

## Recitation Worksheet Six

Name:

Key

UGA ID:

### Textbook:

Chemistry & Chemical Reactivity

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### Instructions:

- This recitation worksheet covers Ch. 5.1-5.5 (heating curves omitted).
- Please enter your first and last name as it appears on the eLC roster (do not use a nickname that is not reflected in eLC).
- Your UGA myID is a combination of letters and numbers (example: Dr. Seivert's MyID is mds73312). **Do not use your 81x number.**
- Your completed worksheet has to be submitted to **Gradescope**. You have multiple options for submission:
  - You may use an app to annotate the worksheet by placing your answers in the answer boxes and showing your work when appropriate. Afterward, submit the worksheet to Gradescope. You will not need to upload anything to eLC.
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  - If you do not have access to a printer, you may type your answers directly into the worksheet PDF and then submit it to Gradescope. Write your work on separate sheets of paper, convert them to a PDF, and upload to the appropriate dropbox on eLC.
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- The following criteria **must** be met to be eligible for full credit:
  - You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope regardless of your submission type.
  - Answers must be written in the corresponding answer boxes.
  - You must show your work when appropriate.
- This worksheet is due no later than **9:00 AM on the Saturday of the recitation week.**
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

1. A silver rod is heated to 150 °C and placed in a beaker of water at room temperature. After some time, both the water and silver rod are at the same temperature. (Assuming no heat is lost to the surroundings,) which of the following is/are **true**?

↳ Technically not an open system - credit given for any answer here

- A. The beaker of water and silver rod together are considered an open system
- B. Thermal equilibrium is met in this process (true)
- C. Heat transferred from the silver rod to the water (true)
- D. All of the above are true
- E. None of the above are true

2. Which of the following are endothermic processes? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

- A. When solid KBr is dissolved in water, the solution gets colder.
- B. When concentrated H<sub>2</sub>SO<sub>4</sub> is added to water, the solution gets very hot.
- C. Water is boiled in a tea kettle.
- D. Water condenses on a cold pipe.

3. Which of the following is a state function?

- A. q
- B. w
- C. q + w → internal energy
- D. q - w
- E. More than one of the options above are state functions
- F. None of the above are state functions

4. What is **true** when heat goes from the surroundings to the system? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

CE

- A. The sign of the heat change in the surroundings is positive
- B. Work is done on the system
- C. The internal energy of the system increases
- D. The potential energy of the surroundings increases
- E. The sign of the heat change in the system is positive

5. Which statement is **true** if  $\Delta H = -85 \text{ J}$ ?

C

- A. The system is gaining 85 J; the surroundings are losing 85 J. The process is exothermic.
- B. The system is gaining 85 J; the surroundings are losing 85 J. The process is endothermic.
- C. The system is losing 85 J; the surroundings are gaining 85 J. The process is exothermic.
- D. The system is losing 85 J; the surroundings are gaining 85 J. The process is endothermic.
- E. Both the system and surroundings are losing 85 J. The process is exothermic.

6. The change in internal energy of a system is  $-123 \text{ J}$ . If  $85 \text{ J}$  of <sup>(positive)</sup> work was done on the system by the surroundings, how much was heat exchanged (in J)? Report your answer in **standard notation**.

-208 J

$$\Delta E = q + w$$

$$-123 \text{ J} = q + 85 \text{ J}$$

$$q = -208 \text{ J}$$

7. Consider a system that <sup>(positive)</sup> absorbs 225 kJ of heat and <sup>(negative)</sup> performs 96 kJ of work on the surroundings at constant pressure. What is the  $\Delta E$  (or  $\Delta U$ ) in this process? What is  $\Delta H$ ? Report your answers in **standard notation**.

