

End of Term 3 Revision Physics



تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ← المناهج الإماراتية ← الصف الثاني عشر المتقدم ← فيزياء ← الفصل الثالث ← ملفات متنوعة ← الملف

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ملفات اكتب للمعلم اكتب للطالب ا اختبارات الكترونية ا اختبارات ا حلول ا عروض بوربوينت ا أوراق عمل
منهج انجليزي ا ملخصات وتقارير ا مذكرات وبنوك ا الامتحان النهائي للمدرس

المزيد من مادة
فيزياء:

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التواصل الاجتماعي بحسب الصف الثاني عشر المتقدم



صفحة المناهج
الإماراتية على
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

المزيد من الملفات بحسب الصف الثاني عشر المتقدم والمادة فيزياء في الفصل الثالث

مراجعة هيكل الامتحان 2026م

1

مراجعة هيكل الامتحان كراسة تدريبية

2

انسباير حلول مراجعة فرق الجهد والتيار الكهربائي وخصائص الدوائر

3

انسباير حلول تجميعية هيكل الفيزياء

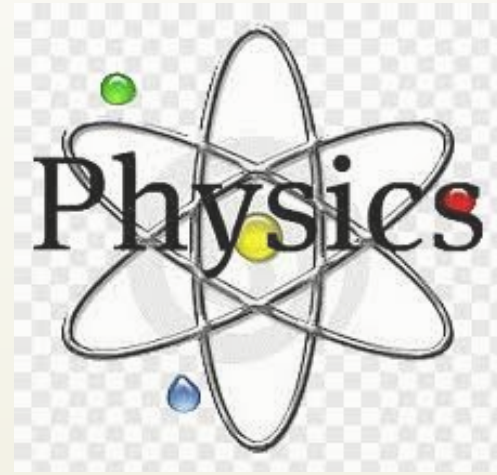
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تجميعية هيكل الفيزياء انسباير بدون حل

5



**BE
READY**



**END OF TERM 3
REVISION
PHYSICS
GRADE 12 ADV**

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1	Explain Planck's concept of quantization of energy Calculate the energy emitted or absorbed by a vibrating atom in a solid using the equation	St. textbook	68
		Practice problems	72

1 Thermal Radiation

Hotter objects emit more total radiation and higher peak frequency.

2 Emission Spectra

As temperature increases, the peak intensity increases and shifts to higher frequency.

3 Planck's Idea

Energy is emitted or absorbed in discrete packets (quanta), not continuously.

$$E = nhf$$
$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

$n = 0, 1, 2, 3, \dots$ (whole numbers)

4 Key Takeaways

- Energy is quantized.
- Higher temperature shifts the peak to higher frequency.
- A vibrating atom can emit only whole-number multiples of hf .
- This idea helped explain observed spectra.

Planck's Quantization of Energy

1. Concept:

Energy is quantized: atoms emit or absorb energy in discrete packets, not continuously.

2. Planck's equation:

$$E = nhf$$

$n = 0, 1, 2, 3, \dots$ integer
 $h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
 f = frequency (Hz)

3. Energy-level ladder:

4. Note: If n or f increases, the emitted/absorbed energy increases.

5. Worked example:

For $n = 2$ and $f = 5.0 \times 10^{14} \text{ Hz}$:

$$E = 2(6.63 \times 10^{-34})(5.0 \times 10^{14})$$
$$= 6.63 \times 10^{-19} \text{ J}.$$

6. Key takeaway:

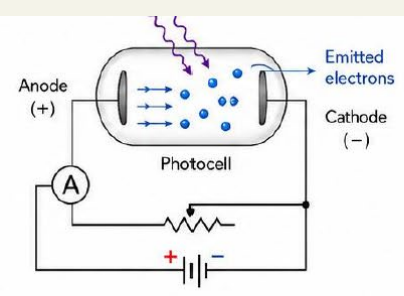
Key idea: energy changes in discrete multiples of hf .



2	Define the photoelectric effect. Explain how the photoelectric effect occurs when light shines on a metal surface.	St. textbook	69
3	Explain that electrons are ejected from the surface of a metal only if the frequency of the radiation is greater than a threshold frequency	St. textbook	70

Photoelectric Effect and Threshold Frequency

- Photoelectric effect:** emission of electrons from the surface of a metal when light of sufficient frequency shines on it.
- Threshold frequency (f_0):** the minimum frequency needed to eject electrons.
- If $f < f_0$: no electrons are emitted, even if intensity increases.
- If $f = f_0$: electrons are just emitted and $KE_{\max} = 0$.
- If $f > f_0$: electrons are emitted; higher intensity gives more current.



Below threshold ($f < f_0$)	At threshold ($f = f_0$)	Above threshold ($f > f_0$)
- No electrons emitted. - Current = 0, regardless of intensity.	- Electrons are just emitted. $KE_{\max} = 0$, current is very small.	- Electrons are emitted. - Higher intensity $\rightarrow$ more current.



FOCUS QUESTION

Concept Overview: The Photoelectric Effect



1 Definition

The **photoelectric effect** is the emission of electrons from a metal surface when light of sufficient frequency strikes it.

2 Photocell

3 Threshold Frequency

Electrons are emitted only if the incident frequency is at least the threshold frequency f_0 .

Current vs. Frequency

4 Intensity vs. Frequency

(a) For $f < f_0$
Current remains zero no matter the intensity.

(b) For $f \geq f_0$
Current increases as intensity increases.

5 Equations

Photon Energy
 $E = hf$

Photon Energy in eV
 $E(\text{eV}) = \frac{1240 \text{ eV} \cdot \text{nm}}{\lambda (\text{nm})}$

Maximum Kinetic Energy
 $KE_{\max} = hf - hf_0$

Photon Energy, Photoelectrons, and Graph Interpretation

1 Photon Energy

$$E = hf$$
$$E = \frac{hc}{\lambda}$$

Shorter wavelength $\rightarrow$ greater energy

2 Maximum Kinetic Energy

$$KE_{\max} = hf - \Phi$$
$$KE_{\max} = h(f - f_0)$$

Example: Photon energy = 4.5 eV, work function = 2.0 eV $\rightarrow KE_{\max} = 2.5$ eV.

3 Graph Clues

Increasing intensity increases photoelectric current, but does not change $KE_{\max}$.

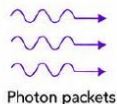
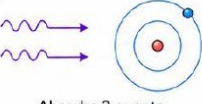
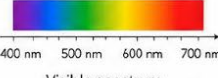


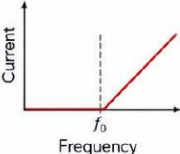
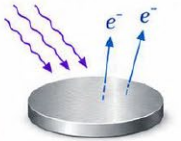
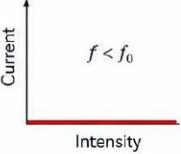
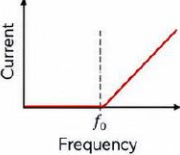
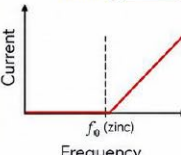
Use the graph to read threshold frequency and determine Planck's constant from the slope.

Planck's Quantization of Energy – $E = nhf$

Objective 1: Explain Planck's concept of quantization of energy and calculate $E = nhf$ for a vibrating atom.

 Level 1	1. In the equation $E = nhf$, the value of n must be: A. any real number B. an integer C. a negative number D. a unit of energy	2. If $n = 0$ in $E = nhf$, the energy emitted or absorbed is: A. hf B. $2hf$ C. 0 D. undefined
 Level 2	3. If frequency f doubles while n stays constant, the energy E will: A. stay the same B. halve C. double D. become zero	4. A vibrating atom emits energy equal to $3hf$. The value of n is: A. 1 B. 2 C. 3 D. 4
 Challenge	5. For $n = 2$ and $f = 5.0 \times 10^{14}$ Hz, using $h = 6.63 \times 10^{-34}$ J·s, the energy is closest to: A. 6.63×10^{-19} J B. 3.32×10^{-19} J C. 1.33×10^{-18} J D. 6.63×10^{-34} J	6. Which statement best describes quantization of energy? A. Energy changes continuously B. Energy exists only in discrete packets C. Frequency is always zero D. Atoms cannot absorb energy

Level 1 1 In Planck's model, energy is emitted in ____. A continuous waves B packets (quanta) C masses D fields  Photon packets	2 In $E = nhf$, h represents ____. A electron charge B Planck's constant C wavelength D intensity $E = nhf$
Level 2 3 If n doubles while f stays constant, the emitted energy will ____. A halve B stay the same C double D become zero 	4 For $n = 1$ and $f = 5 \times 10^{14}$ Hz, the emitted energy is given by ____. A h/f B hf C nh/f D f/h $E = nhf$
Level 3 5 If an atom absorbs 2 quanta of frequency f, the absorbed energy is ____. A hf B $2hf$ C h/f D $2f/h$  Absorbs 2 quanta	6 A solid emits 6.6×10^{-19} J at frequency 5×10^{14} Hz. The value of n is closest to ____. A 1 B 2 C 10 D 20  Visible spectrum

1 Electrons are ejected from a metal only when the incident frequency is ____ the threshold frequency. A less than B equal to or greater than C independent of D opposite to 	2 Threshold frequency depends mainly on the metal's ____. A color B material/work function C intensity D size 	3 Increasing intensity of light when $f < f_0$ will ____ electron emission. A start B not cause C double D reverse 
4 At the threshold frequency, the minimum photon energy is ____. A 0 B hf_0 C h/f_0 D f_0/h 	5 Cesium has a lower threshold frequency than zinc. Which metal ejects electrons more easily with visible light? A zinc B cesium C both equally D impossible to tell 	6 Visible light often fails to eject electrons from zinc because its frequency is usually ____ zinc's threshold frequency. A above B below C equal to D unrelated to 

Threshold Frequency

Objective 3: Explain that electrons are ejected only if the radiation frequency is greater than a threshold frequency.

 Level 1	1. Threshold frequency f_0 is the: A. maximum frequency B. minimum frequency needed to eject electrons C. light speed D. metal mass	2. If incident frequency is less than f_0, photoelectrons: A. are emitted slowly B. are not emitted C. have high KE D. increase current
 Level 2	3. At $f = f_0$, the emitted electrons have maximum kinetic energy: A. zero B. equal to h C. very large	4. Threshold frequency depends mainly on the: A. color of the wire B. type of metal C. intensity only D. ammeter reading
 Challenge	5. If light is below threshold, which change can start emission? A. increase intensity only B. use a larger metal plate C. increase frequency D. lower current	6. A metal with a lower work function generally has: A. higher f_0 B. lower f_0 C. same f_0 for all metals D. no threshold



4	Calculate the energy of a photon given its wavelength or frequency. Calculate the maximum kinetic energy of an electron ejected due to the photoelectric effect	Example problem 1,2 Practice problems	74,76
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1 Photon energy is given by ____.

