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

Unit 1: Thermochemistry and Energy Transfer

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

Name _____ Period _____

Lesson 1.1 — Where the Energy Comes From: Bonds, Burning and Missouri's Power

FLUENCY

1. Burning ethanol has $\Delta H = -1{,}367$ kJ per mole. Is the reaction exothermic or endothermic, and does the system gain or lose energy?

2. Using H–H = 436.0 and O=O = 498.4 kJ/mol, how much energy is needed to break the bonds in 1 mol of H_2 and ½ mol of O_2?

3. Burning methane releases 802.6 kJ per mole by the bond model. How much energy is released by 0.250 mol?

4. On an energy diagram, are the products drawn higher or lower than the reactants for an endothermic reaction? What does the vertical gap show?

APPLICATION

5. Estimate ΔH for $2H_2 + O_2 \rightarrow 2H_2O(g)$ using the bond energies in this lesson's reading. The NIST formation enthalpy of water vapor gives $2 \times (-241.826) = -483.652$ kJ. How close are they?

6. The bond model gives −2,054.6 kJ/mol for propane (gas water) while NIST formation data give −2,043.13 kJ/mol. Calculate the percent error of the bond model.

7. Use the bond-model result for propane (−2,054.6 kJ/mol) and its molar mass (44.0956 g/mol) to find the energy released per gram.

8. How much energy is released by burning 1.00 kg of methane (bond model, −802.6 kJ/mol, molar mass 16.0425 g/mol)?

CHALLENGE

9. A mixture of hydrogen and oxygen releases a lot of energy overall, yet it needs a spark to start. Using the idea that bonds must break before new bonds form, explain this, and sketch the energy diagram.

10. The bond model gives the methane reaction with gaseous water: −802.6 kJ. Vaporizing one mole of liquid water takes 44.0 kJ. Convert the result to the reaction that makes liquid water and say which value is closer to the measured NIST combustion enthalpy of about −890 kJ/mol.

REVIEW

11. How many moles of methane are in 25.0 g? (CH_4 = 16.0425 g/mol)

12. What mass of CO_2 forms when 10.0 g of CH_4 burns completely? (CO_2 = 44.0095 g/mol)

13. What volume does 1.00 mol of an ideal gas occupy at 1.00 atm (101,325 Pa) and 25.0 °C (298.15 K)? Use R = 8.314 J/(mol·K).

Lesson 1.2 — Calorimetry: Measuring Energy Transfer at Home

FLUENCY

1. How much energy warms 250.0 g of water from 20.0 °C to 44.0 °C? (c = 4.184 J/(g·°C))
2. A 50.0 g metal sample absorbs 450 J and warms by 20.0 °C. What is its specific heat?
3. Mix 150.0 g of water at 60.0 °C with 50.0 g of water at 20.0 °C in an ideal calorimeter. What is the final temperature?
4. NIST-JANAF lists iron's molar heat capacity as 25.094 J/(mol·K) and its molar mass is 55.845 g/mol. Calculate its specific heat in J/(g·°C).

APPLICATION

5. Part A: 80.0 g of water at 55.0 °C is added to 120.0 g of water at 20.0 °C in a calorimeter and the highest steady temperature is 33.6 °C. Find the calorimeter constant.

6. Part B, using your constant of 24.6 J/°C: 150.0 g of steel washers at 50.0 °C go into 100.0 g of water at 20.0 °C and the mixture reaches 24.0 °C. Find the washers' specific heat and its percent difference from 0.449.

7. Part C: 10.0 g of baking soda dissolves in 100.0 g of water, and the temperature falls from 21.0 °C to 17.2 °C. With C_{cal} = 36.2 J/°C, find the energy absorbed per gram of baking soda.

8. Using Run 1 in this lesson's reading, the hot water lost 5,774 J and the cool water gained 5,314 J. What percent of the lost heat went somewhere other than the cool water?

CHALLENGE

9. A student forgets the calorimeter constant in Run 1's Part B, using only $100.0 \times 4.184 \times 3.8$ for the energy gained. Calculate the specific heat they would report and how far off it is from the correct 0.454.

10. A 200.0 g iron block at 90.0 °C goes into 300.0 g of water at 20.0 °C in an ideal calorimeter (c_{Fe} = 0.449). Find the final temperature and the energy transferred, and state how the thermal energy is distributed at the end.

REVIEW

11. How many moles of iron are in 150.0 g of steel washers, treated as pure iron (55.845 g/mol)?

12. How many grams of water form when 2.00 g of H_2 (2.01588 g/mol) burns completely? $2H_2 + O_2 \rightarrow 2H_2O$ (H_2O = 18.0153 g/mol)

13. What volume does 0.250 mol of an ideal gas occupy at 1.00 atm (101,325 Pa) and 25.0 °C? (R = 8.314 J/(mol·K))

Lesson 1.3 — Hess's Law and Fuel Energy with NIST Data

FLUENCY

1. The NIST formation enthalpy of $H_2O(l)$ is −285.830 kJ/mol. What is ΔH for $H_2 + ½O_2 \rightarrow H_2O(l)$? For $2H_2O(l) \rightarrow 2H_2 + O_2$?

2. Why is $\Delta_f H°$ of $O_2(g)$ equal to zero?

3. Use $\Delta_f H°$ of CO_2 (−393.51) and CO (−110.53) kJ/mol to find ΔH for $CO + ½O_2 \rightarrow CO_2$.

4. Methane releases 890.57 kJ per mole (liquid water). With a molar mass of 16.0425 g/mol, what is the energy per gram?

APPLICATION

5. Calculate the combustion enthalpy of liquid ethanol, $C_2H_5OH(l) + 3O_2 \rightarrow 2CO_2 + 3H_2O(l)$, using $\Delta_f H^\circ = -276.0$ kJ/mol for ethanol (±2).

