Take notes while watching the following video tutorials to prepare for the "Atomic Structure and Nuclear Chemistry Activity".

Atoms & Elements Part O: Atomic Structure - An Introduction

Electrostatics – an underlying force throughout chemistry

The word ATOM is derived from

the Greek ATMOS meaning "uncut" or "indivisible."

460 – 370 B.C. Democritus uses the term "**atmos**" as a proponent of the discontinuous matter concept

1808 Dalton's Atomic Theory

- 1. Elements are made of tiny particles called atoms.
- 2. All atoms of a given element are identical.
- 3. The atoms of a given element are different from those of any other element.
- 4. Atoms of one element can combine with atoms of other elements to form compounds. A given compound always has the same relative numbers and types of atoms.
- 5. Atoms are indivisible in chemical processes. That is, atoms are not created or destroyed in chemical reactions. A chemical reaction simply changes the way the atoms are grouped together.

Late 1890's JJ Thomson shows atoms contain negative particles - electrons

JJ Thomson proposes that atoms must also contain positive particles to give the atom an overall zero charge – **protons**

Late 1890's Lord Kelvin proposes the "plum pudding" model for the atom

1911 Rutherford proposes the "**nuclear atom**" – an atom with a dense center of positive charge (the **nucleus**) surrounded by tiny electrons in an otherwise empty space (grape / mile)



1919 Rutherford determined that a proton had the same magnitude of charge as an electron (proton = +1 and electron = -1)

- 1932 Rutherford demonstrated the existence of **neutrons** in most nuclei. The neutron has no charge (neutral) and is slightly more massive than a proton.
- 1932 Chadwick determined the existence of **isotopes** atoms with the same number of protons, but with different numbers of neutrons (only major change to Dalton's original atomic theory)

What have we learned since 1932?

subatomic particle	relative charge	relative mass

Atomic number:

Mass number:

Isotopes:

Let's put it all together.

Atoms are the basic building blocks of matter. Matter is defined as anything with MASS & VOLUME. What is the relationship between atomic structure and matter?

renould table of the Element	Periodic	Table	of the	Element
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1 Group IA	-																18 Group VIIIA
1 H 1.01	2 Group IIA											13 Group IIIA	14 Group IVA	15 Group VA	16 Group VIA	17 Group VIIA	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 0 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30	3 Group IIIB	4 Group IVB	5 Group VB	6 Group VIB	7 Group VIIB	8 Group	9 Group VIIIB-	10 Group	11 Group - IB	12 Group IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr . 52.00	25 Mn 54.94	26 Fe 55.84	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br .79.90	36 Kr 83.80
37 IRb 85.47	38 Sr 87.62	39 ¥ 88.91	40 Zz 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Su 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hff 178.49	73 Ta 180.95	74 W 183,84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 T1 204.38	82 РЬ 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (269)	109 Mt (268)	110 (271)	111 (272)	112 - (277)		114 (289)		116 		118 (293)
				58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Тъ 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 ¥b 173.04	71 Lu 174.97
				90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (248)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (260)	102 No (259)	103 Lr (262)

Keeping the terms straight - the path to Mastery!

Atoms vs Elements vs Compound	Atoms	VS	Elements	VS	Compound
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Atom: the smallest component of an element

Element: substance composed of only 1 type of atom

Compound: substance composed of a fixed ratio of atoms

 H_2O

 $C_6H_{12}O_6$

One formula unit of Ca₃(PO₄)₂ contains ______ elements and _______atoms. A = 9; 13 B = 3; 9 C = 3; 13 D = 3; 5 Atoms & Elements Part 1:

Atomic Structure: Isotopes and the Nucleus Atoms are the building blocks of matter.

What is the definition of matter?

There are 3 subatomic particles that are the building block of atoms. What are the 3 subatomic particles and their charges?

Which subatomic particle(s) create the mass of an atom?

Which subatomic particle(s) create the volume of an atom?

What is the atomic number of an atom? What is its symbol?

What is the mass number of an atom? What is its symbol?

Is every atom of an element identical? Why or why not?

What are isotopes?

Distinguishing between Isotopes

What is the mass number of an atom containing 42 protons, 42 electrons, and 47 neutrons?

Write the elemental symbol for the isotope above using the z^{AE} format.

Iodine has an atomic number of 53. I-131 is used in the medical treatment of thyroid conditions. How many neutrons and protons are contained in the nucleus of this isotope?

The Average Atomic Mass of an element is a weighted average of the mass of its isotopes based on their natural abundance.

Do all elements have the same distribution of isotopes?

The isotopic distribution for chromium is shown below. The atomic number for chromium is 24.

Isotope	% Abundance
⁵⁰ Cr	4.345
⁵² Cr	83.79
⁵³ Cr	9.50
⁵⁴ Cr	2.365

Which isotope is the lightest?

Which isotope is the most abundant?

Which isotope has the largest number of neutrons?

The Atomic Number and Average Atomic Mass are listed with each element on the periodic table.



