Recitation Worksheet Seven: Exam Two Review

Name: Key | UGA ID:

Textbook:
Chemistry & Chemical Reactivity
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Instructions:

- This recitation worksheet is a review for Exam Two.
- Exam coverage: Ch. 3.4-3.9, 4, 5.
- You **do not** need to submit it to Gradescope.
- The answer key has been posted with this worksheet to eLC.
- The **recitation session during the exam week (October 7-10) is still mandatory**. Your attendance will be recorded.
- A periodic table and formula sheet are attached to the end of this worksheet.

1. A sugar and salt solution is prepared by adding 10.0 g of sucrose and 0.50 g of sodium chloride to 500. mL of water. What is/are the solute(s)?

→ solvent

C

A. Sugar
B. Salt
C. Sugar and salt
D. Water
E. Sugar, salt, and water

2. A researcher mixes 50. mL of water with 1.0 L of liquid ethanol. Which is the solvent?

→ greater volume

B

A. Water
B. Ethanol
C. Both
D. This cannot be determined

3. Which of the following equations best represents the dissolution of mercury(I) nitrate in water?

mercury (I) : Hg_2^{2+}

$Hg_2(NO_3)_2$

C

A. $Hg_2(NO_3)_2$ (s) → $Hg_2(NO_3)_2$ (l)
B. $HgNO_3$ (s) → Hg^+ (aq) + NO_3^- (aq)
C. $Hg_2(NO_3)_2$ (s) → Hg_2^{2+} (aq) + 2 NO_3^- (aq)
D. $Hg_2(NO_3)_2$ (s) → 2 Hg^+ (aq) + 2 NO_3^- (aq)
E. $Hg_2(NO_3)_2$ (s) → 2 Hg^+ (aq) + 2 N^- (aq) + 2 O_3 (aq)
F. $Hg_2(NO_3)_2$ (s) → 2 Hg^+ (aq) + 2 N^{3-} (aq) + 6 O^{2-} (aq)

4. A lab technician goes to lab and dissolves 5 moles of each the following compounds below in water. Which of these compounds is expected to produce the most moles of particles upon dissolving?

E

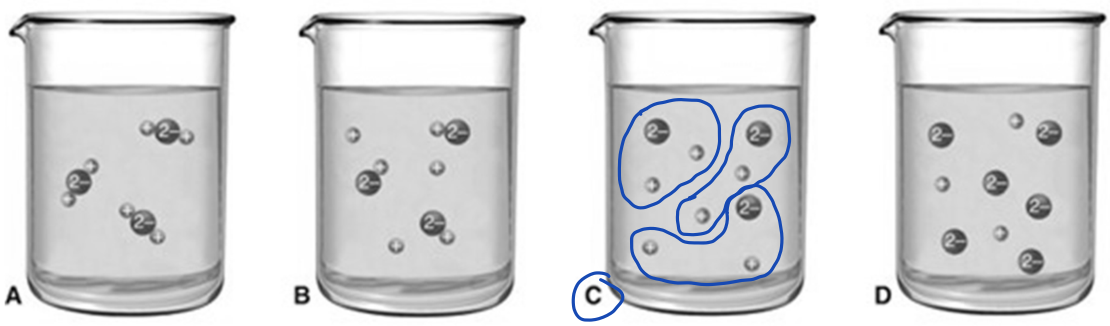
A. NO_2
B. $C_{16}H_{19}N_3O_5S$
C. $Mg(ClO_3)_2$
D. $CH_3CH_2CH_2CH_2CH_2CH_2OH$
E. Na_3N

$Na_3N_{(s)} \xrightarrow{H_2O} 3Na^+_{(aq)} + N^{3-}_{(aq)}$ (1 mole being dissolved)

5. Which image best depicts potassium sulfate dissolved in water? (H_2O molecules are not shown in the drawings.)

$K_2SO_{4\,(s)} \xrightarrow{H_2O} 2K^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

C



6. Which of the following are non-electrolytes? Select any that apply and answer with capital letters with no spaces in between (e.g. ABCDE).

AFG

A. C_4H_9OH → alcohol
B. HCl
C. $Mg(C_2H_3O_2)_2$
D. C_3H_7COOH → organic acid
E. NaOH
F. C_6H_{12}
G. N_2O_4

7. Which of the following aqueous solutions will be the poorest conductor of electrical current?

A

A. sucrose → nonelectrolyte
B. sodium chloride
C. potassium nitrate
D. lithium hydroxide
E. sulfuric acid

strong electrolytes

8. Which of the following compounds are **weak** electrolytes? Select any that apply and answer with capital letters and no spaces (e.g. ABCDE).

BCE

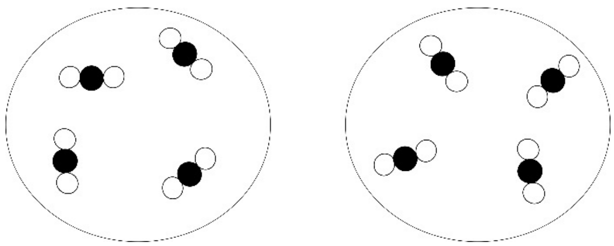
A. HBr
B. CH_3COOH
C. NH_3
D. $Ba(OH)_2$
E. H_2SO_3
F. $C_5H_{11}OH$
G. CH_4

9. Which of the following options below is **not** a strong base?

C

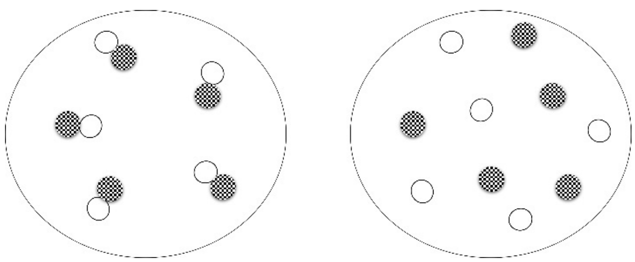
A. NaOH
B. KOH
C. $Mg(OH)_2$
D. $Ca(OH)_2$
E. $Sr(OH)_2$
F. All of the above are strong bases

10. The following compounds are shown before and after being dissolved in water. Label them as (A) strong, (B) weak, or (C) non-electrolytes.



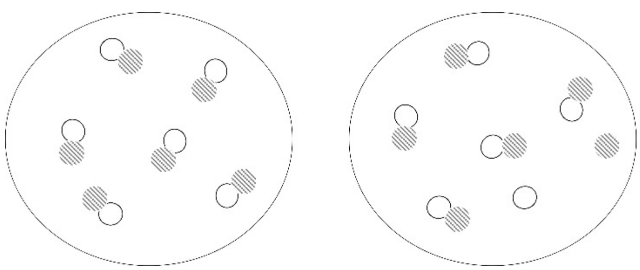
I.

C



II.

A



III.

B

11. A student goes to the lab and starts cleaning out an old lab cabinet. While cleaning, they find a bottle of an unknown white solid. The curious student carefully adds the solid to a beaker of water and they note that the solid immediately dissolves. To the same beaker of water, they add an aqueous solution of Li_2SO_4, in which a white precipitate immediately forms. Based on these observations, which of the compounds below are potential identities of the unknown solid? Select any that apply and answer with capital letters and no spaces (e.g. ABCDE).

AE

A. $BaCl_2$ → soluble
B. $PbCl_2$ → insoluble
C. NaCl
D. $AlCl_3$
E. $CaCl_2$

(C–E) soluble

$BaCl_{2(aq)} + Li_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2LiCl_{(aq)}$

$2NaCl_{(aq)} + Li_2SO_{4(aq)} \rightarrow 2LiCl_{(aq)} + Na_2SO_{4(aq)}$ (no precipitate)

$2AlCl_{3(aq)} + 3Li_2SO_{4(aq)} \rightarrow 6LiCl_{(aq)} + Al_2(SO_4)_{3(aq)}$ (no precipitate)

$CaCl_{2(aq)} + Li_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + 2LiCl_{(aq)}$

12. When these pairs of aqueous solutions are mixed, which will **NOT** result in the formation of a precipitate?

D

A. ammonium iodide + silver nitrate $AgI_{(s)}$
B. potassium carbonate + barium hydroxide $BaCO_{3(s)}$
C. ammonium phosphate + barium chloride $Ba_3(PO_4)_2$
D. potassium chloride + iron(III) nitrate
E. lead(II) nitrate + potassium bromide $PbBr_{2(s)}$

13. What is the total ionic equation for the balanced formula equation below?

$$2\ HC_2H_3O_2\ (aq) + K_2CO_3\ (aq) \rightarrow H_2O\ (l) + CO_2\ (g) + 2\ KC_2H_3O_2\ (aq)$$

↳ weak acid!

$\boxed{C}$

A. $2\ H^+\ (aq) + 2\ C_2H_3O_2^-\ (aq) + 2\ K^+\ (aq) \rightarrow 2\ KC_2H_3O_2\ (aq)$

B. $2\ H^+\ (aq) + 2\ C_2H_3O_2^-\ (aq) + 2\ K^+\ (aq) + CO_3^{2-}\ (aq) \rightarrow 2\ H^+\ (l) + O^{2-}\ (l) + C^{4+} + 2\ O^{2-}\ (g) + 2\ K^+\ (aq) + 2\ C_2H_3O_2^-\ (aq)$

C. $2\ HC_2H_3O_2\ (aq) + 2\ K^+\ (aq) + CO_3^{2-}\ (aq) \rightarrow H_2O\ (l) + CO_2\ (g) + 2\ K^+\ (aq) + 2\ C_2H_3O_2^-\ (aq)$

D. $2\ H^+\ (aq) + 2\ C_2H_3O_2^-\ (aq) \rightarrow H_2O\ (l) + 2\ C_2H_3O_2^-\ (aq)$

E. $2\ C_2H_3O_2^-\ (aq) + 2\ K^+\ (aq) \rightarrow 2\ KC_2H_3O_2\ (aq)$

14. When hydrochloric acid is added to potassium sulfide the products are hydrogen sulfide gas and potassium chloride. What is/are the spectator ion(s) in this reaction? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

AC

A. K^+
B. H^+
C. Cl^-
D. S^{2-}
E. There are no spectator ions in this reaction

$2HCl_{(aq)} + K_2S_{(aq)} \rightarrow H_2S_{(g)} + 2KCl_{(aq)}$

$2H^+_{(aq)} + \cancel{2Cl^-_{(aq)}} + \cancel{2K^+_{(aq)}} + S^{2-}_{(aq)} \rightarrow H_2S_{(g)} + \cancel{2K^+_{(aq)}} + \cancel{2Cl^-_{(aq)}}$

15. Copper(II) nitrate reacts with potassium sulfide. What is/are the spectator ion(s) in this reaction? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

BC

A. Cu^{2+}
B. NO_3^-
C. K^+
D. S^{2-}
E. SO_4^{2-}
F. There are no spectator ions in this reaction

$Cu(NO_3)_{2\,(aq)} + K_2S_{(aq)} \rightarrow 2KNO_{3\,(aq)} + CuS_{(s)}$

$Cu^{2+}_{(aq)} + \cancel{2NO_3^-_{(aq)}} + \cancel{2K^+_{(aq)}} + S^{2-}_{(aq)} \rightarrow \cancel{2K^+_{(aq)}} + \cancel{2NO_3^-_{(aq)}} + CuS_{(s)}$

