10.6: Nuclear and Chemical Reactions (Exercises)

These are homework exercises to accompany Chapter 10 of the University of Kentucky's LibreText for CHE 103 - Chemistry for Allied Health. Answers are below the questions.

Questions

10.1: Nuclear Radiation

(click here for solutions)

Q10.1.1

Write the symbol for the isotope described.

a. 12 protons, 12 electrons, 13 neutrons
b. 17 protons, 17 electrons, 20 neutrons
c. 53 protons, 53 electrons, 78 neutrons
d. 92 protons, 92 electrons, 146 neutrons

Q10.1.2

Determine the number of protons, neutrons, and electrons in each isotope.

a. $^{195}_{77}\text{Ir}$
b. $^{209}_{82}\text{Pb}$
c. $^{211}_{84}\text{Po}$
d. $^{237}_{93}\text{Np}$

Q10.1.3

Fill in the missing numbers in each equation.

a. $^{196}_{82}\text{Pb} + {}^{0}_{-1}\text{e} \rightarrow {}^{\_\_}_{\_\_}\text{Tl}$
b. $^{28}_{15}\text{P} \rightarrow {}^{\_\_}_{\_\_}\text{Si} + {}^{0}_{1}\text{e}$
c. $^{226}_{88}\text{Ra} \rightarrow {}^{\_\_}_{\_\_}\text{Rn} + {}^{4}_{2}\alpha$
d. $^{73}_{30}\text{Zn} \rightarrow {}^{\_\_}_{\_\_}\text{Ga} + {}^{0}_{-1}\text{e}$

Q10.1.4

Fill in the blanks for each of the nuclear reactions below. State the type of decay in each case.

a. $^{198}_{79}\text{Au} \rightarrow$ _____ $+ {}^{0}_{-1}\text{e}$
b. $ce^{57}_{27}Co + {}^{0}_{-1}\text{e} \rightarrow$ _____
c. $^{230}_{92}\text{U} \rightarrow$ _____ $+ {}^{4}_{2}\text{He}$
d. $^{128}_{56}\text{Ba} \rightarrow$ _____ $+ {}^{0}_{1}\text{e}$
e. $^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} +$ _____
f. $^{239}_{94}\text{Pu} \rightarrow {}^{235}_{92}\text{U} +$ _____

Q10.1.5

Write balanced nuclear reactions for each of the following.

a. Francium-220 undergoes alpha decay.
b. Arsenic-76 undergoes beta decay.
c. Uranium-231 captures an electron.
d. Promethium-143 emits a positron.

10.2: Fission and Fusion

(click here for solutions)

Q10.2.1

Describe the main difference between fission and fusion.

Q10.2.2

What is the difference between the fission reactions used in nuclear power plants and nuclear weapons?

Q10.2.3

How do the doses of radioisotopes used in diagnostic procedures and therapeutic treatment compare to one another?

10.3: Half-Life

(click here for solutions)

Q10.3.1

What percent of a sample remains after one half-life? Three half-lives?

Q10.3.2

The half-life of polonium-218 is 3.0 min. How much of a 0.540 mg sample would remain after 9.0 minutes have passed?

Q10.3.3

The half-life of hydrogen-3, commonly known as tritium, is 12.26 years. If 4.48 mg of tritium has decayed to 0.280 mg, how much time has passed?

Q10.3.4

The half-life of protactinium-234 is 6.69 hours. If a 0.812 mg sample of Pa-239 decays for 40.14 hours, what mass of the isotope remains?

Q10.3.5

2.86 g of a certain radioisotope decays to 0.358 g over a period of 22.8 minutes. What is the half-life of the radioisotope?

Q10.3.6

Use Table 10.3.2 above to determine the time it takes for 100. mg of carbon-14 to decay to 6.25 mg.

Q10.3.7

A radioisotope decays from 55.9 g to 6.99 g over a period of 72.5 hours. What is the half-life of the isotope?