Nuclear Chemistry Part 1:

Nuclear Structure Review & Introduction to Nuclear Chemistry

Symbols for 3 isotopes of carbon:

 $^{12}6C$ $^{13}6C$ $^{14}6C$ carbon-12 carbon-13 carbon-14 How many protons are in carbon-12? How many neutrons are in carbon-12? How many protons are in carbon-13? How many neutrons are in carbon-13? How many protons are in carbon-14? How many neutrons are in carbon-14? What is the same about the isotopes of carbon? What is different about the isotopes of carbon? What does the subscripted 6 represent? What is the name and symbol for the subscripted 6? What do the superscripted 12, 13, & 14 represent? What is the name and symbol for the superscripted 12, 13, & 14? Radioisotopes: unstable isotopes

Radioactive decay: the nucleus of a radioactive isotope undergoes a natural process to become a more stable nucleus

Background Radiation: radiation from natural sources

Artificial Radioisotopes: man-made isotopes

Average Exposure to Radiation from Common Sources

Source: National Council on Radiation Protection and Measurements, NCRP Report No. 93 (1993)

Source	Dose (mrem/year)
Natural Sources	
Cosmic rays	27
Terrestrial radiation (rock, buildings)	28
Inside the body (K-40 and Ra-226)	39
Radon in the air	200
Total	294
Artificial Sources	
Medial x-rays	39
Nuclear medicine	14
Consumer products	10
Nuclear power plants	O.5
All others	1.5
Total	65
Grand Total	359

The major types of radiation



Electromagnetic Radiation



Nuclear Chemistry Part 2: Nuclear Reactions

Nuclear Reaction: a change in the composition of the nucleus of an atom

3 Types

1) radioactive decay

Unstable nuclei eject subatomic particles &/or high energy photons of light to stabilize

- 2) fusion
 - Combining nuclei into larger nuclei stars & the sun

3) fission

Splitting the nuclei of atoms – power plants & bombs

				Relative		
Type of	Symbol	Mass #	Charge	penetrating	Shielding	Biological
Radiation		(A)		ability	required	hazard
Alpha						None unless
particle	$lpha$, ${}^4{}_2$ He	4	2+	Very low	Clothing	inhaled
Beta					Heavy cloth,	Mainly to
particle	β, ⁰ -1e	0	1–	Low	plastic	eyes, skin
Gamma					Lead or	Whole body
ray	γ, ⁰ 0γ	0	0	Very high	concrete	
						Whole body
Neutron	1 _o n	1	0	Very high	Water, lead	
					Heavy cloth,	Mainly to
Positron	β ⁺ , ⁰ ₊₁ e	0	1+	Low	plastic	eyes, skin

Nuclear decay does NOT depend on the environment of the atom.

Temperature, pressure, or type of compound do NOT change radioactive decay.

ALL nuclear reactions are exothermic – releasing a HUGE amount of energy from the nucleus.

 α -Decay & Balancing Nuclear Reactions

 $^{238}_{92}U \rightarrow ^{234}_{90}Th$ + α + γ

Type of radioactivity released?

How does the total number of protons in the reactant compare with the total number of protons in the products?

How does the mass number of the reactant compare with the mass number of the products?

Does the γ -ray effect the mass balance of the reaction above?

Is the nuclear reaction above balanced?

Predict the product of the following nuclear reaction.

$$^{222}_{86}Rn \rightarrow$$
 + α + γ

 β -Decay of Neutron-rich Isotopes

 $^{1}_{0}n \rightarrow ^{1}_{1}p + ^{0}_{-1}e$

 β particles are produced from an unstable nucleus when a neutron is transformed into a proton releasing a high energy electron.

Practice - complete the nuclear reaction below.

$$^{133}_{54}Xe \rightarrow$$
 + $^{0}_{-1}e$

Positron Decay of Proton-rich Isotopes

 $^{1}_{1}p \rightarrow ^{1}_{0}n + ^{0}_{+1}e$

A positron is produced from an unstable nucleus when a proton is transformed into a neutron releasing a high energy positron.

Practice - complete the nuclear reaction below.

$$\rightarrow$$
 ⁷⁹₃₆Kr + ⁰₊₁e

X rays and Gamma Radiation



Nuclear decays often occur in a series before reaching a stable isotope. Identify the types of radioactive decay in the series shown above.

Decay series for $^{238}U \rightarrow ^{206}Pb$



Balance the following nuclear reactions and identify the type(s) of radioactivity given off.



Nuclear Chemistry Part 3: Half-lives of Radioisotopes

 $t_{1/2}$ = half-life



	Radiation	
Radioisotope	type	Half-life
barium-131	γ	11.6 days
carbon-14	β	5730 yr
chromiuim-51	γ, x-rays	27.8 days
iodine-131	β	8.1 days
cobalt-60	β, γ	5.3 yr
uranium-238	α, β, γ	4.5 x 10 ⁹ yr

Use the following table to answer the questions below.

Consider a 100. g sample of ⁵¹Cr.

- a) How long will it take 1/2 of the sample to decay?
- b) How many grams of ⁵¹Cr will remain after 83.4 days?

Considering only the half-lives of ¹⁴C and ¹³¹Ba, which would be more appropriate for internal usage for medical tests? Explain.

What percent of ¹⁴C remains in a sample estimated to be 17,000 years old?