16. What is the net ionic equation for the balanced formula equation below?

$$2\ HClO_4\ (aq) + FeO\ (s) \rightarrow Fe(ClO_4)_2\ (aq) + H_2O\ (l)$$

$\boxed{D}$

$$2H^+_{(aq)} + \cancel{2ClO_4^-}_{(aq)} + FeO_{(s)} \rightarrow Fe^{2+}_{(aq)} + \cancel{2ClO_4^-}_{(aq)} + H_2O_{(l)}$$

$$2H^+_{(aq)} + FeO_{(s)} \rightarrow Fe^{2+}_{(aq)} + H_2O_{(l)}$$

A. $2\ ClO_4^-\ (aq) + Fe^{2+}\ (aq) \rightarrow Fe(ClO_4)_2\ (aq)$

B. $2\ H^+\ (aq) + OH^-\ (aq) \rightarrow H_2O\ (l)$

C. $2\ H^+\ (aq) + Fe^{2+}\ (aq) + O^{2-}\ (aq) \rightarrow Fe^{2+}\ (aq) + H_2O\ (l)$

D. $2\ H^+\ (aq) + FeO\ (s) \rightarrow Fe^{2+}\ (aq) + H_2O\ (l)$

E. $2\ ClO_4^-\ (aq) + 2\ H^+\ (aq) + Fe^{2+}\ (aq) + O^{2-}\ (aq) \rightarrow Fe(ClO_4)_2\ (aq) + H_2O\ (l)$

17. What is the net ionic equation for the balanced formula equation below?

$$NH_4Cl\ (aq) + NaOH\ (aq) \rightarrow NH_3\ (g) + H_2O\ (l) + NaCl\ (aq)$$

$\boxed{B}$

$$NH_4^+{}_{(aq)} + \cancel{Cl^-}_{(aq)} + \cancel{Na^+}_{(aq)} + OH^-_{(aq)} \rightarrow NH_3\ (g) + H_2O_{(l)} + \cancel{Na^+}_{(aq)} + \cancel{Cl^-}_{(aq)}$$

$$NH_4^+{}_{(aq)} + OH^-_{(aq)} \rightarrow NH_3\ (g) + H_2O_{(l)}$$

A. $Cl^-\ (aq) + Na^+\ (aq) \rightarrow NaCl\ (aq)$

B. $NH_4^+\ (aq) + OH^-\ (aq) \rightarrow NH_3\ (g) + H_2O\ (l)$

C. $NH_4^+\ (aq) + Na^+\ (aq) + OH^-\ (aq) \rightarrow N^{3-}\ (g) + 3\ H^+\ (g) + 2\ H_2O\ (l) + Na^+\ (aq)$

D. $2\ H^+\ (aq) + OH^-\ (aq) \rightarrow H_2O\ (l)$

E. $N^{3-}\ (aq) + 4\ H^+\ (aq) + OH^-\ (aq) \rightarrow NH_3\ (g) + H_2O\ (l)$

18. Label the following as an (A) acid-base, (B) precipitation, or (C) oxidation-reduction (redox) reaction.

A $HCl\ (aq) + KOH\ (aq) \rightarrow KCl\ (aq) + H_2O\ (l)$

B $CuCl\ (aq) + KOH\ (aq) \rightarrow KCl\ (aq) + CuOH\ (s)$

A $H^+\ (aq) + OH^-\ (aq) \rightarrow H_2O\ (l)$

C $2\ Fe\ (s) + 3\ Cl_2\ (g) \rightarrow 2\ FeCl_3\ (s)$

19. Label the following as an (A) acid-base, (B) precipitation, or (C) oxidation-reduction (redox) reaction.

A $2\ HCl\ (aq) + Ba(OH)_2\ (aq) \rightarrow BaCl_2\ (aq) + 2\ H_2O\ (l)$

C $C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (g)$

B $ZnCl_2\ (aq) + 2\ NaOH\ (aq) \rightarrow 2\ NaCl\ (aq) + Zn(OH)_2\ (s)$

20. Which of these compounds will **not** undergo an acid-base (neutralization) reaction with $HClO_4$?

$\boxed{E}$

A. NaOH
B. $Sr(OH)_2$
C. NH_3
D. CH_3NH_2
E. H_2SO_4
F. More than one of the above options

bases

21. In which substance does nitrogen have the lowest (most negative) oxidation state?

$\boxed{E}$

A. N_2
B. NF_3
C. NO_2
D. NO_3^-
E. NH_3

$\overset{0}{N_2}$ $\overset{+3\ \ -1}{NF_3}$ ($+3\ \ -3$) $\overset{+4\ \ -2}{NO_2}$ ($+4\ \ -4$) $\overset{+5\ \ -2}{NO_3^-}$ ($+5\ \ -6 = -1$) $\overset{-3\ \ +1}{NH_3}$ ($-3\ \ +3$)

22. Which of the following unbalanced half-reactions represent **reduction**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

$\boxed{BC}$

A. $Cu \rightarrow CuCl_2$

B. $CrO_2 \rightarrow CrO$

C. $SO_4^{2-} \rightarrow S^{2-}$

D. $Mg \rightarrow MgO$

E. $SF_4 \rightarrow SF_6$

$\overset{+4\ \ -2}{CrO_2} \rightarrow \overset{+2\ \ -2}{CrO}$ ($+4\ \ -4$)

$\overset{+6\ \ -2}{SO_4^{2-}} \rightarrow \overset{-2}{S^{2-}}$ ($+6\ \ -8 = -2$)

$\overset{0}{Mg} \rightarrow \overset{+2\ \ -2}{MgO}$

$\overset{+4\ \ -1}{SF_4} \rightarrow \overset{+6\ \ -1}{SF_6}$ ($+4\ \ -4$; $+6\ \ -6$)

$\overset{0}{Cu} \rightarrow \overset{+2\ \ -1}{CuCl_2}$ ($+2\ \ -2$)

23. Consider the oxidation-reduction reaction below and answer the following questions. Write the **chemical formula** in the boxes below.

$$\_\_\_\_ Cl_2\ (g) + \_\_\_\_ Fe^{2+}\ (aq) \rightarrow \_\_\_\_ Fe^{3+}\ (aq) + \_\_\_\_ Cl^{-}\ (aq)$$

I. What species is oxidized? $\boxed{Fe^{2+}}$

II. What species is reduced? $\boxed{Cl_2}$

III. Fully balance the equation and list the coefficients as whole numbers with no commas or spaces (e.g. 1234).

$\boxed{1222}$

IV. How many electrons were transferred after balancing the equation? Answer by using an integer (e.g. 0, 1, etc.).

$\boxed{2}$

$$2e^- + Cl_{2\ (g)} \rightarrow 2Cl^-_{(aq)}$$

$$\left(Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + 1e^-\right) \times 2$$

$$\cancel{2e^-} + Cl_{2\ (g)} \rightarrow 2Cl^-_{(aq)}$$

$$2Fe^{2+}_{(aq)} \rightarrow 2Fe^{3+}_{(aq)} + \cancel{2e^-}$$

$$Cl_{2(g)} + 2Fe^{2+}_{(aq)} \rightarrow 2Fe^{3+}_{(aq)} + 2Cl^-_{(aq)}$$

24. Consider the oxidation-reduction reaction below and answer the following questions. Write the **chemical formula** in the boxes below.

$$\overset{-2}{H_2S}\,(g) + \overset{0}{Cl_2}\,(g) \rightarrow 2\,\overset{-1}{HCl}\,(s) + \overset{0}{S}\,(s)$$

I. What species is oxidized? $\boxed{H_2S \text{ or } S^{2-}}$

II. What species is reduced? $\boxed{Cl_2}$

III. What species is the oxidizing agent? $\boxed{Cl_2}$

IV. What species is the reducing agent? $\boxed{H_2S}$

25. Identify the oxidizing agent and the reducing agent in the following reaction.

$$8\,\overset{-3\ +1}{NH_3}\,(g) + 6\,\overset{+4\ -2}{NO_2}\,(g) \rightarrow 7\,\overset{0}{N_2}\,(g) + 12\,\overset{+1\ -2}{H_2O}\,(l)$$

$-3\ +3 = 0 \qquad +4\ -4 \qquad +2\ -2$

$\boxed{A}$

A. NO_2 oxidizing agent, NH_3 reducing agent
B. NH_3 oxidizing agent, NO_2 reducing agent
C. NH_3 oxidizing agent, N_2 reducing agent
D. NO_2 oxidizing agent, N_2 reducing agent
E. N_2 oxidizing agent, H_2O reducing agent

NH_3: N → (−3 → 0) loses e⁻s, oxidized, red. agent

NO_2: N → (+4 → 0) gains e⁻s, reduced, oxid. agent

26. Consider the following oxidation-reduction reaction.

$$Al\ (s) + Br_2\ (l) \rightarrow Al^{3+}\ (aq) + Br^{-}\ (aq)$$

In the balanced chemical equation, how many bromide ions are present?

$\boxed{E}$

$(Al(s) \rightarrow Al^{3+}(aq) + 3e^{-}) \times 2$

$(2e^{-} + Br_2(l) \rightarrow 2Br^{-}(aq)) \times 3$

$2Al(s) \rightarrow 2Al^{3+}(aq) + 6e^{-}$

$6e^{-} + 3Br_2(l) \rightarrow 6Br^{-}(aq)$

$2Al(s) + 3Br_2(l) \rightarrow 2Al^{3+}(aq) + 6Br^{-}(aq)$

A. 0
B. 1
C. 2
D. 3
E. 6

27. Consider the equation given below:

$$P_4\ (s) + Mn\ (s) \rightarrow P^{3-}\ (aq) + Mn^{6+}\ (aq)$$

What is the balanced oxidation half reaction?

$\boxed{E}$

$12e^{-} + P_4(s) \rightarrow 4P^{3-}(aq)$ (reduction)

$Mn(s) \rightarrow Mn^{6+}(aq) + 6e^{-}$ (oxidation)

A. P_4 (s) + 3 e^{-} → P^{3-} (aq)
B. P_4 (s) → P^{3-} (aq) + 3 e^{-}
C. P_4 (s) → 4 P^{3-} (aq) + 12 e^{-}
D. P_4 (s) + 12 e^{-} → 4 P^{3-} (aq)
E. Mn (s) → Mn^{6+} (aq) + 6 e^{-}
F. Mn (s) + 6 e^{-} → Mn^{6+} (aq)

28. A 500. mL sample of octane (C_8H_{18}) combusts with excess oxygen according to the **unbalanced** reaction below. If the density of octane is 0.70 g/mL, how many grams of carbon dioxide are produced? Report your answer in **standard notation**.

$$\underline{\ 2\ }\ C_8H_{18}\ (l) + \underline{\ 25\ }\ O_2\ (g) \rightarrow \underline{\ 16\ }\ CO_2\ (g) + \underline{\ 18\ }\ H_2O\ (g)$$

$\boxed{1100}$ g

$d = m/v$

$0.70\ g/mL = \dfrac{m}{500.\ mL} \rightarrow m = 350\ g$ (2 SF)

$$350\ g \left(\frac{mol}{114.26\ g}\ C_8H_{18}\right)\left(\frac{16\ mol\ CO_2}{2\ mol\ C_8H_{18}}\right)\left(\frac{44.01\ g}{mol}\right)$$

2 SF

29. A rod of 150. g of pure iron is exposed to air and rusts due to the presence of oxygen. How many grams of rust (iron(III) oxide) are produced? Report your answer in **standard notation**.