Q10.3.8

A sample of a radioisotope with a half-life of 9.0 hours has an activity of 25.4 mCi after 36 hours. What was the original activity of the sample?

Q10.3.9

What volume of a radioisotope should be given if a patient needs 125 mCi of a solution which contains 45 mCi in 5.0 mL?

Q10.3.10

Sodium-24 is used to treat leukemia. A 36-kg patient is prescribed 145 μCi/kg and it is supplied to the hospital in a vial containing 250 μCi/mL. What volume should be given to the patient?

Q10.3.11

Using information from the previous question and knowing the half-life of Na-24 is 15 hours, calculate the total dose in μCi given to the patient. How long will it take for the radioactivity to be approximately 80 μCi?

Q10.3.12

Lead-212 is one of the radioisotopes used in the treatment of breast cancer. A patient needs a 15 μCi dose and it is supplied as a solution with a concentration of 2.5 μCi/mL. What volume does the patient need? Given the half-life of lead is 10.6 hours, what will be the radioactivity of the sample after approximately four days?

10.4: Physical and Chemical Changes

(click here for solutions)

Q10.4.1

Identify each of the following as a physical or chemical change.

a. melting ice
b. boiling water
c. cooking eggs
d. dissolving salt in water
e. burning match
f. metal reacting with HCl
g. mixing NaCl and KCl
h. decomposition of hydrogen peroxide

Q10.4.2

Give two signs that indicate a chemical change is occurring.

Q10.4.3

What doesn't change when a substance undergoes a physical change?

10.5: Chemical Equations

(click here for solutions)

Q10.5.1

Identify the reactants and products in each chemical reaction.

a. In photosynthesis, carbon dioxide and water react to form glucose and oxygen.
b. Magnesium oxide forms when magnesium is exposed to oxygen gas.

Q10.5.2

Write grammatically correct sentences that completely describe the chemical reactions shown in each equation. You may need to look up the names of elements or compounds.

a. $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$
b. $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$
c. $2Cs(s) + 2H_2O(l) \rightarrow 2CsOH(aq) + H_2(g)$

Q10.5.3

How many atoms of each element are represented by the following combinations of coefficients and chemical formulas?

a. $5Br_2$
b. $2NH_3$
c. $4(NH_4)_2SO_4$
d. $2CH_3COOH$
e. $3Fe(NO_3)_3$
f. $2K_3PO_4$

Q10.5.4

Balance the following equations.

a. $Zn(s) + HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
b. $Li(s) + N_2(g) \rightarrow Li_3N(s)$
c. $Ca(OH)_2 + HBr \rightarrow CaBr_2 + H_2O$
d. $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$
e. $NH_3 + CuO \rightarrow Cu + N_2 + H_2O$

Q10.5.5

Balance the following equations.

a. $Fe(s) + Cl_2(g) \rightarrow FeCl_3(g)$
b. $C_4H_{10}O + O_2 \rightarrow CO_2 + H_2O$
c. $As + NaOH \rightarrow Na_3AsO_3 + H_2$
d. $SiO_2 + HF \rightarrow SiF_4 + H_2O$
e. $N_2 + O_2 + H_2O \rightarrow HNO_3$

Answers

10.1: Nuclear Radiation

Q10.1.1

Write the symbol for the isotope described.

a. $^{25}_{12}Mg$
b. $^{37}_{17}Cl$
c. $^{131}_{53}I$
d. $^{238}_{92}U$

Q10.1.2

a. 77 protons, 77 electrons, 118 neutrons
b. 82 protons, 82 electrons, 127 neutrons
c. 84 protons, 84 electrons, 127 neutrons
d. 93 protons, 93 electrons, 144 neutrons

Q10.1.3

a. $^{196}_{82}Pb + {}^{0}_{-1}e \rightarrow {}^{196}_{81}Tl$
b. $^{28}_{15}P \rightarrow {}^{28}_{14}Si + {}^{0}_{1}e$
c. $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$
d. $^{73}_{30}Zn \rightarrow {}^{73}_{31}Ga + {}^{0}_{-1}e$

