RLP-CHEMB · RLP Chemistry B — Energy, Equilibrium, Earth Systems and Nuclear Chemistry

Unit 4: Nuclear Chemistry, Carbon Materials and Engineering Design

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 4.1 — Two Missouri Reactors: Decay, Half-Life and Binding Energy

FLUENCY

1. A sample starts with 200 g of an isotope whose half-life is 1600 years. How much remains after 6,400.0 years?

2. A wood sample has 25% of the carbon-14 of living wood. Using a half-life of 5,730 years, estimate its age.

3. Thorium-230 (Z = 90) undergoes alpha decay. Write the daughter nuclide.

4. Strontium-90 (Z = 38) undergoes beta decay. Write the daughter nuclide.

5. Iodine-131 has a half-life of 8.02 days. How much of a 160.0 mg sample remains after 32.08 days?

6. What fraction of an iodine-131 sample remains after 16.04 days (half-life 8.02 days)?

APPLICATION

7. Start with 100.0 mg of iodine-131 (half-life 8.02 days). How much remains after 30.0 days?

8. How many days does it take for iodine-131 to fall to 1.00% of its original amount?

9. Tritium has a half-life of 12.3 years. How much of a 5.00 mg sample remains after 50.0 years?

10. Find the binding energy and the binding energy per nucleon of carbon-12 (6 H-1 atoms 1.00782503 u each, 6 neutrons 1.00866492 u each, C-12 = 12.000000 u; 1 u = 931.494 MeV).

CHALLENGE

11. The fusion reaction H-2 + H-3 → He-4 + n releases 17.59 MeV per reaction. Calculate the energy per mole of reactions in kJ (1 MeV = 1.602×10^{-13} J) and compare it to 890.57 kJ/mol for burning methane.

12. Uranium-235 has 7.591 MeV binding energy per nucleon; fission fragments average about 8.5 MeV per nucleon. Estimate the energy released by one fission of a U-235 nucleus.

13. Explain why iron-56 is the end point of energy release for both fission and fusion.

REVIEW

14. How many moles are in 36.0 g of CH_4?

15. A gas occupies 4.5 L at 100 kPa. At constant temperature, what volume does it occupy at 250 kPa?

16. How much heat is needed to warm 250.0 g of water from 20.0 °C to 45.0 °C? (c = 4.184 J/(g °C))

17. Use NIST enthalpies of formation (CH_4 −74.6, CO_2 −393.51, H_2O(l) −285.83 kJ/mol) to find ΔH for $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O(l)$.

Lesson 4.2 — Modeling Decay: Half-Life Lab and the St. Louis Record

FLUENCY

1. An isotope has a half-life of 4 days. How long until only 1/8 of the original sample remains?

2. A wood sample has 12.5% of the carbon-14 of living wood. Using a half-life of 5,730 years, estimate its age.

3. In the coin model, you start with 100 coins and remove the ones that land heads each round. How many are expected to remain after 5 rounds?

4. In the dice model (a die showing 1 is removed), what is the half-life in rounds?

5. Radon-222 has a half-life of 3.8 days. Find its decay constant λ.

6. What fraction of thorium-230 (half-life 77,000 years) remains after 154,000 years?

APPLICATION

7. A sample contains 8.00 g of radium-226 (half-life 1,600 years). How much remains after 4,800 years?

8. What fraction of a thorium-230 sample is left after 1,600 years? What percent has decayed?

9. In run B of the lab reading, 60 dice fell to 5 dice after 12 rounds. Using only these two numbers, estimate the half-life in rounds.

10. MDNR reports the Army Corps has removed more than 1.27 million cubic yards of material from St. Louis FUSRAP sites. Convert to cubic meters ($1\ \text{yd}^3 = 0.7646\ \text{m}^3$).

CHALLENGE

11. A sample has 1.00×10^6 atoms of radon-222 ($\lambda = 0.182$ per day). How many atoms decay in the first day, approximately, and how many per second?

12. How many days until 99% of a radon-222 sample (half-life 3.8 days) has decayed?

13. Explain, in three sentences using half-lives, why EPA and MDNR documents say radium-226 levels at West Lake were expected to increase in the future even though the waste does not change.

REVIEW

14. How many moles are in 180.0 g of $C_6H_{12}O_6$?

15. A gas at 101.3 kPa and 25 °C occupies 5.0 L. What volume does it occupy at 150.0 kPa and 37 °C?

16. For 2 Mg + O_2 → 2 MgO, what mass of MgO forms from 12.15 g Mg? (Mg 24.305, MgO 40.304 g/mol)

17. What is the pH of 0.0010 M HCl, a strong acid?

Lesson 4.3 — Carbon Chains: Ethanol Fuel, Polymers and Plastic Waste

FLUENCY

1. Find the molar mass of ethanol, C_2H_5OH (C_2H_6O).

2. An alkane has 12 carbon atoms. What is its formula?

3. How many moles of ethene (C_2H_4, 28.054 g/mol) are in 14.0 kg of polyethylene?

4. In the fermentation of glucose, how many moles of ethanol form from 1.00 mol of glucose?

APPLICATION

5. What is the theoretical mass of ethanol from 1.00 kg of glucose? (glucose 180.156 g/mol)

6. Ethanol releases 29.71 kJ per gram. How much energy is released by burning 1.00 kg?

7. What mass of CO_2 forms when 1.00 kg of ethanol burns completely ($C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$)?

