

## Lecture 2 CH131 Summer 1

Thursday, May 21, 2020

- Example problems: Chemical formulas, equations, and reaction yields
- Limiting reagent recipe

Next lecture: Limiting reagent recipe; Begin ch3

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[TP] Which contains the most molecules?

- 0% 1. 1 g of  $H_2$  ✓  
 32% 2. 45 g of  $Cl_2$   
 21% 3. 28 g of  $N_2$   
 47% 4. 24 g of  $CH_4$

→ mols

|    |    |
|----|----|
| H  | 1  |
| Cl | 35 |
| N  | 14 |
| C  | 12 |

$$1g \times \frac{mol}{(2 \times 1)g} = 0.5 mol$$

$$45g \times \frac{mol}{(2 \times 35)g} = 0.64$$

$$28g \times \frac{mol}{(2 \times 14)g} = 1.0 mol$$

$$24g \times \frac{mol}{(12 + 4 \times 1)g} = 1.5 mol$$

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## Mass to molecules

Which contains the most molecules?



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## Mass to molecules

Which contains the most molecules?

$$\left\{ \begin{array}{l} 1g \text{ of } H_2: 1g \times \frac{mol}{2g} = 0.5 mol \\ 45g \text{ of } Cl_2: 45g \times \frac{mol}{(2 \times 35)g} = 0.64 mol \\ 28g \text{ of } N_2: 28g \times \frac{mol}{(2 \times 14)g} = 1.0 mol \\ 24g \text{ of } CH_4: 24g \times \frac{mol}{(12 + 4 \times 1)g} = 1.5 mol \end{array} \right.$$

$$1g \times \frac{1}{2g/mol}$$

$$\frac{6 \times 10^{23} \text{ molecules}}{mol}$$



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**[Quiz]** Which of the following contains the **largest** number of atoms?

11% 1. 187 g of liquid mercury, Hg  
 5% 2. 1400 u of uranium, U  
 79% 3.  $6 \times 10^{24}$  atoms of sodium, Na  
 5% 4. 2 mol of hydrogen gas, H<sub>2</sub>

Handwritten calculations:  
 $187 \text{ g} \times \frac{1 \text{ mol}}{200.59 \text{ g}} \times N_A$   
 $1400 \text{ u} \times \frac{1 \text{ atom}}{238.03 \text{ u}} \times N_A$   
 $6 \times 10^{24} \text{ atoms} \times \frac{1 \text{ mol}}{6 \times 10^{23}} \times N_A$   
 $2 \text{ mol} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2} = 4 \text{ mol}$

Handwritten atomic masses:  
 Hg 200.59  
 U 238.03  
 Na 22.990  
 H 1.008  
 $N_A = 6 \times 10^{23} / \text{mol}$

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**Problem: 7e 2.1; 8e 1.25**

$N_A = 6.022 \times 10^{23}$

1. Compute the mass (in grams) of a single iodine atom if the relative atomic mass of iodine is 126.90447 on the accepted scale of atomic masses (based on <sup>12</sup>C as the relative atomic mass of <sup>12</sup>C).

Handwritten calculations:  
 $1 \text{ atom of I weighs } 126.90447 \text{ u} \times \frac{1 \text{ g}}{N_A}$   
 $= \frac{126.90447 \text{ g}}{6.02214129 \times 10^{23}}$   
 $= 2.1072981 \times 10^{-22} \text{ g}$

Handwritten notes:  
 ① u  
 ②  $1 \text{ u} = \frac{1 \text{ g}}{N_A}$   
 ③ sig. figs.

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**Problem: 7e 2.3; 8e 1.27**

3. Compute the relative molecular masses of the following compounds on the <sup>12</sup>C scale:

(a) P<sub>2</sub>O<sub>10</sub> (b) BrCl  
 (c) Ca(NO<sub>3</sub>)<sub>2</sub> (d) KMnO<sub>4</sub>  
 (e) (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>

Handwritten calculations for (e) (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>:  
 $S = 32.065$   
 $4 O = 4 \times 15.9994 = 63.9976$   
 $2 N = 2 \times 14.0067 = 28.0134$   
 $8 H = 8 \times 1.0079$

Handwritten sum:  
 $32.065$   
 $63.9976$   
 $28.0134$   
 $8.0632$   
 $\hline 132.138$

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**Problem: 7e 2.7; 8e 1.31**

7. The vitamin A molecule has the formula C<sub>20</sub>H<sub>30</sub>O, and a molecule of vitamin A<sub>2</sub> has the formula C<sub>28</sub>H<sub>48</sub>O. Determine how many moles of vitamin A<sub>2</sub> contain the same number of atoms as 1.000 mol vitamin A.

