helps determine the age of organic matter.**

(b) It helps determine the composition of matter.

(c) It helps determine the usefulness of matter.

(d) It helps determine whether the matter is radioactive or not.

■ **Explanation**

Carbon-14 is a radioactive isotope naturally present in all living things. When an organism dies, it stops absorbing carbon-14, and the existing carbon-14 begins to decay at a known rate. Archaeologists measure the remaining carbon-14 in artifacts like wood, bone, or cloth to calculate how long ago the organism died.

(viii) What does keep the particles present in the nucleus intact?

✓ **(a) Particles are held together by strong nuclear force.**

(b) Particles are held together by weak nuclear force.

(c) Particles are held together by electrostatic force.

(d) Particles are held together by dipolar force.

Explanation

Protons in the nucleus are positively charged and should repel each other due to electrostatic force (c). However, the nucleus stays intact because of the “Strong Nuclear Force,” which is a powerful attractive force that acts between protons and neutrons at very short distances, overpowering the repulsion.

(ix) How do electrons keep themselves away from the oppositely charged nucleus?

(a) By keeping themselves stationary

✓ **(b) By revolving around the nucleus**

(c) Due to their wave-like nature

(d) A magnetic field around the nucleus keeps them away

Explanation

The negatively charged electron is attracted to the positively charged nucleus. To avoid falling into the nucleus, it revolves around it at high speeds. This creates a centrifugal force (outward push) that perfectly balances the electrostatic force of attraction (inward pull), keeping the electron in its orbit.

(x) Rubidium consists of two isotopes ^{85}Rb and ^{87}Rb. The percent abundance of the light isotope is 72.2%. What is the percent abundance of the heavier isotope? Its atomic mass is 85.47

(a) 15%

✓ **(b) 27.8%**

(c) 37%

(d) 72%

■ **Explanation**

The total abundance of all naturally occurring isotopes of an element must always equal 100%. Abundance of lighter isotope (^{85}Rb) = 72.2%. Abundance of heavier isotope (^{87}Rb) = 100% – 72.2% = 27.8%. (Verification using atomic mass: (85 × 72.2/100) + (87 × 27.8/100) = 61.37 + 24.186 = 85.556, close to 85.47 given the dataset.)

2 Questions for Short Answers

i. Why is it said that almost all the mass of an atom is concentrated in its nucleus?

Answer:

The nucleus contains protons and neutrons, which are relatively massive particles. A single proton or neutron is about 1,836 times heavier than an electron. Although electrons occupy a vast space around the nucleus, their actual mass is negligible. Therefore, the total mass of an atom is practically the sum of the masses of its protons and neutrons, which are packed tightly in the nucleus.

ii. Why are elements different from one another?

Answer:

Elements differ from one another based on their atomic number, which is the number of protons in their nucleus. For example, an atom with 1 proton is hydrogen, and an atom with 2 protons is helium. Changing the number of protons fundamentally changes the chemical and physical properties of the element.

iii. How many neutrons are present in $^{210}{}_{83}Bi$?

Answer:

The number of neutrons is calculated by subtracting the atomic number (number of protons) from the mass number. Mass Number = 210, Atomic Number = 83. Number of Neutrons = 210 – 83 = 127 neutrons.

iv. Why is tritium ($^{3}_{1}H$) a radioactive element?

Answer:

Tritium has 1 proton and 2 neutrons in its nucleus, giving it a neutron-to-proton ratio of 2:1. This ratio is significantly higher than what is considered stable for light elements (which prefer a 1:1 ratio). To achieve stability, the nucleus undergoes radioactive decay, emitting beta particles to convert a neutron into a proton.

v. How can an atom absorb and evolve energy?

Answer:

An atom absorbs energy when its electrons jump from a lower energy level (ground state) to a higher energy level (excited state) by absorbing a specific quantum of energy (photon). Conversely, an atom emits (evolves) energy when an excited electron falls back from a higher energy level to a lower one, releasing that energy as a photon of light.

3 Constructed Response Questions

i. Why does the energy of electron increase as we move from first shell to second shell?

Answer:

As we move from the first shell to the second, the electron gets farther away from the positively charged nucleus. Because the electrostatic force of attraction decreases with distance, the electron is less tightly bound to the nucleus. To move to this outer, less tightly bound position, the electron must gain potential energy. Thus, the energy level increases.

ii. Why is it needed to lower the pressure of the gas inside the discharge tube?

Answer:

Lowering the pressure drastically reduces the number of gas molecules inside the tube. This increases the mean free path of the ions and electrons. They can accelerate to very high speeds without colliding with other gas molecules. When these high-speed particles strike the electrodes/gas, they generate cathode rays (electrons) and canal rays (protons) for observation.

iii. What is the classical concept of an electron? How has this concept changed with time?

Answer:

The classical concept, based on Rutherford's model, viewed the electron as a tiny, solid, negatively charged particle revolving around the nucleus in fixed planetary orbits, similar to planets orbiting the sun. This concept changed with the advent of quantum mechanics (Bohr, de Broglie, Schrödinger). Electrons are now understood to possess wave-particle duality. Instead of definite orbits, they exist in “orbitals”—regions of probability described by complex mathematical wave functions, acting more like a spread-out cloud of negative charge.

