Chapter 8: Journey Inside the Atom

Exercises — Revise, Reflect, Refine

Q1 Choose the correct options and explain the reason for the correct and incorrect options in the context of Ernest Rutherford's gold foil experiment: (i) The experiment clearly showed the existence of neutrons in the nucleus. (ii) The results disproved the plum pudding model and led to the idea of a nucleus at the centre of the atom. (iii) The large deflection of a few alpha particles indicated that most of the mass of the atom and positive charge are packed into a tiny centre. (iv) The way alpha particles were deflected showed that electrons move around the nucleus.

SOLUTION

(i) INCORRECT. Rutherford's gold foil experiment used alpha particles and detected them with a ZnS screen. Neutrons carry no charge and cannot be detected by this method. The existence of neutrons was discovered later by James Chadwick in 1932.

(ii) CORRECT. Most alpha particles passed straight through the gold foil with no deflection, showing the atom is mostly empty space. A few were deflected at various angles, leading Rutherford to conclude that positive charge and most mass are concentrated in a small, dense nucleus at the centre. This directly disproved Thomson's plum pudding model, in which positive charge was spread uniformly throughout the atom.

(iii) CORRECT. The very small number of alpha particles that bounced back or were deflected at very large angles (close to 180°) showed that they had encountered an extremely concentrated region of positive charge and mass. This region — the nucleus — occupies only a tiny volume compared with the whole atom.

(iv) INCORRECT. The deflection patterns of alpha particles gave information about the nucleus (its charge, size, and mass concentration). The experiment provided no direct evidence about the positions or motion of electrons. The behaviour of electrons was addressed later by Bohr's model.

Answer: Correct statements: (ii) and (iii). Incorrect statements: (i) and (iv).

Q2 Which of the following statements are correct or incorrect according to the Bohr's atomic model? Give a reason for each statement. (i) Electrons lose energy while moving in fixed orbits and slowly fall into the nucleus. (ii) Electrons can exist anywhere around the nucleus with no fixed energy. (iii) Electrons revolve around the nucleus in orbits of fixed energy without losing energy. (iv) Electrons can be found between energy levels as they move around the nucleus.

SOLUTION

(i) INCORRECT. According to Bohr's model, electrons revolving in their fixed (stationary) orbits do NOT lose energy. Loss of energy during orbital motion was the flaw in classical theory that Bohr's model specifically solved by postulating that electrons in fixed orbits do not radiate energy.

(ii) INCORRECT. Bohr's model states that electrons can only exist in specific, fixed orbits (energy levels) around the nucleus — not anywhere. Each orbit corresponds to a definite energy value.

(iii) CORRECT. This is a core postulate of Bohr's atomic model. Electrons move in fixed circular orbits called stationary states or energy shells (K, L, M, N, …). While in these orbits, electrons do not radiate energy and their total energy remains constant.

(iv) INCORRECT. In Bohr's model, electrons can only be in the specific allowed energy levels (orbits). They cannot exist in the space between orbits. An electron jumps directly from one orbit to another when it absorbs or emits a fixed quantum of energy — it does not travel through the intermediate space as a particle with a defined position.

Answer: Correct: (iii). Incorrect: (i), (ii), and (iv).

Q3 The composition of the nuclei of three atomic species X, Y, and Z are given as follows. X: protons = 18, neutrons = 19. Y: protons = 17, neutrons = 18. Z: protons = 17, neutrons = 20. Explain the relation between the following: (i) Y and Z, (ii) Z and X.

SOLUTION

Calculate the mass number (A = protons + neutrons) for each species:
X: A = 18 + 19 = 37
Y: A = 17 + 18 = 35
Z: A = 17 + 20 = 37

(i) Relation between Y and Z:
Y has 17 protons and Z has 17 protons — the same atomic number (same element, Chlorine).
But Y has mass number 35 and Z has mass number 37 — different mass numbers (different numbers of neutrons).
Y and Z are ISOTOPES — atoms of the same element with the same number of protons but different numbers of neutrons.

(ii) Relation between Z and X:
Z has 17 protons and X has 18 protons — different atomic numbers (different elements).
But Z has mass number 37 and X also has mass number 37 — the same mass number.
Z and X are ISOBARS — atoms of different elements that have the same mass number.

