PSC-436

Changes in Matter

There are **three kinds of changes** that matter can undergo:

1. Physical Changes

2. Chemical Changes

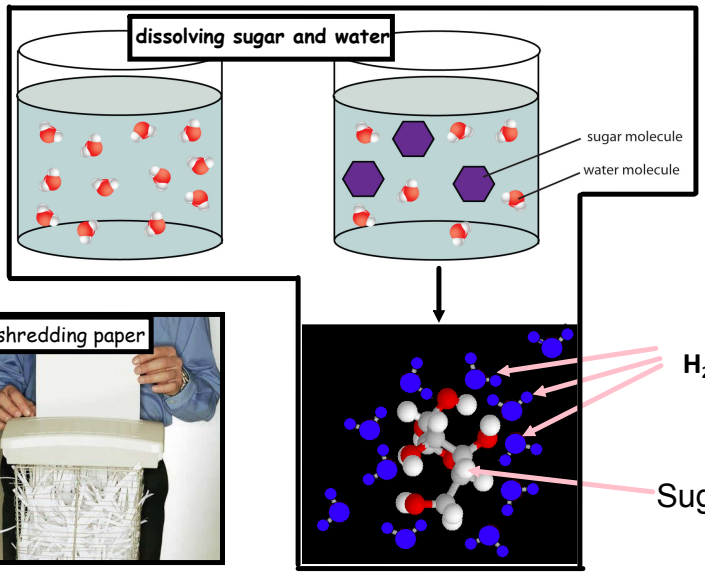
3. Nuclear Changes

Important for you: understand the basic differences between these types of changes; also be able to identify examples as being physical, chemical, or nuclear changes.

1. Physical Changes

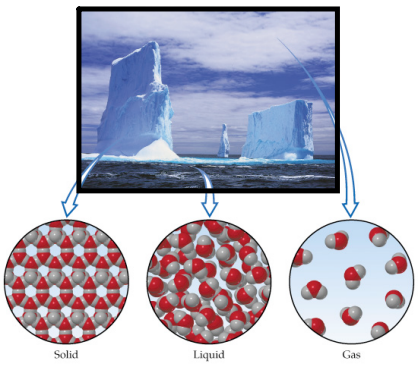
= changes where the identity of the substance is not changed

Examples:



All **phase changes** are **physical changes**!

Solid ⟷ Liquid ⟷ Gas



The molecules are the same regardless of whether they exist as a solid, liquid, or gas. They just move further apart as they go from solid to liquid, and liquid to gas.

gaseous H_2O ⟶ liquid H_2O

condensation of water

(this is just gaseous water in the air condensing into liquid water because of touching a cool surface)

liquid H_2O ⟶ solid H_2O

water freezing into icicles

solid H_2O ⟶ liquid H_2O

melting ice cubes

liquid H_2O ⟶ gaseous H_2O

boiling water

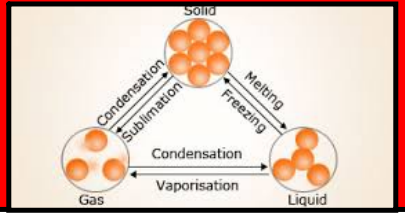
Here's another interesting phase change: the sublimation of dry ice...

solid CO_2 ⟶ gaseous CO_2

Solid carbon dioxide, CO_2 sublimates directly into gaseous carbon dioxide!

"dry ice" is frozen CO_2 (carbon dioxide). It is at **-78.5°C**

Terms for phase changes:



Cellular Respiration

$$C_6H_{12}O_6 + O_2 \xrightarrow{ATP} CO_2 + H_2O$$

gas we exhale

CO_2

H_2O → in urine

exhale: $H_2O(gas) \xrightarrow{cold\ window} H_2O(l)$ condensation

2. Chemical Changes = changes where new substances (new molecules) are produced.

Examples:

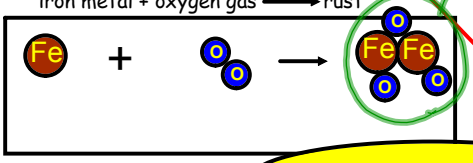
Formation of rusts (metal oxides):