A $E = hf$
B $E = mv$
C $E = IR$
D $E = Pt$

Photon Energy

$E = hf$

h = Planck's constant
 f = frequency

2 For a fixed medium, a shorter wavelength means ____ photon energy.

A lower
B the same
C higher
D zero

$E = \frac{hc}{\lambda}$

For fixed h and c ,
 $E \propto \frac{1}{\lambda}$

3 A photon of frequency 6×10^{14} Hz has energy closest to ____.

A 4×10^{-20} J
B 4×10^{-19} J
C 4×10^{-18} J
D 4 J

Useful Formula

$E = hf$

$h = 6.626 \times 10^{-34}$ J·s

4 The maximum photoelectron kinetic energy is given by ____.

A $KE_{\max} = hf + hf_0$
B $KE_{\max} = hf - hf_0$
C $KE_{\max} = h/f_0$
D $KE_{\max} = f/h$

Photoelectric Effect

$KE_{\max} = hf - hf_0$

hf = photon energy
 hf_0 = work function

5 If a 3.0 eV photon strikes a metal with work function 2.2 eV, $KE_{\max}$ is ____.

A 0.8 eV
B 5.2 eV
C 1.5 eV
D 2.2 eV

$KE_{\max} = hf - hf_0$

Values in eV can be used directly in this equation.

6 A 620 nm photon has less energy than a 400 nm photon because energy is ____ wavelength.

A directly proportional to
B inversely proportional to
C unrelated to
D equal to

$E = \frac{hc}{\lambda}$



400 nm 700 nm

Shorter $\lambda \rightarrow$ Higher E

Photon Energy and Maximum Kinetic Energy

Objective 4: Calculate photon energy from wavelength or frequency and calculate the maximum kinetic energy of an ejected electron.

Level 1

1. Photon energy is given by:

A. $E = mc^2$ **B.** $E = hf$
C. $p = mv$ **D.** $V = IR$

2. If wavelength decreases, photon energy:

A. decreases **B.** remains the same
C. increases **D.** becomes zero

Level 2

3. A photon of wavelength 620 nm has energy closest to:

A. 2.0 eV **B.** 6.2 eV
C. 0.2 eV **D.** 12.4 eV

4. If a photon has energy 4.5 eV and the work function is 2.0 eV, $KE_{\max}$ is:

A. 2.5 eV **B.** 6.5 eV
C. 2.0 eV **D.** 0.5 eV

Challenge

5. A higher-frequency photon has:

A. lower energy **B.** no energy
C. greater energy **D.** the same energy

6. Which photon has the greatest energy?

A. 700 nm **B.** 500 nm
C. 400 nm **D.** 900 nm



5	Explain that the maximum kinetic energy of photoelectrons is independent of the intensity of incident electromagnetic radiation. Explain that the current due to photoelectrons (photoelectric current) is proportional to the intensity of incident electromagnetic radiation.	St. textbook	70-73
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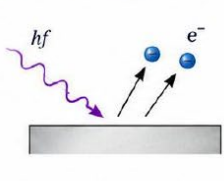
1 Increasing light intensity at frequency above f_0 mainly increases the ____.

A threshold frequency
B number of emitted electrons / current
C work function
D KE_{max}



2 The maximum kinetic energy of photoelectrons depends primarily on ____.

A intensity
B frequency
C area of metal
D ammeter reading



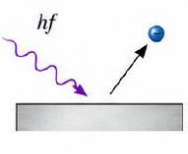
3 With frequency fixed and above f_0 , doubling intensity will roughly ____ the photoelectric current.

A halve
B double
C make it zero
D not change it



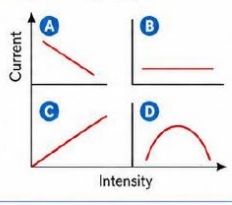
4 If intensity increases while frequency stays unchanged, KE_{max} will ____.

A increase greatly
B decrease
C stay the same
D become negative



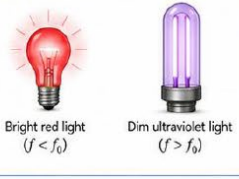
5 Which graph best matches photoelectric current versus intensity when $f \geq f_0$?

A downward line
B horizontal zero line
C upward straight line
D parabola opening down



6 Bright red light below f_0 and dim ultraviolet light above f_0 shine on a metal. Which produces photoelectrons?

A red only
B ultraviolet only
C both
D neither



Intensity, Current, and Kinetic Energy

Objective 5: Explain that KE_{max} is independent of intensity, while photoelectric current is proportional to intensity.

Level 1

1. For light above threshold, increasing intensity mainly increases the:

A. photoelectric current B. KE_{max}
C. threshold frequency D. work function

2. For light above threshold, maximum kinetic energy depends on:

A. intensity only B. frequency only
C. area of metal only D. color of ammeter

Level 2

3. If frequency is below threshold, increasing intensity will:

A. eject more electrons B. increase KE_{max}
C. produce no photoelectrons D. double current

4. Doubling the intensity of above-threshold light means:

A. more photons each second B. larger work function
C. smaller current D. lower frequency

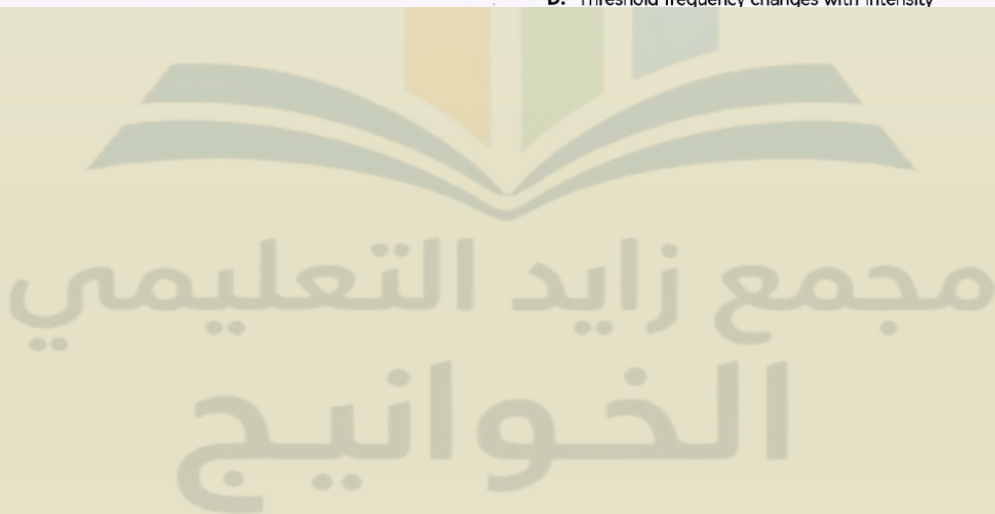
Challenge

5. The photoelectric current is proportional to:

A. wavelength B. intensity of incident light
C. slope of graph only D. metal mass

6. Which statement is correct?

A. Higher intensity always raises KE_{max}
B. Higher intensity above threshold raises current, not KE_{max}
C. Current is independent of intensity
D. Threshold frequency changes with intensity



6	Interpret the graph of maximum kinetic energy of an electron ejected from a metal versus the frequency of incident photon and determine graphically the threshold frequency and Planck's constant.	St. textbook	75
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1 On a $KE_{\max}$ versus frequency graph, the x-intercept represents the ____.

A intensity
B threshold frequency
C wavelength
D current

5 The y-value on this graph gives the ____ of the emitted electrons.

A total charge
B maximum kinetic energy
C threshold frequency
D intensity

2 The slope of the $KE_{\max}$ versus frequency graph equals ____.

A Planck's constant h
B electron charge e
C speed of light c
D work function

6 For a photon frequency greater than f_0 , $KE_{\max}$ is expected to be ____.

A negative
B zero or positive
C impossible
D independent of frequency

3 If the line crosses the x-axis at 5×10^{14} Hz, then f_0 is ____.

A 5×10^{14} Hz
B 0
C h
D 5 eV

4 A steeper line on the same graph indicates a ____ value of h .

A smaller
B larger
C zero
D variable

Interpreting $KE_{\max}$ vs Frequency Graphs

Objective 6: Interpret a $KE_{\max}$ vs frequency graph and determine the threshold frequency and Planck's constant.

Level 1

1. In a graph of $KE_{\max}$ vs frequency, the x-intercept represents:

A. Planck's constant **B.** threshold frequency
C. current **D.** wavelength

2. The slope of the $KE_{\max}$ vs frequency graph equals:

A. h **B.** c
C. e **D.** Φ

Level 2

3. At frequencies below the x-intercept, $KE_{\max}$ is:

A. positive **B.** maximum
C. zero / no emission **D.** equal to h

4. If Metal X has a graph shifted to the right of Metal Y, Metal X has:

A. lower threshold frequency **B.** higher threshold frequency
C. same work function **D.** lower slope

Challenge

5. Parallel lines for different metals on a $KE_{\max}$ vs frequency graph indicate:

A. different Planck constants **B.** same slope and same h
C. same threshold frequency **D.** no photoelectric effect

6. A line crosses the x-axis at 5×10^{14} Hz. This value is the metal's:

A. intensity **B.** threshold frequency
C. current **D.** photon energy

1 A metal has $f_0 = 4.5 \times 10^{14}$ Hz. Light of frequency 6×10^{14} Hz strikes it. Which statement is true?

A No electrons are emitted
B Electrons are emitted and $KE_{\max} > 0$
C Current is zero regardless of intensity
D Photon energy is less than hf_0 .

2 An atom absorbs 3 quanta of frequency 5×10^{14} Hz. The total absorbed energy is closest to ____.

A 1.0×10^{-18} J
B 1.0×10^{-19} J
C 5 J
D 15 J

Photon Energy

$E = hf$

$E \text{ (eV)} = \frac{1240 \text{ eV} \cdot \text{nm}}{\lambda \text{ (nm)}}$

3 Which change increases photocurrent without changing $KE_{\max}$?

A increase intensity only
B increase threshold frequency
C use longer wavelength
D reduce the number of photons

4 On a $KE_{\max}$ versus frequency graph, the x-intercept is 5×10^{14} Hz and the slope is 6.6×10^{-34} J · s. The work function is closest to ____.