Q10.1.4

a. $^{198}_{79}Au \rightarrow {}^{198}_{80}Hg + {}^{0}_{-1}e$, beta
b. $^{57}_{27}Co + {}^{0}_{-1}e \rightarrow {}^{57}_{26}Fe$, electron capture
c. $^{230}_{92}U \rightarrow {}^{226}_{90}Th + {}^{4}_{2}He$, alpha
d. $^{128}_{56}Ba \rightarrow {}^{128}_{55}Cs + {}^{0}_{1}e$, positron
e. $^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$, beta
f. $^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}\alpha$ (or can show as ${}^{4}_{2}He$), alpha

Q10.1.5

a. $^{220}_{87}Fr \rightarrow {}^{4}_{2}He + {}^{216}_{85}At$
b. $^{76}_{33}As \rightarrow {}^{0}_{-1}e + {}^{76}_{34}Se$
c. $^{231}_{92}U + {}^{0}_{-1}e \rightarrow {}^{231}_{91}Pa$
d. $^{143}_{61}Pm \rightarrow {}^{0}_{1}e + {}^{143}_{60}Nd$

10.2: Fission and Fusion

Q10.2.1

During fission, big nuclei split into smaller nuclei. During fusion, nuclei combine to form large nuclei.

Q10.2.2

Fission in nuclear power plants is controlled through limiting the availability of neutrons. Nuclear weapons are uncontrolled once the process initiates.

Q10.2.3

Diagnostic amounts are much smaller than therapeutic amounts.

10.3: Half-Life

Q10.3.1

1 half-life: 50%

3 half-lives: 12.5%

Q10.3.2

Time	Half-lives	Amount			
0 minutes		0.540 mg			
3 minutes	1	0.270 mg			
6 minutes	2	0.135 mg			
9 minutes	3	0.0675 mg			

Q10.3.3

Amount	Half-lives	Time			
4.48 mg		0 years			
2.24 mg	1	12.26 years			
1.12 mg	2	24.52 years			
0.560 mg	3	36.78 years			
0.280 mg	4	49.04 years			

Q10.3.4

Time	Half-lives	Amount			
0 hours		0.812 mg			
6.69 hours	1	0.406 mg			
13.38 hours	2	0.203 mg			
20.07 hours	3	0.102 mg			
26.76 hours	4	0.0508 mg			
33.45 hours	5	0.0254 mg			
40.14 hours	6	0.0127 mg			

Q10.3.5

Amount	Half-lives				
2.86 g					
1.43 g	1				
0.715 g	2				
0.358 g	3				

It takes three half-lives to go from 2.86 g to 0.358 g in a total time of 22.8 minutes.

$22.8\ min\ \div\ 3\ = 7.60\ min$

One half-life is 7.60 minutes.

Q10.3.6

Amount	Half-lives	Time			
100. mg		0 years			
50.0 mg	1	5730 years			
25.0 mg	2	11460 years			
12.5 mg	3	17190 years			
6.25 mg	4	22920 years			

Q10.3.7

Amount	Half-lives				
55.9 g					
28.0 g	1				
14.0 g	2				
6.99 g	3				

It takes three half-lives to go from 55.9 g to 6.99 g in a total time of 72.5 hours.

$72.5\ hr\ \div\ 3\ = 24.2\ hr$

One half-life is 24.2 hours.

Q10.3.8

Fill in the time and half-lives from top to bottom. Start at the bottom of the amount column to fill it in because we know where we end up but not where we started.

Time	Half-lives	Activity			
0 hours		406 mCi			
9.0 hours	1	203 mCi			
18 hours	2	102 mCi			
27 hours	3	50.8 mCi			
36 hours	4	25.4 mCi	← **START HERE**		

Q10.3.9

$125\ mCi \left(\frac{5.0\ mL}{45\ mCi}\right) = 14\ mL$

Q10.3.10

Sodium-24 is used to treat leukemia. A 36-kg patient is prescribed 145 μCi/kg and it is supplied to the hospital in a vial containing 250 μCi/mL. What volume should be given to the patient?