$\boxed{214}$ g

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

$$150.\ g\ Fe \left(\frac{mol}{55.85\ g}\ Fe\right)\left(\frac{2\ mol\ Fe_2O_3}{4\ mol\ Fe}\right)\left(\frac{155.65\ g}{mol}\ Fe_2O_3\right)$$

3 SF

30. When 8.00×10^{22} molecules of ammonia react with an excess of oxygen according to the balanced chemical equation shown below, how many grams of nitrogen gas are produced? Report your answer in **standard notation**.

$$4\ NH_3\ (g) + 3\ O_2\ (g) \rightarrow 2\ N_2\ (g) + 6\ H_2O\ (g)$$

$\boxed{1.86}$ g

$$\left(8.00e22\ \text{molecules}\ NH_3\right)\left(\frac{1\ mol\ NH_3}{6.022e23\ \text{molecules}}\right)\left(\frac{2\ mol\ N_2}{4\ mol\ NH_3}\right)\left(\frac{28.02\ g}{mol}\ N_2\right)$$

31. Consider the following balanced reaction below. How many moles of oxygen are required to produce 2.33 moles of water? Assume that there is excess C_3H_7SH present. Report your answer in **standard notation**.

$$C_3H_7SH\ (l) + 6\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + SO_2\ (g) + 4\ H_2O\ (g)$$

$\boxed{3.50}$ moles

$$2.33 \text{ mol } H_2O \left(\frac{6 \text{ mol } O_2}{4 \text{ mol } H_2O}\right)$$

32. Consider a reaction in which 23.00 g of gaseous dinitrogen tetrahydride reacts with excess gaseous dinitrogen tetroxide to form gaseous nitrogen and gaseous water. In this scenario, how many **total atoms** of the products will form? Report your answer in **scientific notation**.

Hint: remember to find the total number of atoms for **both** products.

$\boxed{3.888} \times 10^{\boxed{24}}$ atoms

$$2\ N_2H_4\ (g) + N_2O_4\ (g) \rightarrow 3\ N_2\ (g) + 4\ H_2O\ (g)$$

$$23.00 \text{ g } N_2H_4 \times \left(\frac{\text{mol}}{32.06 \text{ g}}\right) \times \left(\frac{3 \text{ mol } N_2}{2 \text{ mol } N_2H_4}\right) \times \left(\frac{6.022e23 \text{ molecules}}{1 \text{ mol}}\right) \times \left(\frac{2 \text{ atoms}}{1\ N_2 \text{ molecule}}\right) = 1.29\underline{6}06 36e24 \text{ atoms}$$

$$23.00 \text{ g } N_2H_4 \times \left(\frac{\text{mol}}{32.06 \text{ g}}\right) \times \left(\frac{4 \text{ mol } H_2O}{2 \text{ mol } N_2H_4}\right) \times \left(\frac{6.022e23 \text{ molecules}}{1 \text{ mol}}\right) \times \left(\frac{3 \text{ atoms}}{1\ H_2O \text{ molecule}}\right) = 2.59\underline{2}1273e24 \text{ atoms}$$

Sum:

$$(1.29\underline{6}0636e24 \text{ atoms}) + (2.59\underline{2}1273e24 \text{ atoms})$$

33. If 0.50 moles of nitrogen gas reacts with 0.50 moles of oxygen gas, how many molecules of nitrogen dioxide are produced? Report your answer in **scientific notation**.

$N_2 + 2O_2 \rightarrow 2NO_2$

$\boxed{3.0} \times 10^{\boxed{23}}$ molecules

$0.50 \text{ mol } N_2 \left(\frac{2 \text{ mol } NO_2}{1 \text{ mol } N_2} \right) \left(\frac{6.022e23 \text{ molecules}}{1 \text{ mol } NO_2} \right) = 6.022e23$ molecules

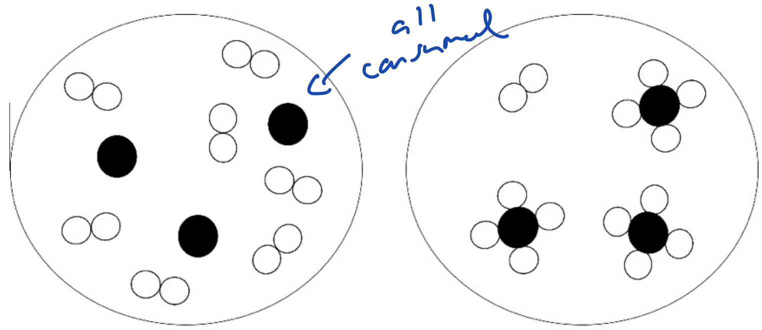
$0.50 \text{ mol } O_2 \left(\frac{2 \text{ mol } NO_2}{2 \text{ mol } O_2} \right) \left(\frac{6.022e23 \text{ molecules}}{1 \text{ mol } NO_2} \right) = 3.011e23$ molecules

↳ limiting

34. The image below shows reactants before a reaction and the products afterward. If black spheres represent carbon and white spheres represent hydrogen, what is the limiting reactant?

$\boxed{B}$

all consumed



Reactants   Products

A. H_2
B. C
C. CH_4

35. What is the percent yield if 65.0 g of methane combusts with excess oxygen according to the balanced reaction below and 62.8 g of water is recovered? Report your answer in **standard notation**.

$$CH_4\ (l) + 2\ O_2\ (g) \rightarrow CO_2\ (g) + 2\ H_2O\ (g)$$

43.0

%

$$65.0\ g \left(\frac{mol\ CH_4}{16.05\ g}\right)\left(\frac{2\ mol\ H_2O}{1\ mol\ CH_4}\right)\left(\frac{18.02\ g}{mol\ H_2O}\right)$$

$= 145.9564$ g H_2O

$$\frac{62.8\ g}{145.9564\ g} \times 100$$

36. A reaction is known to have a low percent yield of 18.29%. If a scientist needs 250.0 g of the product for the next step in their procedure, what theoretical yield (g) should they plan for? Report your answer in **standard notation**.

this is actual yield

1367

g

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

$$18.29 = \frac{250.0\ g}{theor.} \times 100$$

$$0.1829 = \frac{250.0\ g}{theor.}$$

37. A student goes to the lab and synthesizes ZnO (s) according to the balanced equation below. If the reaction was executed using 5.00 grams of ZnS (s) in the presence of excess O_2 (g), how many grams of ZnO (s) did they collect if the percent yield was 23.53 %? Report your answer in **standard notation**.

$$2\ ZnS\ (s) + 3\ O_2\ (g) \rightarrow 2\ ZnO\ (s) + 2\ SO_2\ (g)$$

0.982

g

$$5.00\ g\ ZnS \left(\frac{mol\ ZnS}{97.45\ g}\right)\left(\frac{2\ mol\ ZnO}{2\ mol\ ZnS}\right)\left(\frac{81.38\ g\ ZnO}{mol}\right)(0.2353)$$

Solid sulfur and oxygen gas react to produce sulfur trioxide as shown below. In a particular experiment, 5.0 g of O_2 are reacted with 6.0 g of S_8. Use this information to answer questions 38 and 39 below.

$$S_8\ (s) + 12\ O_2\ (g) \rightarrow 8\ SO_3\ (g)$$

38. If we assume complete consumption of the limiting reactant, what is the identity of the reactant that still remains at the end of the reaction?

$\boxed{B}$ (work below)

A. O_2 → limiting
B. S_8
C. SO_3
D. Impossible to tell from given information

39. What is the % yield of SO_3 in this experiment if 7.9 g of SO_3 are isolated? Report your answer in **standard notation**.

$\boxed{95}$ %

limiting

$$5.0\ g\ O_2 \left(\frac{mol}{32\ g}\ O_2\right)\left(\frac{8\ mol\ SO_3}{12\ mol\ O_2}\right)\left(\frac{80.07\ g\ SO_3}{mol}\right) = 8.\underline{3}4063\ g$$

$$6.0\ g\ S_8 \left(\frac{mol}{256.56\ g}\ S_8\right)\left(\frac{8\ mol\ SO_3}{1\ mol\ S_8}\right)\left(\frac{80.07\ g\ SO_3}{mol}\right) = 1\underline{9}.98036\ g$$

$$\%\ yield = \frac{7.9\ g}{8.\underline{3}4063\ g} \times 100 = 9\underline{4}.7171\ \%$$

40. If 9.0 g of iron is reacted with 9.0 g of water according to the chemical equation shown below, what mass (g) of the excess reactant is leftover? Report your answer in **standard notation** and **two significant figures**.

$$3\ Fe\ (s) + 4\ H_2O\ (l) \rightarrow Fe_3O_4\ (s) + 4\ H_2\ (g)$$

$\boxed{5.1}$ g

$$9.0\ g\ Fe \times \left(\frac{mol}{55.85\ g}\ Fe\right) \times \left(\frac{1\ mol\ Fe_3O_4}{3\ mol\ Fe}\right) \times \left(\frac{231.55\ g}{mol}\right) = 12.43778\ g\ Fe_3O_4$$

$$9.0\ g\ H_2O \times \left(\frac{mol}{18.02\ g}\ H_2O\right) \times \left(\frac{1\ mol\ Fe_3O_4}{4\ mol\ H_2O}\right) \times \left(\frac{231.55\ g}{mol}\right) = 28.91163\ g\ Fe_3O_4$$

1st approach

$$(28.91163\ g - 12.43778\ g)\ Fe_3O_4 \times \left(\frac{mol}{231.55\ g}\ Fe_3O_4\right) \times \left(\frac{4\ mol\ H_2O}{1\ mol\ Fe_3O_4}\right) \times \left(\frac{18.02\ g}{mol}\right) = 5.1\ g\ H_2O$$

2nd approach

$$12.43778\ g\ Fe_3O_4 \times \left(\frac{mol}{231.55\ g}\ Fe_3O_4\right) \times \left(\frac{4\ mol\ H_2O}{1\ mol\ Fe_3O_4}\right) \times \left(\frac{18.02\ g}{mol}\right) = 3.871799\ g\ H_2O$$

(used)

$$\underset{\text{(starting)}}{9.0\ g\ H_2O} - \underset{\text{(used)}}{3.871799\ g\ H_2O} = 5.1\ g\ H_2O$$

* multiple approaches may be taken!

41. Ammonia gas can be produced through the following reaction at high temperature and pressure:

actual yield

$$N_2\ (g) + 3\ H_2\ (g) \rightarrow 2\ NH_3\ (g)$$

A laboratory setup is known to complete this reaction with a percent yield of 23.81%. If 107.9 g of ammonia gas (molar mass = 17.04 g/mol) needs to be produced, how many grams of nitrogen gas (molar mass = 28.02 g/mol) should be introduced to an excess of hydrogen gas?

