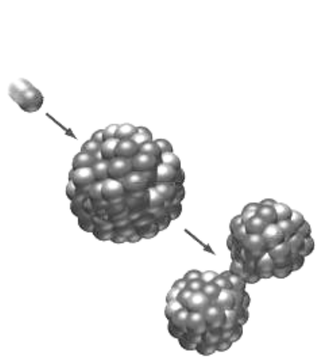
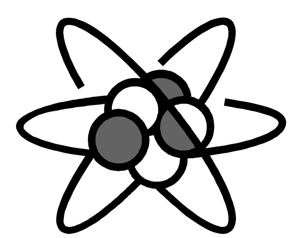
Higher Physics Homework Tutorials

Unit 3

Radiation & Matter
Version 2.0





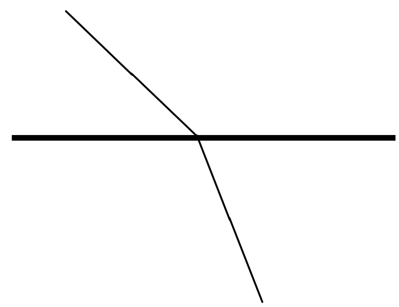
Tutorial 1
Waves & Radiation Revision

1. Give a good quality definition for each of the following words, relating to electromagnetic waves such as light:

   Frequency , Wavelength , Amplitude , Velocity ,
   Refraction , Diffraction , Interference

2. For each of the following waves, calculate:
   (a) The distance travelled by a light wave in 14.8 seconds.
   (b) The frequency of light in air if its wavelength is 520nm.
   (c) The wavelength of a 12000Hz sound wave in air.
   (d) The frequency of a microwave with a wavelength of 4 cm.
   (e) The distance travelled per minute by a water wave of frequency 0.8Hz and wavelength 6m

3. Copy the diagram shown into your jotter carefully.
   The diagram shows a ray of light passing from air into perspex.
   Mark on this diagram:
   A normal line
   Arrows indicating the direction of travel
   The angle of incidence
   The angle of refraction



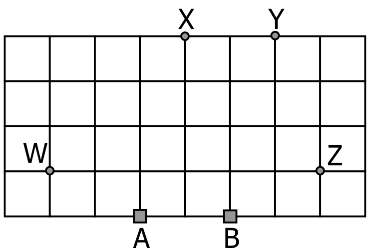
4. Construct a table showing the three types of nuclear radiation and the approximate thickness and material of the shielding required to block it

5. A sample of plutonium has a half life of 36days. If its current activity is 8000MBq, calculate its activity 108 days from now.

6. The same sample of plutonium from Q5 was actually prepared 72 days ago. What was its original activity?

Tutorial 2
Interference 1

1. The diagram shows a 1m grid and the position of two coherent sources of sound (A & B). For each other position (W, X, Y, & Z), calculate the path difference.



2. Describe what is meant by the terms *constructive interference* and *destructive interference*. Include in your description the effect on the waves in question.

3. Two audio speakers are producing coherent sound waves. Explain why a person walking in front of the speakers will hear changes in the volume of sound even though the speakers are producing sounds of constant amplitude.

4. Pupils curious about the effect in Q3 replicate this experiment in the Lab. They detect a position of **minimum** volume where the path difference is 0.58m. They determine that this is the second minimum. Determine the wavelength of the sound, and hence its frequency.

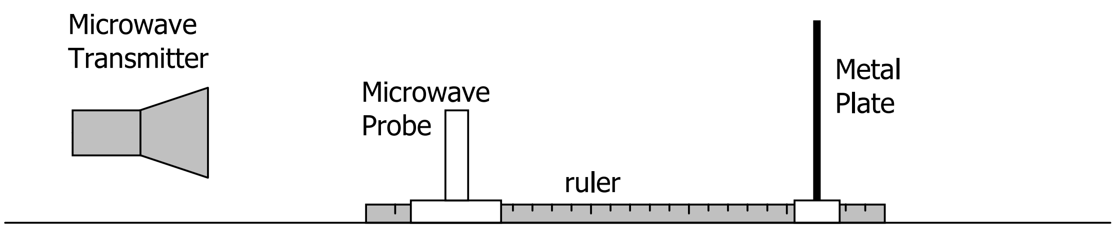
5. Two speakers producing coherent sound are positioned 1.8m apart. A pupil is standing immediately in front of **one** of the speakers, 3m away from it. The position he is standing at represents the second maximum. Calculate the wavelength and therefore the frequency of the sound.