Answer: (i) Y and Z are isotopes (same proton number 17, different mass numbers 35 and 37). (ii) Z and X are isobars (same mass number 37, different proton numbers 17 and 18).

Q4 What conclusion did Rutherford draw about the position and characteristics of the atom's positively charged part based on the few alpha particles that bounced back or were deflected at large angles in the gold foil experiment?

SOLUTION

In the gold foil experiment, the vast majority of alpha particles passed straight through the foil, but a very small number (about 1 in 20,000) were deflected at large angles or even bounced straight back.

From this observation, Rutherford concluded:
1. Position: The entire positive charge and nearly all the mass of the atom are concentrated in an extremely small region at the centre of the atom, which he called the nucleus.
2. Size: The nucleus must be very small compared to the total size of the atom. Since most alpha particles passed through undeflected, the atom is mostly empty space.
3. Charge and mass: The nucleus carries a large positive charge (to strongly repel the positively charged alpha particles at close range), and its mass is very

large compared to the alpha particles (which is why some alpha particles bounced back rather than pushing the nucleus aside).

4. The electrons must be revolving around the nucleus in the empty space outside it.

Answer: Rutherford concluded that the atom's positive charge and nearly all its mass are concentrated in a very small, dense region at the centre called the nucleus. The nucleus is tiny compared to the overall size of the atom, and the rest of the atom is mostly empty space.

Q5 Explain and arrange the following statements in the correct chronological order to show how atomic models have evolved over time. (i) Bohr's model proposed that electrons move in fixed orbits around the nucleus, each with a definite energy. (ii) Thomson's model depicted the atom as a 'plum pudding' with electrons embedded in a sphere of positive charge. (iii) Rutherford's model proposed that atoms have a dense central nucleus. (iv) Dalton's model described atoms as indivisible particles.

SOLUTION

Chronological order: (iv) → (ii) → (iii) → (i)

(iv) Dalton's model (early 19th century): John Dalton proposed that all matter is made of tiny, indivisible, indestructible particles called atoms. He did not suggest any internal structure — atoms were considered the smallest unit of matter.

(ii) Thomson's model (1897): After J. J. Thomson discovered the electron, he proposed the 'plum pudding' model. The atom was pictured as a sphere of uniformly distributed positive charge with negatively charged electrons embedded in it like plums in a pudding. This was the first model with internal structure.

(iii) Rutherford's model (1911): Based on his gold foil experiment, Rutherford replaced the plum pudding model with a nuclear model. He proposed that the atom has a small, dense, positively charged nucleus at the centre, with electrons revolving around it in the mostly empty space outside.

(i) Bohr's model (1913): Niels Bohr improved Rutherford's model by adding quantised energy levels. Electrons revolve in specific fixed orbits (shells) around the nucleus without losing energy. Each orbit corresponds to a definite energy, and electrons can jump between orbits by absorbing or emitting energy.

Answer: Correct chronological order: (iv) Dalton → (ii) Thomson → (iii) Rutherford → (i) Bohr.

Q6 Electrons move around the nucleus in orbits. Why do they not fly away from the atom? Explain what keeps them attracted to the nucleus.

SOLUTION

Electrons are negatively charged (-1 charge each) and the nucleus contains protons, which are positively charged (+1 charge each).

Opposite charges attract each other according to Coulomb's law. The electrostatic force of attraction between the negatively charged electrons and the positively charged nucleus acts as a centripetal force, pulling the electrons continuously towards the nucleus.

This inward electrostatic attraction balances the tendency of the electrons to fly outward (due to their circular motion). As long as the electron remains in its fixed orbit, these forces are balanced and the electron neither flies away nor falls into the nucleus.

According to Bohr's model, electrons occupy only those orbits where this balance is maintained (stationary states). In these orbits the electrons do not radiate energy, so they remain stable and do not spiral inward.

Answer: Electrons do not fly away because the electrostatic (Coulomb) force of attraction between the negatively charged electron and the positively charged nucleus acts as a centripetal force, holding the electron in its orbit. This attractive force prevents the electron from leaving the atom.

Q7 Assertion (A): The discovery of subatomic particles helped in understanding the atomic structure. Reason (R): The number of electrons is equal to the number of protons in an atom. Choose the correct option: (i) Both A and R are true, and R is the correct explanation of A. (ii) Both A and R are true, but R is not the correct explanation of A. (iii) A is true, but R is false. (iv) A is false, but R is true.

