

Formulae:

$$K = \frac{1}{2}mv^2, \quad p = mv, \quad P = \frac{E}{t}, \quad E_0 = m_0c^2$$

$$E = hf, \quad c = \lambda f, \quad K_{\max} = hf - \phi_0, \quad p = \frac{h}{\lambda}, \quad \lambda = \frac{h}{p}$$

$$\Delta p_x \Delta x \geq \frac{h}{2\pi}, \quad \Delta E \Delta t \geq \frac{h}{2\pi}, \quad E_n = -(13.6eV) \frac{Z^2}{n^2}$$

$$N = N_0 e^{-t/\tau}, \quad R = \frac{\Delta N}{\Delta t} = \lambda N = R_0 e^{-t/\tau}, \quad T_{1/2} = \tau \ln 2$$

Constants and conversions:

$$|q_e| = 1.60 \times 10^{-19} \text{ C}, \quad k = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2, \quad m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}, \quad 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}, \quad c = 3.00 \times 10^8 \text{ m/s}$$

$$1 \text{ Ci} = 3.70 \times 10^{10} \text{ decays/second}$$

$$m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg} = 5.486 \times 10^{-4} \text{ u} = .511 \text{ MeV}/c^2$$

$$m_{\text{proton}} = 1.007 276 \text{ u}, \quad m_{\text{neutron}} = 1.008 665 \text{ u}$$

$$1 \text{ u} = 1.660 540 \times 10^{-27} \text{ kg} = 931.5 \text{ MeV}/c^2$$

Advice/Info:

- Look both ways repeatedly before crossing the street.
- Make sure your name and your seat number are in the appropriate places.
- Show your work clearly for full credit.
- Ask questions if you have them.
- Circle your answers if you want me to find them.
- All numeric values are good to at least 3 significant figures.
- Take a deep breath and have fun.
- **You should have three (3) pages in this exam, not including the cover sheet.**
- 100 points are possible.

When you turn in this exam, be sure to pick up your assignment for next week.

Poetry:

Pale, pubescent beasts
Roam through the streets
And coffee-shops
Their prey gather in herds
Of stiff knee-length skirts
And white ankle-socks
But while they search for a mate
My type hibernate
In bedrooms above
Composing their songs of love

Young, uniform minds
In uniform lines
And uniform ties
Run round with trousers on fire
And signs of desire
They cannot disguise
While I try to find words
As light as the birds
That circle above
To put in my songs of love

Fate doesn't hang on a wrong or right choice
Fortune depends on the tone of your voice
So sing while you have time
Let the sun shine down from above
And fill you with songs of love

-B. Folds

Multiple choice: Each question is worth 5 points.

1. If energy is released in a nuclear decay, the mass of the products must be _____ the mass of the original nucleus.

A. equal to	B. less than	C. greater than
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2. Electrons are emitted from a metal surface when the metal is illuminated by light of frequency f . How will the kinetic energy of each electron change if *more* photons of the same frequency shine upon the metal?

A. No change in each electron's kinetic energy.	B. Each electron will have a greater kinetic energy.	C. Each electron will have a lower kinetic energy.	D. No sure prediction can be made.	E. 42
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3. Electrons are emitted from a metal surface when the metal is illuminated by light of frequency f . How will the kinetic energy of each electron change if this *frequency* of the light is increased, while the intensity remains constant?

A. No change in each electron's kinetic energy.	B. Each electron will have a greater kinetic energy.	C. Each electron will have a lower kinetic energy.	D. No sure prediction can be made.	E. 42
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4. Bohr found that electrons could only "orbit" an atom at very specific energy levels and with very specific angular momentums. This is a consequence of electrons being

A. waves.	B. particles.	C. charges.	D. massless.	E. clever.
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5. You have two radioactive sources, one with alpha decay and the other with beta decay. How could you tell which is which?

A. The beta particles are easier to block with a piece of paper.	B. The alpha particles are easier to block with a piece of paper.	C. The beta particles have zero charge.	D. The alpha particles have zero charge.	E. More than one answer is correct.
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6. You have two radioactive sources, one with alpha decay and the other with gamma decay. How could you tell which is which?