A 3.3×10^{-19} J
B 8.0×10^{-20} J
C 5×10^{14} J
D 6.6×10^{-34} J

5 A photon of wavelength 500 nm strikes a metal with work function 2.0 eV. $KE_{\max}$ is closest to ____.

A 0.48 eV
B 2.48 eV
C 1.52 eV
D 0 eV

$E \text{ (eV)} = \frac{1240 \text{ eV} \cdot \text{nm}}{\lambda \text{ (nm)}}$

6 Which statement best compares low-intensity UV and high-intensity red light on zinc?

A Red light ejects more electrons
B UV ejects electrons; red may not eject any
C Both eject the same $KE_{\max}$
D Intensity alone determines emission

- 37 A metal has threshold frequency $f_0 = 6.0 \times 10^{14}$ Hz and is illuminated with light of frequency 8.0×10^{14} Hz. Using $h = 6.63 \times 10^{-34}$ J·s, $KE_{\max}$ is closest to:
 A 1.33×10^{-19} J B 5.30×10^{-19} J
 C 6.63×10^{-34} J D 0 J
- 38 A 400-nm photon strikes a metal with work function 2.0 eV. The maximum kinetic energy is closest to:
 A 0.40 eV
 B 1.10 eV
 C 2.00 eV
 D 3.10 eV
- 39 Two beams have the same above-threshold frequency, but beam A has greater intensity. Compared with beam B, beam A produces:
 A greater current and same $KE_{\max}$
 B same current and greater $KE_{\max}$
 C lower current and same $KE_{\max}$
 D no emission

- 40 A $KE_{\max}$ versus frequency graph has slope 4.14×10^{-15} eV·s. This slope represents:
 A the work function
 B threshold wavelength
 C Planck's constant in eV·s
 D photon current
- 41 If no electrons are emitted from a metal, which single change is most likely to start emission?
 A decrease frequency
 B increase frequency above threshold
 C decrease intensity
 D cool the ammeter
- 42 A metal has threshold wavelength $\lambda_0 = 500$ nm. Its work function is closest to:
 A 0.50 eV
 B 1.24 eV
 C 2.48 eV
 D 5.00 eV

LESSON RECAP

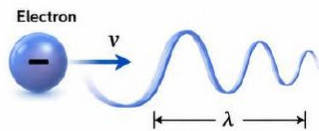
- $E = hf$
- $E = \frac{hc}{\lambda} = \frac{1240 \text{ eV} \cdot \text{nm}}{\lambda}$
- $KE_{\max} = hf - \phi$
- threshold frequency = x-intercept of $KE_{\max}$ vs f graph
- slope = h



LEARNING OBJECTIVES

- 7 Describe the de Broglie wavelength as the wavelength associated with a moving particle, and calculate the de Broglie wavelength for a moving particle using $\lambda = \frac{h}{p} = \frac{h}{mv}$.

- 8 Describe that the more precisely a particle's position is measured, the greater the uncertainty in simultaneously measuring its momentum, and vice versa.



Heisenberg Uncertainty Principle

There is a limit to how precisely a particle's position and momentum can be known at the same time.

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$



KEY VOCABULARY

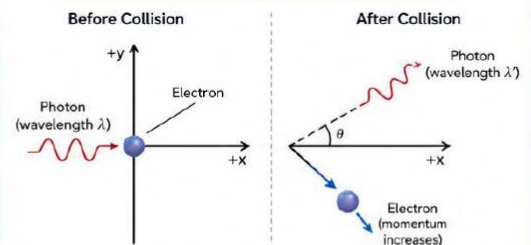
- de Broglie wavelength
- Heisenberg uncertainty principle
- Momentum
- Diffraction



WHAT YOU WILL LEARN

- ✓ Calculate de Broglie wavelength using $\lambda = \frac{h}{p} = \frac{h}{mv}$.
- ✓ Explain how measuring position affects momentum and vice versa.

VISUALIZING THE UNCERTAINTY PRINCIPLE



Measuring position with a photon changes the electron's momentum. Shorter λ (higher energy) gives better position but greater momentum uncertainty.

QUICK EXAMPLE (de Broglie Wavelength)

An electron is accelerated through a potential difference of 75 V. What is its de Broglie wavelength?

Answer: $\lambda = 1.4 \times 10^{-10}$ m (= 0.14 nm)



مجمع زايد التعليمي
 الخوانيج

7	Describe the de Broglie wavelength as the wavelength associated with a moving particle.	Example problem 3	80
	Calculate the de Broglie wavelength for a moving particle ($\lambda = \frac{h}{p} = \frac{h}{mv}$)	Practice problems	

LEARNING OBJECTIVE

7 Describe the de Broglie wavelength as the wavelength associated with a moving particle and calculate it using $\lambda = \frac{h}{p} = \frac{h}{mv}$.

MAIN CONCEPT

Matter particles such as electrons can exhibit wave behavior. The de Broglie wavelength (λ) is the wavelength associated with a moving particle.

DE BROGLIE WAVELENGTH

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

λ = wavelength (m)
 h = Planck's constant (6.63×10^{-34} J·s)
 p = momentum (kg·m/s)
 m = mass (kg)
 v = speed (m/s)

A MOVING ELECTRON AS A WAVE

KEY INSIGHT

Large mass or high speed
→ smaller de Broglie wavelength.

When...	Then...
Mass ↑	Wavelength (λ) ↓
Speed ↑	Wavelength (λ) ↓

MINI EXAMPLE: ELECTRON ACCELERATED THROUGH 75 V

- Find the electron's speed (from kinetic energy)
 $\frac{1}{2}mv^2 = e\Delta V \Rightarrow v = \sqrt{\frac{2e\Delta V}{m_e}} \quad v = 5.1 \times 10^6$ m/s
- Find the momentum
 $p = m_e v \quad p = 4.6 \times 10^{-24}$ kg·m/s
- Find the de Broglie wavelength
 $\lambda = \frac{h}{p} \quad \lambda = 1.4 \times 10^{-10}$ m
- Express in nanometers
1 nm = 10^{-9} m $\lambda = 1.4 \times 10^{-10}$ m = 0.14 nm

WHY EVERYDAY OBJECTS DON'T SHOW OBVIOUS WAVE BEHAVIOR

Electron	Mass = 9.11×10^{-31} kg Wave nature observable ($\lambda \approx 0.14$ nm at 75 V)
Bowling Ball	Mass ≈ 7.0 kg Extremely tiny λ ($\sim 10^{-35}$ m at 8.5 m/s) No observable wave behavior

LEVEL 1

1 The de Broglie wavelength is associated with which of the following?

A A moving particle
B A stationary object only
C An electric field only
D Temperature only

LEVEL 2

3 If a particle's momentum increases, what happens to its de Broglie wavelength?

A Increases
B Decreases
C Stays the same
D Becomes zero

LEVEL 3

5 An electron has momentum p. What happens to its de Broglie wavelength if the momentum becomes 2p?

A It becomes 2λ
B It becomes λ/2
C It stays the same (λ)
D It becomes zero

2 Which formula correctly represents the de Broglie wavelength?

A $\lambda = h/p$
B $\lambda = p/h$
C $\lambda = h/mv^2$
D $\lambda = mv/h$

de Broglie Wavelength

$$\lambda = \frac{h}{p}$$

4 Which particle would have the larger de Broglie wavelength if all move with the same speed?

A Electron
B Proton
C Bowling ball
D Truck

6 A student compares an electron and a tennis ball. Which statement best explains why wave behavior is more noticeable for the electron?

A The electron has no charge.
B The electron has much less mass.
C The electron moves much slower.
D The electron has higher kinetic energy.

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8	Describe that the more precisely a particle's position is measured, the more the uncertainty in simultaneously measuring the particle's momentum, and vice versa	St. textbook	81
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MAIN CONCEPT

At the atomic scale, position and momentum **cannot both** be known with unlimited precision at the same time. Measuring one more precisely increases the uncertainty in the other.

THE HEISENBERG UNCERTAINTY PRINCIPLE

$$\Delta x \Delta p \geq \frac{h}{4\pi} \approx \frac{\hbar}{2}$$

Δx = uncertainty in position (m)
 Δp = uncertainty in momentum (kg·m/s)
 h = Planck's constant = $6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
 $\hbar$ = reduced Planck's constant = $1.05 \times 10^{-34} \text{ J} \cdot \text{s}$

ANALOGY: FLASHLIGHT AND PITCHER'S MOUND

Wide beam (low precision) → Hard to locate exact spot

Narrow beam (high precision) → Pinpoints location better

WHY IT MATTERS

This principle sets a fundamental limit on all measurements at the atomic and subatomic scale. It is essential for understanding atomic structure and quantum behavior.

MEASURING POSITION CHANGES MOMENTUM

Before Collision: Photon (wavelength λ) and Electron.

After Collision: Photon (wavelength λ') and Electron (momentum increases).

The photon's collision with the electron disturbs the electron's momentum. The better we know the electron's position, the more we disturb its momentum.

KEY INSIGHT

Shorter wavelength (higher energy) photons provide better position measurement but cause a greater change in the electron's momentum.

Shorter λ (higher energy) → Better position measurement → Greater disturbance of momentum

REMEMBER

- More precise position → Less precise momentum
- More precise momentum → Less precise position

LEVEL 1 – BASIC UNDERSTANDING

1 The uncertainty principle relates which two quantities?

A. position and momentum
 B. mass and charge
 C. speed and temperature
 D. energy and volume

LEVEL 2 – CONCEPT APPLICATION

3 Which equation best represents the uncertainty principle?

A. $\Delta x \Delta p = 0$
 B. $\Delta x + \Delta p \geq h$
 C. $\Delta x \Delta p \geq \frac{h}{4\pi}$
 D. $\Delta x \Delta p \leq \frac{h}{4\pi}$

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

LEVEL 3 – HIGHER THINKING

5 Measuring an electron's position very precisely causes its momentum to become what?

A. more uncertain
 B. exactly zero
 C. constant
 D. easier to predict

2 If the uncertainty in position decreases, what happens to the uncertainty in momentum?

A. increases
 B. decreases
 C. unchanged
 D. becomes zero

4 Why does using a shorter-wavelength photon improve position measurement?

A. Smaller wavelength gives finer detail.
 B. It increases the mass of the photon.
 C. It reduces the electron's charge.
 D. It removes the photon's momentum.

