5.1 The nuclear model of the atom

Name: _____ Class: _____ Date: _____ **Total: 19 marks**

0 Vocabulary

Word	Example
atom /'ætəm/ 原子	An **atom** has a nucleus and electrons. **原子**由原子核和电子组成。
nucleus /'nju:kliəs/ 原子核	The **nucleus** is at the centre of an atom. **原子核**位于原子的中心。
electron /ɪ'lektrɒn/ 电子	An **electron** has a negative charge. **电子**带负电。
orbit /'ɔ:bɪt/ 轨道	The Moon's **orbit** takes about 27 days. 月球沿**轨道**运行一周约需 27 天。
charge /tʃɑ:dʒ/ 电荷	A proton has a positive **charge**. 质子带正**电荷**。
mass /mæs/ 质量	The **mass** of this bag of rice is 5 kg. 这袋大米的**质量**是 5 kg。
ion /'aɪɒn/ 离子	An **ion** is an atom that has gained or lost electrons. **离子**是得到或失去电子的原子。
alpha particle /'ælfə 'pɑ:tɪkl/ α 粒子	An **alpha particle** has two protons and two neutrons. 一个α **粒子**有两个质子和两个中子。
gold foil /gəʊld fɔɪl/ 金箔	Rutherford fired alpha particles at thin **gold foil**. 卢瑟福用阿尔法粒子轰击薄**金箔**。
scattering /'skætərɪŋ/ 散射	The **scattering** of alpha particles showed that atoms have a nucleus. α 粒子的**散射**表明原子有原子核。
deflected /dɪ'flektɪd/ 偏转	A few alpha particles were **deflected** back by the gold foil. 少数 α 粒子被金箔**偏转**了回来。
nucleon /'nju:klɪən/ 核子	A proton or a neutron is a **nucleon**. 质子或中子都叫作**核子**。

Word	Example
proton /ˈprəʊtɒn/ 质子	A **proton** has a positive charge. **质子**带正电。
relative /ˈrelətɪv/ 相对	The **relative** mass of a proton is 1. 质子的**相对**质量为 1。
neutron /ˈnjuːtrɒn/ 中子	A **neutron** has no charge. **中子**不带电。
proton number 质子数 /ˈprəʊtɒn ˈnʌmbə/	Carbon has a **proton number** of 6. 碳的**质子数**是 6。
nucleon number 核子数 /ˈnjuːklɪən ˈnʌmbə/	The **nucleon number** counts protons and neutrons. **核子数**是质子和中子的总数。
nuclide /ˈnjuːklaɪd/ 核素	Carbon-14 is a **nuclide**. Carbon-14 是一种**核素**。
isotope /ˈaɪsətəʊp/ 同位素	Carbon-14 is an **isotope** of carbon. Carbon-14 是碳的一种**同位素**。
nuclear fission /ˈnjuːklɪə ˈfɪʃn/ 核裂变	**Nuclear fission** splits a big nucleus into two. **核裂变**将一个大原子核分裂成两个。
energy /ˈenədʒi/ 能量	Food gives your body the **energy** it needs to move. 食物为你的身体提供运动所需的**能量**。
nuclear fusion 核聚变 /ˈnjuːklɪə ˈfjuːʒn/	**Nuclear fusion** powers the Sun. **核聚变**为太阳提供能量。
hydrogen /ˈhaɪdrədʒn/ 氢	Water contains **hydrogen** and oxygen. 水含有**氢**和氧。
helium /ˈhiːlɪəm/ 氦	An alpha particle is a **helium** nucleus. α 粒子是一个**氦**原子核。
unstable /ʌnˈsteɪbl/ 不稳定	An **unstable** nucleus gives out radiation. **不稳定**的原子核会释放辐射。
radioactive /ˌreɪdɪəʊˈæktɪv/ 放射性	**Radioactive** material gives out radiation. **放射性**物质会释放辐射。
decay /dɪˈkeɪ/ 衰变	Uranium nuclei **decay** slowly. 铀原子核会缓慢**衰变**。
spontaneous /spɒnˈteɪnɪəs/ 自发	Decay is **spontaneous**: nothing outside makes it happen. 衰变是**自发**的：它的发生不需要外界作用。