$\Delta E =$   kJ

$\Delta E = q + w = 225 \text{ kJ} - 96 \text{ kJ}$

$\Delta H =$   kJ

$\Delta H = q$  at constant pressure

8. In which of the following reactions would PV work occur? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

- A.  $\text{N}_2 (\text{g}) + \text{O}_2 (\text{g}) \rightarrow 2 \text{NO} (\text{g})$
- B.  $\text{N}_2 (\text{g}) + 3 \text{H}_2 (\text{g}) \rightarrow 2 \text{NH}_3 (\text{g})$
- C.  $3 \text{Mg} (\text{s}) + \text{N}_2 (\text{g}) \rightarrow \text{Mg}_3\text{N}_2 (\text{s})$
- D.  $\text{C} (\text{s}) + \text{O}_2 (\text{g}) \rightarrow \text{CO}_2 (\text{g})$
- E.  $\text{Ba}(\text{OH})_2 (\text{aq}) + \text{H}_2\text{SO}_4 (\text{aq}) \rightarrow \text{BaSO}_4 (\text{aq}) + 2 \text{H}_2\text{O} (\text{l})$

9. In which of the following reactions would PV work **not** occur?

- A.  $2 \text{C}_2\text{H}_6 (\text{g}) + 7 \text{O}_2 (\text{g}) \rightarrow 4 \text{CO}_2 (\text{g}) + 6 \text{H}_2\text{O} (\text{l})$
- B.  $\text{CO} (\text{g}) + \text{H}_2\text{O} (\text{g}) \rightarrow \text{CO}_2 (\text{g}) + \text{H}_2 (\text{g})$
- C.  $8 \text{N}_2\text{O}_5 (\text{g}) \rightarrow 16 \text{NO}_2 (\text{g}) + 4 \text{O}_2 (\text{g})$
- D.  $\text{Ba} (\text{s}) + \text{CO}_2 (\text{g}) + \frac{1}{2} \text{O}_2 (\text{g}) \rightarrow \text{BaCO}_3 (\text{s})$
- E.  $2 \text{Na} (\text{s}) + 2 \text{H}_2\text{O} (\text{l}) \rightarrow 2 \text{NaOH} (\text{aq}) + \text{H}_2 (\text{g})$
- F. More than one of the options above
- G. None of the options above

10. Samples of copper, silver, and gold are all subjected to equal amounts of heat. Which metal will undergo the **smallest change** in temperature if they all have equal masses? The molar heat capacities of each metal are given in the table below.

C

Metal	Molar Heat Capacity ( $\text{J mol}^{-1} \text{K}^{-1}$ )
Copper	24.4
Silver	24.9
Gold	25.6

- A. Copper  
 B. Silver  
 C. Gold  
 D. The change of temperature will be the same since equal amounts of heat are being applied.

11. Samples of 100. g of each of the metals pictured below are all heated, then placed in identical coffee cup calorimeters where they all reach the same final temperature. Which was initially heated to the **highest** temperature?

Mg: 1.024  
J/g $\cdot$  $^{\circ}$ C

Pb: 0.128  
J/g $\cdot$  $^{\circ}$ C

Cu: 0.385  
J/g $\cdot$  $^{\circ}$ C

Fe: 0.449  
J/g $\cdot$  $^{\circ}$ C

B

↓  
 lowest specific heat,  
 heated to highest initial temp.  
 to reach same final temp.

- A. Magnesium  
 B. Lead  
 C. Copper  
 D. Iron  
 E. All of them would cause identical temperature changes in the calorimeters

12. Liquid bromine has a specific heat of  $0.226 \text{ J g}^{-1} \text{ K}^{-1}$ . What is liquid bromine's molar heat capacity (in  $\text{J/mol}\cdot^{\circ}\text{C}$ )? Report your answer in **standard notation**.

36.1

J/mol $\cdot$  $^{\circ}$ C

MM  $\text{Br}_2 = 159.8 \text{ g/mol}$

$$\left( \frac{0.226 \text{ J}}{\text{g K}} \right) \times \left( \frac{159.8 \text{ g}}{\text{mol}} \right) = \frac{36.1148 \text{ J}}{\text{mol K}} = \frac{36.1148 \text{ J}}{\text{mol } ^{\circ}\text{C}}$$

( $^{\circ}\text{C} = \text{K}$ )

13. Consider an experiment in which it is determined that 2.66 kJ of heat is required to raise the temperature of 80.0 g of an unknown organic compound by 15.0 K. Based on this information, what is the specific heat of the organic compound (in J/g·K)?