6 Which situation best illustrates the uncertainty principle at the atomic scale?

A. Measuring an electron's position with a short-wavelength photon.
 B. Measuring a car's speed with a speedometer.
 C. Timing a runner with a stopwatch.
 D. Weighing an object on a scale.

1 An electron and a proton have the same de Broglie wavelength. Which particle has the greater momentum, or are they equal?

A. The electron has greater momentum.
 B. The proton has greater momentum.
 C. They have equal momentum.
 D. Cannot be determined with the given information.

2 A particle's speed doubles while its mass stays constant. What happens to its de Broglie wavelength?

A. It doubles.
 B. It halves.
 C. It remains the same.
 D. It becomes four times larger.

$$\lambda = \frac{h}{mv}$$

Mass (m) constant
 $v \rightarrow 2v$
 What happens to λ ?

3 A scientist wants a more precise position measurement of an electron. Which choice best explains the trade-off according to the uncertainty principle?

A. Position becomes more precise, so momentum becomes more uncertain.
 B. Momentum becomes more precise, so position becomes more uncertain.
 C. Both position and momentum become more precise.
 D. Neither position nor momentum is affected.

4 In a thought experiment, using a very short-wavelength photon to locate an electron changes which quantity most directly?

A. The electron's charge.
 B. The electron's mass.
 C. The electron's momentum.
 D. The electron's spin.

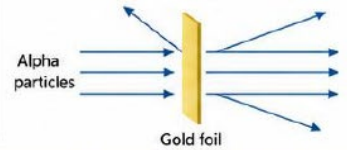
9	Describe the electron distribution within the atom according to Thomson's model. Describe how Rutherford's alpha particles scattering experiment led to the revision of Thomson's model of the atom and the introduction of the atomic nucleus	St. textbook	82-83
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Objective 9: Thomson Model and Rutherford Scattering

Thomson's Plum-Pudding Model



Rutherford's Gold-Foil Experiment



LEVEL 1

Q1. In Thomson's model, the atom's positive charge is:

A) concentrated in a nucleus
B) spread uniformly through the atom
C) carried by neutrons
D) absent

Q2. In Thomson's model, electrons are:

A) embedded in a positive sphere
B) orbiting a nucleus
C) inside the nucleus
D) moving in fixed shells

LEVEL 2

Q3. In Rutherford's gold-foil experiment, most alpha particles:

A) bounced straight back
B) passed through undeflected
C) were absorbed
D) turned into electrons

Q4. A few alpha particles were strongly deflected because the atom has:

A) a tiny dense positive nucleus
B) a large negative center
C) magnetic poles
D) no empty space

LEVEL 3

Q5. Which statement best revised Thomson's model?

A) Atoms are mostly empty space
B) Atoms have no electrons
C) Positive charge is spread out evenly
D) Nucleus contains only electrons

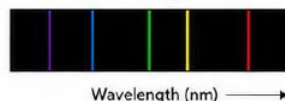
Q6. Evidence that the nucleus is very small comes from the fact that:

A) all alpha particles were deflected
B) most alpha particles passed through
C) electrons are light
D) atoms emit light

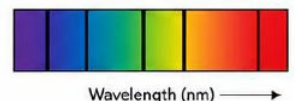
10	Explain how the composition of an unknown gas sample can be determined using its emission and absorption spectrum	St. textbook	84-85
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Objective 10: Using Emission and Absorption Spectra

Emission Spectrum



Absorption Spectrum



LEVEL 1

Q1. To identify an unknown gas sample, scientists usually:

A) compare its spectrum with known spectra
B) measure its mass only
C) observe its color in daylight
D) count its atoms

Q2. A bright-line spectrum is produced when:

A) excited atoms emit specific wavelengths
B) white light passes through a prism only
C) a solid is heated strongly
D) light is completely blocked

LEVEL 2

Q3. If an unknown gas shows the same emission lines as neon, the sample most likely contains:

A) neon
B) hydrogen only
C) carbon dioxide
D) no element can be identified

Q4. In an absorption spectrum, the dark lines represent wavelengths that are:

A) absorbed by the gas
B) reflected by the detector
C) created by the prism
D) changed into electrons

LEVEL 3

Q5. If the dark lines in a gas sample occur at the same wavelengths as sodium's bright emission lines, the sample contains:

A) sodium
B) helium
C) oxygen
D) nitrogen

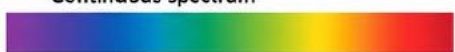
Q6. Spectroscopy is useful for identifying gases because each element:

A) interacts with specific wavelengths
B) has the same spectral pattern
C) glows with white light only
D) changes into another element

11	Explain that the absorption spectrum of an element is a unique pattern, which serves as a fingerprint of that element.	St. textbook	85-86
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Objective 11: Absorption Spectrum as an Element Fingerprint

Continuous spectrum



Absorption spectrum



LEVEL 1

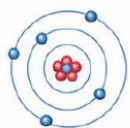
Q1. An absorption spectrum appears as:

- A) dark lines on a continuous spectrum
- B) bright lines on a black background
- C) one single color only
- D) random colored dots



Q2. The pattern of absorption lines for an element is unique because it depends on the element's:

- A) electron energy levels
- B) container shape
- C) room temperature only
- D) density of air



LEVEL 2

Q3. If two samples have identical absorption spectra, they most likely contain the:

- A) same element
- B) same volume only
- C) same pressure only
- D) same temperature only



Q4. Absorption spectra are called element fingerprints because:

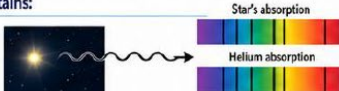
- A) each element has a distinctive pattern
- B) all elements share one pattern
- C) they identify molecules only
- D) they show mass directly



LEVEL 3

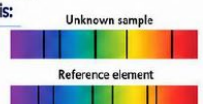
Q5. A star's atmosphere shows dark lines that exactly match helium's absorption lines. This is evidence that the atmosphere contains:

- A) helium
- B) carbon only
- C) sodium only
- D) no gas at all



Q6. If an unknown sample's absorption pattern does not match a reference element, the best conclusion is:

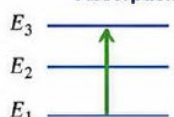
- A) it is a different element or mixture
- B) the sample must be hydrogen
- C) absorption spectra are not useful
- D) all gases have identical spectra



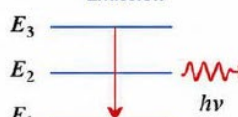
12	Explain that an atom can transition from an initial energy state (E_i) to a final energy state (E_f) by absorbing or emitting a photon whose energy equals the difference between the two states.	St. textbook	85-86
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Objective 12: Atomic Energy Transitions

Absorption



Emission



LEVEL 1

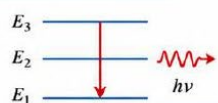
Q1. If an atom moves from a lower energy state to a higher energy state, it must:

- A) absorb a photon
- B) emit a photon
- C) lose an electron
- D) split its nucleus



Q2. The energy of the absorbed or emitted photon equals:

- A) the difference between the two energy states
- B) the total mass of the atom
- C) the charge of the nucleus
- D) the orbit radius only



LEVEL 2

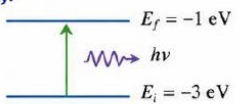
Q3. When an electron drops from $n = 4$ to $n = 2$, the atom:

- A) emits a photon
- B) absorbs a photon
- C) becomes neutral
- D) loses all its energy



Q4. An atom changes from $E_i = -3 \text{ eV}$ to $E_f = -1 \text{ eV}$. The photon involved must have energy:

- A) 2 eV absorbed
- B) 2 eV emitted
- C) 4 eV emitted
- D) 1 eV absorbed



LEVEL 3

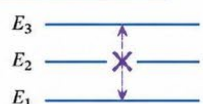
Q5. Only certain wavelengths are absorbed or emitted by an atom because atomic energy levels are:

- A) quantized
- B) continuous
- C) random
- D) identical for all atoms



Q6. If a photon's energy does not exactly match the required energy difference, the transition will:

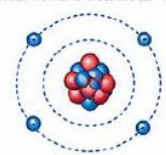
- A) not occur
- B) always occur
- C) double in energy
- D) produce two electrons



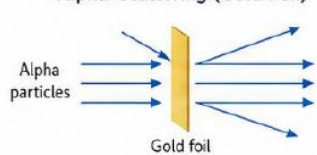
13	Describe Rutherford's nuclear model of the atom, as a small dense positively charged nucleus surrounded by orbiting electrons (planetary model), and explain why this model cannot explain the stability and the observed line emission spectra of atoms.	St. textbook	86-87
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Objective 13: Rutherford's Nuclear Model and Its Limitations

Rutherford's Nuclear Model



Alpha-Scattering (Gold Foil)



LEVEL 1

Q1. Rutherford's nuclear model describes the atom as:

- A) a small positive nucleus with electrons around it
- B) a solid positive sphere with embedded electrons
- C) only a cloud of protons
- D) a single neutral particle

LEVEL 2

Q2. Most alpha particles passed through gold foil because atoms are mostly:

- A) empty space
- B) solid metal
- C) negative charge
- D) neutrons

LEVEL 3

Q3. A few alpha particles were strongly deflected because:

- A) positive charge is concentrated in a tiny nucleus
- B) electrons are very heavy
- C) atoms are magnetic
- D) alpha particles lose mass

LEVEL 1

Q4. Rutherford's planetary model cannot explain atomic stability because orbiting electrons should:

- A) radiate energy and fall into the nucleus
- B) become neutrons
- C) stop moving instantly
- D) create continuous matter

LEVEL 2

Q5. Rutherford's model cannot explain the observed line spectra because it predicts:

- A) continuous radiation rather than discrete lines
- B) no electrons in atoms
- C) no nucleus in atoms
- D) only one energy level

LEVEL 3

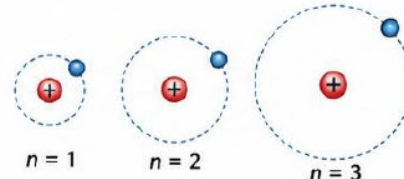
Q6. In Rutherford's model, most of the atom's mass is concentrated in the:

- A) nucleus
- B) electron cloud
- C) outer shell
- D) empty space

14	Calculate the total energy of a Hydrogen atom Describe that the radius of the electron's orbit in Hydrogen atom is proportional to n^2 , while the energy of the atom is inversely proportional to n^2 .	Example problem 4 Practice problems	92
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Objective 14: Hydrogen Energy and Orbit Radius

$$E_n = -\frac{13.6 \text{ eV}}{n^2}$$
$$r_n = n^2 r_1$$



LEVEL 1

Q1. Rutherford's nuclear model describes the atom as:

