

Energy levels, radioactive decay and binding energy

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to calculate photon energies from energy levels, balance nuclear equations, apply half-lives and convert mass defects into energy. They climb from simple recall to AP-style multi-step reasoning and data analysis. They suit AP Physics 2 unit 15 and the modern physics sections of A level courses.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 15

Problem 1 Counting protons and neutrons (easy)

Count the particles in two nuclei.

1. How many protons and neutrons are in $^{14}_6\text{C}$?
2. How many protons and neutrons are in $^{235}_{92}\text{U}$?

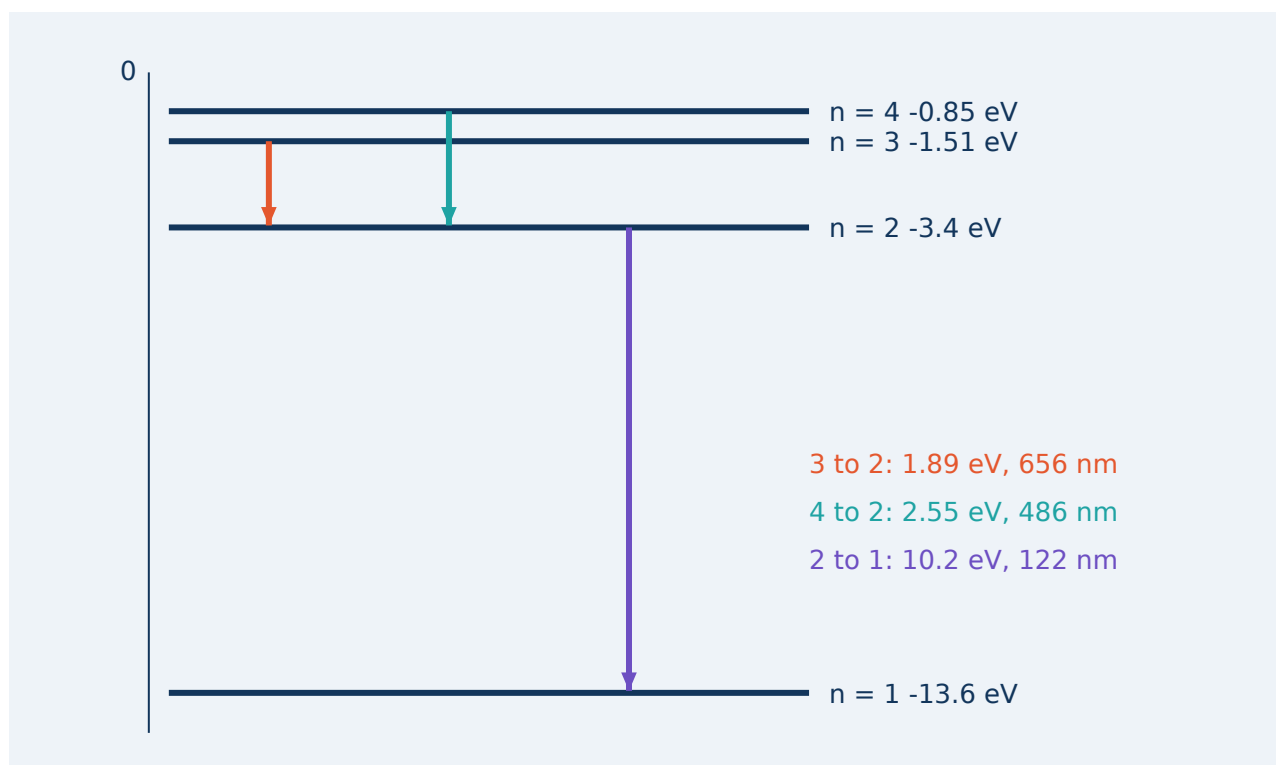
Problem 2 Hydrogen energy levels (easy)

Use $E = -13.6 \text{ eV} / n^2$.

1. Calculate the energies for $n = 1, 2, 3$ and 4 .
2. Calculate the energy needed to remove an electron from $n = 2$.

Problem 3 A visible hydrogen line (easy)

Aarav in Pune studies the diagram of hydrogen levels.



Hydrogen energy levels with three emission transitions.

1. Calculate the energy of the photon emitted in the transition $n = 4$ to $n = 2$.
2. Calculate its wavelength using $hc = 1240 \text{ eV}\cdot\text{nm}$.

Problem 4 Absorbing a photon (easy)

A hydrogen atom is in its ground state ($n = 1$).

1. Calculate the energy needed to excite it to $n = 2$.
2. State whether it can absorb a photon of 11.0 eV, and explain.

Problem 5 Alpha decay equation (easy)

Radium-226 ($Z = 88$) undergoes alpha decay to radon.

1. Write the nuclear equation.
2. State the mass number and atomic number of the daughter nucleus.

Problem 6 Beta decay equation (easy)

Cobalt-60 ($Z = 27$) decays by beta minus emission.