$36\ kg \left(\frac{145\ \mu Ci}{kg}\right) \left(\frac{1\ mL}{250\ \mu Ci}\right) = 21\ mL$

Q10.3.11

$21\ mL\left(\frac{250\ \mu Ci}{mL}\right) = 5250\ \mu Ci$ is the total dose received

Amount	Half-lives	Time			
5250 µCi		0 hours			
2625 µCi	1	15 hours			
1313 µCi	2	30 hours			
656 µCi	3	45 hours			
328 µCi	4	60 hours			
164 µCi	5	75 hours			
82 µCi	6	90 hours			

Q10.3.12

Lead-212 is one of the radioisotopes used in the treatment of breast cancer. A patient needs a 15 µCi dose and it is supplied as a solution with a concentration of 2.5 µCi/mL. What volume does the patient need? Given the half-life of lead is 10.6 hours, what will be the radioactivity of the sample after approximately four days?

Volume given: $15\ \mu Ci\left(\frac{1\ mL}{2.5\ \mu Ci}\right) = 6.0\ mL$

Elapsed time in hours: $4\ days\left(\frac{24\ hr}{day}\right) = 96\ hr$

Time	Half-lives	Activity			
0 hours		15 µCi			
10.6 hours	1	7.5 µCi			
21.2 hours	2	3.8 µCi			
31.8 hours	3	1.9 µCi			
42.4 hours	4	0.94 µCi			
53.0 hours	5	0.47 µCi			
63.6. hours	6	0.23 µCi			
74.2 hours	7	0.12 µCi			
84.8 hours	8	0.059 µCi			
95.6 hours	9	0.029 µCi			

10.4: Physical and Chemical Changes

Q10.4.1

a. physical
b. physical
c. chemical
d. physical
e. chemical
f. chemical
g. physical
h. chemical

Q10.4.2

Any two from change in color, formation of gas (i.e. bubbles), formation of precipitate, odor, change in temperature.

Q10.4.3

chemical composition (i.e. chemical formula is the same)

10.5: Chemical Equations

Q10.5.1

a. reactants: carbon dioxide and water; products: glucose and oxygen
b. reactants: magnesium and oxygen; product: magnesium oxide

Q10.5.2

Descriptions may vary.

a. Two moles of liquid hydrogen peroxide decomposes to form two moles of liquid water and one mole of gaseous hydrogen.
b. One mole of solid copper(II) carbonate decomposes to form one mole each of solid copper(II) oxide and gaseous carbon dioxide.
c. Two moles of solid cesium react with 2 moles of liquid water to form 2 moles of aqueous cesium hydroxide and 1 mole of gaseous hydrogen.

Q10.5.3

a. 10 Br
b. 2 N, 6 H
c. 8 N, 32 H, 4 S, 16 O
d. 4 C, 8 H, 4 O
e. 3 Fe, 9 N, 27 O
f. 6 K, 2 P, 8 O

Q10.5.4

a. $Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
b. $6\ Li(s) + N_2(g) \rightarrow 2\ Li_3N(s)$
c. $Ca(OH)_2 + 2\ HBr \rightarrow CaBr_2 + 2\ H_2O$
d. $2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$
e. $2\ NH_3 + 3\ CuO \rightarrow 3\ Cu + N_2 + 3\ H_2O$

Q10.5.5

a. $2\ Fe(s) + 3\ Cl_2(g) \rightarrow 2\ FeCl_3(g)$
b. $C_4H_{10}O + 6\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$
c. $2\ As + 6\ NaOH \rightarrow 2\ Na_3AsO_3 + 3\ H_2$
d. $SiO_2 + 4\ HF \rightarrow SiF_4 + 2\ H_2O$
e. $2\ N_2 + 5\ O_2 + 2\ H_2O \rightarrow 4\ HNO_3$