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iv. Why the nuclei of the radioactive elements are unstable?

Answer:

Radioactive nuclei are unstable because they have an imbalance in the ratio of protons to neutrons (often too many neutrons). This imbalance means the strong nuclear force (which holds the nucleus together) cannot overcome the electrostatic repulsion between the large number of protons. To reach a more stable state, these nuclei spontaneously emit radiation (alpha, beta, or gamma) to shed excess energy and particles.

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v. During discharge tube experiments, how did the scientists conclude that the same type of electrons and protons are present in all the elements?

Answer:

When scientists (like Thomson and Goldstein) repeated the discharge tube experiments using different gases (e.g., hydrogen, oxygen, nitrogen), they observed that the charge-to-mass ratio (e/m) of the cathode rays and canal rays remained constant regardless of the gas used. Since the properties of these particles did not depend on the source material, they concluded that electrons and protons are fundamental, universal subatomic particles present in all atoms.

4 Descriptive Questions

i. Explain the structure of a hydrogen atom.

Answer:

The hydrogen atom is the simplest atom in existence.

• **Nucleus:** It contains exactly 1 proton and 0 neutrons. The mass of the atom is almost entirely due to this single proton.

• **Electrons:** It has exactly 1 electron revolving around the nucleus.

• **Arrangement:** In the Bohr model, this single electron revolves in the first energy level (K-shell, n=1). Because there are no other electrons, the hydrogen atom's electronic configuration is simply 1.

ii. How does the theory of atomic structure explain the ionization of atoms by a radioactive isotope?

Answer:

Radioactive isotopes emit high-energy particles (alpha, beta) and rays (gamma) during decay. When these highly energetic emissions strike nearby atoms, they transfer enough energy to the atoms' electrons. This energy can knock one or more electrons completely out of the atom's orbit, overcoming the electrostatic attraction of the nucleus. The resulting atom, which now has an unequal number of protons and electrons, becomes a positively charged ion. This process is called ionization.

iii. What is radioactivity? Explain any three applications of radioactive isotopes.

Answer:

Radioactivity is the spontaneous emission of radiation (alpha particles, beta particles, or gamma rays) from the unstable nucleus of an atom as it transforms into a more stable state. Three applications:

1. **Medical Science:** Radioactive isotopes like Cobalt-60 are used in radiation therapy to destroy cancer cells. Iodine-131 is used to diagnose and treat thyroid disorders.

2. **Archaeology (Radiocarbon Dating):** Carbon-14 is used to accurately determine the age of ancient organic artifacts, fossils, and mummies up to 50,000 years old.

3. **Energy Production:** Uranium-235 is used as nuclear fuel in power plants to generate electricity through controlled nuclear fission reactions.

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iv. Find out the relative atomic mass of mercury from the following data.

Isotope	Abundance	Isotope	Abundance
^{196}Hg	0.0146%	^{199}Hg	16.34%
^{198}Hg	10.02%	^{200}Hg	23.13%
^{201}Hg	13.22%	^{202}Hg	29.80%
^{204}Hg	6.85%		

Solution: Relative Atomic Mass = Σ(Mass of Isotope × Relative Abundance) / 100

- 196 × 0.0146 = 2.8616
- 198 × 10.02 = 1983.96
- 199 × 16.34 = 3251.66
- 200 × 23.13 = 4626.00
- 201 × 13.22 = 2657.22
- 202 × 29.80 = 6019.60
- 204 × 6.85 = 1397.40

Sum of all products = 2.8616 + 1983.96 + 3251.66 + 4626.00 + 2657.22 + 6019.60 + 1397.40 = **19938.7016**

Dividing by 100 → **Relative Atomic Mass = 19938.7016 / 100** ≈ **199.387 amu**

(Note: The actual atomic mass of mercury is 200.59; the slight variance is due to the provided dataset not summing exactly to 100% and minor rounding.)

5 Investigative Questions

i. How can scientists synthesize elements in the laboratory?

Answer:

Scientists synthesize new elements through a process called nuclear transmutation. They use particle accelerators (like cyclotrons) to accelerate light atomic nuclei (e.g., helium or carbon) to extremely high speeds and smash them into heavy target nuclei (e.g., lead or uranium). When the nuclei collide and fuse, they create a new, heavier element with a higher atomic number. Alternatively, they can bombard heavy nuclei with neutrons in nuclear reactors to trigger neutron capture, leading to beta decay and the formation of a new element.

ii. A system just like our solar system exists in an atom. Comment on this statement.

Answer:

This statement refers to the Rutherford Planetary Model of the atom, which likened the atom to a solar system where the nucleus is the sun and electrons are planets orbiting it. While this is a helpful introductory analogy to visualize the massive empty space and the central concentration of mass in an atom, it is not entirely accurate. Unlike planets in a solar system which have fixed, predictable elliptical orbits, electrons do not orbit in defined paths. According to modern quantum mechanics, electrons exist in “electron clouds” or orbitals, where we can only predict the probability of finding an electron at a given location. Therefore, the solar system model is an oversimplification of atomic reality.

✓

Well Done!

You've completed the full Chapter 2 exercise on Atomic Structure.
Revise these solutions regularly to strengthen your concepts.