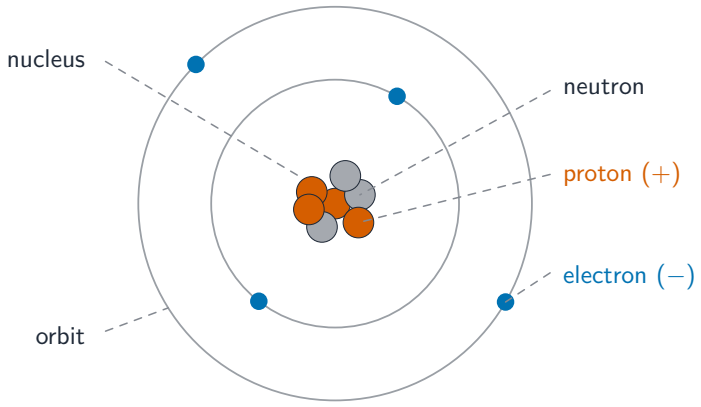
Word	Example
random /ˈrændəm/ 随机	Decay is **random**: we cannot say which nucleus decays next. 衰变是**随机**的：我们无法确定下一个衰变的是哪个原子核。
detector /dɪˈtektə/ 探测器	A Geiger–Müller tube is a radiation **detector**. 盖革 - 米勒管是一种辐射**探测器**。
count rate /kaʊnt reɪt/ 计数率	The **count rate** is 120 counts per minute. **计数率**为每分钟 120 次。
gamma radiation γ 射线 /ˈgæmə ˌreɪdɪˈeɪʃn/	**Gamma radiation** needs thick lead to stop it. γ **射线**需要用厚铅板才能挡住。
electric field /ɪˈlektrɪk fiːld/ 电场	A charged ball has an **electric field** around it. 带电小球周围有**电场**。
magnetic field 磁场 /mægˈnetɪk fiːld/	A magnet has a **magnetic field** around it. 磁铁周围有**磁场**。
stable /ˈsteɪbl/ 稳定	A **stable** sort keeps equal items in the same order. **稳定**的排序会保持相等元素的原有顺序。
bacteria /bækˈtɪərɪə/ 细菌	Chlorine kills **bacteria** in drinking water. 氯可以杀死饮用水中的**细菌**。
sterilise /ˈsterəlaɪz/ 消毒	Chlorine is used to **sterilise** water by killing germs. 氯通过杀死病菌来给水**消毒**。
radioactive waste 放射性废物	**Radioactive waste** from hospitals and power stations must be disposed of safely. 医院和发电站产生的**放射性废物**必须安全处理。

1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later: follow the steps and you can do the Practice and Exam-style questions yourself.

■ The nuclear atom

particle	relative charge	relative mass	where
proton	$+1$	1	nucleus
neutron	0	1	nucleus
electron	-1	about $\frac{1}{2000}$	orbits round the nucleus



Almost all the mass is in the tiny nucleus; the atom is mostly empty space

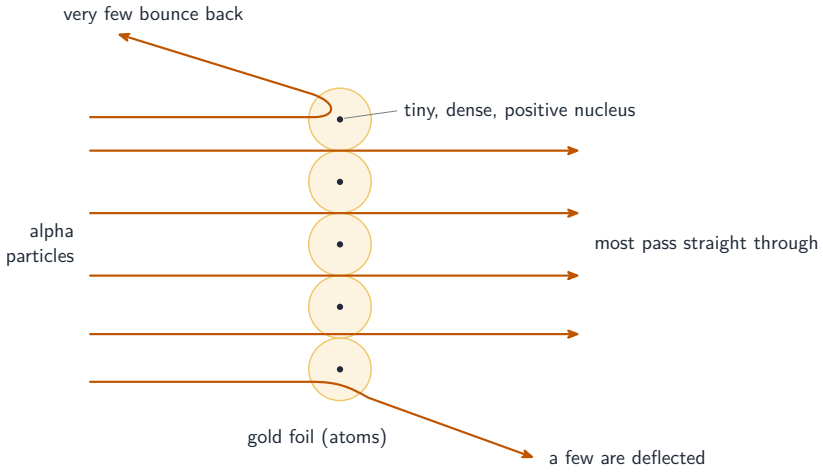
- **Nuclide notation** 核素符号 ${}^{A}_{Z}\mathrm{X}$: proton number Z (bottom), nucleon number A = protons + neutrons (top). Neutrons = $A - Z$; a neutral atom has Z electrons.
- **Isotopes** 同位素: atoms of the same element (same Z) with different numbers of neutrons (different A).

■ Worked example 1: reading nuclide notation

How many protons, neutrons and electrons are in a neutral atom of ${}^{197}_{79}\mathrm{Au}$?

1. Protons = Z = **79**; a neutral atom has as many electrons: **79**.
2. Neutrons = $A - Z = 197 - 79 =$ **118**.

■ Alpha-particle scattering



Most pass straight through (empty space); a few bounce back (small, heavy, positive nucleus)

observation	conclusion
most alpha particles pass straight through	the atom is mostly empty space
some are deflected (repelled)	the nucleus is positively charged
a very few bounce back	the nucleus is very small and contains most of the mass

Alpha particles are used because they are **positively charged**, so they are repelled by the positive nucleus; neutrons have no charge and would not be deflected by it.

