Unit 6 · Atomic Structure

HARDER PRACTICE QUESTIONS

Full marks 36

Write your answers on separate paper. Show your working. Use $E_n = -\frac{13.6}{n^2}$ eV for hydrogen, 1 eV = 1.602×10^{-19} J, h = 6.626×10^{-34} J s. Other masses and charges: 1 u = 1.6605×10^{-27} kg; electron 0.000549 u, proton 1.00728 u, neutron 1.00866 u.

1 Spot the error [3]

Dorje was asked how much energy a hydrogen atom gives out when its electron drops from the fourth orbit to the second. He wrote:

"The jump is $4 - 2 = 2$ orbits, so $E = 13.6 \div 2^2 = \mathbf{3.40\ eV}$."

Find his mistake and work out the right answer. Is the light's frequency higher or lower than that of hydrogen's red line (1.89 eV)?

2 All the jumps [5]

A hydrogen electron starts in the fourth orbit and can fall to the first by any route.

i. Work out the energies of the first four levels, and list every different jump it could make.

ii. Which jump gives out the least energy, and which the most? Give each in eV.

iii. Find the frequency of the light from the jump that gives out the most.

3 Predict, then explain [3]

Write your prediction first, then explain it.

A hydrogen atom has its electron in the first orbit. Three packets of energy arrive, one at a time: 10.2 eV, 11.0 eV and 12.09 eV. Which of them can the atom take in, by Bohr's model, and where does the electron go each time?

4 Where has the mass gone? [4]

The mass of a chlorine-35 atom is 34.969 u. It has 17 protons, 18 neutrons and 17 electrons.

i. Add up the masses of its particles.

ii. How much mass is missing, in u and in kg? Where has it gone?

iii. What percentage of the atom's mass (34.969 u) is its electrons?

5 A chain of nuclei [4]

Start with carbon-14, Z = 6. Atom Q is an isobar of it with one more proton. Atom R is an isotone of Q with one more proton. Atom S is an isotope of R with two more neutrons.

i. Copy and complete a table with Z, N and A for carbon-14, Q, R and S.

ii. Which elements are Q, R and S? Name each as you would carbon-14. (Z = 7 is nitrogen, Z = 8 is oxygen.)

iii. Are carbon-14 and S isotopes, isobars or isotones of each other? Show why.

6 Is the report possible? [4]

Element M (made up for this question) has three isotopes with masses 20.0 u, 21.0 u and 22.0 u.

i. It is 90.0% M-20, and its average atomic mass is 20.18. Find the percentages of the other two.

ii. A second report says another sample of M, from a rock, has an average atomic mass of 22.3. Without any more data, explain why this report must be wrong.

7 Which law? [3]

Aakriti has lab results for an element X (made up for this question) and oxygen. In each sample all of the X and all of the oxygen combined.

Sample	Mass of X (g)	Mass of oxygen (g)
A	3.0	2.0
B	6.0	4.0
C	1.5	2.0

i. Which two samples are the same compound? Which law does that fit?
ii. Which law does the third sample fit, with the others? Show it with a calculation.

8 Which explanation fits the evidence? [3]

A very few alpha particles bounced back from the gold foil. Two students explain it:
Anju: "They hit the electrons in the gold atoms and bounced off."
Rizwan: "They were pushed back by something small, heavy and positively charged."
Which explanation does the evidence support? Explain, with two reasons from what you know about the alpha particle and the electron, why the other can't be right.

9 Comparing two beams [4]

Thomson found e/m of the particles in cathode rays to be the same whatever the gas. The canal rays' value changes with the gas, and is largest for hydrogen.

i. From the table of particles, find e/m for a proton. (Charge 1.602×10^{-19} C, mass 1.6726×10^{-27} kg.)
ii. The electron's value is 1.76×10^{11} C/kg. How many times larger is it than the proton's? What does that number tell you?
iii. Why do canal rays change with the gas when cathode rays don't?

10 Estimate [3]

A gold atom is about 0.29 nm across and its nucleus about 20,000 times smaller across.

i. Geiger's foil was 0.000086 mm thick. Estimate how many atoms thick it was.
ii. About what fraction of a gold atom's **volume** does the nucleus fill? (Volume goes as the cube of the width.)
iii. A hydrogen atom is about 60,000 times wider than its proton. If it were blown up to the size of a football ground, 100 m across, how wide would the proton be?

11 Design it (not marked)

Design a marble test like the one in the unit, under a sheet of cardboard, to find out whether what is hidden is **one big object** or **a few small objects spread over the same area**. Write what you would do, what you would keep the same each time, how many marbles you would need, and what result would decide it. How is the problem like choosing between two models of the atom?