Iron oxide →

Reactants Products

$Fe + O_2 \longrightarrow Fe_2O_3$

iron metal + oxygen gas → rust

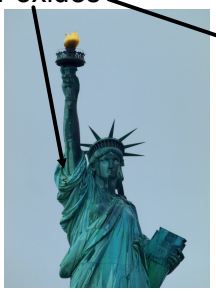


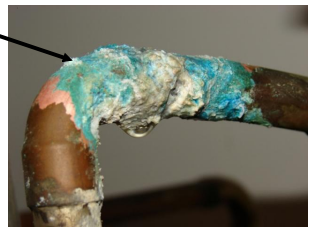
Fe_2O_3

brown rust

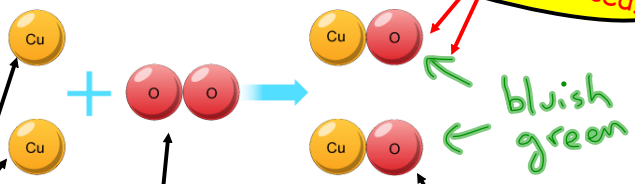
new molecules produced!

Copper oxides →





new molecules produced!



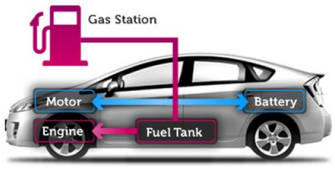
blush green

Cu atoms react with O_2 molecules to produce CuO molecules

Burning (always involves oxygen gas reacting with something):

Synonyms:
Combustion = Burning

Burning gasoline:



new molecules produced!

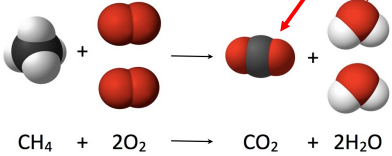
What the engine needs — Products of combustion

$C_8H_{18} + 12\,O_2 \Rightarrow 8\,CO_2 + 9\,H_2O$

Isooctane Oxygen Carbon dioxide Water

Burning methane:

new molecules produced!



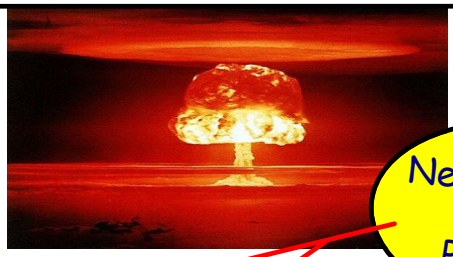
$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

3. Nuclear Changes

= changes where new ELEMENTS (on periodic table) are produced.

Fission:

e.g.s:



New Elements Produced

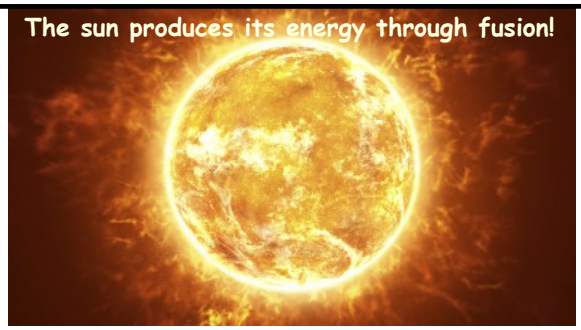
$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{140}_{56}Ba + ^{93}_{36}Kr + 3\ ^{1}_{0}n$$

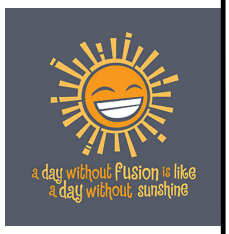
&

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{144}_{54}Xe + ^{90}_{38}Sr + 2\ ^{1}_{0}n$$

Fusion:

e.g.:





the Sun fuses 620 million metric tons of hydrogen each second

Deuterium + Deuterium ⟶ Helium + energy

$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He$ + energy

New Element Produced

Alpha decay

α-decay

e.g.

$$^{222}_{88}Ra \longrightarrow ^{4}_{2}He + ^{218}_{86}Rn$$

Reactant isotope

α-particle

Product isotope

Beta decay

β-decay

e.g.