Tutorial 3
Interference 2

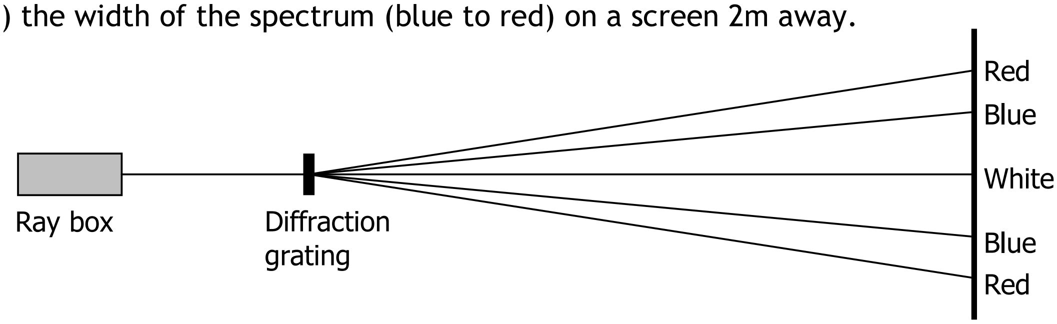
1. Lasers exhibit interference when passes through a diffraction grating. For each of the following, use the data given to determine the gap separation ‘d’ in metres.
   (a) 500 lines / mm
   (b) 44000 lines / m
   (c) 1900 lines / cm
   (d) 8500 lines / inch   (1inch = 0.0254 m)

2. A laser is passed through a diffraction grating which is 2 metres from a white screen. The diffraction grating used is marked as having 450 lines / mm.
   If the wavelength of the laser is 633nm, calculate:
   (a) the angle between the central and second maximum.
   (b) the distance between the central and second maxima on the screen.

3. The apparatus in the diagram below can be used to measure the wavelength of microwaves. **Describe in detail** the procedures and calculations involved in calculating this wavelength.