C

$$2.66 \text{ kJ} \times \left( \frac{1000 \text{ J}}{1 \text{ kJ}} \right) = 2660 \text{ J}$$

$$q = mc\Delta T$$

$$2660 \text{ J} = 80.0 \text{ g} (c) (15.0 \text{ K})$$

$$c = 2.22 \text{ J/g}\cdot\text{K}$$

- A. 0.115 J/g·K  
 B.  $2.22 \times 10^{-3}$  J/g·K  
 C. 2.22 J/g·K  
 D.  $-1.29 \times 10^{-4}$  J/g·K  
 E.  $1.29 \times 10^{-4}$  J/g·K

14. A 50.00 g piece of a silver wire was heated on a hot plate and then allowed to cool on a benchtop. After some time, the silver wire loses  $3.320 \times 10^5$  mJ of heat resulting in a final temperature of 32.00 °C. What was the silver wire's initial temperature (in °C) before cooling, given the molar heat capacity of silver is  $24.90 \text{ J mol}^{-1} \text{ K}^{-1}$ ? Report your answer in **standard notation**.

60.77 °C

loses heat:  $-3.320 \times 10^5 \text{ mJ}$

$$q = mc\Delta T$$

→ °C = K

$$-3.320 \times 10^5 \text{ mJ} \times \left( \frac{10^{-3} \text{ J}}{1 \text{ mJ}} \right) = (50.00 \text{ g} \times \frac{\text{mol}}{107.87 \text{ g}}) (24.90 \text{ J/mol}\cdot\text{K}) (32.00 \text{ }^\circ\text{C} - T_i)$$

$$-332.0 \text{ J} = (11.5416705 \text{ J/}^\circ\text{C}) (32.00 \text{ }^\circ\text{C} - T_i)$$

$$-332.0 \text{ J} = 369.333457 \text{ J} - (11.5416705 \text{ J/}^\circ\text{C}) (T_i)$$

$$-701.333457 \text{ J} = -(11.5416705 \text{ J/}^\circ\text{C}) (T_i) \rightarrow T_i = 60.76533 \text{ }^\circ\text{C}$$

15. Sample one (100. g of metal X at 25°C) is placed in contact with sample two (110. g of metal X at 30°C). Which of the following statements are true? Select any that apply and answer with capital letters and no spaces (e.g. ABCDE).

BD

- A. The final temperature of sample two will be higher than the final temperature of sample one  
 B. The temperatures of the samples will change due to an exchange of thermal energy in the metals  
 C. Thermal energy of the samples could be exchanged as either heat or work  
 D. The initial energy of sample two is higher than that of sample one  
 E. The temperature change will be the same for both samples

16. A 28.0 g iron sample is heated to a target temperature and then is allowed to cool over a given period of time in which it loses 80.0 J of heat. After losing this amount of heat, the temperature of the iron sample is determined to be 72.5 °C. If iron has a specific heat of 0.450 J/g·K, what was the initial (target) temperature of the iron sample (in °C)? Report your answer in **standard notation**.

78.8

$$q = mc\Delta T$$

$$-80.0 \text{ J} = (28.0 \text{ g})(0.450 \text{ J/g}\cdot\text{C})(72.5^\circ\text{C} - T_i)$$

$$-80.0 \text{ J} = 913.5 \text{ J} - (12.6 \text{ J/}^\circ\text{C})(T_i)$$

$$-993.5 \text{ J} = (-12.6 \text{ J/}^\circ\text{C})(T_i) \rightarrow T_i = 78.8^\circ\text{C}$$

17. A 25.0 g sample of gold is heated to 90.00 °C and placed in 155 mL of cyclohexane ( $d = 0.779 \text{ g/cm}^3$ ). After some time, the temperature of both the cyclohexane and gold reaches a final temperature of 24.05 °C. Assuming no heat is lost to the surroundings, what was the original temperature of cyclohexane (in °C)? Report your answer to **three significant figures** and **standard notation**.