A. The gamma particles would be bent by a magnetic field, but the alpha particles would not.	B. The alpha particles would be bent by a magnetic field, but the gamma particles would not.	C. You could hear the gamma particles, but not the alpha particles.	D. You could hear the alpha particles, but not the gamma particles.	E. More than one answer is correct.
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SITUATION I: Falling to pieces

A. [10 points] Imagine that you're in the lab, playing with a nuclear isotope whose half life is 57.0 minutes. How long will you need to wait until the count rate that measure for a sample of this isotope changes so that it is 1/8 of its original value?

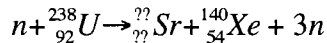
The easy way: $\frac{1}{8} = \left(\frac{1}{2}\right)^3$, so three half life periods have transpired: $t = 3T_{1/2} = 3(57\text{min}) = 171\text{min}$

The slightly harder way:

$$N = N_0 e^{-t/T} \rightarrow e^{-t/T} = \frac{N}{N_0} = \frac{1}{8} \rightarrow -t/T = \ln \frac{1}{8}$$

$$\rightarrow t = -T \ln \frac{1}{8} = -\frac{T \cdot \ln 2}{\ln 2} \ln \frac{1}{8} = 171\text{min}$$

B. [25 points] In class we did not give an example of a fission reaction (although you did have homework problems on it). Fortunately, every nuclear reaction has its energy release calculated in the same way. For example:



The atomic mass of ${}^{238}\text{U}$ is 238.050 784 u, the atomic mass of ${}^{96}\text{Sr}$ is 95.921 750 u, and the atomic mass of ${}^{140}\text{Xe}$ is 139.921 610 u.

The mass of a neutron, designated by the n in the reaction, is on your cover sheet, along with the masses of a few other things.

- a. In this reaction, the nucleus ${}_{??}^{??}\text{Sr}$ has some information missing. What are its values for A (number of nucleons) and Z (number of charges)? (Be careful: all nucleons are accounted for in the equation.)

remember: neutrons have $A=1$, $Z=0$, so:

$$0 + 92 = Z + 54 + 0 \rightarrow Z = 38$$

$$1 + 238 = A + 140 + 3 \rightarrow A = 96$$

- b. Calculate the energy released in this fission reaction.

You can subtract electron masses, but they're the same on each side. So I'll just use atomic masses:

$$\Delta m = (m_n + m_U) - (m_{\text{Sr}} + m_{\text{Xe}} + 3m_n)$$

$$= (238.050784\text{u}) - (95.921750\text{u} + 139.921610\text{u} + 2(1.008665\text{u}))$$

$$= \boxed{.190094\text{u}}$$

$$E = \Delta mc^2 = (.190094\text{u}) \left(\frac{931.5\text{MeV}}{1\text{u}} \right) e^2 = \boxed{177.1\text{MeV}}$$

SITUATION II: Lots o' particles

1. [20 points] The maximum wavelength a photon can have and still eject an electron from a copper surface is 464 nm. If the wavelength of each photon is changed to 400 nm, what is the maximum speed of each electron ejected?

$$1. \text{ if } K=0, \quad 0 = \frac{hc}{\lambda} - \phi$$

$$\phi = \frac{hc}{\lambda} = \frac{1240 \text{ eV nm}}{464 \text{ nm}} = \underline{2.67 \text{ eV}}$$

$$2. \quad K = \frac{hc}{\lambda} - \phi$$

$$\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi$$

$$v = \sqrt{\frac{2}{m} \left(\frac{hc}{\lambda} - \phi \right)}$$

$$v = \sqrt{\frac{2}{9.11 \times 10^{-31} \text{ kg}} \left(\frac{1.6 \times 10^{-19} \text{ J}}{\text{eV}} \right) \left(\frac{1240 \text{ eV nm}}{400 \text{ nm}} - 2.67 \text{ eV} \right)}$$

$$v = \underline{3.88 \times 10^5 \frac{\text{m}}{\text{s}}}$$

2. [15 points]. Find the wavelength of the radiation emitted when a hydrogen atom makes a transition from the $n=3$ state to the $n=1$ state.

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

$$-13.6 \text{ eV} \left(\frac{1}{3^2} - \frac{1}{1^2} \right) = \frac{hc}{\lambda}$$

$$\lambda = \frac{1240 \text{ eV nm}}{12.1 \text{ eV}} = \underline{103 \text{ nm}}$$