$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$$

Reactant

Product isotope

β particle

Classify each of the changes below as being physical (P), chemical (C), or nuclear (N):

C 1. Baking soda and vinegar react and bubbling results:

$$NaHCO_3 + HC_2H_3O_2 \longrightarrow NaC_2H_3O_2 + H_2O + CO_2$$

P 2. A magnet is used to pick up iron filings.

C 3. During photosynthesis a green plant uses carbon dioxide and water to produce glucose (a simple sugar).

$$CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$$

N 4. Carbon-14 isotopes are unstable and decay into Nitrogen-14.

P 5. Salt is dissolved in water.

C 6. A peeled apple turns brown. (oxidation)

C 7. An egg white (albumin) turns from clear to white as it cooks.

P 8. Bronze (alloy) is made by melting Copper and Tin, mixing them together, and then letting the mixture re-solidify.

C 9. Wood is burned: $C + O_2 \longrightarrow CO_2$

N 10. Heat is released when Uranium-238 changes into Thorium-234.

P 11. Napthalene, $C_{10}H_8$, is the main ingredient of mothballs. Napthalene is a solid that sublimates to release the aromatic gas characteristic of mothballs.

C 12. A silver ring tarnishes over time. $Ag + O_2 \rightarrow Ag_2O$ (oxidation)

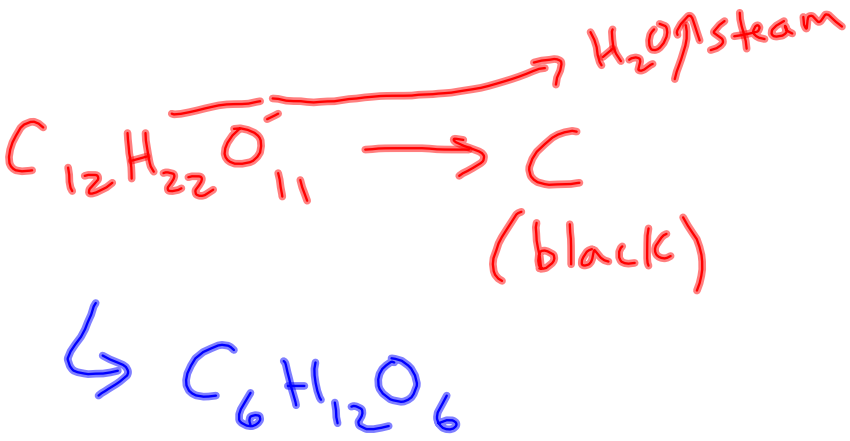
P 13. The inside of your car windows fog-up on a rainy day.

C 14. Protein is digested by enzymes in the stomach.

N 15. Insects are sterilized using gamma rays, which are a biproduct as Cobalt-60 decays to Nickel-60.

For each item below, describe two changes that could be made to the item that would constitute physical changes, and two changes that would constitute chemical changes.

	2 physical changes	2 chemical changes
an apple	Slicing chopping bite, chew	-Make pie - " apple sauce - browning
a block of wax	-melt it -cut - make candle - add color or fragrance	1. Burn
a glass of milk	-heat - drink -Add Nesquik	- digesting - cooking - add vinegar - make cheese or yoghurt - Going bad
a cup of sugar	- dissolve into ____. - Powder it or make into cubes	-cooking (caramelizes) - digesting
a piece of paper	- cut - fold - make airplane -shred - wet/chew.	- burn - yellows (oxidizes)
A block of silver	- make jewelry - melt - make alloy	-rust $Ag + CuSO_4 \rightarrow Ag_2SO_4 + Cu$


H_2O ↑ steam
$C_{12}H_{22}O_{11}$
C
(black)
$C_6H_{12}O_6$

Writing Equations for Alpha- and Beta- Decay Reactions

Alpha Decay (α-decay)

e.g. $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$

reactant isotope; product isotope

Law of conservation of mass hold true since 234 + 4 = 238. Total mass reactants = total mass reactants!

He nucleus

Rules:

1. $^{4}_{2}He$ an α-particle) is always produced
2. total mass on reactant side = total mass on product side
3. atomic number total reactant side = atomic number total product side

Fill in the blanks:

Alpha- and beta-decay are also called transmutations. For example, U-238 "transmutes" into Th-234, and Pb-214 "transmutes" into Bi-214.