SOLUTION

Evaluate Assertion (A): 'The discovery of subatomic particles helped in understanding the atomic structure.'
This is TRUE. The discovery of the electron (Thomson, 1897), the proton (Rutherford, 1919), and the neutron (Chadwick, 1932) directly led to progressively

more accurate models of the atom — from the plum pudding model to the nuclear model and then Bohr's model.

Evaluate Reason (R): 'The number of electrons is equal to the number of protons in an atom.'
This is also TRUE for a neutral atom. The atomic number (Z) equals the number of protons, and in a neutral (uncharged) atom, the number of electrons equals the number of protons so that the atom carries no net charge.

Does R correctly explain A?
No. The equality of electrons and protons explains why an atom is electrically neutral — it does NOT explain how the discovery of subatomic particles helped understand atomic structure. R is a consequence of atomic neutrality, not the reason that discovering subatomic particles advanced our understanding of atomic structure.

Therefore, both A and R are true, but R is not the correct explanation of A.
Correct option: (ii)

Answer: (ii) Both A and R are true, but R is not the correct explanation of A.

Q8 Magnesium is essential for many biological processes, including muscle contraction. For an atom of magnesium with a mass number of 24 and atomic number 12, determine the number of (i) protons, (ii) neutrons, (iii) electrons, and also illustrate the arrangement of electrons in a magnesium atom.

SOLUTION

Given: Mass number (A) = 24, Atomic number (Z) = 12

(i) Number of protons = Atomic number = 12

(ii) Number of neutrons = Mass number - Atomic number = 24 - 12 = 12

(iii) Number of electrons = Number of protons (neutral atom) = 12

Electron arrangement in Magnesium (Z = 12):
Shell K (n=1): maximum 2 electrons → 2 electrons
Shell L (n=2): maximum 8 electrons → 8 electrons
Shell M (n=3): remaining electrons → 12 - 2 - 8 = 2 electrons

Electronic configuration of Mg: 2, 8, 2
The 2 electrons in the outermost shell (M) are the valence electrons.

Answer: (i) Protons = 12, (ii) Neutrons = 12, (iii) Electrons = 12. Electronic configuration: K=2, L=8, M=2 (written as 2,8,2).

Q9 Find the following information for the elements shown in Fig. 8.17 (four atomic diagrams labelled a, b, c, d): (i) Name of the element, (ii) Symbol, (iii) Total number of electrons, (iv) Number of valence electrons, (v) Valency of the element, (vi) Number of protons, (vii) Atomic number.

SOLUTION

Reading the electron arrangements from Fig. 8.17:

Diagram (a): 2 shells — inner shell: 2 electrons, outer shell: 1 electron. Total electrons = 3.
Z = 3 → Element: Lithium (Li)
Electronic config: 2, 1. Valence electrons = 1. Valency = 1 (tends to lose 1 electron).

Diagram (b): 2 shells — inner shell: 2 electrons, outer shell: 5 electrons. Total electrons = 7.
Z = 7 → Element: Nitrogen (N)
Electronic config: 2, 5. Valence electrons = 5. Valency = 3 (needs 3 electrons to complete the octet).

Diagram (c): 3 shells — shell 1: 2 electrons, shell 2: 8 electrons, shell 3: 3 electrons. Total electrons = 13.
Z = 13 → Element: Aluminium (Al)
Electronic config: 2, 8, 3. Valence electrons = 3. Valency = 3 (tends to lose 3 electrons).

Diagram (d): 2 shells — inner shell: 2 electrons, outer shell: 7 electrons. Total electrons = 9.
Z = 9 → Element: Fluorine (F)
Electronic config: 2, 7. Valence electrons = 7. Valency = 1 (needs 1 electron to complete the octet).

Summary table:

Property	(a)	(b)	(c)	(d)
Name	Lithium	Nitrogen	Aluminium	Fluorine
Symbol	Li	N	Al	F

Property	(a)	(b)	(c)	(d)
Total e^-	3	7	13	9
Valence e^-	1	5	3	7
Valency	1	3	3	1
Protons	3	7	13	9
Atomic no.	3	7	13	9

Answer: (a) Lithium (Li), Z=3, 3 electrons, 1 valence electron, valency 1. (b) Nitrogen (N), Z=7, 7 electrons, 5 valence electrons, valency 3. (c) Aluminium (Al), Z=13, 13 electrons, 3 valence electrons, valency 3. (d) Fluorine (F), Z=9, 9 electrons, 7 valence electrons, valency 1.