6. Find the energy per gram and per mole of CO_2 for octane, C_8H_{18} ($\Delta_c H = -5{,}470.55$ kJ/mol, 114.2285 g/mol).

7. Burning methane to give gaseous water releases 802.56 kJ/mol; to give liquid water, 890.57. Find the difference and explain it.

8. How many grams of CO_2 are produced per megajoule (1,000 kJ) of energy released by methane and by octane (liquid water)? (CO_2 = 44.0095 g/mol)

CHALLENGE

9. Burning carbon to CO releases −110.53 kJ per mole and burning it all the way to CO_2 releases −393.51 kJ. What percent of the full energy is released in the first step, and where is the rest?

10. Using $\Delta_f H°(NH_3) = -45.94$ kJ/mol, calculate ΔH for $N_2 + 3H_2 \rightarrow 2NH_3$ and classify it. Why can a table of formation enthalpies give this value although you never measured the reaction itself?

REVIEW

11. What mass of CO_2 forms from 100.0 g of propane? $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ (44.0956 and 44.0095 g/mol)

12. How many moles are in 46.07 g of ethanol (molar mass 46.0684 g/mol)?

13. What volume of CO_2 gas, at 25.0 °C and 101,325 Pa, forms from 1.00 mol of propane burned completely? (R = 8.314 J/(mol·K))

Lesson 1.4 — Energy Conversion Devices and Efficiency

FLUENCY

1. A U.S. coal plant has a 2024 average heat rate of 10,777 Btu/kWh. Calculate its efficiency (one kWh = 3,412 Btu).
2. Find the efficiency of a nuclear plant with a heat rate of 10,443 Btu/kWh and a petroleum plant at 11,200 Btu/kWh.
3. What percent of the fuel energy becomes waste heat in the coal plant above?
4. Name the main energy conversions in a coal plant, in order.

APPLICATION

5. Estimate the coal burned for Labadie's 14,401,714 MWh in 2024, using a heat rate of 10,777 Btu/kWh and Missouri coal at 8,884 Btu/lb. Give the answer in million short tons (2,000 lb).

6. Callaway (nuclear) generated 10,525,784 MWh in 2024. Using a heat rate of 10,443 Btu/kWh, how many Btu of waste heat did it release? (kWh = 3,412 Btu)

7. Suppose (illustrative) that 6.0 percent of the electricity from the coal plant is lost in the wires before it reaches a house. What fraction of the coal's energy reaches the house?

8. A pumped-storage plant (illustrative numbers) uses 100.0 MWh to pump water uphill and then generates 78.0 MWh when the water is released. Find its round-trip efficiency and net generation.

CHALLENGE

9. A natural gas plant (efficiency 44.0 percent) burns methane, releasing 802.56 kJ per mole with gaseous water. Calculate the grams of CO_2 produced per kWh of electricity (3,600 kJ) and compare it with Missouri's 2024 average of 1,456 lb/MWh (about 660 g/kWh).

10. How many kilograms of Missouri coal (20.7 kJ/g) deliver the same energy as 1.00 kg of methane (55.5 kJ/g)? Why does that matter for a power plant's fuel handling?

REVIEW

11. Burning 1.00 mol of propane releases 2,219.15 kJ (liquid water). How much energy does 250.0 g release? (molar mass 44.0956 g/mol)

12. A 100.0 g sample of water absorbs 3,350 J. By how many degrees does it warm?

13. How many moles of CO_2 are produced when 3.00 mol of methane burns completely?

Unit 1 checkpoint

1. A reaction has ΔH = +45 kJ. It is
   A. exothermic; the surroundings warm
   B. endothermic; the surroundings cool
   C. exothermic; the surroundings cool
   D. endothermic; the surroundings warm
2. Using H–H = 436.0, O=O = 498.4 and O–H = 463.5 kJ/mol, the ΔH for H₂ + ½O₂ → H₂O(g) is _____ kJ.
3. True or false: Breaking chemical bonds absorbs energy, and forming bonds releases energy.
4. How much energy warms 200.0 g of water by 10.0 °C? (c = 4.184 J/(g·°C))
   A. 84 J
   B. 836.8 J
   C. 8,368 J
   D. 20 J
5. A 60.0 g metal absorbs 540 J and warms by 20.0 °C. Its specific heat is _____ J/(g·°C).
6. True or false: In a real foam-cup calorimeter the cool water usually gains slightly less heat than the hot water loses, because the cup also absorbs some.
7. Δ_rH is calculated from formation enthalpies as
   A. ΣΔ_fH(reactants) − ΣΔ_fH(products)
   B. ΣnΔ_fH(products) − ΣnΔ_fH(reactants)
   C. the sum of all Δ_fH values
   D. the product of the Δ_fH values
8. Using Δ_fH° of −393.51 for CO₂ and −110.53 for CO (kJ/mol), ΔH for CO + ½O₂ → CO₂ is _____ kJ.
9. True or false: Burning methane to produce liquid water releases more energy than producing gaseous water.

10. A power plant has a heat rate of 8,500 Btu/kWh. Its efficiency is about
    A. 28 percent
    B. 40 percent
    C. 60 percent
    D. 85 percent
11. True or false: A heat engine can convert all of its input thermal energy into useful work if it is built carefully enough.
12. A steel-wool warmer absorbs 3,518 J while the iron could theoretically release 22,173 J. The fraction captured is about
    A. 1.6 percent
    B. 15.9 percent
    C. 84 percent
    D. 100 percent

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