Fission and fusion

- **Fission:** a large nucleus (such as uranium-235) absorbs a neutron and splits into two smaller nuclei, releasing neutrons and energy.
- **Fusion:** two light nuclei join to form a heavier nucleus, releasing energy; it powers the Sun.

Worked example 2: a nuclide equation

Two hydrogen-2 nuclei, ${}^{2}_{1}\mathrm{H}$, fuse to make a helium nucleus and a neutron, ${}^{1}_{0}\mathrm{n}$. Write the equation.

1. Nucleon numbers balance: $2 + 2 = A + 1$, so $A = 3$.
2. Proton numbers balance: $1 + 1 = Z + 0$, so $Z = 2$ (helium).
3. $$ {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} $$

2 Practice

2.1 State what is meant by an isotope. [1]

isotope

2.2 For ${}^{23}_{11}\mathrm{Na}$, write down the number of protons and the number of neutrons. [2]

${}^{23}_{11}\mathrm{Na}$

2.3 Name the two particles in a nucleus and state the relative charge of each. [2]

nucleus

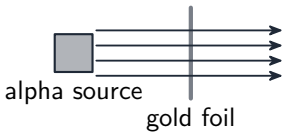
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2.4 State what is meant by the nucleon number of a nuclide. [1]

nucleon number

3 Exam-style questions

3.1 In the alpha-scattering experiment, most alpha particles pass straight through the foil. This shows the atom is: [1]



- ☐ **A** solid throughout
- **B** mostly empty space
- **C** negatively charged
- **D** very large

3.2 The scattering of alpha particles by a thin gold foil supports the nuclear model of the atom. Why are alpha particles used rather than neutrons? [1]



- ☐ **A** They travel more slowly.
- **B** They are heavier.
- **C** They are larger in diameter.
- **D** They have a positive charge.

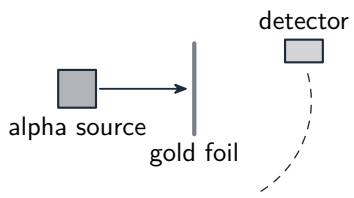
3.3 The nuclide $^{40}_{19}\mathrm{K}$ is given.

(a) State the number of protons, neutrons and electrons in a neutral atom. [3]

$^{40}_{19}\mathrm{K}$

(b) An isotope of potassium is $^{39}_{19}\mathrm{K}$. State how its nucleus differs from $^{40}_{19}\mathrm{K}$. [1]

3.4 In the alpha-particle scattering experiment, alpha particles were fired at a thin gold foil. State two conclusions about the nucleus from this experiment, and the observation that supports each. [4]

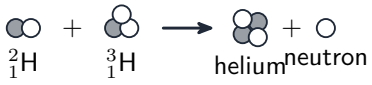


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3.5 Deuterium, $^{2}_{1}\mathrm{H}$, is an isotope of hydrogen. A deuterium nucleus fuses with a tritium nucleus, $^{3}_{1}\mathrm{H}$, to form a helium nucleus and a neutron.

(a) Explain what is meant by nuclear fusion. [1]

(b) Write the nuclide equation for this reaction. [2]



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Solutions

Each answer shows the steps, then the **result**.

2.1

- atoms of the same element (same proton number) with different numbers of neutrons

2.2

- protons = 11
- neutrons = $23 - 11 =$ **12**

2.3

- proton: relative charge +1
- neutron: relative charge 0

2.4

- the total number of protons and neutrons in the nucleus

3.1 B

- most passing straight through shows the atom is mostly empty space

3.2 D

- the positive alpha particles are repelled by the positive nucleus; uncharged neutrons would not be

3.3

(a) protons = 19

- neutrons = $40 - 19 =$ **21**
- electrons = 19

(b) it has one fewer neutron (20 instead of 21)

3.4

Any two conclusions, each with its observation:

- the nucleus is very small compared with the atom; most alpha particles pass straight through the foil
- the nucleus is positively charged; some alpha particles are deflected, repelled by the nucleus
- the nucleus contains most of the mass of the atom; a very few alpha particles bounce back

3.5

(a)

- two light nuclei join to form a heavier nucleus, releasing energy

(b)

- nucleons: $2 + 3 = 4 + 1$; protons: $1 + 1 = 2 + 0$, so helium is ${}^{4}_{2}\mathrm{He}$

$$ {}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} $$

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