$\boxed{D}$

$$23.81\ \% = \frac{107.89\ g}{\text{theor.}} \times 100$$

$$0.2381 = \frac{107.89\ g}{\text{theor.}}$$

$$\text{theor.} = 453.12899\ g\ NH_3$$

A. 3.726 g
B. 13.30 g
C. 21.12 g
D. 372.6 g
E. 453.2 g

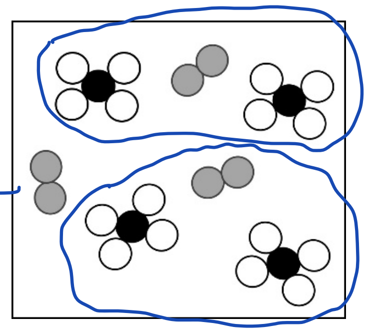
$$453.12899\ g\ NH_3 \times \left(\frac{mol}{17.04\ g}\ NH_3\right) \times \left(\frac{1\ mol\ N_2}{2\ mol\ NH_3}\right) \times \left(\frac{28.02\ g}{mol}\right)$$

42. Methane reacts with chlorine to produce hydrogen and chloromethane according to the chemical equation:

$$2\ CH_4\ (g) + Cl_2\ (g) \rightarrow 2\ CH_3Cl\ (g) + H_2\ (g)$$

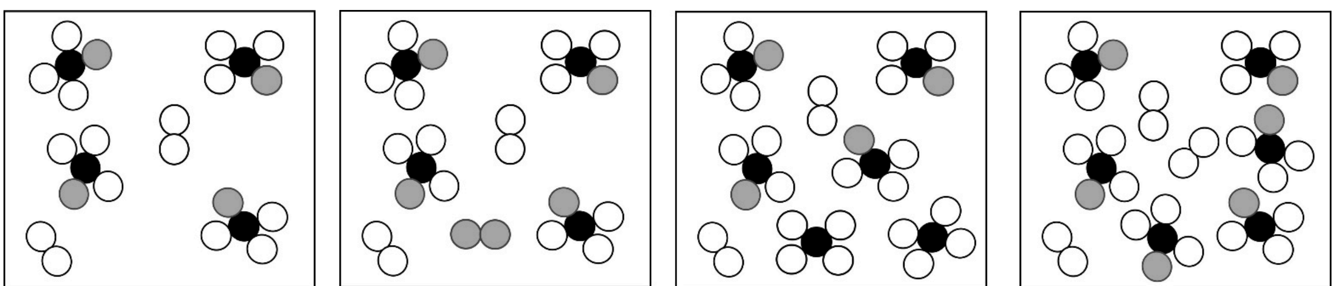
Given the initial reaction mixture shown in the figure (black spheres represent carbon, white spheres represent hydrogen, and gray spheres represent chlorine), which figure best represents the mixture after the reaction has ended?

→ 2 CH₃Cl + H₂



excess ←

→ 2 CH₃Cl + H₂



A B C D

B

43. Cumene is a compound containing only carbon and hydrogen that is used in the production of acetone and phenol in the chemical industry. Combustion of 47.6 mg cumene produces 156.8 mg carbon dioxide and 42.8 mg water. What is the empirical formula of cumene? Answer by listing the chemical formula with the carbon first and then hydrogen (e.g. C_xH_y).

$\boxed{C_3H_4}$

$$156.8 \text{ mg } CO_2 \times \left(\frac{1 \text{ g}}{1000 \text{ mg}}\right) \times \left(\frac{\text{mol } CO_2}{44.01 \text{ g}}\right) \times \left(\frac{1 \text{ mol C}}{1 \text{ mol } CO_2}\right) = 0.0035628 \text{ mol C}$$

$$42.8 \text{ mg } H_2O \times \left(\frac{1 \text{ g}}{1000 \text{ mg}}\right) \times \left(\frac{\text{mol } H_2O}{18.02 \text{ g}}\right) \times \left(\frac{2 \text{ mol H}}{1 \text{ mol } H_2O}\right) = 0.0047502 \text{ mol H}$$

$$0.0035628 \text{ mol C} / 0.0035628 \text{ mol C} = 1 \times 3 = 3$$

$$0.0047502 \text{ mol H} / 0.0035628 \text{ mol C} = 1.33 \times 3 = 4$$

44. Amylose is a carbohydrate and a component of starch, which plants use to store energy. Carbohydrates are so named because they are complex molecules composed of carbon, hydrogen, and oxygen. Combustion analysis of 1.00 g of amylose yields 1.63 g CO_2 and 0.556 g H_2O.

What is the mass of oxygen that was present in the original sample of amylose? Report your answer in **standard notation**.

0.45	g

What is the empirical formula of amylose? Answer by listing the chemical formula with the carbon first, then hydrogen, then oxygen (e.g. $C_xH_yO_z$).

$C_6H_{10}O_5$

$$1.63\ g\ CO_2 \left(\frac{mol\ CO_2}{44.01\ g}\right)\left(\frac{1\ mol\ C}{1\ mol\ CO_2}\right) = 0.03\underline{7}0370\ mol\ C \rightarrow 0.44\underline{4}815\ g\ C$$

$$0.556\ g\ H_2O \left(\frac{mol\ H_2O}{18.02\ g}\right)\left(\frac{2\ mol\ H}{1\ mol\ H_2O}\right) = 0.061\underline{7}052\ mol\ H \rightarrow 0.062\underline{3}263\ g\ H$$

mass of oxygen: $1.00\ g - 0.44\underline{4}815\ g - 0.062\underline{3}263\ g = 0.45\underline{2}855\ g\ O$

$\downarrow$

$0.030\underline{8}037\ mol\ O$

$$0.03\underline{7}0370\ mol\ C / 0.030\underline{8}037\ mol\ O = 1.2 \times 5 = 6$$

$$0.061\underline{7}052\ mol\ H / 0.030\underline{8}037\ mol\ O = 2 \times 5 = 10$$

$$0.030\underline{8}037\ mol\ O / 0.030\underline{8}037\ mol\ O = 1 \times 5 = 5$$

45. A researcher is making 750. mL of a 0.34 M sucrose solution. How many moles of sucrose are required? Report your answer in **standard notation**.

0.26	moles

$M = mol/L$

$$0.34\ M = \frac{mol}{750.\ mL\left(\frac{1}{1000\ mL}\right)}$$

46. How many total ions are in 1.00 L of a 0.175 M solution of K_2CrO_4? (molar mass = 182.94 g/mol)

D

A. 9.57 × 10^{-4}
B. 1.05 × 10^{23}
C. 2.11 × 10^{23}
D. 3.16 × 10^{23}
E. 7.38 × 10^{23}

$$K_2CrO_{4(s)} \xrightarrow{H_2O} \underline{2}K^+_{(aq)} + \underline{1}CrO_{4(aq)}^{2-}$$

$M = mol/L$

$0.175\ M = mol/1.00L \rightarrow 0.175\ mol$

$$0.175\ mol\ K_2CrO_4\left(\frac{6.022e23\ \text{formula units}}{1\ mol}\right)\left(\frac{3\ \text{ions}}{1\ \text{formula unit}}\right)$$

47. How much water will you need to **add** to 500 mL of a 2.50 M KCl solution to prepare a 1.00 M KCl solution?

C

A. 250 mL
B. 500 mL
C. 750 mL
D. 1250 mL
E. 1500 mL

$(500.\ mL)(2.50\ M) = (V_2)(1.00\ M)$

$V_2 = 1250\ mL$

$-500.\ mL$

$750\ mL$

48. How many molecules of sucrose ($C_{12}H_{22}O_{11}$) are contained in 14.3 mL of 0.140 M sucrose solution?

$$0.140\ M = \frac{mol}{\left(14.3\ mL \times \frac{1\ L}{1000\ mL}\right)} \rightarrow 0.002002\ mol$$

$\boxed{A}$

A. 1.21×10^{21} molecules
B. 6.15×10^{22} molecules
C. 1.63×10^{23} molecules
D. 5.90×10^{24} molecules
E. 1.21×10^{22} molecules

$$0.002002\ mol \times \left(\frac{6.022e23\ molecules}{1\ mol}\right)$$

49. What is the concentration of an $AlCl_3$ solution if 150. mL of the solution contains 550. mg of Cl^- ion? Report your answer in **standard notation**.

$\boxed{0.0345}$ M

$$AlCl_{3(s)} \xrightarrow{H_2O} Al^{3+}_{(aq)} + 3Cl^-_{(aq)}$$

$$550.\ mg\left(\frac{1\ g}{1000\ mg}\right)\left(\frac{mol}{35.45\ g\ Cl^-}\right)\left(\frac{1\ mol\ AlCl_3}{3\ mol\ Cl^-}\right)\left(\frac{1}{0.150\ L}\right)$$

50. Determine the total moles of ions in a solution made by diluting 50.0 mL of a 0.874 M solution of sodium carbonate to a total volume of 250. mL. Report your answer in **standard notation**.

$\boxed{0.131}$ moles

$$Na_2CO_{3(s)} \xrightarrow{H_2O} 2Na^+_{(aq)} + 1CO_3^{2-}_{(aq)}$$

$$(50.0\ mL)(0.874\ M) = (250.\ mL)(x) \rightarrow 0.1748\ M$$

$$0.1748\ M = \frac{mol}{0.250\ L} \rightarrow 0.0437\ mol\ Na_2CO_3$$

$$0.0437\ mol\ Na_2CO_3\left(\frac{3\ mol\ ions}{1\ mol\ Na_2CO_3}\right) = 0.1311\ mol$$

51. A solution with a total volume of 1000.0 mL contains 37.1 g $Mg(NO_3)_2$ [MW = 148.33 g/mol].

If 20.0 mL of this solution is removed, placed in a new flask, and then diluted with water until the new volume equals 500.0 mL, what is the concentration of nitrate ion? Report your answer in **standard notation**.

0.0200

M

$$37.1\ g\ Mg(NO_3)_2 \times \left(\frac{mol}{148.33\ g}\right) \times \left(\frac{1}{1.0000\ L}\right) = 0.250118\ M\ Mg(NO_3)_2$$

$$(20.0\ mL)(0.250118\ M) = (500.00\ mL)(M_2)$$

$$M_2 = 0.010005\ M\ Mg(NO_3)_2$$

$$\frac{0.010005\ mol\ Mg(NO_3)_2}{L} \times \frac{2\ mol\ NO_3^-}{1\ mol\ Mg(NO_3)_2} = 0.020009\ M\ NO_3^-$$

52. Which of the following solutions will have the **highest molarity of chloride ions** after being diluted to a total volume of 1.0 L?