- A) a small positive nucleus with electrons around it
- B) a solid positive sphere with embedded electrons
- C) only a cloud of protons
- D) a single neutral particle

LEVEL 2

Q2. Most alpha particles passed through gold foil because atoms are mostly:

- A) empty space
- B) solid metal
- C) negative charge
- D) neutrons

LEVEL 3

Q3. A few alpha particles were strongly deflected because:

- A) positive charge is concentrated in a tiny nucleus
- B) electrons are very heavy
- C) atoms are magnetic
- D) alpha particles lose mass

LEVEL 1

Q4. Rutherford's planetary model cannot explain atomic stability because orbiting electrons should:

- A) radiate energy and fall into the nucleus
- B) become neutrons
- C) stop moving instantly
- D) create continuous matter

LEVEL 2

Q5. Rutherford's model cannot explain the observed line spectra because it predicts:

- A) continuous radiation rather than discrete lines
- B) no electrons in atoms
- C) no nucleus in atoms
- D) only one energy level

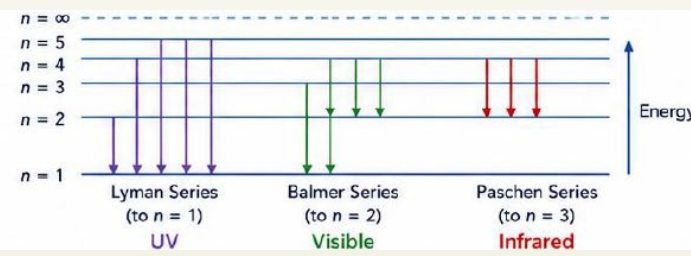
LEVEL 3

Q6. In Rutherford's model, most of the atom's mass is concentrated in the:

- A) nucleus
- B) electron cloud
- C) outer shell
- D) empty space

15	Explain that the Lyman, Balmer and Paschen series and the energy levels and transitions correspond to them	St. textbook	91
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Objective 15: Lyman, Balmer and Paschen Series



LEVEL 1

Q1. The Lyman series consists of transitions that end at:

A) $n = 1$
B) $n = 2$
C) $n = 3$
D) $n = 4$

Q2. The Balmer series is mainly found in the:

A) visible region
B) ultraviolet region
C) gamma region
D) radio region

LEVEL 2

Q3. The Paschen series corresponds to transitions that end at:

A) $n = 3$
B) $n = 2$
C) $n = 1$
D) $n = 5$

Q4. Which transition belongs to the Balmer series?

A) $n = 4$ to $n = 2$
B) $n = 4$ to $n = 1$
C) $n = 5$ to $n = 3$
D) $n = 2$ to $n = 1$

LEVEL 3

Q5. Which series generally has the highest-energy photons?

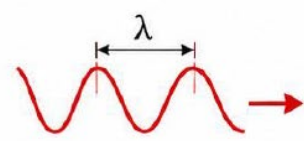
A) Lyman
B) Balmer
C) Paschen
D) all are equal

Q6. Arrange the series from lowest to highest photon energy:

A) Paschen, Balmer, Lyman
B) Lyman, Balmer, Paschen
C) Balmer, Lyman, Paschen
D) Balmer, Paschen, Lyman

16	Calculate the energy, frequency, and wavelength of an emitted or absorbed photon as an atom transition from an initial energy level to a final energy level	Example problem 5 Practice problems	93
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Objective 16: Photon Energy, Frequency and Wavelength



Constants

$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$
 $c = 3.00 \times 10^8 \text{ m/s}$
 $hc = 1240 \text{ eV}\cdot\text{nm}$

LEVEL 1

Q1. A photon with energy 2.48 eV has a wavelength closest to:

A) 500 nm
B) 250 nm
C) 700 nm
D) 1000 nm

$E = \frac{hc}{\lambda}$

Q2. If a transition emits a photon of 4.0 eV, the frequency is closest to:

A) $9.7 \times 10^{14} \text{ Hz}$
B) $1.0 \times 10^{12} \text{ Hz}$
C) $3.0 \times 10^8 \text{ Hz}$
D) $6.6 \times 10^{34} \text{ Hz}$

$E = hf$

LEVEL 2

Q3. A photon of wavelength 413 nm has energy closest to:

A) 3.0 eV
B) 1.0 eV
C) 6.0 eV
D) 0.3 eV

$E = \frac{hc}{\lambda}$

Q4. If an emitted photon has frequency $6.0 \times 10^{14} \text{ Hz}$, its energy is closest to:

A) $3.98 \times 10^{-19} \text{ J}$
B) $6.0 \times 10^{-34} \text{ J}$
C) $1.80 \times 10^{23} \text{ J}$
D) $2.00 \times 10^{-14} \text{ J}$

$E = hf$

LEVEL 3

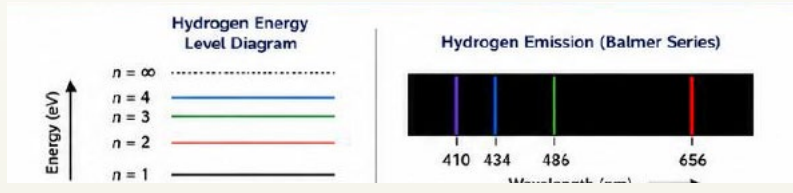
Q5. In hydrogen, the transition from $n = 3$ to $n = 2$ produces a photon with wavelength closest to:

A) 656 nm
B) 121 nm
C) 1875 nm
D) 97 nm

$n = 3$
 $n = 2$
 $n = 1$

Q6. Which statement is correct?

A) Shorter wavelength means greater photon energy
B) Shorter wavelength means lower frequency
C) Longer wavelength means greater energy
D) Energy is unrelated to wavelength



Q1. Rutherford observed that most alpha particles passed straight through gold foil. The best conclusion is that atoms are:

- A) mostly empty space
- B) mainly negative charge
- C) solid spheres
- D) made only of nuclei

Q2. An unknown gas has bright lines at the same wavelengths as hydrogen. The best conclusion is that the gas contains:

- A) hydrogen
- B) sodium only
- C) helium only
- D) no identifiable element

Q3. A continuous spectrum passing through a cool sodium gas shows dark lines exactly where sodium emits bright lines. This means the cool gas:

- A) absorbs those same wavelengths
- B) creates new wavelengths
- C) blocks all light equally
- D) contains no sodium

Q4. An atom drops from 5.0 eV to 2.0 eV. The emitted photon wavelength is closest to:

- A) 413 nm
- B) 1240 nm
- C) 620 nm
- D) 248 nm

Q5. Which atomic model fails because orbiting electrons should continuously radiate energy?

- A) Rutherford's planetary model
- B) Thomson's model
- C) Dalton's model
- D) Democritus's model

Q6. In hydrogen, if n changes from 2 to 4, the orbit radius becomes:

- A) 4 times larger
- B) 2 times larger
- C) 8 times larger
- D) half as large

Q7. Which transition belongs to the Lyman series?

- A) n = 3 to n = 1
- B) n = 3 to n = 2
- C) n = 4 to n = 3
- D) n = 2 to n = 4

Q8. A photon with wavelength 97 nm most likely belongs to the:

- A) Lyman series
- B) Balmer series
- C) Paschen series
- D) microwave region

LEVEL 1

Q9. The total energy of a hydrogen atom at n = 4 is closest to:

- A) -0.85 eV
- B) -13.6 eV
- C) -3.4 eV
- D) -1.51 eV

Q10. For the hydrogen transition n = 3 to n = 2, the emitted photon frequency is closest to:

- A) 4.6×10^{14} Hz
- B) 6.0×10^{16} Hz
- C) 1.0×10^{12} Hz
- D) 9.7×10^{14} Hz

LEVEL 2

Q11. An unknown sample has an absorption spectrum that exactly matches helium's. Which statement is best?

- A) helium is present in the sample
- B) only hydrogen is present
- C) the sample must be a solid
- D) spectra cannot identify elements

Q12. If the wavelength of an emitted photon becomes shorter, then its energy:

- A) increases
- B) decreases
- C) stays the same
- D) becomes zero

$$E = \frac{hc}{\lambda}$$

LEVEL 3

Q13. The shortest-wavelength line in the Balmer series comes from a transition that ends at n = 2 from:

- A) a very high n level
- B) n = 3 only
- C) n = 1
- D) n = 2

Q14. In hydrogen, absorbing a 10.2 eV photon most likely causes the transition:

- A) n = 1 to n = 2
- B) n = 2 to n = 1
- C) n = 3 to n = 2
- D) n = 4 to n = 3

LEVEL 4

Q15. The main reason each element has a unique absorption spectrum is that each element has:

- A) its own set of energy levels
- B) the same nucleus size
- C) identical electron masses
- D) the same number of shells

Q16. As the principal quantum number n increases in hydrogen, the spacing between adjacent energy levels generally:

- A) becomes smaller
- B) becomes larger
- C) stays constant
- D) becomes zero immediately

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17	Illustrate that, in the Bohr model, the circumference of a stable electron orbit must be an integer multiple of the de Broglie wavelength ($2\pi r = n\lambda$), as a result of combining de Broglie and Bohr ideas.	St. textbook	95
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Bohr Model + de Broglie Waves

FOCUS QUESTION

Why are only some electron orbits stable?

LEARNING OBJECTIVE 17

Illustrate that, in the Bohr model, the circumference of a stable electron orbit must be an integer multiple of the de Broglie wavelength: $2\pi r = n\lambda$.

KEY CONCEPT

In the Bohr model combined with de Broglie's idea:

- A **stable orbit** occurs when a whole-number number of de Broglie wavelengths fits exactly around the orbit's circumference.
- If the wave does not fit exactly, the orbit is **unstable**.

TAKEAWAY

Only standing-wave orbits are stable.

Q1 (Level 1) In Bohr's model combined with de Broglie's idea, a stable orbit occurs when:

A) the electron stops moving C) the wavelength is zero
B) $2\pi r = n\lambda$ D) the radius is always 1 m

Q2 (Level 1) Which value of n corresponds to an allowed stable orbit?

A) 2.5 C) 4
B) 3.2 D) 0.7

2\pi r = n\lambda

$n = 1, 2, 3, \dots$

1) $n = 3$

Stable condition
Three complete cycles per orbit

2) $n = 5$

Stable condition
Five complete cycles per orbit

3) $n = 2.9$

Unstable condition
Wave does not close around the orbit

Practice: Stable Orbits and de Broglie Waves

Objective 17 Practice — Using $2\pi r = n\lambda$

REMEMBER!