Specific heat of gold = 0.129 J/g·°C

Specific heat of cyclohexane = 1.85 J/g·°C

23.1

°C

$$q_{\text{gold}} = -q_{\text{cyclohexane}}$$

$$mC\Delta T = -mC\Delta T$$

$$(25.0 \text{ g})(0.129 \text{ J/g}\cdot\text{C})(24.05^\circ\text{C} - 90.00^\circ\text{C}) =$$

$$-(155 \text{ mL} \times 0.779 \text{ g/mL})(1.85 \text{ J/g}\cdot\text{C})(24.05^\circ\text{C} - T_i)$$

$$-212.68875 \text{ J} = -5172.27691 \text{ J} + (223.37825 \text{ J/}^\circ\text{C})(T_i)$$

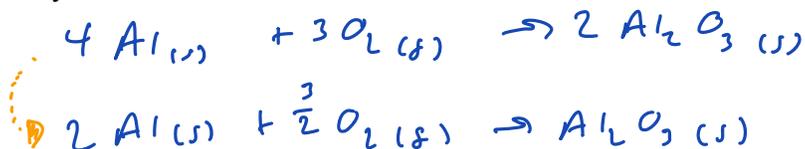
$$5159.58816 \text{ J} = (223.37825 \text{ J/}^\circ\text{C})(T_i)$$

$$T_i = 23.1^\circ\text{C}$$

18. The **standard heat of formation** of aluminum oxide is -1669.8 kJ/mol. What is the heat exchanged (kJ) when 100.0 g of aluminum is converted to aluminum oxide with excess oxygen via this reaction? Report your answer in **standard notation**.

-3095

kJ



↳ 3095 kJ okay here

"exchanged" could imply positive or negative  
future assessments will use neutral wording, so please answer with correct sign

$$100.0 \text{ g Al} \times \left( \frac{1 \text{ mol Al}}{26.98 \text{ g}} \right) \times \left( \frac{1 \text{ mol Al}_2\text{O}_3}{2 \text{ mol Al}} \right) \times \left( \frac{-1669.8 \text{ kJ}}{1 \text{ mol Al}_2\text{O}_3} \right)$$

19. Consider an experiment in which 45.0 g of diboron hexahydride reacts with 45.0 g of chlorine gas according to the balanced reaction below. How much energy is exchanged (in kJ) based on this information and the  $\Delta H_{\text{rxn}}$  given below? Report your answer in **standard notation**.



$$\Delta H_{\text{rxn}} = -1396 \text{ kJ/mol}$$

-148

kJ

↳ 148 kJ okay here!

"exchanged" could imply positive or negative  
future assessments will use neutral wording, so please answer with correct sign

$$45.0 \text{ g B}_2\text{H}_6 \times \left( \frac{1 \text{ mol B}_2\text{H}_6}{27.68 \text{ g}} \right) \times \left( \frac{2 \text{ mol BCl}_3}{1 \text{ mol B}_2\text{H}_6} \right) = 3.25195 \text{ mol BCl}_3$$

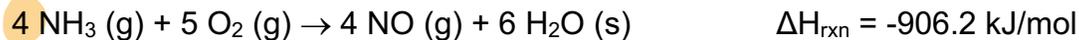
$$45.0 \text{ g Cl}_2 \times \left( \frac{1 \text{ mol Cl}_2}{70.90 \text{ g}} \right) \times \left( \frac{2 \text{ mol BCl}_3}{6 \text{ mol Cl}_2} \right) = 0.211566 \text{ mol BCl}_3$$

↳ limiting

↳ theor. yield

$$0.211566 \text{ mol BCl}_3 \times \left( \frac{-1396 \text{ kJ}}{2 \text{ mol BCl}_3} \right) = -147.673 \text{ kJ}$$