D

A. 100.0 mL of 0.30 M $AlCl_3$
B. 150.0 mL of 0.15 M $AlCl_3$
C. 50.0 mL of 0.60 M $AlCl_3$
D. 200.0 mL of 0.40 M $AlCl_3$

$$(0.1000\ L)(0.30\ M) = (1.0\ L)(M_2) \rightarrow M_2 = 0.030\ M\ AlCl_3 \xrightarrow{\times 3} 0.090\ M\ Cl^-$$

$$(0.1500\ L)(0.15\ M) = (1.0\ L)(M_2) \rightarrow M_2 = 0.0225\ M\ AlCl_3 \xrightarrow{\times 3} 0.0675\ M\ Cl^-$$

$$(0.0500\ L)(0.60\ M) = (1.0\ L)(M_2) \rightarrow M_2 = 0.030\ M\ AlCl_3 \xrightarrow{\times 3} 0.090\ M\ Cl^-$$

$$(0.2000\ L)(0.40\ M) = (1.0\ L)(M_2) \rightarrow M_2 = 0.080\ M\ AlCl_3 \xrightarrow{\times 3} 0.24\ M\ Cl^-$$

53. A solution of 100. mL of 0.400 M KNO_3 and a solution of 200. mL of 0.500 M $Mg(NO_3)_2$ are combined. What is the concentration of the nitrate ion in the resulting solution?

$\boxed{E}$

A. 0.333 M
B. 0.133 M
C. 0.450 M
D. 0.467 M
E. 0.800 M

$0.400\ M = \frac{mol}{0.100\ L} \rightarrow 0.0400\ mol\ KNO_3$

$0.0400\ mol\ KNO_3 \times \left(\frac{1\ mol\ NO_3^-}{1\ mol\ KNO_3}\right) = 0.0400\ mol\ NO_3^-$

$0.500\ M = \frac{mol}{0.200\ L} \rightarrow 0.100\ mol\ Mg(NO_3)_2$

$0.100\ mol\ Mg(NO_3)_2 \times \left(\frac{2\ mol\ NO_3^-}{1\ mol\ Mg(NO_3)_2}\right) = 0.200\ mol\ NO_3^-$

sum of NO_3^- : $0.0400\ mol\ NO_3^- + 0.200\ mol\ NO_3^- = 0.240\ mol\ NO_3^-$

$M = \frac{0.240\ mol\ NO_3^-}{0.300\ L} = 0.800\ M\ NO_3^-$

54. How many liters of a 2.0 M H_3PO_4 solution are required to react with 7.25 g of Zn? Start by balancing the equation below. Report your answer in **standard notation**.

_2_ H_3PO_4 (aq) + _3_ Zn (s) → _1_ $Zn_3(PO_4)_2$ (aq) + _3_ H_2 (g)

$\boxed{0.037}$ L

$7.25\ g\ Zn \times \left(\frac{mol}{65.38\ g\ Zn}\right) \times \left(\frac{2\ mol\ H_3PO_4}{3\ mol\ Zn}\right) = 0.0739268\ mol\ H_3PO_4$

$M = mol/L$

$2.0\ M = 0.0739268\ mol / L \rightarrow 0.037\ L$

55. Approximately 6.159 grams of an unknown metal chloride compound (MCl) is dissolved in water, and then precipitated out with 106.4 mL of 0.3015 M $AgNO_3$ solution. Assuming the equation provided below is balanced, determine the mass percent of chlorine. Report your answer in **standard notation**.

$$MCl\ (aq) + AgNO_3\ (aq) \rightarrow AgCl\ (s) + MNO_3\ (aq)$$

$\boxed{18.46}$ %

$M = \frac{mol}{L} \rightarrow 0.3015\ M = \frac{mol}{0.1064\ L} \rightarrow 0.0320796\ mol\ AgNO_3$

$0.0320796\ mol\ AgNO_3 \times \left(\frac{1\ mol\ MCl}{1\ mol\ AgNO_3}\right) \times \left(\frac{1\ mol\ Cl^-}{1\ mol\ MCl}\right) \times \left(\frac{35.45\ g\ Cl^-}{mol}\right)$

$= 1.13722182\ g\ Cl^-$

$\frac{1.13722182\ g\ Cl^-}{6.159\ g\ sample} \times 100 = 18.4673906\ \%$

56. If 30.00 mL of a 0.500 M K_2SO_4 solution is mixed with 20.00 mL of a 0.400 M $Pb(C_2H_3O_2)_2$ solution, and 1.813 grams of solid are collected, what is the percent yield of the reaction? Start by balancing the equation below. Report your answer in **standard notation**.

actual yield

$$\underline{\ 1\ }\ K_2SO_4\ (aq) + \underline{\ 1\ }\ Pb(C_2H_3O_2)_2\ (aq) \rightarrow \underline{\ 2\ }\ KC_2H_3O_2\ (aq) + \underline{\ 1\ }\ PbSO_4\ (s)$$

$\boxed{74.7}$ %

$M = \frac{mol}{L} \rightarrow 0.500\ M = \frac{mol}{0.03000\ L} \rightarrow 0.0150\ mol\ K_2SO_4$

$M = \frac{mol}{L} \rightarrow 0.400\ M = \frac{mol}{0.02000\ L} \rightarrow 0.00800\ mol\ Pb(C_2H_3O_2)_2$

$0.0150\ mol\ K_2SO_4 \times \left(\frac{1\ mol\ PbSO_4}{1\ mol\ K_2SO_4}\right) \times \left(\frac{303.27\ g}{mol}\right) = 4.54905\ g$

$0.00800\ mol\ Pb(C_2H_3O_2)_2 \times \left(\frac{1\ mol\ PbSO_4}{1\ mol\ Pb(C_2H_3O_2)_2}\right) \times \left(\frac{303.27\ g}{mol}\right) = 2.42616\ g$

limiting

$\%\ yield = \frac{1.813\ g}{2.42616\ g} \times 100$

57. A student finds an unknown bottle of solid. Based on the worn-out label, they at least know the bottle contains a hydroxide ion and an alkali metal.

To determine the bottle's identity, they dissolve 17.422 grams of the solid in water, and then neutralize the bottle's contents using 34.00 mL of 5.00 M HCl solution. Assuming the equation provided below is balanced, what is the most probable alkali metal ("M") in the unknown compound?

$$MOH\ (aq) + HCl\ (aq) \rightarrow MCl\ (aq) + H_2O\ (l)$$

$\boxed{D}$

$5.00 \text{ mol/L HCl} \, (0.03400 \text{ L}) \left(\frac{1 \text{ mol MOH}}{1 \text{ mol HCl}} \right) = 0.170 \text{ mol MOH}$

A. Li^+
B. Na^+
C. K^+
D. Rb^+
E. Cs^+

molar mass MOH $= \frac{17.422 \text{ g}}{0.170 \text{ mol}} = 102.482 \text{ g/mol}$

$102.482 \text{ g/mol} - \underbrace{17.01 \text{ g/mol}}_{\text{molar mass OH}} = \underbrace{85.47 \text{ g/mol}}_{\text{molar mass Rb}}$

58. A student places 2.80 g of phosphoric acid (H_3PO_4) [MW = 98.00 g/mol] into 150.0 mL of a 1.00 M sodium hydroxide (NaOH) solution. What are the concentrations of the ions given below after the reaction goes to completion, if the total volume remains constant? * Report your answers in **standard notation** and to **three significant figures**.

$[Na^+]$ = $\boxed{1.00}$ M

$[PO_4^{3-}]$ = $\boxed{0.190}$ M

$[OH^-]$ = $\boxed{0.429}$ M

$[H^+]$ = $\boxed{0.00}$ M

for NaOH,

$M = mol/L$

$1.00\ M = mol / 0.1500\ L$

0.1500 mol NaOH

(used below)

formula

$$H_3PO_{4(aq)} + 3NaOH_{(aq)} \rightarrow Na_3PO_{4(aq)} + 3H_2O_{(l)}$$

total

$$3H^+_{(aq)} + PO_4^{3-}{}_{(aq)} + 3Na^+_{(aq)} + 3OH^-_{(aq)} \rightarrow 3Na^+_{(aq)} + PO_4^{3-}{}_{(aq)} + 3H_2O_{(l)}$$

net

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

spectators: Na^+, PO_4^{3-}

$$2.80\ g\ H_3PO_4 \times \left(\frac{mol}{98.00\ g}\right)\left(\frac{1\ mol\ Na_3PO_4}{1\ mol\ H_3PO_4}\right) = 0.028\underline{5}714\ mol\ Na_3PO_4$$

↳ limiting

$$0.15\underline{0}0\ mol\ NaOH \times \left(\frac{1\ mol\ Na_3PO_4}{3\ mol\ NaOH}\right) = 0.05\underline{0}0\ mol\ Na_3PO_4$$

↳ excess

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for OH^-, excess reactant that is <u>not</u> a spectator

0.0500 mol − 0.0285714 mol = 0.0214286 mol Na_3PO_4

$$0.0214286 \text{ mol } Na_3PO_4 \times \left(\frac{3 \text{ mol } NaOH}{1 \text{ mol } Na_3PO_4}\right) \times \left(\frac{1 \text{ mol } OH^-}{1 \text{ mol } NaOH}\right) = 0.0642858 \text{ mol } OH^-$$

$$M = \frac{0.0642858 \text{ mol } OH^-}{0.1500 \text{ L}} = \boxed{0.429 \text{ M} = [OH^-]}$$

for PO_4^{3-} (spectator),

$$2.80 \text{ g } H_3PO_4 \times \left(\frac{\text{mol}}{98.00 \text{ g}}\right)\left(\frac{1 \text{ mol } PO_4^{3-}}{1 \text{ mol } H_3PO_4}\right) = 0.0285714 \text{ mol } PO_4^{3-}$$

$$M = \frac{\text{mol}}{\text{L}} = \frac{0.0285714 \text{ mol } PO_4^{3-}}{0.1500 \text{ L}} = \boxed{0.190 \text{ M} = [PO_4^{3-}]}$$

for Na^+ (spectator),

we start with 150.0 mL of 1.00 M NaOH. upon addition of H_3PO_4, the volume remains constant, so the concentration of NaOH will not change:

$$1.00 \text{ M NaOH} \rightarrow \frac{1.00 \text{ mol NaOH}}{\text{L}} \cdot \frac{1 \text{ mol } Na^+}{1 \text{ mol NaOH}} = \boxed{1.00 \text{ M} = [Na^+]}$$

for $[H^+]$,

H_3PO_4 is limiting, and H^+ is not a spectator, so its final concentration is: $\boxed{0.00 \text{ M} = [H^+]}$

Total volume = 73.9 mL

59. Consider the balanced reaction below in which 52.0 mL of 2.35 M $AgNO_3$ was added to 21.9 mL of 4.60 M NaCl. What are the concentrations of the ions given below after the reaction goes to completion? States of matter have been omitted from the reaction below. Report your answers in **standard notation** and to **three significant figures**.

$$AgNO_{3\,(aq)} + NaCl_{(aq)} \rightarrow NaNO_{3\,(aq)} + AgCl_{(s)}$$

$[Ag^+]$ = $\boxed{0.290}$ M

$[NO_3^-]$ = $\boxed{1.65}$ M

$[Na^+]$ = $\boxed{1.36}$ M

$[Cl^-]$ = $\boxed{0.00}$ M

for $AgNO_3$,
$M = mol/L \rightarrow 2.35\ M = \frac{mol}{0.0520\ L}$
$\downarrow$
0.1222 mol $AgNO_3$

for NaCl,
$M = mol/L \rightarrow 4.60\ M = \frac{mol}{0.0219\ L}$
$\downarrow$
0.10074 mol NaCl

total: $Ag^+_{(aq)} + NO_{3\,(aq)}^- + Na^+_{(aq)} + Cl^-_{(aq)} \rightarrow Na^+_{(aq)} + NO^-_{3\,(aq)} + AgCl_{(s)}$

net: $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

spectators: Na^+, NO_3^-

$0.1222\ mol\ AgNO_3 \times \left(\frac{1\ mol\ AgCl}{1\ mol\ AgNO_3}\right) = 0.1222\ mol\ AgCl$