1. $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$
2. $^{230}_{90}Th \rightarrow {}^{226}_{88}Ra + {}^{4}_{2}He$

mass number

3. Write the equation for the α-decay of Po-210.

$^{210}_{84}Po \rightarrow {}^{4}_{2}He + {}^{206}_{82}Pb$ $\quad 7 = 4 + 3$

4. Write the equation for the α-decay of Rn-222.

$^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}Po$ $\quad 7 = 3 + 4$

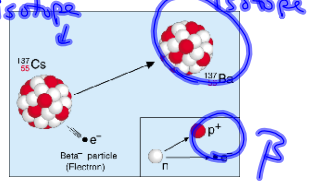
Beta Decay (β-decay)

e.g. $^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}\bar{e}$

Rules:

1. $^{0}\bar{e}$ (a β-particle) is always produced
2. mass reactant isotope = mass product isotope (since mass $\bar{e}$ = 0)
3. atomic number of product isotope is 1 more than that of reactant isotope

reactant isotope; product isotope



According to the law of conservation of mass, the mass of the product isotope must equal the mass of the reactant isotope (for beta decay). This is because, within the nucleus of the reactant isotope, a neutron converts into a proton and an electron. The electron (with negligible mass) is all that's lost. The proton has the same mass as the neutron, so the mass is unchanged.

Fill in the blanks:

1. $^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}\bar{e}$
2. $^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}\bar{e}$

3. Write the equation for the β-decay of Pa-234.

$^{234}_{91}Pa \rightarrow {}^{0}\bar{e} + {}^{234}_{92}U$

4. Write the equation for the β-decay of Ac-227.

$^{227}_{89}Ac \rightarrow {}^{227}_{90}Th + {}^{0}\bar{e}$

1. Write the equation for the α-decay of:

a) Po-214 $^{214}_{84}Po \rightarrow {}^{4}_{2}He + {}^{210}_{82}Pb$

b) U-234 $^{234}_{92}U \rightarrow {}^{230}_{90}Th + {}^{4}_{2}He$

c) Th-228 $^{228}_{90}Th \rightarrow {}^{4}_{2}He + {}^{224}_{88}Ra$

d) Bi-212 $^{212}_{83}Bi \rightarrow {}^{208}_{81}Tl + {}^{4}_{2}He$

e) Rn-220 $^{220}_{86}Rn \rightarrow {}^{216}_{84}Po + {}^{4}_{2}He$

2. Write the equation for the β-decay of:

a) Ra-228 $^{228}_{88}Ra \rightarrow {}^{228}_{89}Ac + {}^{0}_{-1}e$

b) Tl-208 $^{208}_{81}Tl \rightarrow {}^{208}_{82}Pb + {}^{0}_{-1}e$

c) Fr-223 $^{223}_{87}Fr \rightarrow {}^{223}_{88}Ra + {}^{0}_{-1}e$

d) Bi-214 $^{214}_{83}Bi \rightarrow {}^{214}_{84}Po + {}^{0}_{-1}e$

e) Pb-212 $^{212}_{82}Pb \rightarrow {}^{212}_{83}Bi + {}^{0}_{-1}e$

3. Fill in the spaces in the following equations:

a. $^{210}_{84}Po \longrightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$

b. $^{90}_{38}Sr \longrightarrow {}^{90}_{39}Y + {}^{0}_{-1}e$

c. $^{222}_{88}Ra \longrightarrow {}^{4}_{2}He + {}^{218}_{86}Rn$

d. $^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

e. $^{131}_{53}I \longrightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$

f. $^{6}_{2}He \longrightarrow {}^{6}_{3}Li + {}^{0}_{-1}e$

g. $^{228}_{90}Th \longrightarrow {}^{224}_{88}Ra + {}^{4}_{2}He$

4. a) For alpha-decay: Explain, according to the law of conservation of mass, why the mass number of the product isotope is 4 less than the mass number of the reactant isotope.

total mass reactants = total mass products

b) For beta-decay: Explain, according to the law of conservation of mass, why the mass number of the product isotope is equal to the mass number of the reactant isotope.