20. A researcher goes to lab and performs the following reaction:

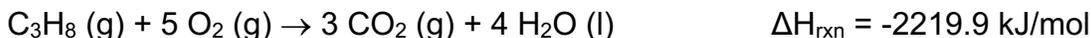


They note upon completion that -1333 kJ of heat is released. How many *atoms* of  $\text{NH}_3$  were used if this reaction was performed in the presence of excess oxygen? Report your answer in **scientific notation**.

$$\boxed{1.417} \times 10^{\boxed{25}} \text{ atoms}$$

$$-1333 \text{ kJ} \times \left( \frac{4 \text{ mol NH}_3}{-906.2 \text{ kJ}} \right) \times \left( \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol NH}_3} \right) \times \left( \frac{4 \text{ total atoms}}{1 \text{ NH}_3 \text{ molecule}} \right)$$

21. In the show *King of the Hill*, the series centers around Hank Hill, an assistant manager who proudly sells "propane and propane accessories", and as expected, is often shown using a propane grill. The combustion of propane in a gas grill is shown in the balanced equation here:



If Hank is cooking for a neighborhood party using his grill (likely a Vogner Charking Imperial) and uses (i.e. **releases**) a total of 788.5 kJ of heat, then what volume of propane (in mL) did he use?  $\rightarrow$  negative

The percent yield of the combustion reaction in his grill is 90.5%, the density of propane is  $1.83 \text{ kg/m}^3$ , and the MW of propane is  $44.11 \text{ g/mol}$ . Report your answer in **standard notation**.

$$\boxed{9460} \text{ mL}$$

$$\% \text{ yield} = \frac{\text{actual}}{\text{theor.}} \times 100$$

$$90.5 \% = \frac{-788.5 \text{ kJ}}{\text{theor.}} \times 100$$

$$\text{theor.} = \frac{-788.5 \text{ kJ}}{0.905} = -871.2707182 \text{ kJ}$$

$$-871.2707182 \text{ kJ} \times \left( \frac{1 \text{ mol C}_3\text{H}_8}{-2219.9 \text{ kJ}} \right) \times \left( \frac{44.11 \text{ g C}_3\text{H}_8}{1 \text{ mol C}_3\text{H}_8} \right) \times \left( \frac{1 \text{ kg}}{1000 \text{ g}} \right) \times \left( \frac{\text{m}^3}{1.83 \text{ kg}} \right) \times \left( \frac{100 \text{ cm}}{1 \text{ m}} \right)^3 \times \left( \frac{1 \text{ mL}}{1 \text{ cm}^3} \right) = 9460.317 \text{ mL}$$

**Extra Practice Questions: these questions will not be graded.**

1. What is the change in internal energy of a system (in kJ) when the system releases 158.5 kJ of heat and the surroundings perform 105.0 kJ of work on the system? Report your answer in **standard notation**.

kJ

$$q = -158.5 \text{ kJ}$$
$$w = +105.0 \text{ kJ}$$

$$\Delta E = q + w = -158.5 \text{ kJ} + 105.0 \text{ kJ}$$

2. A gas releases 638 J of heat and does 257 J of work on the surroundings. What is the change in energy of the system and what does it mean?

$$q = -638 \text{ J}$$

$$w = -257 \text{ J}$$

$$\Delta E = (-638 \text{ J}) + (-257 \text{ J})$$

- A.  $\Delta E = 895 \text{ J}$ , energy flows into the system and the reaction is endothermic
- B.  $\Delta E = 895 \text{ J}$ , energy flows out the system and the reaction is exothermic
- C.  $\Delta E = -895 \text{ J}$ , energy flows into the system and the reaction is endothermic
- D.  $\Delta E = -895 \text{ J}$ , energy flows out the system and the reaction is exothermic

3. Which of the following is an exothermic process?

- A. Baking an apple pie
- B. A sample of liquid gold solidifying
- C. Hydrogen peroxide evaporating from your skin
- D. Ice melting in your hand

$$\rightarrow 1.856e4 \text{ J}$$

4. A 187 g sample of an organic compound requires 18.56 kJ amount of heat to raise the temperature from 25.4 °C to 83.1 °C. What is the specific heat of the compound (in J/g·K)? Report your answer in **standard notation**.