1. Write the nuclear equation.
2. State the atomic number of the daughter.

Problem 7 Counting half-lives (medium)

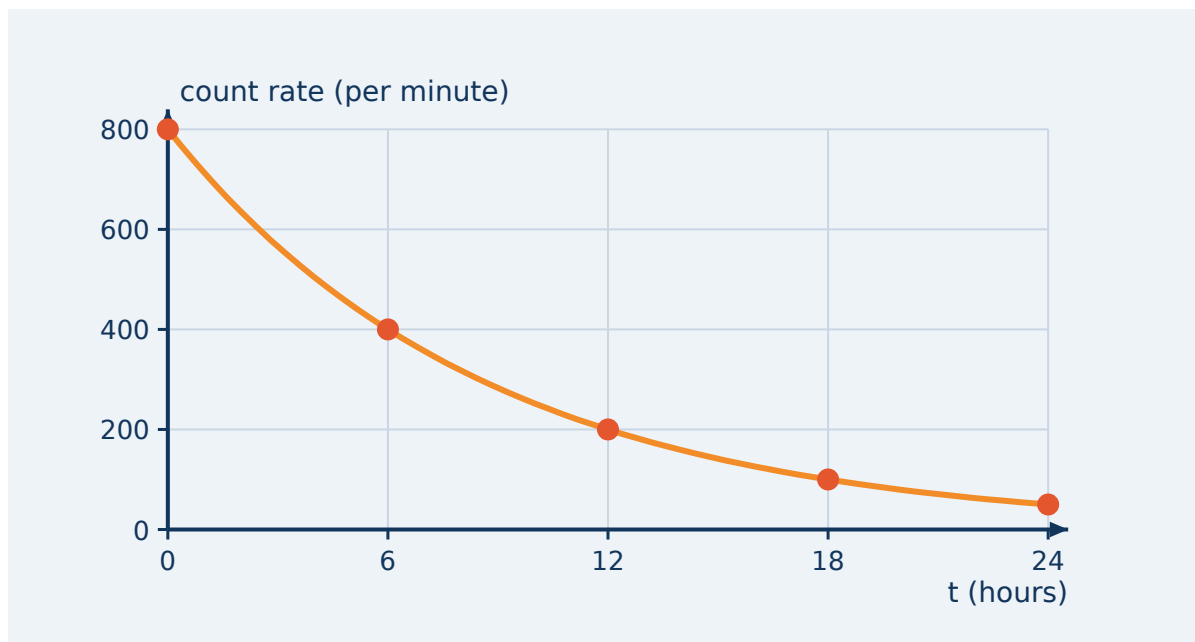
Chiamaka in Lagos has 64 g of an isotope with half-life 5.0 days.

1. Calculate the mass left after 15 days.

2. Calculate the mass left after 20 days.
3. State the fraction left after 15 days.

Problem 8 Reading a decay graph (medium)

A student records the count rate from a sample.



Count rate against time.

1. Read the half-life.
2. Predict the count rate at 30 hours.
3. Explain why the rate never reaches exactly zero.

Problem 9 Mass to energy (medium)

Diego in Texas imagines converting 1.0 g of matter completely to energy.

1. Calculate the energy released using $c = 3.00 \times 10^8$ m/s.
2. Compare it with the energy of 1 tonne of TNT, which is 4.2×10^9 J.

Problem 10 Unit conversion for mass defect (medium)

A nuclear reaction loses a mass of 0.0050 u. Use $1 \text{ u} = 931.5 \text{ MeV}/c^2$ and $1 \text{ MeV} = 1.60 \times 10^{-13} \text{ J}$.

1. Calculate the energy released in MeV.
2. Convert the answer to joules.

Problem 11 Identify the radiation (medium)

Kofi in Accra measures the net count rate of a source with different absorbers between the source and a detector.

Absorber	none	paper	3 mm aluminium	5 cm lead
Net counts per minute	1200	1190	400	5

1. Decide which radiations are emitted.
2. Estimate the fraction of the count rate due to each.

Problem 12 Carbon dating (medium)

Carbon-14 has a half-life of 5730 years. A bone has less carbon-14 than living tissue.

1. Calculate the age if 12.5 % of the original carbon-14 remains.
2. Estimate the age range if 30 % remains.
3. Calculate the age for 30 % using logarithms.

Problem 13 Why spectra are lines (medium)

Hot hydrogen gas gives a spectrum of bright lines, but a hot filament gives a continuous rainbow.

1. Explain why the gas gives lines.
2. Explain why a cool gas placed in front of the filament produces dark lines.

Problem 14 Lyman and Balmer lines (medium)

Compare the transitions $n = 2$ to $n = 1$ and $n = 3$ to $n = 2$ in hydrogen. Use $hc = 1240 \text{ eV}\cdot\text{nm}$.

1. Calculate the energy of each photon.
2. Calculate the wavelength of each.
3. State the region of the spectrum for each.

Problem 15 Binding energy of the deuteron (medium)

Use proton 1.007276 u, neutron 1.008665 u and deuteron 2.013553 u, with $1 \text{ u} = 931.5 \text{ MeV}$.