$2\pi r = n\lambda$

- Stable orbit** → whole-number multiple of λ
- Not stable** → non-integer multiple

Q3 (Level 2) If the circumference of an orbit equals 5λ , what is the quantum number n ?

A) 2.5 C) 10
B) 5 D) $\frac{1}{5}$

Q4 (Level 2) Which statement best explains why the orbit for $n = 3$ is stable?

A) The electron is motionless
B) The wave has three complete cycles around the orbit
C) The orbit has zero radius
D) The wavelength is infinite

Q5 (Level 2) An orbit has circumference $2\pi r = 4.2\lambda$. According to the Bohr-de Broglie model, this orbit is:

A) stable because n is greater than 1
B) stable because the wave nearly fits
C) unstable because n is not an integer
D) unstable because λ is always zero

TAKEAWAY

Only when $2\pi r = n\lambda$ with integer n does the wave close on itself and the orbit is stable.

Allowed orbit

Wavelength fits exactly:
 $2\pi r = n\lambda$ ($n = \text{integer}$)

Nonallowed orbit

Wavelength does not fit:
 $2\pi r = n\lambda$ ($n \neq \text{integer}$)

Higher-Level Check and Challenge

Objective 17 — Level 3 and Challenge MCQs

VISUAL RECAP

Bohr + de Broglie condition for stable electron orbits:

$2\pi r = n\lambda$

MINI CONCEPT

Allowed orbit = standing wave;
nonallowed orbit = destructive mismatch.

Q6 (Level 3) For a stable orbit, the electron's de Broglie wavelength is 0.50 nm and $n = 6$. What is the orbit circumference?

A) 0.083 nm
B) 3.0 nm
C) 6.5 nm
D) 12 nm

Q7 (Level 3) If an orbit has radius r , which equation represents the allowed wavelengths for stable motion?

A) $\lambda = 2\pi rn$
B) $\lambda = \frac{2\pi r}{n}$
C) $\lambda = \frac{n}{2\pi r}$
D) $\lambda = \frac{r}{n}$

CHALLENGE MCQ

$n = 2.8$

Q7 (Challenge) A student claims that an orbit with $n = 2.8$ should be stable because it is close to 3. Which is the best response?

A) Correct, because approximate closure is enough
B) Correct, because only large n values matter
C) Incorrect, because only integer numbers of wavelengths form a standing wave
D) Incorrect, because de Broglie wavelength is unrelated to orbit stability

THINK LIKE A PHYSICIST

Only exact whole-number wave fits produce stable standing-wave orbits.

18	Define the mass number, A, as the total number of nucleons (protons and neutrons) in an atomic nucleus ($A=Z + N$). Represent nuclei of isotopes using the notation, where 'Z' is the atomic number and 'A' is the mass number	St. textbook	107-108
		Practice problems	109

The Nucleus

What is inside an atom?

LESSON OVERVIEW

The nucleus is a tiny, dense, positively charged region at the center of an atom. It contains **protons** and neutrons (nucleons). Isotopes have the same number of protons but different numbers of neutrons. Nucleons are held together by the **strong nuclear force**. Because the actual mass of a nucleus is less than the sum of its parts, a **mass defect** exists and **binding energy** is released to hold the nucleus together.

Nucleons

Proton (p)
Charge = +e

Neutron (n)
Charge = 0

Isotope Notation

${}_Z^AX$

X = element symbol
A = mass number (total nucleons)
Z = atomic number (protons)

Isotopes: Same Z, Different A

${}_1^1\text{H}$ ${}_1^2\text{H}$ ${}_1^3\text{H}$

1p 0n 1p 1n 1p 2n

Binding Energy per Nucleon

Average binding energy per nucleon (MeV)

Number of nucleons (A)

Very stable nuclei

Light nuclei (less stable) Most stable (Iron-56) Heavy nuclei (less stable)

${}_1^2\text{H}$ ${}_6^{12}\text{C}$ ${}_{26}^{56}\text{Fe}$ ${}_{52}^{131}\text{Te}$ ${}_{92}^{235}\text{U}$

Key Ideas: Nucleus $\approx$ size 10^{-14} m | Extremely dense | Strong nuclear force binds nucleons | Mass defect $\rightarrow$ Binding energy

18 MCQ in 3 levels + 6 challenge MCQ

Objective 18: Mass Number and Isotope Notation

$A = Z + N$

Atomic number (Z):
The number of **protons** in the nucleus.

Neutron number (N):
The number of neutrons in the nucleus.

Mass number (A):
The total number of nucleons (protons + neutrons).

$A = Z + N$

Isotope Notation

Mass number (A)
Total nucleons (protons + neutrons)

${}_Z^AX$

Element symbol

Atomic number (Z)
Number of protons

$A = Z + N$

Examples

Hydrogen Isotopes (Z = 1)

${}_1^1\text{H}$ ${}_1^2\text{H}$ ${}_1^3\text{H}$

1 proton 0 neutrons A = 1 1 proton 1 neutron A = 2 1 proton 2 neutrons A = 3

Carbon-14 Example

${}_6^{14}\text{C}$

6 protons (Z = 6)
8 neutrons (N = 8)
A = 14 = 6 + 8

Key Takeaways

- Isotopes of an element have the same atomic number (Z) but different neutron numbers (N).
- Neutral atoms of isotopes have the same number of electrons because Z is the same.
- The mass number is the total number of nucleons: A = protons + neutrons (or A = Z + N).

Key Ideas: Z = number of protons | N = number of neutrons | A = Z + N | Isotope notation: ${}_Z^AX$

Objective 18 – MCQ Practice

6 questions in 3 levels

Level 1

1. What does the mass number A represent?

A. number of protons B. number of electrons
C. total number of nucleons D. number of neutrons

2. In the notation ${}_{11}^{23}\text{Na}$, the atomic number Z is:

A. 23 B. 11
C. 12 D. 34

11
Na
Sodium
22.99

Level 2

3. An oxygen isotope has Z = 8 and N = 10. Which isotope is it?

A. ${}_8^{16}\text{O}$ B. ${}_8^{18}\text{O}$
C. ${}_{10}^{18}\text{O}$ D. ${}_8^{10}\text{O}$

4. Which pair are isotopes of the same element?

A. ${}_6^{12}\text{C}$ and ${}_6^{14}\text{C}$ B. ${}_6^{14}\text{C}$ and ${}_7^{14}\text{N}$
C. ${}_1^1\text{H}$ and ${}_2^4\text{He}$ D. ${}_8^{16}\text{O}$ and ${}_7^{14}\text{N}$

${}_6^{12}\text{C}$ vs ${}_6^{14}\text{C}$

Level 3

5. A nucleus contains 17 protons and 20 neutrons. Its symbol is:

A. ${}_{17}^{37}\text{Cl}$ B. ${}_{17}^{20}\text{Cl}$
C. ${}_{20}^{37}\text{Cl}$ D. ${}_{37}^{17}\text{Cl}$

6. Which statement is correct?

A. Isotopes have same A and different Z B. Isotopes have same Z and different N
C. Isotopes have different Z and same N D. Isotopes always have same mass

Scales of mass

- 19 Define the strong nuclear force as a very short-range attractive force that acts between nucleons (proton-proton, neutron-neutron, and proton-neutron) when they are very close together, as in the atomic nucleus.
- Define the mass defect as the difference between the actual mass of an atomic nucleus and the sum of the masses of its constituent nucleons

St. textbook

109

Objective 19: Strong Nuclear Force and Mass Defect

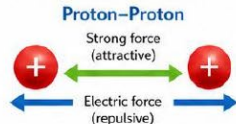


The Strong Nuclear Force

The strong nuclear force is a very **short-range attractive** force that acts between nucleons (protons and neutrons) only when they are extremely close together in the nucleus.

It is much stronger than the electric force at distances of about a nucleon's radius.

Range of the strong force $\approx 10^{-15}$ m



At very short distances, the attractive strong force overcomes the electric repulsion and holds protons together.

Nucleon Pairs and Forces

Neutron-Neutron



Two neutrons attract each other by the strong nuclear force.

Proton-Neutron



A proton and a neutron also attract each other by the strong force.



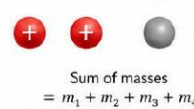
Mass Defect

When nucleons bind together to form a nucleus, the actual mass of the nucleus is **less** than the sum of the masses of the separate nucleons.

$$\text{mass defect, } \Delta m = (\text{sum of masses of separate nucleons}) - (\text{actual nucleus mass})$$

The "missing" mass (Δm) is converted into **binding energy** that holds the nucleus together.

Before Binding



$$\text{Sum of masses} = m_1 + m_2 + m_3 + m_4$$

After Binding (Nucleus)



$$\text{Actual nucleus mass} = M_{\text{nucleus}}$$

$$\Delta m = (m_1 + m_2 + m_3 + m_4) - M_{\text{nucleus}} > 0$$

★ **Key Ideas:** Strong force is short-range and attractive | Acts between all nucleon pairs | Mass defect (Δm) $\rightarrow$ binding energy

Objective 19 – MCQ Practice

6 questions in 3 levels

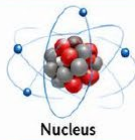
Level 1



Recall & Understand

1. The strong nuclear force is mainly:

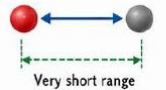
- A. long-range repulsive
- B. short-range attractive
- C. long-range attractive
- D. short-range electrical



Nucleus

2. The strong nuclear force acts between:

- A. electrons only
- B. protons only
- C. nucleons close together
- D. atoms far apart



Very short range

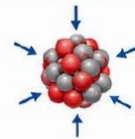
Level 2



Apply & Analyze

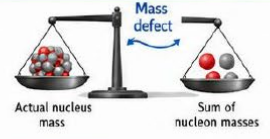
3. Why doesn't the nucleus fly apart?