1.72
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 J/g·°C

$$q = mc\Delta T$$

$$1.856e4 \text{ J} = (187 \text{ g})(c)(83.1^\circ\text{C} - 25.4^\circ\text{C})$$

$$1.856e4 \text{ J} = (187 \text{ g})(c)(57.7^\circ\text{C})$$

$$c = 1.72 \text{ J/g}\cdot^\circ\text{C}$$

$$\rightarrow 5250 \text{ J}$$

5. A 50.0 g aluminum sample originally at 26.5 °C absorbs 5.25 kJ of heat. If aluminum has a specific heat of 0.385 J/g·K, what will be the new temperature of the aluminum sample (in °C)? Report your answer in **standard notation**.

299
-----

 °C

$$q = mc\Delta T$$

$$5250 \text{ J} = (50.0 \text{ g})(0.385 \text{ J/g}\cdot^\circ\text{C})(T_f - 26.5^\circ\text{C})$$

$$5250 \text{ J} = (19.25 \text{ J/}^\circ\text{C})(T_f) - 510.125 \text{ J}$$

$$5760.125 \text{ J} = (19.25 \text{ J/}^\circ\text{C})(T_f)$$

6. A 30.0 g sample of water at 280. K is mixed with 50.0 g water at 330. K. Calculate the final temperature (K) of the mixture assuming no heat loss to the surroundings. The specific heat capacity of water is 4.184 J/g·K. Report your answer in **standard notation**.

311
-----

 K

$$-q_{\text{H}_2\text{O}}(30.0 \text{ g}) = q_{\text{H}_2\text{O}}(50.0 \text{ g})$$

$$-mc\Delta T = mc\Delta T$$

$$-30.0 \text{ g}(4.184 \text{ J/g}\cdot\text{K})(T_f - 280. \text{ K}) =$$

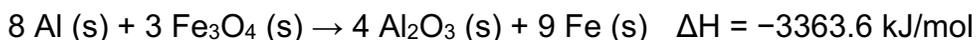
$$50.0 \text{ g}(4.184 \text{ J/g}\cdot\text{K})(T_f - 330. \text{ K})$$

7. Which of the following reactions would result in PV work? Select any that apply and answer with capital letters and no spaces (e.g. ABCDE).

ACD

- A.  $\text{Mg (s)} + \text{Br}_2 \text{(g)} \rightarrow \text{MgBr}_2 \text{(s)}$
- B.  $\text{HCl (aq)} + \text{NaOH (aq)} \rightarrow \text{NaCl (aq)} + \text{H}_2\text{O (l)}$
- C.  $2 \text{C}_3\text{H}_7\text{OH (g)} + 9 \text{O}_2 \text{(g)} \rightarrow 6 \text{CO}_2 \text{(g)} + 8 \text{H}_2\text{O (g)}$
- D.  $\text{C (s)} + 2 \text{F}_2 \text{(g)} \rightarrow \text{CF}_4 \text{(g)}$
- E.  $\text{C (s)} + 2 \text{I}_2 \text{(s)} \rightarrow \text{Cl}_4 \text{(s)}$

8. Given the following reaction:



Determine the change in enthalpy (kJ) when excess aluminum reacts with 30.0 g  $\text{Fe}_3\text{O}_4$  (molar mass = 231.55 g/mol). Report your answer in **standard notation**.

-145

kJ

$$30.0 \text{ g Fe}_3\text{O}_4 \times \left( \frac{1 \text{ mol}}{231.55 \text{ g}} \right) \times \left( \frac{-3363.6 \text{ kJ}}{3 \text{ mol Fe}_3\text{O}_4} \right)$$

9. Determine the mass of HF (in grams) required to release  $5.20 \times 10^3 \text{ J}$  of energy using the balanced equation and  $\Delta H_{\text{rxn}}$  given below. Report your answer in **standard notation**.