↳ excess

$0.10074\ mol\ NaCl \times \left(\frac{1\ mol\ AgCl}{1\ mol\ NaCl}\right) = 0.10074\ mol\ AgCl$

↳ limiting

for Cl^-,
limiting, and not a spectator, so $\boxed{[Cl^-] = 0.00\ M}$

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for Ag^+, excess, and not a spectator,

0.1222 mol AgCl − 0.10074 mol AgCl = 0.02146 mol AgCl

$$0.02146 \text{ mol AgCl} \times \left(\frac{1 \text{ mol } AgNO_3}{1 \text{ mol AgCl}}\right) \times \left(\frac{1 \text{ mol } Ag^+}{1 \text{ mol } AgNO_3}\right) = 0.02146 \text{ mol } Ag^+$$

$$[Ag^+] = \frac{0.02146 \text{ mol } Ag^+}{0.0739 \text{ L}} = \boxed{0.290 \text{ M } Ag^+}$$

for Na^+ (spectator ion),

$(21.9 \text{ mL})(4.60 \text{ M}) = (73.9 \text{ mL})(M_2)$

$M_2 = 1.36319$ M NaCl

$$1.36319 \text{ M NaCl} \times \left(\frac{1 \text{ mol } Na^+}{1 \text{ mol NaCl}}\right) = \boxed{1.36 \text{ M } Na^+}$$

for NO_3^- (spectator ion),

$(52.0 \text{ mL})(2.35 \text{ M}) = (73.9 \text{ mL})(M_2)$

$M_2 = 1.65359$ M $AgNO_3$

$$1.65359 \text{ M } AgNO_3 \times \left(\frac{1 \text{ mol } Ag^+}{1 \text{ mol } AgNO_3}\right) = \boxed{1.65 \text{ M } NO_3^-}$$

60. A 0.0500 L sample of 2.00 M HCl is neutralized with 0.0500 L of $Ba(OH)_2$, according to the balanced equation below.

$$2\ HCl\ (aq) + Ba(OH)_2\ (aq) \rightarrow 2H_2O\ (l) + BaCl_2\ (aq)$$

Based on this information, what is the initial concentration of $Ba(OH)_2$?

$\boxed{B}$

for HCl,

$M = mol/L \rightarrow 2.00\ M = \frac{mol}{0.0500\ L} \rightarrow 0.100\ mol\ HCl$

$0.100\ mol\ HCl \times \left(\frac{1\ mol\ Ba(OH)_2}{2\ mol\ HCl}\right) = 0.0500\ mol\ Ba(OH)_2$

for $Ba(OH)_2$,

$M = \frac{0.0500\ mol}{0.0500\ L} = 1.00\ M$

A. 0.500 M
B. 1.00 M
C. 1.50 M
D. 2.00 M
E. 2.50 M

61. What volume (in mL) of a 0.185 M solution of sulfuric acid is needed to neutralize 35.0 mL of a 0.215 M solution of potassium hydroxide? Report your answer in **standard notation**.

$\boxed{20.3}$ mL

$H_2SO_4\ (aq) + 2\ KOH\ (aq) \rightarrow K_2SO_4\ (aq) + 2H_2O$

$0.215\ M = \frac{mol}{(35.0\ mL / 1000\ mL)\ L} \rightarrow 0.007525\ mol\ KOH$

$0.007525\ mol\ KOH \left(\frac{1\ mol\ H_2SO_4}{2\ mol\ KOH}\right)\left(\frac{L}{0.185\ mol\ H_2SO_4}\right)\left(\frac{1000\ mL}{1\ L}\right)$

62. Of the following, which is a state function? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

AD

A. Enthalpy
B. Heat
C. Work
D. Internal Energy
E. None of the above

63. Which of the following statements about energy is/are **true**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

BC

A. The energy stored in bonds is a type of kinetic energy (potential)
B. Thermal energy is a type of kinetic energy
C. A reaction that releases heat is considered exothermic
D. None of the above are true

64. Which of the following are forms of **kinetic** energy? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

AD

A. The energy associated with random molecular motion
B. The energy stored in chemical bonds
C. The energy of a stretched spring
D. The energy of a ball rolling down a hill
E. The energy resulting from position, composition, or condition

65. The combustion of liquid hydrogen and liquid oxygen produces water vapor to propel a rocket into space. Which of the following would a chemist most likely define as part of the system? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

ABC

A. $H_2(l)$
B. $O_2(l)$
C. $H_2O(g)$
D. The fuel tank
E. The rocket
F. The atmosphere around the rocket
G. The Earth

66. What is *true* about heat but *false* about work?

D

A. The SI unit is the joule
B. It is a force acting over a distance
C. It is one of the ways internal energy can be exchanged
D. It is the transfer of thermal energy due to a temperature difference
E. More than one of the above is true about heat but false about work

67. A student is making popcorn on the stove but wants to practice their thermochemistry definitions. The popcorn container starts to expand as the stovetop heats it (like in the picture below). The student says that, for the system, q = +52 J and w = -18 J. What have they likely defined as the system?

A

A. The popcorn container
B. The stove top
C. The kitchen
D. The house

68. Which of the following reactions **would not** result in pressure-volume work by either the system or the surroundings? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

CD

A. C_3H_4 (g) + 2 H_2 (g) → C_3H_8 (g) 3 mol (g) → 1 mol (g)

B. 2 H_2 (g) + O_2 (g) → 2 H_2O (l) 3 mol (g) → 0 mol (g)

C. 2 C_3H_4 (g) + 8 O_2 (g) → 6 CO_2 (g) + 4 H_2O (g) 10 mol (g) → 10 mol (g)

D. Fe_2O_3 (s) + 3 CO (g) → 2 Fe (s) + 3 CO_2 (g) 3 mol (g) → 3 mol (g)

E. 2 NH_3 (g) → N_2 (g) + 3 H_2 (g) 2 mol (g) → 4 mol (g)

F. All of the reactions listed would result in pressure-volume work

69. Which of the following reactions **would** result in pressure-volume work by either the system or the surroundings? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

BC

A. 2 NaCl (aq) + $Pb(NO_3)_2$ (aq) → 2 $NaNO_3$ (aq) + $PbCl_2$ (s) 0 mol (g) → 0 mol (g)

B. 2 C_8H_{18} (l) + 25 O_2 (g) → 16 CO_2 (g) + 18 H_2O (g) 25 mol (g) → 34 mol (g)

C. I_2 (s) → I_2 (g) 0 mol (g) → 1 mol (g)

D. CH_4 (g) + F_2 (g) → CH_2F_2 (g) + H_2 (g) 2 mol (g) → 2 mol (g)

E. C_2H_5OH (s) → C_2H_5OH (l) 0 mol (g) → 0 mol (g)

70. A student goes to the lab and performs a synthesis reaction in a large round bottom flask. The last step of the synthesis involves heating the reaction to a high temperature, and then allowing it to cool down to room temperature. To expedite the process, they decide to submerge the flask in a liquid solvent to facilitate heat transfer from the flask to the solvent.

Given the information below, which of the following would be most efficient at cooling the flask?

Solvent	Molar mass (g/mol)	Specific heat (kJ/kg·K)
Propylene glycol	76.09	2.50
Methanol	32.04	2.51
Ethanol	46.07	2.85

E

A. Propylene glycol because it has the lowest specific heat
B. Propylene glycol because it has the highest molar mass
C. Either propylene glycol or methanol because they both have similar specific heats that are both the lowest in the table
D. Methanol because it has a very low specific heat and the lowest molar mass
E. Ethanol because it has the highest specific heat

71. If 100. g of each of the following metals is heated to 100°C and placed in a coffee-cup calorimeter, which metal would cause the **lowest** rise in temperature?

C

A. Sn: 0.218 J/g·°C

B. Ag: 0.239 J/g·°C

C. Au: 0.126 J/g·°C

smallest heat capacity

D. Al: 0.921 J/g·°C

→ positive

72. A hot air balloon is filled with gas. Upon absorbing 934 J of heat, the gas expands, performing 478 J of work. What is the change in internal energy in Joules?

→ negative

$\boxed{C}$

$$\Delta E = q + w$$
$$= 934\ J + (-478\ J)$$

A. 1412 J
B. -456 J
C. 456 J
D. -1412 J

73. What is **true** about enthalpy?

$\boxed{B}$

A. It is path-dependent
B. It is equal to the heat exchanged at a constant pressure
C. It is equal to the heat exchanged at a constant volume
D. It is always a positive value

74. A piece of copper metal with a mass of 150. g is placed into a refrigerator. If the initial temperature of the metal was 23.0°C, and it is cooled to 5.0°C, how much heat (kJ) did the refrigerator absorb? The specific heat of copper is 0.380 J/g·K.

°C = K

$\boxed{C}$

$$q = mc\Delta T$$
$$= (150.\ g)(0.380\ J/g\cdot K)(5.0°C - 23.0°C)$$
$$= -1.026e3\ J$$
$$= -1.026\ kJ \rightarrow \text{copper lost this}$$

A. 7.11 kJ
B. -1.03 kJ
C. 1.03 kJ
D. 790. kJ
E. -790. kJ

refrigerator gained this

75. A technician goes to the lab and finds a 1252 g block of metal that has been heated to 157.2 °C. Over the duration of some time, the block loses 1.53 kJ of energy. What is the new temperature after this change in energy has occurred? The specific heat of the metal is 0.279 J/g·°C.

$q = mc\Delta T$

$\boxed{B}$ $-1.53\ kJ \left(\frac{1000\ J}{1\ kJ}\right) = 1252\ g\ (0.279\ J/g\cdot{}^\circ C)(T_F - 157.2^\circ C)$

$T_F = 152.8\ ^\circ C$

A. 161.6 °C
B. 152.8 °C
C. 143.3 °C
D. 135.6 °C
E. 157.2 °C (negligible change)

76. A solution of 50.0 mL of sodium hydroxide (d = 1.10 g/mL) absorbs 1712 J of heat. If sodium hydroxide has a specific heat of 4.10 J/g·°C, how many degrees will the temperature of the solution go up? Report your answer in **standard notation**.

$\boxed{7.59}$ °C

$q = mc\Delta T$

$1712\ J = (50.0\ mL)(1.10\ g/mL)(4.10\ J/g\cdot{}^\circ C)(\Delta T)$

$\Delta T = 7.59\ ^\circ C$

77. A 20.0 g block of aluminum is heated to 75.0°C and is then placed on a 10.0 g sheet of copper at room temperature (22.0°C). The specific heat capacity for aluminum is 0.900 J/g·°C and the specific heat capacity for copper is 0.385 J/g·°C. What is the final temperature of the aluminum assuming that no heat is lost to the surroundings? Report your answer in **standard notation**.