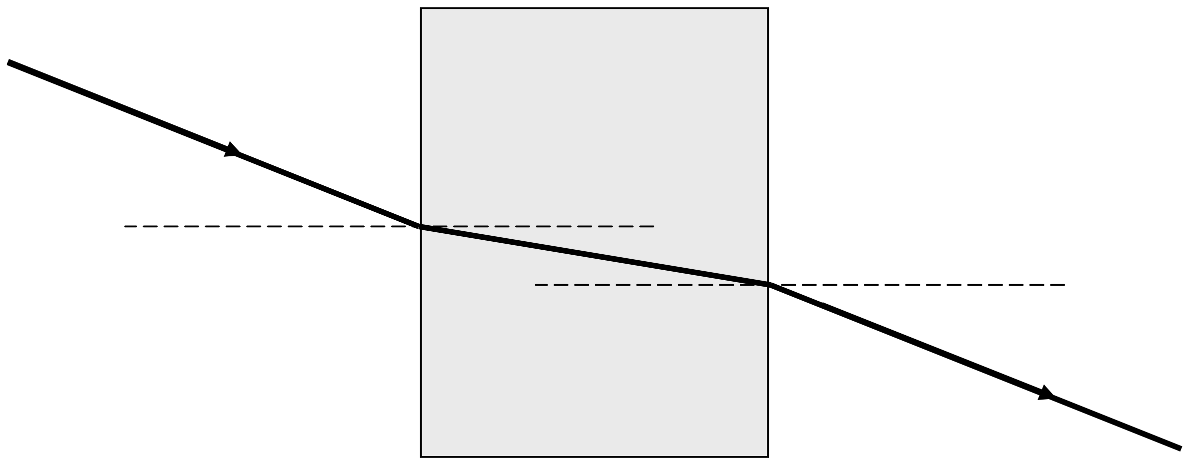


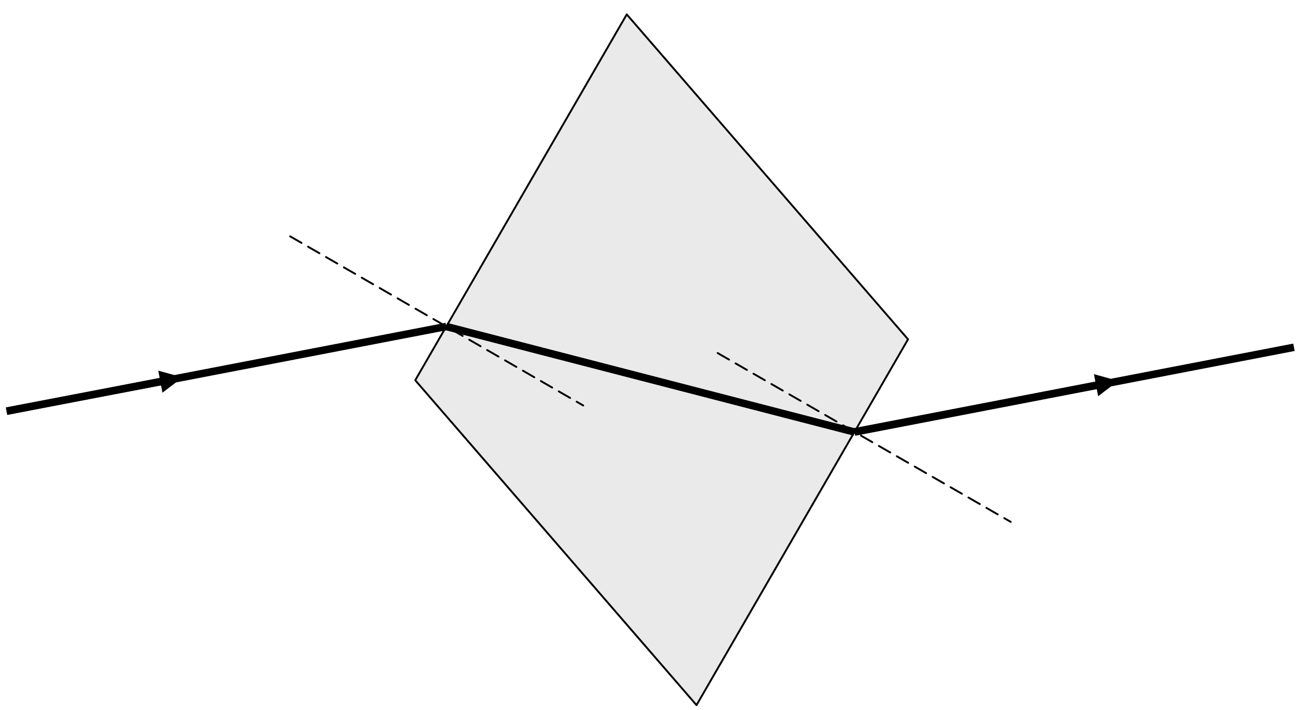
4. A ray box is set up to shine a beam of white light through a diffraction grating which has 240 lines / mm. This apparatus produces a white central maximum with a spectrum on each side. If we assume visible light ranges from 400nm to 700nm calculate:
   (a) the angle between the central maximum and the blue edge of the spectrum
   (b) the angle between the central maximum and the red edge of the spectrum
   (c) the width of the spectrum (blue to red) on a screen 2m away.



Tutorial 4
Simple Refraction

1. For each of the diagrams below, measure and note the angles of incidence and refraction and use these to calculate the refractive index of the material.



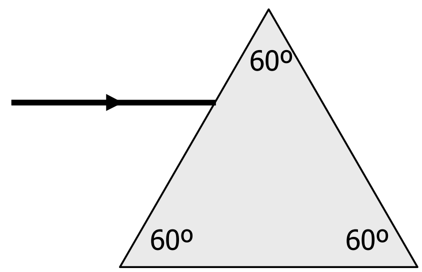


Tutorial 5
Complex Refraction

Material	Refractive Index	Material	Refractive Index
Air	1.00	Ruby	1.76
Water	1.33	Diamond	2.42
Pure Glass	1.50	Flint Glass	1.61

1. Calculate the critical angle for each of the materials in the table above.

2. Light is shone into a ruby prism horizontally in the arrangement shown. Redraw the diagram (large) and show the path taken by the light through the prism until it exits. Mark the sizes of all angles of incidence, refraction and reflection.



3. Draw a circle in your jotter which is 4cm in diameter (use compasses!). This will represent a circular prism of pure glass.