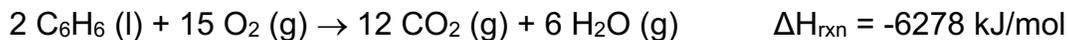
2.26

g

$$-5.20 \times 10^3 \text{ J} \times \left( \frac{1 \text{ kJ}}{1000 \text{ J}} \right) = -5.20 \text{ kJ}$$

$$-5.20 \text{ kJ} \times \left( \frac{4 \text{ mol HF}}{-184 \text{ kJ}} \right) \times \left( 20.01 \text{ g/mol HF} \right) = 2.262 \text{ g HF}$$

10. Determine the volume of  $C_6H_6$  required to release  $1.82 \times 10^6$  J of energy using the balanced combustion reaction and  $\Delta H_{rxn}$  given below. Note: the density of  $C_6H_6$  is 0.879 g/mL. Report your answer in **standard notation**.

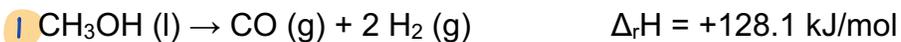


51.5

 mL

$$\begin{aligned}
 & -1.82 \times 10^6 \text{ J} \times \left( \frac{1 \text{ kJ}}{1000 \text{ J}} \right) = -1820 \text{ kJ} \\
 & -1820 \text{ kJ} \times \left( \frac{2 \text{ mol } C_6H_6}{-6278 \text{ kJ}} \right) \times \left( \frac{78.12 \text{ g } C_6H_6}{\text{mol}} \right) \times \left( \frac{\text{mL}}{0.879 \text{ g}} \right) \\
 & \qquad \qquad \qquad = \underline{\underline{51.5292 \text{ mL}}}
 \end{aligned}$$

11. What volume (mL) of methanol ( $CH_3OH$ , density = 0.791 g/mL, molar mass = 32.04 g/mol) is required to consume 500. kJ of heat according to the following balanced chemical reaction?



C

- A. 125 mL
- B. 6.49 mL
- C. 158 mL
- D. 98.9 mL
- E. 10.4 mL

$$500. \text{ kJ} \times \left( \frac{1 \text{ mol } CH_3OH}{128.1 \text{ kJ}} \right) \times \left( \frac{32.04 \text{ g}}{\text{mol}} \right) \times \left( \frac{\text{mL}}{0.791 \text{ g}} \right)$$

# Periodic Table of the Elements

1																		2												
1 <b>H</b> 1.01	2																2 <b>He</b> 4.00													
3 <b>Li</b> 6.94	4 <b>Be</b> 9.01															5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18									
11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31															13 <b>Al</b> 26.98	14 <b>Si</b> 28.09	15 <b>P</b> 30.97	16 <b>S</b> 32.06	17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95									
19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.87	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.63	33 <b>As</b> 74.92	34 <b>Se</b> 78.97	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80													
37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.95	43 <b>Tc</b> [97]	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29													
57 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33															72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> [209]	85 <b>At</b> [210]	86 <b>Rn</b> [222]
87 <b>Fr</b> [223]	88 <b>Ra</b> [226]															104 <b>Rf</b> [267]	105 <b>Db</b> [268]	106 <b>Sg</b> [269]	107 <b>Bh</b> [270]	108 <b>Hs</b> [269]	109 <b>Mt</b> [277]	110 <b>Ds</b> [281]	111 <b>Rg</b> [282]	112 <b>Cn</b> [285]	113 <b>Nh</b> [286]	114 <b>Fl</b> [290]	115 <b>Mc</b> [290]	116 <b>Lv</b> [293]	117 <b>Ts</b> [294]	118 <b>Og</b> [294]
57 <b>La</b> 138.91	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> [145]	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.05	71 <b>Lu</b> 174.97																
89 <b>Ac</b> [227]	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> [237]	94 <b>Pu</b> [244]	95 <b>Am</b> [243]	96 <b>Cm</b> [247]	97 <b>Bk</b> [247]	98 <b>Cf</b> [251]	99 <b>Es</b> [252]	100 <b>Fm</b> [257]	101 <b>Md</b> [258]	102 <b>No</b> [259]	103 <b>Lr</b> [262]																