$\boxed{65.7}$ °C

$$q_{Al} = -q_{Cu}$$

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

$$(20.0\,g)(0.900\,J/g°C)(T_F - 75.0°C) = -(10.0\,g)(0.385\,J/g°C)(T_F - 22.0°C)$$

$$(18.0\,J/°C)(T_F) - 1350\,J = (-3.85\,J/°C)(T_F) + 84.7\,J$$

$$(21.85\,J/°C)(T_F) = 1434.7\,J$$

$$T_F = 65.7\,°C$$

78. The value of ΔH° for the reaction below is -3351 kJ. The value of $\Delta H°_f$ for Al_2O_3(s) is ________ kJ. Report your answer in **standard notation**.

standard enthalpy of formation

$$2\,Al\,(s) + 3\,O_2\,(g) \rightarrow 2\,Al_2O_3\,(s)$$

reduce to 1 mole of product

$\boxed{-1676}$ kJ

$$\frac{-3351\,kJ}{2}$$

79. Hydrogen gas and bromine gas react to form hydrogen bromide gas. How much heat is exchanged (in kJ) when 155 grams of HBr (MW = 80.91 g/mol) is formed in this reaction? Report your answer in **standard notation**.

$$H_2\,(g) + Br_2\,(g) \rightarrow 2\,HBr\,(g) \qquad \Delta_rH° = -72\text{ kJ/mol}$$

$\boxed{-69}$ kJ

$155\text{ g HBr}\left(\frac{\text{mol}}{80.91\text{ g}}\text{HBr}\right)\left(-\frac{72\text{ kJ}}{2\text{ mol}}\right)$

80. A student goes to the lab to perform the balanced reaction below using 7.22 g of highly reactive potassium metal and 14.59 mL iodine monochloride (d = 3.24 g/cm^3). Upon completion, how much heat is exchanged in this reaction? Report your answer in **standard notation**.

m = 47.2716 g

$$2\,K\,(s) + ICl\,(l) \rightarrow KCl\,(s) + KI\,(s) \qquad \Delta_rH° = -65.2\text{ kJ/mol}$$

$\boxed{-6.02}$ kJ

$7.22\text{ g K}\left(\frac{\text{mol}}{39.10\text{ g}}\right)\left(\frac{1\text{ mol KCl}}{2\text{ mol K}}\right) = 0.0923274\text{ mol KCl}$
(limiting)

$47.2716\text{ g ICl}\left(\frac{\text{mol}}{162.35\text{ g}}\text{ICl}\right)\left(\frac{1\text{ mol KCl}}{1\text{ mol ICl}}\right) = 0.291171\text{ mol KCl}$

$0.0923274\text{ mol KCl} \times \left(-\frac{65.2\text{ kJ}}{\text{mol}}\right)$
(limiting)

81. What is **false** about a coffee-cup calorimeter?

$\boxed{C}$

A. It is a form of constant-pressure calorimetry
B. Any heat change by the system is equal but opposite to the heat change of the calorimeter
C. The heat exchanged measured must have correction made for PV work before the enthalpy can be calculated
D. The heat exchanged is equal to the enthalpy change
E. More than one of the above is false

82. Sodium chloride absorbs 3.6 kJ of heat per mole that is dissolved in water. If 29.0 g of NaCl is dissolved in a coffee cup calorimeter with an initial temperature of 22.4°C, what will the final temperature (°C) of the calorimeter be? Assume the total mass of the solution is 150. g, and the specific heat of the calorimeter is 4.18 J/g·°C. Report your answer in **standard notation**.

$\boxed{19.6}$ °C

$29.0 \text{ g NaCl} \times \left(\frac{\text{mol}}{58.44 \text{ g}}\right)\left(\frac{3.6 \text{ kJ}}{\text{mol}}\right) = 1.78645 \text{ kJ} \rightarrow 1.78645e3 \text{ J}$

$-q_{cal} = q_{rxn}$

$q_{cal} = mC\Delta T$

$-1.78645e3 \text{ J} = (150. \text{ g})(4.18 \text{ J/g°C})(T_F - 22.4\text{°C})$

$-1.78645e3 \text{ J} = (627 \text{ J/°C})(T_F) - (1.40448e4 \text{ J})$

$\boxed{T_F = 19.6\text{°C}}$

83. A coffee cup calorimeter initially contains 150. g of water at 25.3°C, and 11.2 g of potassium bromide is added to the water. After the potassium bromide dissolves, the final temperature is 20.1°C. Calculate the enthalpy change for dissolving the salt in J/g of potassium bromide. Assume the specific heat capacity of the solution is 4.18 J/g·°C, the final mass of the solution is the combined mass of solute and solvent, and that no heat is transferred to the surroundings or to the calorimeter. Report your answer in **standard notation**.

310	J/g

$q_{cal} = mC\Delta T$

$= (150.\ g + 11.2\ g)(4.18\ J/g\,°C)(20.1 - 25.3\ °C)$

$= (161.2\ g)(4.18\ J/g\,°C)(-5.2\ °C)$

$= -3503.8432\ J$

$q_{cal} = -q_{rxn}$

$q_{rxn} = +3503.8432\ J$

$q_{rxn}\ (\text{in } J/g) = +3503.8432\ J / 11.2\ g = 312.843\ J/g$

84. An undergraduate student goes to chemistry lab to perform the bomb calorimetry experiment using benzoic acid (q_{comb} = -3225 kJ/mol; molar mass = 122.12 g/mol). They see a temperature change of approximately 4.10 ºC. If the heat capacity of the calorimeter is 12.1 kJ/ºC, what was the starting mass of benzoic acid used (in g)? Report your answer in **standard notation**.

1.88	g

$q_{cal} = C_{cal}\Delta T$

$= (12.1\ kJ/°C)(4.10\ °C)$

$= 49.61\ kJ$

$q_{cal} = -q_{comb}$

$$-49.61\ kJ\left(\frac{mol}{-3225\ kJ}\right)\left(\frac{122.12\ g}{mol}\right) = 1.88\ g$$

85. A 6.16 g sample of benzene (C_6H_6), an organic compound with a q_{comb} = -41.74 kJ per gram of benzene, is combusted in a bomb calorimeter. What will the change in temperature of the bomb calorimeter be (in ºC) if the heat capacity of the calorimeter is 50.4 kJ/K? Report your answer in **standard notation**.

5.10	ºC

$6.16 \text{ g } C_6H_6 \times \left(\frac{-41.74 \text{ kJ}}{\text{g}}\right) = -257.1184 \text{ kJ} \quad (q_{comb.})$

$q_{cal} = -q_{comb.}$

$q_{cal} = (+) 257.1184 \text{ kJ}$

$q_{cal} = C_{cal} \Delta T$

$(+) 257.1184 \text{ kJ} = (50.4 \text{ kJ/K})(\Delta T)$

$\Delta T = 5.10 \text{ K} = 5.10 \text{ °C}$

86. A bomb calorimetry experiment is performed with xylose, $C_5H_{10}O_5$, as the combustible substance. The data obtained are:

Mass of xylose burned: 1.183 g $\times \left(\frac{\text{mol}}{150.15 \text{ g}}\right) = 0.00787879 \text{ mol}$
Heat capacity of calorimeter: 4.728 kJ/ºC
Initial calorimeter temperature: 23.29 ºC
Final calorimeter temperature: 27.19 ºC

Based on this information, what is the heat of combustion of xylose in kJ/mol? Report your answer in **scientific notation**.

-2.34×10^3	kJ/mol

$q_{cal} = C_{cal} \Delta T$

$= (4.728 \text{ kJ/°C})(27.19 \text{ °C} - 23.29 \text{ °C})$

$= (4.728 \text{ kJ/°C})(3.90 \text{ °C})$

$= 18.4392 \text{ kJ}$

$q_{cal} = -q_{comb} \rightarrow q_{comb} = -18.4392 \text{ kJ}$

$q_{comb} \text{ (in kJ/mol)} = \frac{-18.4392 \text{ kJ}}{0.00787879 \text{ mol}} = -2.34036\text{e}3 \text{ kJ/mol}$

87. Given the information below, what is ΔH_{rxn} for:

$$C_3H_4\ (g) + 2\ H_2\ (g) \rightarrow C_3H_8\ (g)$$

$H_2\ (g) + \frac{1}{2}\ O_2\ (g) \rightarrow H_2O\ (l)$	ΔH_{rxn} = -285.8 kJ/mol	x 2
$C_3H_4\ (g) + 4\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 2\ H_2O\ (l)$	ΔH_{rxn} = -1937.0 kJ/mol	keep
$C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (l)$	ΔH_{rxn} = -2219.1 kJ/mol	flip

Report your answer in **standard notation** and **one decimal place**.

$\boxed{-289.5}$ kJ/mol

$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$

$C_3H_4\ (g) + 4O_2\ (g) \rightarrow 3\ CO_2\ (g) + 2\ H_2O\ (l)$

$3\ CO_2\ (g) + 4\ H_2O\ (l) \rightarrow C_3H_8\ (g) + 5O_2\ (g)$

$(2 \times -285.8\ kJ/mol) + (-1937\ kJ/mol) + (+2219.1\ kJ/mol)$

88. Given the information below, what is ΔH_{rxn} for:

$$CH_4\ (g) + NH_3\ (g) \rightarrow HCN\ (g) + 3\ H_2\ (g)?$$

$N_2\ (g) + 3\ H_2\ (g) \rightarrow 2\ NH_3\ (g)$	ΔH_{rxn} = -91.8 kJ/mol	switch; x 1/2
$C\ (s) + 2\ H_2\ (g) \rightarrow CH_4\ (g)$	ΔH_{rxn} = -74.9 kJ/mol	switch
$H_2\ (g) + 2\ C\ (s) + N_2\ (g) \rightarrow 2\ HCN\ (g)$	ΔH_{rxn} = 270.3 kJ/mol	x 1/2

Report your answer in **standard notation** and **one decimal place**.