8. EIA lists gasoline as 120,214 Btu/gal. If ethanol has 30% less energy per gallon, what is the energy of E10 (10% ethanol, 90% gasoline by volume) in Btu per gallon, and the percent below gasoline?

CHALLENGE

9. A polyethylene molecule contains 2,000 ethene units. Find its molar mass.

10. PET forms from terephthalic acid (166.13 g/mol) and ethylene glycol (62.07 g/mol), releasing 2 H_2O per repeat unit ($C_{10}H_8O_4$). Find the repeat-unit mass and the mass of water released per 1.000 kg of PET.

11. EPA reports 2018 U.S. plastics: generation 35,680, recycled 3,090 and landfilled 26,970 thousand tons. Calculate the percent recycled and percent landfilled.

REVIEW

12. How many moles are in 36.0 g of CO_2?

13. A gas occupies 12 L at 200 kPa. At constant temperature, what volume does it occupy at 300 kPa?

14. Use NIST enthalpies of formation (CH_4 −74.6, CO_2 −393.51, H_2O(l) −285.83 kJ/mol) to find ΔH for $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$(l).

15. What volume does 1.00 mol of an ideal gas occupy at 298 K and 1.00 atm? (R = 0.08206 L atm/(mol K))

Lesson 4.4 — Lead for Batteries: Mining, Recycling and a Decision Model

FLUENCY

1. What percent of galena (PbS) is lead by mass?

2. What percent of sphalerite (ZnS) is zinc by mass?

3. USGS reports 1,000 thousand tons of secondary lead is 70% of apparent consumption. Estimate consumption.

4. A decision matrix has weights [0.4, 0.3, 0.2, 0.1] and an option's scores [4, 4, 4, 3]. Find its weighted total.

APPLICATION

5. How many tonnes of SO_2 form per tonne of lead when PbS is roasted ($2\ PbS + 3\ O_2 \rightarrow 2\ PbO + 2\ SO_2$), assuming all lead and sulfur are from PbS?

6. A concentrate is 70.0% PbS by mass. How many tonnes of lead are in 500.0 tonnes of concentrate?

7. In the lead-supply model (consumption growing 3% a year from 1,428.6 thousand tons, recycling fixed at 70%), how much primary lead is needed in year 5?

8. Compare the ten-year total primary lead needed with recycling fixed at 70% and with recycling rising 2 points a year to 88%. How large is the difference?

CHALLENGE

9. Options A, B and C have scores [3, 2, 3, 5], [4, 4, 4, 3] and [1, 3, 4, 1] on four criteria. With weights [0.4, 0.3, 0.2, 0.1] B wins. With weights [0.2, 0.2, 0.2, 0.4], find all three totals and say what the result shows.

10. A lead-acid battery plate reaction oxidizes lead: $Pb \rightarrow Pb^{2+} + 2e^{-}$. How many hours can 1.00 kg of lead supply a steady 10.0 A? (F = 96,485 C/mol)

11. In two or three sentences, explain one trade-off between mining more lead and raising recycling, using one number from the USGS data.

REVIEW

12. How many moles are in 4.5 g of Fe_2O_3?

13. A balloon holds 1.5 L at 0 °C. At constant pressure, what is its volume at 80 °C?

14. What is the pH of 0.0050 M NaOH?

15. How much heat is needed to warm 250.0 g of water from 20.0 °C to 45.0 °C? (c = 4.184 J/(g °C))

Unit 4 checkpoint

1. The beta decay of cesium-137 (atomic number 55) makes a daughter with atomic number
   A. 54
   B. 55
   C. 56
   D. 57
2. After 3 half-lives, the fraction of a radioisotope remaining is
   A. 1/3
   B. 1/6
   C. 1/8
   D. 1/9
3. Fusion releases more energy per nucleon than fission mainly because
   A. light nuclei are lower in mass number
   B. the binding energy per nucleon rises steeply for the lightest nuclei
   C. fusion needs no neutrons
   D. fusion produces gamma rays only
4. The mass defect of helium-4 is 0.03038 u. Using 1 u = 931.494 MeV, its binding energy is _____ MeV.
5. True or false: Radium-226 can build up in waste that contains thorium-230 even if nothing is added.
6. The ethanol energy per gram (29.71 kJ/g) compared with octane (47.89 kJ/g) is
   A. higher
   B. lower
   C. equal
   D. cannot be calculated
7. True or false: Condensation polymerization releases a small molecule such as water.
8. An alkane with 8 carbon atoms has _____ hydrogen atoms.
9. In a weighted decision matrix, the weights should
   A. each equal 1
   B. sum to 1.00
   C. be chosen after seeing which option wins
   D. all be different
10. With weights 0.4, 0.3, 0.2, 0.1 and scores 4, 4, 4, 3, the weighted total is _____.
11. True or false: A computer model's results depend on its stated assumptions, so a sensitivity check is part of good modeling.

12. USGS says secondary lead is about 70 percent of U.S. apparent lead consumption. This mostly comes from
    A. new mines
    B. recycled lead-acid batteries
    C. imports of ore
    D. the Strategic stockpile
13. Burning methane to deliver 73,000 MWh of electricity at 50 percent efficiency releases about
    A. 2,600 t of CO₂
    B. 26,000 t of CO₂
    C. 260,000 t of CO₂
    D. no CO₂

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