## Formula Sheet

### Length

1 kilometer = 0.62137 mile

1 inch = 2.54 centimeters (exactly)

1 Ångstrom =  $1 \times 10^{-10}$  meter

### Energy

1 joule =  $1 \text{ kg}\cdot\text{m}^2/\text{s}^2$

1 calorie = 4.184 joules

1 Calorie = 1 kilocalorie = 1000 calories

1 L·atm = 101.325 joules

### Pressure

1 pascal =  $1 \text{ N}/\text{m}^2 = 1 \text{ kg}/\text{m}\cdot\text{s}^2$

1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in<sup>2</sup>

1 bar =  $1 \times 10^5$  Pa (exactly)

### Temperature

0 K =  $-273.15^\circ\text{C}$

K =  $^\circ\text{C} + 273.15$

$^\circ\text{C} = (5/9)(^\circ\text{F} - 32)$

### Mass

1 kg = 2.205 lbs

### Volume

1 mL =  $1 \text{ cm}^3 = 1 \text{ cc}$

### Constants

$c = 2.998 \times 10^8 \text{ m}/\text{sec}$

$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{sec}$

$R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K} = 8.314 \text{ J}/\text{mol}\cdot\text{K}$

Specific heat of water =  $4.184 \text{ J}/\text{g}\cdot\text{K}$

Mass of an electron:  $9.109 \times 10^{-31} \text{ kg}$

Mass of a proton:  $1.673 \times 10^{-27} \text{ kg}$

$RH = 2.18 \times 10^{-18} \text{ J}$

Specific heat of water =  $4.184 \text{ J}/\text{g}\cdot\text{K}$

Avogadro's number:  $6.022 \times 10^{23}$

$F = 96485 \text{ J}/(\text{V}\cdot\text{mol } e^-)$

$K_w = 1.0 \times 10^{-14}$  at  $25^\circ\text{C}$

$k_b = 1.381 \times 10^{-23} \text{ J}/\text{K}$

### Equations

$(P + a(n^2/V^2))\cdot(V - nb) = nRT$

molar mass (M) =  $nRT/PV$

density (d) =  $MP/RT$

$$KE = \frac{3}{2}RT$$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{\text{Rate of effusion A}}{\text{Rate of effusion B}} = \sqrt{\frac{MW_B}{MW_A}}$$

$$\Delta E = -2.18 \times 10^{-18} J \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\ln \left( \frac{P_2}{P_1} \right) = \frac{\Delta H_{vap}}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$C_g = kP_g$$

$$P_{\text{solution}} = P_{\text{solvent}} X_{\text{solvent}}$$

$$P_{\text{solution}} = \sum P_j = \sum P_j X_j$$

$$\pi = MRT_i$$

### **Thermodynamic and Electrochemistry**

$$S = k_b \times \ln(W)$$

$$\Delta S = q_{\text{rev}}/T$$

$$\Delta G = \Delta G^\circ + RT \cdot \ln Q$$

$$R = 8.314 \text{ J/mol}\cdot\text{K}$$

$$\Delta G^\circ = -RT \cdot \ln K$$

$$\Delta G = -nFE_{\text{cell}}$$

$$E^\circ_{\text{cell}} = RT/nF \ln K$$

$$E^\circ_{\text{cell}} = (0.0257/n) \ln K = (0.0592/n) \log K$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (RT/nF) \ln Q$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (0.0257/n) \ln Q$$

$$\text{Electrolysis: } Q \text{ (total charge)} = I \times t = n \times F$$

### **Integrated Rate Laws & half-life**

$$\ln \frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$\ln \frac{k_2}{k_1} = -\frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

### **Equilibrium and Acid / Base**

$$K_p = K_c \times (RT)^{\Delta n}$$

$$\ln \frac{K_2}{K_1} = \frac{\Delta H_{rxn}^\circ}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$