Q10 Both Rutherford's and Bohr's models have electrons orbiting the nucleus. Why did Rutherford's model fail to explain atomic stability, while Bohr's model succeeded?

SOLUTION

Rutherford's model and the problem of stability:
According to classical electrodynamics, a charged particle (like an electron) moving in a curved path continuously radiates electromagnetic energy. In Rutherford's model, electrons orbit the nucleus in circular paths. A continuously radiating electron would lose energy progressively, causing it to spiral inward toward the nucleus in a very short time (estimated at about 10^{-8} seconds). The atom should collapse — but atoms are in fact stable. Rutherford's model could not explain this.

How Bohr's model solves the stability problem:
Bohr introduced two key postulates that break with classical physics:
1. Electrons can only occupy certain specific orbits (energy levels/shells) around the nucleus. While in these 'stationary states', electrons do NOT radiate energy, even though they are accelerating.
2. Energy is emitted or absorbed only when an electron jumps from one allowed orbit to another — not during orbital motion.

By postulating that electrons in fixed orbits do not lose energy, Bohr's model

directly explains why atoms are stable. The electron has no mechanism to spiral inward as long as it stays in an allowed orbit.

In essence, Rutherford treated electrons as classical charged particles (which should radiate), while Bohr applied the quantum concept to restrict electrons to non-radiating stationary states.

Answer: Rutherford's model failed because classical physics requires an accelerating electron to continuously radiate energy, causing it to spiral into the nucleus — making the atom unstable. Bohr's model succeeded by postulating that electrons in fixed allowed orbits do not radiate energy, keeping the atom stable.

Q11 An atom ^{70}X has 31 electrons. How many neutrons are there in its nucleus?

SOLUTION

Given: Mass number (A) = 70, number of electrons = 31.

For a neutral atom, the number of electrons equals the atomic number (Z).
Therefore: Z = 31

Number of neutrons = Mass number - Atomic number
Neutrons = A - Z = 70 - 31 = 39

Answer: The nucleus contains 39 neutrons.

Q12 An atom has 79 protons and a mass number of 197. Calculate (i) the number of neutrons, and (ii) the number of electrons.

SOLUTION

Given: Number of protons = 79, Mass number (A) = 197.

Since the number of protons = atomic number, Z = 79.

(i) Number of neutrons = Mass number - Atomic number
Neutrons = 197 - 79 = 118

(ii) For a neutral atom, number of electrons = number of protons = 79.

Answer: (i) Number of neutrons = 118. (ii) Number of electrons = 79. (This atom is Gold, Au.)

Q13 Complete the Table 8.5 (columns: Atomic number | Mass number | Number of neutrons | Number of protons | Number of electrons | Name of element). Given rows: Row 1: Z=5, neutrons=6. Row 2: A=14, electrons=7, name=Nitrogen. Row 3: A=24, protons=12. Row 4: Z=15, neutrons=16. Row 5: A=1, neutrons=0.

SOLUTION

For each row, use: A = Z + neutrons; protons = Z; electrons = Z (neutral atom).

Row 1: Z = 5, neutrons = 6
A = 5 + 6 = 11; protons = 5; electrons = 5; Element with Z=5 is Boron (B).

Row 2: A = 14, electrons = 7, name = Nitrogen
Z = electrons = 7; neutrons = 14 - 7 = 7; protons = 7.

Row 3: A = 24, protons = 12
Z = 12; neutrons = 24 - 12 = 12; electrons = 12; Element with Z=12 is Magnesium (Mg).

Row 4: Z = 15, neutrons = 16
A = 15 + 16 = 31; protons = 15; electrons = 15; Element with Z=15 is Phosphorus (P).

Row 5: A = 1, neutrons = 0
Z = 1 - 0 = 1; protons = 1; electrons = 1; Element with Z=1 is Hydrogen (H).