Shown below is a portion of the decay series for plutonium-241. The series has two kinds of arrows: shorter arrows pointing to the right and longer arrows pointing left.

- a) Label the arrows to indicate the type of nuclear decay that is occurring.
- b) Give the elemental symbol with Z and A to indicate the resulting isotope from the decay series shown.



Atomic Structure Introduction dabe© – page 20

Nuclear Chemistry Part 4: Biological Effects of Ionizing Radiation Radiation can damage DNA causing genetic mutations by breaking phosphoester bonds close to each other on opposing strands of DNA

 α , β , β^+ , γ and x-rays interact with matter causing ion formation.

The biological effects of radiation depend on 1) energy of the radiation

Type of Radiation	Energy of Radiation	Penetrating distance into water
α	3 – 9 MeV	0.02 – 0.04 mm
β, β+	0 –3 MeV	0 – 4 mm
x-rays	100 eV – 10 keV	0.01 – 1 cm
γ-rays	10 keV – 10 MeV	1 – 20 cm

2) penetrating power of the radiation

Measurement of Radiation

Geiger-Muller Counter

Electricity is conducted through gas that contains charged particles.

Film Badges – dosimeters

Units of Radiation Intensity

- 1) Number of radioactive emissions
- 2) Absorbed Dose
- 3) Effective Dose

Absorbed Dose vs Effective Dose

1 Rad of α causes 20x the damage of 1 Rad of γ -rays

1 rem of α causes the same damage as 1 rem of $\gamma\text{-rays}$

Radiation Units and their Abbreviations

Aspect being Described	Unit	Symbol
Amount of Radioactive Decay	Bequerel	Bq
	Curie	Ci
Absorbed Dose	Gray	Gy
	Radiation absorbed dose	Rad
Effective Dose	Sievert	Sv
	Roentgen equiv man	rem

Health Effects of Ionizing Radiation depend on the following:

- 1) intensity of the energy of the radiation
- 2) length of exposure to the radiation
- whether the radioactive source is inside or outside the body

2 types of effects

1) Acute	Effective Dose (Sv)	Symptoms
	0.05-0.2	None
	0.2-0.5	Temporary decrease in white blood cell count.
	0.5-1.0	Headache and increased risk of infection. Possible temporary male sterility.
	1.0–2.0	LD ₁₀ ; nausea, hair loss, fatigue. Loss of white blood cells; temporary male sterility.
	2–3	LD_{35} ; loss of hair all over the body, fatigue and general illness. High risk of infection.
	3-4	LD ₅₀ ; uncontrollable bleeding in the mouth. Permanent sterility in women.
	4-6	LD ₆₀ ; death resulting from internal bleeding and infection. Permanent female sterility.
	6-10	LD ₁₀₀ ; death after 14 days.

2)Chronic

To minimize exposure

- 1) Shielding
- 2) Distance -Intensity is inversely proportional to the square of the distance.

Nuclear Chemistry Part 5: Nuclear Medicine

1) Medical Imaging

General procedure:

- a) radioactive isotope is administered
- b) radioactive isotope is allowed to metabolize
- c) radiation is measured for location and intensity
- d) computer processing translates data into images
- 2) Radiation Therapy

Selective destruction of pathological cells and tissues

Medical Applications of Radioisotopes

Isotope	Half-life	Medical Application
		Gastrointestinal tract diagnosis; measuring
Ce-141	32.5 days	blood flow to the heart
Ga-67	78 hour	Abdominal imaging; tumor detection
Ga-68	68 min	Detect pancreatic cancer
		Treatment of leukemia, excess red blood
P-32	4.3 days	cells, pancreatic cancer
1–125	60 days	Treatment of brain cancer
		Imaging thyroid; treatment of Graves'
I-131	8 days	disease, goiter, and hyperthyroidism;
		treatment of thyroid and prostate cancer
Sr-85	65 days	Detection of bone lesions; brain scans
F-18	109 min	PET scans for brain activity &
		tumor detection
Tc-99m	6 hours	Imaging of skeleton and heart muscle,
		brain, liver, heart, lungs, bone, spleen,
		kidney and thyroid; most widely used
		radioisotope in nuclear medicine

Fusion

 $^{2}_{1}H$ + $^{3}_{1}H$ \rightarrow $^{4}_{2}He$ + $^{1}_{0}n$ + 5.3 x 10⁸ kcal/mol of He

Compare with the energy released from chemical bonds:

 $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + H_2O(l) + 213 \text{ kcal}$

Trans-uranium elements are produced by fusion reactions.

 $^{252}_{98}Cf + {}^{10}_{5}B \rightarrow {}^{257}_{103}Lr + 5{}^{1}_{0}n$

Fission - the source of bombs and energy

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

For every 235_{92} U nucleus, more than 1 neutron is generated.

Chain Reaction: only 1 of the neutrons produced reacts with another nucleus

Expanding or Branching Reaction: more than 1 of the neutrons produces additional fission reactions

Critical: a constant-rate chain reaction

Supercritical: a branching chain reaction that will lead to an explosion

Nuclear bombs

Nuclear Power

Remember: ALL forms of energy have negative consequences.