- A. gravity dominates
- B. electrons hold it together
- C. strong nuclear force overcomes proton repulsion at short range
- D. magnetic force cancels charge



4. Mass defect is the difference between:

- A. actual nucleus mass and sum of nucleon masses
- B. proton mass and neutron mass
- C. atom mass and electron mass
- D. charge and mass number



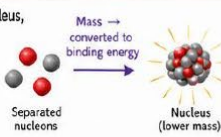
Level 3



Evaluate & Extend

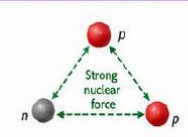
5. If separated nucleons have more mass than the nucleus, the missing mass has been converted into:

- A. electric charge
- B. binding energy
- C. extra neutrons
- D. atomic number



6. Which interaction pair is bound by strong nuclear force in the nucleus?

- A. proton-proton only
- B. proton-neutron only
- C. neutron-neutron only
- D. all nucleon pairs



★ **Key Ideas:** Strong force is short-range and very strong | Binds nucleons and overcomes proton repulsion | Mass defect $\rightarrow$ binding energy

18 MCQ in 3 levels + 6 challenge MCQ

20	Calculate the mass defect of an atomic nucleus. Calculate the binding energy of an atomic nucleus.	Example problem 1 Practice problems	111
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Objective 20: Mass Defect and Binding Energy Calculations

Method: From Nucleon Masses to Binding Energy

Nucleon Number

$$A = Z + N$$

A = mass number
 Z = number of protons
 N = number of neutrons

Mass Defect

$$\Delta m = (\text{sum of masses of separate nucleons}) - (\text{actual nucleus mass})$$

Binding Energy

$$BE = \Delta m c^2$$

where c is the speed of light

Conversion

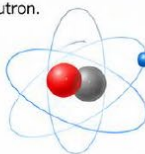
$$1 \text{ u} = 931.49 \text{ MeV}/c^2$$

Mini Example: Deuterium (${}^2\text{H}$)

Deuterium (${}^2\text{H}$) has 1 proton and 1 neutron.

Given

- $m_p = 1.007825 \text{ u}$
- $m_n = 1.008665 \text{ u}$
- Actual mass of ${}^2\text{H} = 2.014102 \text{ u}$
- $1 \text{ u} = 931.49 \text{ MeV}/c^2$



- Sum of separate nucleon masses**
 $1.007825 + 1.008665 = 2.016490 \text{ u}$
- Mass defect**
 $\Delta m = 2.016490 - 2.014102 = 0.002388 \text{ u}$
- Binding energy**
 $BE = \Delta m c^2 = 0.002388 \times 931.49 = 2.22 \text{ MeV}$

✓ The binding energy of deuterium is 2.22 MeV (total for the nucleus).

1 Identify Protons and Neutrons



From the isotope notation ${}_Z^AX$, determine Z (protons) and $N = A - Z$ (neutrons).

2 Calculate Sum of Separate Masses



Add the masses of individual protons and neutrons:
 $Z \times m_p + N \times m_n$

3 Find Mass Defect (Δm)



Subtract the actual nucleus mass from the sum to get the mass defect.
 $\Delta m = m_{\text{sum}} - m_{\text{nucleus}}$

4 Convert Δm to Binding Energy



Multiply the mass defect by $931.49 \text{ MeV}/c^2$ to get the binding energy (BE).
 $BE = \Delta m \times 931.49$

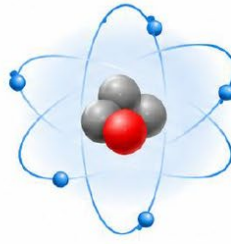
Worked Example: Tritium

PROBLEM

Find the mass defect and binding energy of tritium (${}^3\text{H}$).

Given:

- mass of hydrogen atom = 1.007825 u
- mass of neutron = 1.008665 u
- mass of tritium atom = 3.016049 u



Tritium (${}^3\text{H}$)

- 1 Proton (p)
Charge = +e
- 2 Neutrons (n)
Charge = 0

1 Mass of separated particles

= mass of 1 proton + mass of 2 neutrons
 $= 1.007825 + 2(1.008665) \text{ u}$

= 3.025155 u

2 Mass defect (Δm)

$\Delta m = (\text{mass of separated particles}) - (\text{mass of tritium atom})$
 $= 3.025155 - 3.016049 \text{ u}$

= 0.009106 u

3 Binding energy (BE)

$BE = \Delta m \times 931.49 \text{ MeV}/\text{u}$
 $= 0.009106 \times 931.49 \text{ MeV}$

$\approx 8.48 \text{ MeV}$

4 Binding energy per nucleon

$BE \text{ per nucleon} \approx BE / A$
 $\approx 8.48 / 3$

$\approx 2.83 \text{ MeV/nucleon}$

 **CHECK YOUR PROGRESS** Why is the mass of the nucleus smaller than the sum of its separate nucleons? Because some mass is converted into binding energy

Objective 20 – MCQ Practice

 6 questions in 3 levels

1 Level 1

1. Which equation is used for binding energy?

A. $E = mc$ B. $E = \Delta m c^2$
C. $E = mv^2$ D. $E = qV$

2. If Δm increases, the binding energy:

A. decreases B. stays zero
C. increases D. becomes negative charge

2 Level 2

3. A nucleus has a mass defect of 0.002 u. Its binding energy is closest to:

A. 0.002 MeV B. 1.86 MeV
C. 18.6 MeV D. 1860 MeV

4. If the sum of free nucleon masses is 4.032 u and the nucleus mass is 4.001 u, the mass defect is:

A. 0.031 u B. 0.004 u
C. 8.033 u D. 28.0 u

3 Level 3

5. A nucleus has binding energy 28 MeV and mass number $A = 4$. Binding energy per nucleon equals:

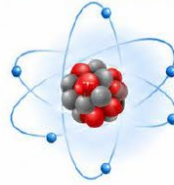
A. 7 MeV B. 24 MeV
C. 32 MeV D. 112 MeV

6. Which sequence is correct when solving nuclear binding problems?

A. count electrons $\rightarrow$ subtract charge $\rightarrow$ find Z
B. find $\Delta m \rightarrow$ use $E = \Delta m c^2 \rightarrow$ convert units if needed
C. find wavelength $\rightarrow$ use $hf \rightarrow$ subtract Z
D. find momentum $\rightarrow$ use $p = mv \rightarrow$ divide by A

Challenge MCQ – Part 1

Mixed application questions



Key Reminders

- Nucleons = protons + neutrons
- Mass number $A = Z + N$
- Mass defect $\Delta m = \sum m_{\text{nucleons}} - m_{\text{nucleus}}$
- Binding energy increases with stability

1 The isotope $^{56}_{26}\text{Fe}$ has 26 protons. How many neutrons does it have?

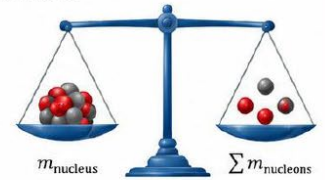
- A. 26 B. 30 C. 56 D. 82

2 Which nucleus would require more energy to separate into free nucleons?

- A. the one with larger binding energy
 B. the one with smaller A only
 C. the one with fewer neutrons
 D. they all require the same energy

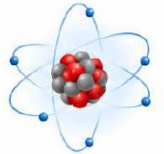
3 A nucleus has 8 protons and 8 neutrons. If its actual nucleus mass is 15.990 u and the sum of its nucleon masses is 16.131 u, the mass defect is:

- A. 0.141 u
 B. 1.41 u
 C. 31.99 u
 D. 0.008 u



Challenge MCQ – Part 2

Final challenge + exit ticket



4 Which nucleus is more stable in terms of binding energy per nucleon?

- A. the one with value closer to zero
 B. the one with larger magnitude binding energy per nucleon
 C. the one with more electrons
 D. the one with smaller Z only

5 For $^{14}_6\text{C}$, which set is correct?

- A. $Z = 14, N = 6, A = 8$
 B. $Z = 6, N = 8, A = 14$
 C. $Z = 8, N = 6, A = 14$
 D. $Z = 6, N = 14, A = 8$

6 A nucleus has $\Delta m = 0.010$ u. Using $1 \text{ u} = 931.5 \text{ MeV}$, its binding energy is:

- A. 0.093 MeV
 B. 9.315 MeV
 C. 93.15 MeV
 D. 931.5 MeV



EXIT TICKET

In one sentence, explain why mass defect is evidence of binding energy.



FOCUS QUESTION

How do nuclei decay, react, and release energy?



LEARNING OBJECTIVES

- 21 Compare alpha, beta, and gamma decays in terms of emitted particles, charge, penetration, and nuclear transmutation.
- 22 Explain that electric charge is conserved in a nuclear reaction, so the total charge is the same on both sides of the equation.
- 23 Write a balanced nuclear equation to describe a simple nuclear reaction, such as the bombardment of a nucleus by an alpha particle.
- 24 Analyze a graph of the number of undecayed radioactive nuclei versus time, determine the half-life, and calculate the amount of radioactive nuclei remaining in a sample.
- 25 Define and describe nuclear fission and nuclear fusion.

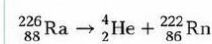
TYPES OF RADIATION

- α Alpha (^4_2He)
 +2 charge
 Least penetration
- β Beta ($^0_{-1}\text{e}$)
 -1 charge
 Medium penetration
- γ Gamma (γ)
 No charge
 Highest penetration

Transmutation Examples

- α decay: $A \rightarrow A-4, Z \rightarrow Z-2$
 β^- decay: $A \rightarrow A, Z \rightarrow Z+1$
 γ decay: $A \rightarrow A, Z \rightarrow Z$

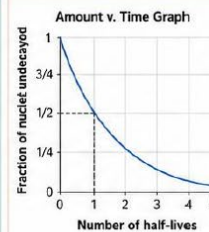
BALANCED NUCLEAR EQUATION



- ✓ Mass number conserved:
 $226 = 4 + 222$
- ✓ Charge conserved:
 $88 = 2 + 86$

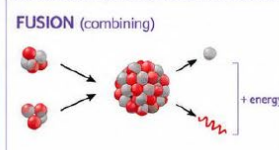
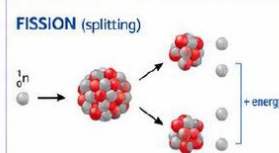
The total mass number and total charge are the same on both sides of the equation.