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## Problem: 7e 2.11; 8e 1.35

11. Aluminum oxide ( $\text{Al}_2\text{O}_3$ ) occurs in nature as a mineral called corundum, which is noted for its hardness and resistance to attack by acids. Its density is  $3.97 \text{ g cm}^{-3}$ . Calculate the number of atoms of aluminum in  $15.0 \text{ cm}^3$  corundum.

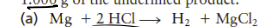


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## Problem: 7e 2.33; 8e 2.21

33. For each of the following chemical reactions, calculate the mass of the underlined reactant that is required to produce  $1.000 \text{ g}$  of the underlined product.



Handwritten calculations for problem 33(c):

$$1.000 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.016 \text{ g}} \times \frac{4 \text{ mol NaBH}_4}{4 \text{ mol H}_2} \times \frac{22.98 \text{ g Na}}{1 \text{ mol Na}} = 4.691 \text{ g Na}$$

Handwritten calculations for problem 33(b):

$$1.000 \text{ g I}_2 \times \frac{1 \text{ mol I}_2}{253.8 \text{ g}} \times \frac{2 \text{ mol CuSO}_4}{1 \text{ mol I}_2} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} = 4.98 \text{ g CuSO}_4$$

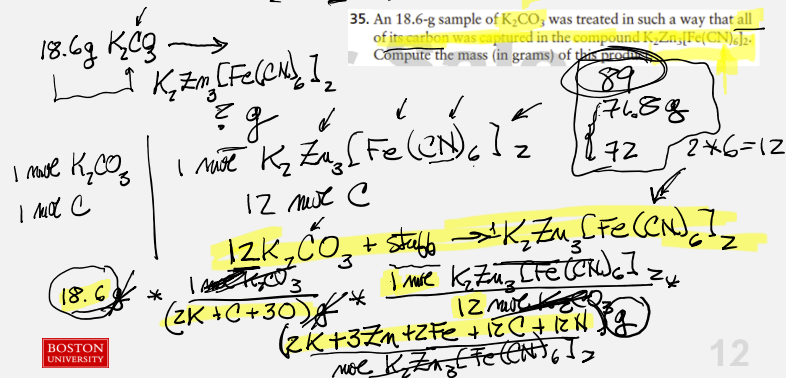


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## Problem: 7e 2.35, 8e 2.23

35. An  $18.6\text{-g}$  sample of  $\text{K}_2\text{CO}_3$  was treated in such a way that all of its carbon was captured in the compound  $\text{K}_2\text{Zn}_3[\text{Fe}(\text{CN})_6]_2$ . Compute the mass (in grams) of this product.

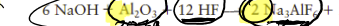


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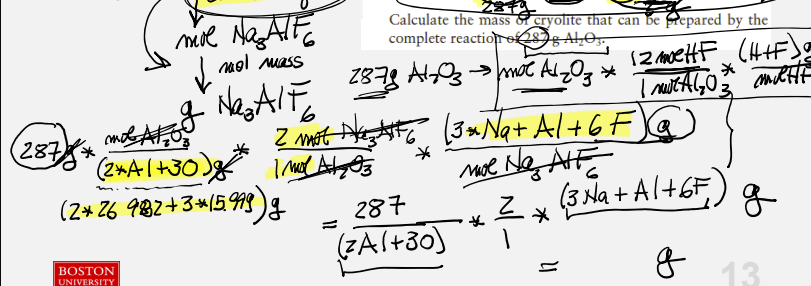
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## Problem: 7e 2.39, 8e 2.27

39. Cryolite ( $\text{Na}_3\text{AlF}_6$ ) is used in the production of aluminum from its ores. It is made by the reaction



Calculate the mass of cryolite that can be prepared by the complete reaction of  $287 \text{ g Al}_2\text{O}_3$ .



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**Problem: 7e 2.47, 8e 2.35**

$\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$

47. When ammonia is mixed with hydrogen chloride (HCl), the white solid ammonium chloride ( $\text{NH}_4\text{Cl}$ ) is produced. Suppose 10.0 g ammonia is mixed with the same mass of hydrogen chloride. What substances will be present after the reaction has gone to completion, and what will their masses be?