   Two parallel rays of light pass into it, with one ray passing straight through the centre and the other ray entering 1.5cm above it.
   Show on your diagram the path of both rays of light as they pass through and out of the block.

   You may measure angles on your diagram, but must show calculations for each reflection or refraction which takes place.

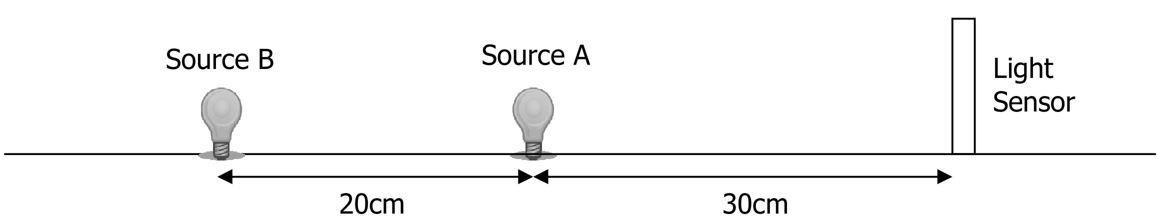
Tutorial 6
Irradiance

1. Calculate the irradiance in Wm^{-2} for each of the following situations:
   (a) 19kW of light falling on a $30m^2$ area.
   (b) 25W of light falling on a 20cm by 40cm area.
   (c) 8kJ of light energy falling on a 0.5m by 0.6m area in 1 minute.

2. A PV solar panel converts 20% of the light energy falling on it into electrical energy. If the solar panel measures 1.6m by 0.8m, and is placed in sunlight with an irradiance of $800Wm^{-2}$, calculate:
   (a) The power of the light falling on the solar panel.
   (b) The electrical power produced by the panel.
   (c) The current produced by the panel if it runs at 12V.
   (d) The energy produced by the panel in 6 hours.

3. A satellite in earth orbit (1.496×10^{11} m from the sun) measures the irradiance as $1470Wm^{-2}$. Calculate the irradiance at each of the following positions:
   (a) Mercury (5.79×10^{10}m from the sun)
   (b) Mars (2.280×10^{11}m from the sun)
   (c) Neptune (4.500×10^{12}m from the sun)
   (d) The Voyager 1 space probe launched 1977, currently 1.58×10^{13}m from the sun

4. A small point source of light is used in the experiment shown in the diagram below. With the sensor exactly 30cm from the source, the reading is $400Wm^{-2}$. Another light source is placed 20cm behind the first source (50cm from the sensor). Assuming the sensor picks up the light from both sources, calculate the total irradiance detected at the sensor when the second source is activated.



Tutorial 7
Photoelectric Effect

Metal	Work Function(J)	Metal	Work Function(J)
Aluminium	6.53×10^{-19}	Lead	6.62×10^{-19}
Calcium	4.64×10^{-19}	Sodium	3.65×10^{-19}
Gold	8.16×10^{-19}	Zinc	6.88×10^{-19}

Plank's Constant = h = 6.63×10^{-34}Js

1. Calculate the threshold frequency for each of the above metals.

2. Calculate the energy of a photon of:
   (a) Red light of wavelength 680nm
   (b) Green light of wavelength 510 nm
   (c) Infrared radiation with a wavelength of 360μm
   (d) Ultraviolet radiation of wavelength 50nm
   (e) Gamma radiation of wavelength 1×10^{-12}m

3. State and explain whether or not photoelectric emission of electrons would occur in each of the following situations:
   (a) Red light from Q2(a) incident on a negatively charged sodium plate
   (b) UV radiation from Q2(d) incident on positively charged zinc plate
   (c) Green light from Q2(b) incident on negatively charged Calcium plate

4. If a negatively charged aluminium plate were irradiated with UV radiation with a wavelength of 250nm, photoelectric emission will occur. Calculate the maximum kinetic energy of an electron emitted from the plate.
   Hence calculate the maximum velocity at which the electron could be emitted.