HALF-LIFE & DECAY



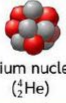
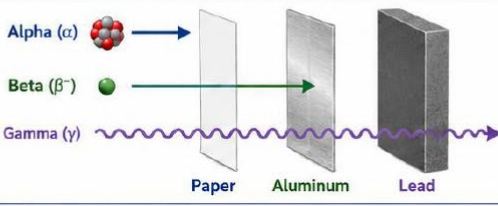
- After 1 half-life: $\frac{1}{2}$ remains
 After 2 half-lives: $\frac{1}{4}$ remains
 After n half-lives: $\left(\frac{1}{2}\right)^n$ remains

FISSION vs. FUSION



21	Compare alpha, beta, and gamma decays in terms of the particles emitted their electric charge, their penetrating ability, and the resulting nuclear transmutation	St. textbook	114
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Objective 21: Compare Alpha, Beta, and Gamma Decay

RADIATION TYPE	EMITTED PARTICLE	ELECTRIC CHARGE	PENETRATING ABILITY	NUCLEAR TRANSMUTATION	SHIELDING AND PENETRATION
Alpha (α)  Helium nucleus (${}^4_2\text{He}$)	Helium nucleus (${}^4_2\text{He}$) 	+2	Least penetrating Stopped by paper	$A \rightarrow A - 4$ $Z \rightarrow Z - 2$	
Beta minus (β^-)  Electron (e^-)	Electron (e^-) 	-1	Medium penetrating Stopped by aluminum	$A \rightarrow A$ $Z \rightarrow Z + 1$	
Gamma (γ)  Photon (γ)	Photon (γ) (electromagnetic radiation) 	0	Most penetrating Requires lead to stop	$A \rightarrow A$ $Z \rightarrow Z$	

KEY NOTES:

- Alpha decay causes $A \rightarrow A - 4$ and $Z \rightarrow Z - 2$.
- Beta-minus decay causes $A \rightarrow A$ and $Z \rightarrow Z + 1$.
- Gamma decay causes $A \rightarrow A$ and $Z \rightarrow Z$.

Level 1 MCQ

- Which radiation is a helium nucleus?
A) Alpha B) Beta C) Gamma D) Neutron
- Which radiation has the greatest penetrating power?
A) Alpha B) Beta C) Gamma D) Positron
- During alpha decay, the atomic number of the parent nucleus:
A) increases by 1 B) decreases by 1
C) decreases by 2 D) stays the same

22	Explain that electric charge is conserved in a nuclear reaction, so the total charge is the same on both sides of the nuclear equation	Example problem 2 Practice problems	116
23	Write a balanced nuclear equation to describe a simple nuclear reaction, such as the bombardment of a nucleus by an alpha particle	Example problem 3 Practice problems	117

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UNITED ARAB EMIRATES
MINISTRY OF EDUCATION

Unit 6 - Module 24: Nuclear and Particle Physics

Objectives 22 & 23: Charge Conservation and Balanced Nuclear Equations

Grade 12 Advanced Stream

Charge is Conserved

- ✓ **Total electric charge** is the same on both sides of a nuclear equation.
- ✓ The sum of **atomic numbers (Z)** must match on both sides.
- ✓ The sum of **mass numbers (A)** must match on both sides.

Example: Alpha Decay (Worked Example)

$${}^{226}_{88}\text{Ra} \rightarrow {}^4_2\text{He} + {}^{222}_{86}\text{Rn}$$

A Mass numbers (A): $226 = 4 + 222$

Z Atomic numbers (Z): $88 = 2 + 86$

✓ Both mass number and charge are conserved. The equation is balanced.

Bombardment Example (Worked Example)

$${}^4_2\text{He} + {}^{14}_7\text{N} \rightarrow {}^1_1\text{H} + {}^{17}_8\text{O}$$

How to balance nuclear equations:

- 1 Identify the missing particle (if any).
- 2 Balance the **mass numbers (A)**.
- 3 Balance the **atomic numbers (Z)**.

✓ Both mass number and charge are conserved. The equation is balanced.

MCQ Practice

4. In a balanced nuclear equation, the sum of the atomic numbers on both sides must be:

A) equal B) zero
C) doubled D) negative

5. In alpha decay, if the parent has $Z = 88$, the daughter has $Z = ?$

A) 84 B) 86
C) 87 D) 90

6. What particle completes ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + ?$

A) beta B) alpha
C) gamma D) proton

7. What particle completes ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^{17}_8\text{O} + ?$

A) neutron B) proton
C) beta D) gamma

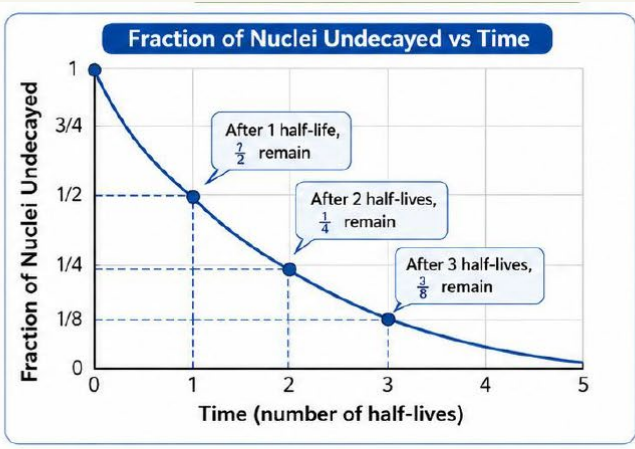
24	Analyze a graph of the number of undecayed radioactive nuclei versus time, and determine the half-life and the amount of radioactive nuclei present at a certain time t Calculate the amount of radioactive nuclei remaining in a sample	St. textbook	117-118
		Practice problems	119

KEY IDEA

Half-life is the time required for half the radioactive nuclei in a sample to decay.

- After 1 half-life, $\frac{1}{2}$ of the nuclei remain.
- After 2 half-lives, $\frac{1}{4}$ remain.
- After 3 half-lives, $\frac{1}{8}$ remain.

Half-life formula:
 $\text{remaining} = \text{original} \times \left(\frac{1}{2}\right)^n$
where n = number of half-lives



WORKED EXAMPLE

A sample starts at 80 g and has a half-life of 5 days.
After 10 days, $n = 2$, so
 $\text{remaining} = 80 \times \left(\frac{1}{2}\right)^2$
 $= 80 \times \frac{1}{4}$
 $= 20 \text{ g}$

NOTE

Shorter half-life means faster decay and higher activity.

MCQ PRACTICE

8. Half-life is the time required for:

A) all nuclei to decay
B) half the nuclei to decay
C) activity to double
D) mass to disappear

9. After 3 half-lives, the fraction remaining is:

A) $\frac{1}{2}$
B) $\frac{1}{4}$
C) $\frac{1}{8}$
D) $\frac{1}{16}$

10. A 40 g sample with a half-life of 2 h has what mass after 4 h?

A) 5 g
B) 10 g
C) 20 g
D) 30 g

25	Define and describe nuclear fission and nuclear fusion	St. textbook	119-123
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Fission

A heavy nucleus splits into smaller nuclei, releasing energy and neutrons. The neutrons can cause more fissions—a chain reaction.

Chain Reaction

Neutrons from one fission cause more fissions to occur.

Feature	Fission	Fusion
Process	Splitting a heavy nucleus	Combining light nuclei
Energy	Releases large amounts of energy	Releases large amounts of energy
Reactions	Uses chain reactions	Does not use chain reactions
Conditions	Occurs in reactors at lower temperatures	Requires very high temperature (millions of kelvin)

Fusion

Light nuclei combine to form a heavier nucleus, releasing energy. This powers the Sun and stars.

Fusion in the Sun

Extreme temperature and pressure allow nuclei to overcome repulsive forces and fuse.

Controlling Fission Reactions

Control rods (e.g., cadmium) absorb neutrons to control the rate of the chain reaction. Inserting rods slows or stops the reaction.

MCQ Practice

11. Nuclear fission is best described as:

A) combining two light nuclei
B) splitting a heavy nucleus
C) absorbing a photon only
D) changing a neutron into a proton

12. The main source of the Sun's energy is:

A) alpha decay
B) beta decay
C) fission
D) fusion

13. In a nuclear reactor, control rods are used to:

A) absorb excess neutrons
B) produce gamma rays
C) increase pressure
D) cool plasma



14. Beta-minus decay emits a(n):

- A) electron
- B) helium nucleus
- C) photon
- D) proton



15. Gamma decay changes:

- A) A and Z
- B) only Z
- C) only the energy state
- D) neutron number only



16. Which quantity is conserved in every nuclear reaction?

- A) density only
- B) electric charge
- C) color
- D) volume



17. The top number in nuclear notation represents:

- A) atomic number
- B) charge
- C) mass number
- D) energy



18. If 25% of a sample remains, how many half-lives have passed?

- A) 1
- B) 2
- C) 3
- D) 4



19. Which process can create a chain reaction?

- A) fusion in a balloon
- B) uranium fission
- C) gamma decay
- D) electron capture only

20

20. Which radiation is usually stopped by paper or skin?

- A) alpha
- B) beta
- C) gamma
- D) X-ray

21

21. In beta-minus decay, the atomic number of the daughter nucleus:

- A) decreases by 2
- B) decreases by 1
- C) increases by 1
- D) stays the same

22

22. Complete: $^{209}_{82}\text{Pb} \rightarrow ^{209}_{83}\text{Bi} + ?$

- A) $^0_{-1}\text{e}$
- B) ^4_2He
- C) ^1_0n
- D) γ only

23

23. A sample has a half-life of 6 days. Starting with 120 g, how much remains after 12 days?

- A) 15 g
- B) 30 g
- C) 60 g
- D) 90 g

24

24. Which statement about fusion is correct?

- A) It occurs by splitting uranium
- B) It joins light nuclei and requires very high temperature
- C) It needs control rods
- D) It produces no energy

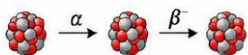
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25. The emitted alpha particle causes the parent nucleus to change its mass number by:

- A) -1
- B) -2
- C) -4
- D) 0

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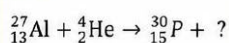
A nucleus emits alpha then beta-minus. Net change is:



- A) A - 4, Z - 1
- B) A - 4, Z - 3
- C) A same, Z + 1
- D) A - 1, Z - 1

27

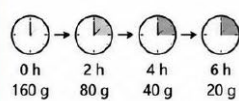
Balance:



- A) ^1_0n
- B) ^1_1H
- C) $^0_{-1}\text{e}$
- D) ^4_2He

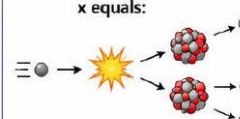
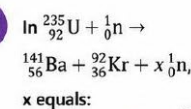
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A 160 g sample with a half-life of 2 h will have what mass after 6 h?



- A) 80 g
- B) 40 g
- C) 20 g
- D) 10 g

29



- A) 1
- B) 2
- C) 3
- D) 4

30

Why does fusion require very high temperature?



- A) to create electrons
- B) to overcome electrostatic repulsion between nuclei
- C) to reduce mass number
- D) to absorb gamma radiation