$\boxed{256.0}$ kJ/mol

$NH_3\ (g) \rightarrow \frac{1}{2}\ N_2\ (g) + \frac{3}{2}\ H_2\ (g)$

$CH_4\ (g) \rightarrow C\ (s) + 2\ H_2\ (g)$

$\frac{1}{2}\ H_2\ (g) + C\ (s) + \frac{1}{2}\ N_2\ (g) \rightarrow HCN\ (g)$

$(+45.9\ kJ/mol) + (+74.9\ kJ/mol) + (135.15\ kJ/mol)$

89. Given the following data:

$2\ ClF\ (g) + O_2\ (g) \rightarrow Cl_2O\ (g) + F_2O\ (g)$	$\Delta H_{rxn} = 167.4$ kJ/mol	$\times \frac{1}{2}$
$2\ ClF_3\ (g) + 2\ O_2\ (g) \rightarrow Cl_2O\ (g) + 3\ F_2O\ (g)$	$\Delta H_{rxn} = 341.4$ kJ/mol	switch ; $\times \frac{1}{2}$
$2\ F_2\ (g) + O_2\ (g) \rightarrow 2\ F_2O\ (g)$	$\Delta H_{rxn} = -43.4$ kJ/mol	$\times \frac{1}{2}$

Calculate ΔH_{rxn} for the following reaction:

$$ClF\ (g) + F_2\ (g) \rightarrow ClF_3\ (g)$$

$\boxed{D}$

A. -217.4 kJ/mol
B. 465.4 kJ/mol
C. -130.6 kJ/mol
D. -108.7 kJ/mol

$ClF\ (g) + \frac{1}{2} O_2\ (g) \rightarrow \frac{1}{2} Cl_2O\ (g) + \frac{1}{2} F_2O\ (g)$

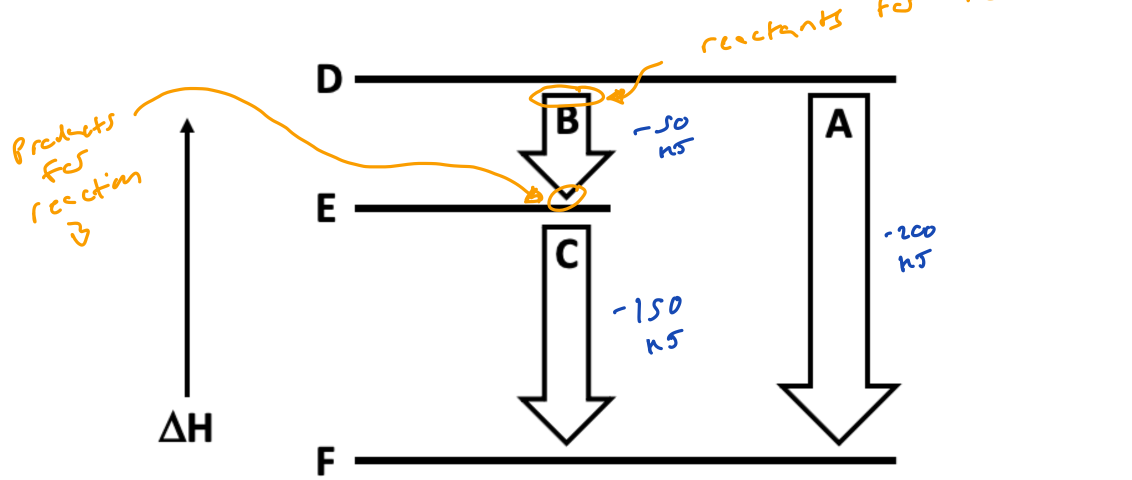
$\frac{3}{2} F_2O\ (g) + \frac{1}{2} Cl_2O\ (g) \rightarrow ClF_3\ (g) + O_2\ (g)$

$F_2\ (g) + \frac{1}{2} O_2\ (g) \rightarrow F_2O\ (g)$

$(167.4\ \text{kJ/mol} \times \frac{1}{2}) + (341.4\ \text{kJ/mol} \times -\frac{1}{2}) +$
$(-43.4\ \text{kJ/mol} \times \frac{1}{2})$

90. Consider the two hypothetical reactions given to yield the net reaction below, in addition to the corresponding Hess's Law diagram.

Reaction 1: $M + X \rightarrow T$ $\Delta H = -50$ kJ
Reaction 2: $T + X \rightarrow Z$ $\Delta H = -150$ kJ
Net Reaction: $M + 2X \rightarrow Z$ $\Delta H = -200$ kJ



Based on the diagram above, Reaction 2 is represented by __________, whereas the reactants M + 2X in the Net Reaction are represented by __________.

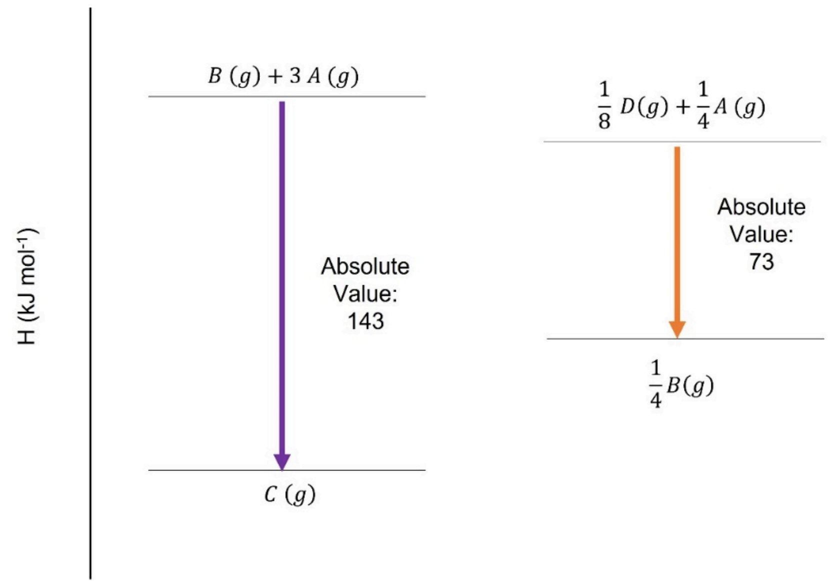
$\boxed{B}$

↓ = negative ΔH

↑ = positive ΔH

A. Arrow A, Line E
B. Arrow C, Line D
C. Arrow B, Line F
D. Arrow A, Line F
E. Arrow C, Line E
F. Arrow B, Line D

91. Given the following hypothetical reactions below...



what is ΔH_{rxn} for the reaction A (g) + 3 B (g) → D (g) + C (g)? Report your answer in **standard notation** and **three significant figures**.

$\boxed{441}$ kJ/mol

$B_{(g)} + 3A_{(g)} \rightarrow C_{(g)}$

switch ×8 $\left(\frac{1}{8} D_{(g)} + \frac{1}{4} A_{(g)} \rightarrow \frac{1}{4} B_{(g)}\right)$

$2B_{(g)} \rightarrow D_{(g)} + 2A_{(g)}$

$B_{(g)} + 3A_{(g)} \rightarrow C_{(g)}$

$A_{(g)} + 3B_{(g)} \rightarrow C_{(g)} + D_{(g)}$

$(-143 \text{ kJ/mol}) + (-8 \times -73 \text{ kJ/mol})$

92. Of the following, $\Delta H°_f$ is **not** zero for ________.

D

A. O_2 (g)
B. C (graphite)
C. N_2 (g)
D. F_2 (s) → F_2 (g)
E. Cl_2 (g)

93. Consider the balanced reactions provided below. Which of the following are standard formation reactions? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

AF

A. C (s, graphite) + 2 H_2 (g) → CH_4 (g)
B. 2 C (s, graphite) + 4 H_2 (g) → 2 CH_4 (g)
C. 2 CO (g) + O_2 (g) → 2 CO_2 (s)
D. CO (g) + ½ O_2 (l) → CO_2 (g)
E. H_2 (g) + ½ O_2 (g) → H_2O (g)
F. H_2 (g) + ½ O_2 (g) → H_2O (l)
G. H_2 (g) + ½ O_2 (l) → H_2O (l)
H. 2 H_2 (g) + O_2 (g) → 2 H_2O (l)
I. CaO (s) + CO_2 (g) → $CaCO_3$ (s)

94. Which of the following is the standard formation reaction of cesium iodide at 298.15 K?

F

iodine in its standard state → I_2 (s)

A. Cs (s) + I (g) → CsI (s)
B. 2 Cs (s) + I_2 (g) → 2 CsI (s)
C. Cs (s) + ½ I_2 (g) → CsI (s)
D. Cs (s) + I (s) → CsI (s)
E. 2 Cs (s) + I_2 (s) → 2 CsI (s)
F. Cs (s) + ½ I_2 (s) → CsI (s)

95. Calculate $\Delta_r H°$ for the reaction below using standard enthalpies of formation provided in the table below. Report your answer in **standard notation** and **one decimal place**.

$\Delta H_f° = 0$

$$4\ NH_3\ (g) + 5\ O_2\ (g) \rightarrow 6\ H_2O\ (g) + 4\ NO\ (g)$$

Substance	$\Delta H°_f$ (kJ/mol)
NH_3 (g)	-45.9
NO (g)	+91.3
H_2O (g)	-241.8

$\boxed{-902.0}$ kJ

$[(6\ mol \times -241.8\ kJ/mol) + (4\ mol \times 91.3\ kJ/mol)]$

$- [(5\ mol \times 0) + (4\ mol \times -45.9\ kJ/mol)]$

96. Calculate $\Delta_r H°$ for the reaction below using standard enthalpies of formation provided in the table below. Report your answer in **standard notation** and **one decimal place**.

$$Fe_2O_3\ (s) + 3\ CO\ (g) \rightarrow 2\ Fe\ (s) + 3\ CO_2\ (g)$$

$\Delta H_f° = 0$

Substance	$\Delta H°_f$ (kJ/mol)
Fe_2O_3 (s)	-824.2
CO (g)	-110.5
CO_2 (g)	-393.5

$\boxed{-24.8}$ kJ

$[(2\ mol \times 0) + (3\ mol \times -393.5\ kJ/mol)]$

$- [(1\ mol \times -824.2\ kJ/mol) + (3\ mol \times -110.5\ kJ/mol)]$

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc [97]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
37 Cs 132.91	56 Ba 137.33		72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra [226]		104 Rf [267]	105 Db [268]	106 Sg [269]	107 Bh [270]	108 Hs [269]	109 Mt [277]	110 Ds [281]	111 Rg [282]	112 Cn [285]	113 Nh [286]	114 Fl [290]	115 Mc [290]	116 Lv [293]	117 Ts [294]	118 Og [294]

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
89 Ac [227]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]

Formula Sheet

Length
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy
1 joule = 1 kg·m^2/s^2
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure
1 pascal = 1 N/m^3 = 1 kg/m·s^2
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in^2
1 bar = 1×10^5 Pa (exactly)

Temperature
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

Mass
1 kg = 2.205 lbs

Volume
1 mL = 1 cm^3 = 1 cc

Constants
c = 2.998×10^8 m/sec
h = 6.626×10^{-34} J·sec
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: 9.109 x 10^{-31} kg
Mass of a proton: 1.673 x 10^{-27} kg
RH = 2.18 x 10^{-18} J
Specific heat of water = 4.184 J/g·K
Avogadro's number: 6.022×10^{23}
F = 96485 J/(V·mol e^-)
$K_w = 1.0 \times 10^{-14}$ at 25 °C
$k_b = 1.381 \times 10^{-23}$ J/K

Equations
$(P + a(n^2/V^2))\cdot(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT

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

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

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

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

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

$C_g = kP_g$
$P_{solution} = P_{solvent}\ X_{solvent}$
$P_{solution} = \sum P_j = \sum P_j X_j$
$\pi = MRTi$

Thermodynamic and Electrochemistry

$S = k_b \times \ln(W)$
$\Delta S = q_{rev}/T$
$\Delta G = \Delta G° + RT \cdot \ln Q$
R=8.314 J/mol.K
$\Delta G° = -RT \cdot \ln K$
$\Delta G = -nFE_{cell}$
$E°_{cell} = RT/nF \ln K$
$E°_{cell} = (0.0257/n) \ln K = (0.0592/n) \log K$
$E_{cell} = E°_{cell} - (RT/nF) \ln Q$
$E_{cell} = E°_{cell} - (0.0257/n) \ln Q$
Electrolysis: Q (total charge) = I × t = n × F

Integrated Rate Laws & half-life

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

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

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

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

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

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

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

Equilibrium and Acid / Base

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

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