5. Explain why photoelectric emission suggests that light can act like a particle.

Tutorial 8
Emission & Absorption

The data below shows an energy level diagram for neutral hydrogen. Figures from this diagram should be used in the following question

$W_3 = -1.30 \times 10^{-19}$ J

$W_2 = -2.43 \times 10^{-19}$ J

$W_1 = -5.44 \times 10^{-19}$ J

$W_0 = -21.8 \times 10^{-19}$ J

1. From the information above, there are six possible frequencies of radiation which could be emitted from an excited hydrogen atom.
   Calculate these frequencies and hence their wavelengths.
   For each of the six, suggest the colour of light or type of radiation emitted

2. When white light is shone through hydrogen gas and then examined, some dark lines appear in the spectrum. Explain with reference to the above energy diagram why the dark lines are present.

3. Explain how viewing the light from a distant star, through either a diffraction grating or a prism, allows scientists to determine the main elements present in the star.

Tutorial 9
Lasers & Semiconductors

1. Laser is an acronym, but what do the letters stand for?

2. Explain the difference between spontaneous and stimulated emission of a photon.

3. Semiconductors can be either P-type or N-type. Explain the meanings of these terms in terms of charge carriers.

4. Explain why a P-N junction diode in a reverse bias arrangement does not allow a current to flow through it.

5. Draw the electrical symbol for a MOSFET and label the three terminals.

6. Draw an electrical circuit showing a photodiode in photovoltaic mode connected to an electric motor.

Tutorial 10
Radioactive Decay Series, Fission & Fusion

For this tutorial you will need to refer to a periodic table. A simplified table is supplied at the back of this tutorial booklet. When naming elements, always give the name or symbol, atomic number and mass number.

1. An atom of polonium-210 emits an alpha particle. Which element remains?

2. An atom of uranium-235 emits a beta particle, what element remains?

3. Detectives find a suspicious material at a crime scene which has almost entirely decayed into Neptunium 237. They are detecting small levels of alpha and beta radiation from the material.
   Assuming the material decayed into Neptunium-237 by a single alpha decay and a single beta decay, what was the original material?

4. Describe the process of nuclear fission explaining why energy is generated during the reaction. Explain why this reaction develops into a chain reaction.

Use the information about the atomic mass of the following isotopes for Q5&6

Particle	Mass(kg)	Particle	Mass(kg)
Uranium-235	$3.9014\text{x}10^{-25}$	Deuterium	$3.3432\text{x}10^{-27}$
Kryptonium-92	$1.5255\text{x}10^{-25}$	Tritium	$5.0066\text{x}10^{-27}$
Barium-141	$2.3392\text{x}10^{-25}$	Helium-4	$6.6450\text{x}10^{-27}$
neutron	$1.6750\text{x}10^{-27}$		

5. The equation below represents a nuclear reaction.
   (a) What type of nuclear reaction is this?
   (b) Calculate the mass lost and hence the energy created in this reaction

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3^{1}_{0}n$$

6. The equation below represents a nuclear reaction.
   (a) What type of nuclear reaction is this?
   (b) Calculate the mass lost and hence the energy created in this reaction

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

Tutorial 11
Dosimetry & Shielding

The following tables provide the radiation weighting factors for different types of radiation for use in the following tutorial.

Radiation	**Weighting Factor**
Alpha	20
Beta	1
Gamma	1
Fast Neutrons	10

1. Give a working definition for each of the following terms:
   Becquerel , Absorbed Dose, Dose Equivalent, Half Life, Half value thickness

2. A scientist is investigating radiation and uses different types of radiation to irradiate a number of different biological samples. For each of the following calculate the absorbed dose, and hence the dose equivalent for each.
   (a) 850μJ of Gamma radiation absorbed by a 0.55g bacterial sample
   (b) 6mJ of alpha radiation absorbed by a 2kg elephant heart
   (c) 25μJ of fast neutrons absorbed by a 0.1g spleen

3. A human being of mass 75kg works in a reactor room 6 days per year, for 3 hours each time, receiving 37μJ of fast neutron radiation for each 3 hour period. Calculate:
   (a) his dose equivalent rate over a single 3 hour shift.
   (b) his effective dose equivalent rate over the whole year.

4. A highly radioactive source emitting gamma radiation is to be encased in steel for safety. A detector in the adjacent room currently detects 4000 counts per minute. How much steel would be required to reduce this to 500 counts per minute. The half value thickness of steel is 3.3cm.

5. Describe in detail and experiment to measure the half value thickness of lead for gamma radiation. Include all the equipment required, measurements taken and calculations performed.

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 * *	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
* *Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]