1. Calculate the mass defect.
2. Calculate the binding energy.
3. Calculate the binding energy per nucleon.

Problem 16 Energy from radium decay (hard)

Radium-226 (226.025410 u) decays to radon-222 (222.017578 u) by emitting an alpha particle (4.002603 u). Use $1 \text{ u} = 931.5 \text{ MeV}$.

1. Calculate the mass lost in the decay.
2. Calculate the energy released.
3. Estimate the kinetic energy of the alpha particle, given that momentum is shared so that

K is inversely proportional to mass.

Problem 17 Activity of a medical tracer (hard)

A hospital sample holds 2.0×10^{10} nuclei of technetium-99m, half-life 6.0 h. Use $A = (\ln 2 / T)N$.

1. Convert the half-life to seconds.
2. Calculate the initial activity in becquerel.
3. Calculate the activity after 18 hours.

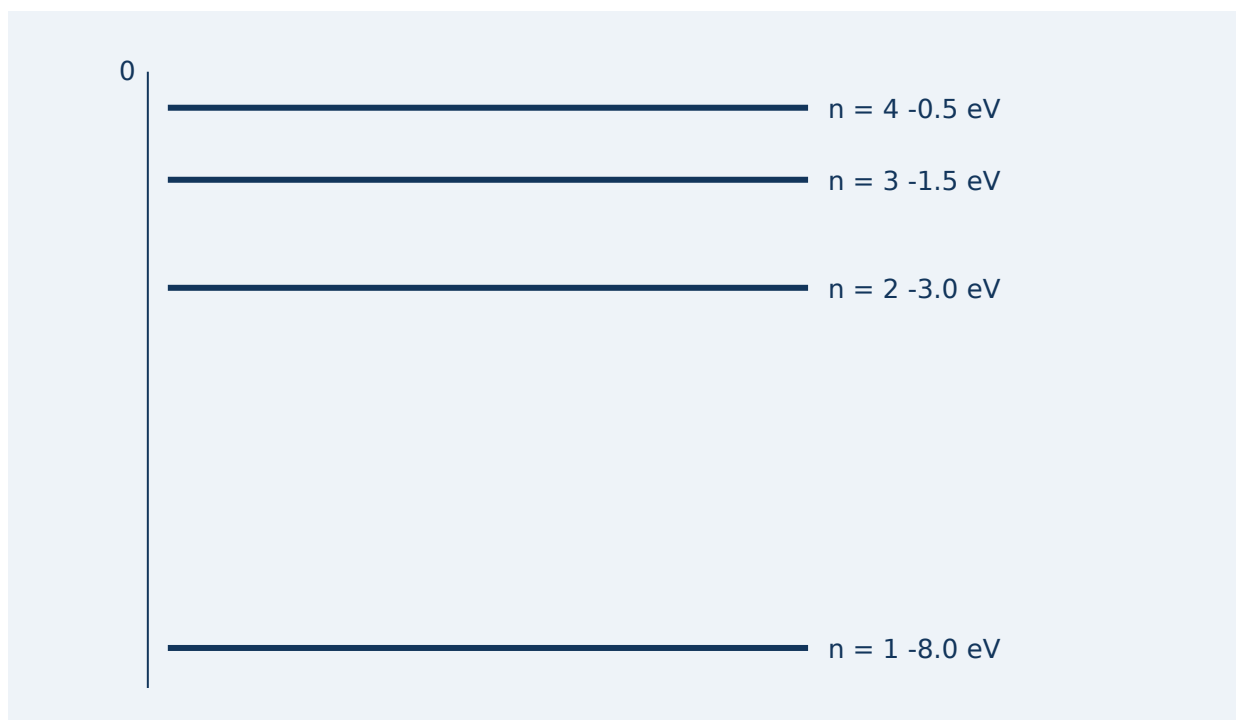
Problem 18 Power of the Sun (hard)

In the Sun, four hydrogen atoms (1.007825 u each) fuse into one helium-4 atom (4.002603 u). The Sun radiates 3.8×10^{26} W. Use $1 \text{ u} = 931.5 \text{ MeV}$ and $c = 3.00 \times 10^8 \text{ m/s}$.

1. Calculate the mass lost in one fusion sequence.
2. Calculate the energy released in MeV.
3. Calculate the mass the Sun converts to energy each second.

Problem 19 Lines from a hypothetical atom (hard)

A hypothetical atom has the energy levels shown. Use $hc = 1240 \text{ eV}\cdot\text{nm}$.



Energy levels of a hypothetical atom.

1. State how many different emission lines are possible from $n = 4$.
2. Calculate the longest wavelength emitted and state its region.
3. Calculate the shortest wavelength emitted.

Problem 20 Half-life from lab data (hard)

A short-lived isotope gives these corrected counts per 10 s in a Geiger counter.

t (min)	0	1	2	3	4	5
counts	480	364	276	209	158	120

1. Plot or inspect the data and estimate the half-life.
2. Check your value using the counts at 0 min and 5 min.
3. Explain why background counts must be subtracted first.