Completed table:

Z	A	Neutrons	Protons	Electrons	Name
5	11	6	5	5	Boron (B)
7	14	7	7	7	Nitrogen (N)
12	24	12	12	12	Magnesium (Mg)
15	31	16	15	15	Phosphorus (P)
1	1	0	1	1	Hydrogen (H)

Answer: Row 1: A=11, protons=5, electrons=5, Boron. Row 2: Z=7, neutrons=7, protons=7. Row 3: Z=12, neutrons=12, electrons=12, Magnesium. Row 4: A=31, protons=15, electrons=15, Phosphorus. Row 5: Z=1, protons=1, electrons=1, Hydrogen.

Q14 Aman was discussing the structure of atom with his classmates. During the discussion, he learnt that an element X has a mass number of 35 and contains 18 neutrons. Based on this information, answer the following questions: (i) How many electrons and protons does element X have? (ii) What is its atomic number? (iii) Identify the element X. (iv) Write its electronic configuration. (v) How many valence electrons does it have? (vi) What will be the mass number if two neutrons are added to its nucleus? (vii) What will be the relation of X with the new atom?

SOLUTION

Given: Mass number (A) = 35, neutrons = 18.

Atomic number (Z) = A - neutrons = 35 - 18 = 17

(i) For a neutral atom: protons = Z = 17; electrons = Z = 17.
Element X has 17 protons and 17 electrons.

(ii) Atomic number = 17.

(iii) The element with Z = 17 is Chlorine (Cl).

(iv) Electronic configuration of Chlorine (Z = 17):
Shell K: 2 electrons
Shell L: 8 electrons
Shell M: 17 - 2 - 8 = 7 electrons
Configuration: 2, 8, 7

(v) Valence electrons = electrons in the outermost shell = 7.

(vi) If 2 neutrons are added to the nucleus:
New neutrons = 18 + 2 = 20
New mass number = Z + new neutrons = 17 + 20 = 37

(vii) The new atom has Z = 17 (same element, Chlorine) but A = 37 instead of 35.
Same atomic number, different mass number => the new atom is an ISOTOPE of element X.
In fact, ^{35}Cl and ^{37}Cl are the two naturally occurring isotopes of Chlorine.

Answer: (i) 17 protons and 17 electrons. (ii) Atomic number = 17. (iii) Chlorine (Cl). (iv) 2, 8, 7. (v) 7 valence electrons. (vi) New mass number = 37. (vii) The new atom is an isotope of X (same protons, different mass number).

Q15 In an atom, there are 12 protons and 12 neutrons in the nucleus. Now, imagine that all the electrons are replaced with some hypothetical particles that have the same charge as electrons but are 500 times heavier. What effect will this replacement have on the atom's: (i) Atomic number, (ii) Atomic mass, (iii) Mass number, (iv) Overall charge.

SOLUTION

The original atom has 12 protons and 12 neutrons in its nucleus, and 12 electrons (since the atom is neutral). This is Magnesium (Mg-24).

(i) Atomic number:
Atomic number = number of protons in the nucleus.
The protons are unchanged (the replacement only involves electrons, which are outside the nucleus).
Atomic number remains 12.

(ii) Atomic mass:
Atomic mass is the total mass of the atom (nucleus + electrons).
Original electron mass ≈ 0.00055 u each; 12 electrons ≈ 0.0066 u (negligible).
The hypothetical particles are 500 times heavier: each has mass = 500 × 0.00055 u ≈ 0.275 u.
12 such particles add 12 × 0.275 ≈ 3.3 u to the atom.
New atomic mass ≈ 24 + 3.3 = 27.3 u — slightly increased compared to the original ~24 u.
Atomic mass increases.

(iii) Mass number:
Mass number is defined as the number of protons + number of neutrons in the nucleus.
Neither the protons nor the neutrons are changed by this replacement.
Mass number remains 24.

(iv) Overall charge:
The hypothetical particles have the same charge as electrons (charge = -1 each).
There are still 12 such particles in the atom: total negative charge = -12.
Total positive charge from 12 protons = +12.
Net charge = +12 + (-12) = 0.
Overall charge remains zero — the atom is still electrically neutral.

Answer: (i) Atomic number: unchanged (remains 12). (ii) Atomic mass: increases (heavy electrons add ~3.3 u, giving ~27.3 u). (iii) Mass number: unchanged (remains 24 — defined only by protons + neutrons). (iv) Overall charge: unchanged (remains 0 — the replacement particles carry the same charge as electrons).