Initial masses:  $\text{NH}_3 = 10.0 \text{ g}$ ,  $\text{HCl} = 10.0 \text{ g}$ ,  $\text{NH}_4\text{Cl} = 0 \text{ g}$

Initial moles:  $\text{NH}_3 = 0.587 \text{ mol}$ ,  $\text{HCl} = 0.274 \text{ mol}$ ,  $\text{NH}_4\text{Cl} = 0 \text{ mol}$

Change in moles:  $\text{NH}_3 = -0.274 \text{ mol}$ ,  $\text{HCl} = -0.274 \text{ mol}$ ,  $\text{NH}_4\text{Cl} = +0.274 \text{ mol}$

Final masses:  $\text{NH}_3 = 5.33 \text{ g}$ ,  $\text{HCl} = 0 \text{ g}$ ,  $\text{NH}_4\text{Cl} = 14.7 \text{ g}$

Final moles:  $\text{NH}_3 = 0.313 \text{ mol}$ ,  $\text{HCl} = 0 \text{ mol}$ ,  $\text{NH}_4\text{Cl} = 0.274 \text{ mol}$

Calculations:

$$10.0 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.03 \text{ g}} = 0.587 \text{ mol NH}_3$$

$$0.587 \text{ mol NH}_3 \times \frac{(14 + 3 \times 1) \text{ g}}{\text{mol NH}_3} = 10.0 \text{ g}$$

$$0.313 \text{ mol NH}_3 \times \frac{(14 + 3 \times 1) \text{ g}}{\text{mol NH}_3} = 5.33 \text{ g}$$

$$10.0 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.46 \text{ g}} = 0.274 \text{ mol HCl}$$

$$0.274 \text{ mol HCl} \times \frac{(1 + 1 + 35.5) \text{ g}}{\text{mol HCl}} = 10.0 \text{ g}$$

$$0.274 \text{ mol HCl} \times \frac{1 \text{ mol NH}_4\text{Cl}}{1 \text{ mol HCl}} = 0.274 \text{ mol NH}_4\text{Cl}$$

$$0.274 \text{ mol NH}_4\text{Cl} \times \frac{(14 + 4 \times 1 + 35.5) \text{ g}}{\text{mol NH}_4\text{Cl}} = 14.7 \text{ g}$$

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**Problem: 7e 2.49, 8e 2.37**

$\text{Fe}_2\text{O}_3 + 3 \text{CO} \rightarrow 2 \text{Fe} + 3 \text{CO}_2$

49. The iron oxide  $\text{Fe}_2\text{O}_3$  reacts with carbon monoxide (CO) to give iron and carbon dioxide:

Initial masses:  $\text{Fe}_2\text{O}_3 = 433.2 \text{ g}$ ,  $\text{CO} = 0 \text{ g}$ ,  $\text{Fe} = 0 \text{ g}$ ,  $\text{CO}_2 = 0 \text{ g}$

Initial moles:  $\text{Fe}_2\text{O}_3 = 2.713 \text{ mol}$ ,  $\text{CO} = 0 \text{ mol}$ ,  $\text{Fe} = 0 \text{ mol}$ ,  $\text{CO}_2 = 0 \text{ mol}$

Change in moles:  $\text{Fe}_2\text{O}_3 = -2.713 \text{ mol}$ ,  $\text{CO} = +5.426 \text{ mol}$ ,  $\text{Fe} = +5.426 \text{ mol}$ ,  $\text{CO}_2 = +5.426 \text{ mol}$

Final masses:  $\text{Fe}_2\text{O}_3 = 0 \text{ g}$ ,  $\text{CO} = 0 \text{ g}$ ,  $\text{Fe} = 5.426 \text{ g}$ ,  $\text{CO}_2 = 5.426 \text{ g}$

Final moles:  $\text{Fe}_2\text{O}_3 = 0 \text{ mol}$ ,  $\text{CO} = 0 \text{ mol}$ ,  $\text{Fe} = 2.713 \text{ mol}$ ,  $\text{CO}_2 = 2.713 \text{ mol}$

Calculations:

$$433.2 \text{ g Fe}_2\text{O}_3 \times \frac{1 \text{ mol Fe}_2\text{O}_3}{159.7 \text{ g}} = 2.713 \text{ mol Fe}_2\text{O}_3$$

$$2.713 \text{ mol Fe}_2\text{O}_3 \times \frac{2 \text{ mol Fe}}{1 \text{ mol Fe}_2\text{O}_3} = 5.426 \text{ mol Fe}$$

$$5.426 \text{ mol Fe} \times \frac{55.85 \text{ g}}{\text{mol Fe}} = 303.0 \text{ g Fe}$$

Theoretical yield = result of all of the  $\text{Fe}_2\text{O}_3$  reacts =  $303.0 \text{ g}$

% yield =  $100\%$   $\frac{\text{actual}}{\text{maximum}} = 100\% \frac{254.3 \text{ g}}{303.0 \text{ g}} = 83.9\%$

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