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[TP] Which contains the most molecules?

4% 1. 1 g of  $\text{H}_2$   
 30% 2. 45 g of  $\text{Cl}_2$   
 21% 3. 28 g of  $\text{N}_2$   
 45% 4. 24 g of  $\text{CH}_4$

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Lecture 3 CH131 Fall 2020  
 Thursday, September 10, 2020

- Compete: Atomic weight
- Chemist's dozen: The mole
- Example problems: Chemical formulas, equations, and reaction yields

Next: Complete example problems; Limiting reagent recipe; Begin ch3:  
 Chemical bonding: The classical description

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[TP] The molar mass of Cl is 35.453 g.  $^{37}\text{Cl}$  has a natural abundance of 24.24%. Which of the following statements is true?

1% 1. The mass of one atom of naturally occurring Cl is 35.453 g divided by Avogadro's number  
 69% 2. The mass of one atom of naturally occurring Cl cannot be 35.453 g divided by Avogadro's number.  
 30% 3. Neither of the statements is true.

✓ 100 lbs  
 ✓ 150 lbs  
 125 lbs

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### Terms to distinguish

**Relative atomic mass,  $A_r$ :** ratio of mass of an isotope relative to mass of 1/12 of one  $^{12}\text{C}$  atom  
 $A_r$  of  $^{13}\text{C}$  is 13.00335 (unitless)

**Atomic mass unit, u:** 1/12 mass of one  $^{12}\text{C}$  atom  
 $1 \text{ u} = (1/12) \times (12 \text{ g}) / N_A = \text{g} / N_A = 1.66054 \times 10^{-24} \text{ g}$

**Atomic weight:** average of relative atomic masses of an element  
 Atomic weight of C is 12.01 (unitless)

**Molar mass,  $M$ :** Mass in grams numerically equal to atomic weight; that is, the mass in grams of  $N_A$  "average atoms" of an element  
 Molar mass of C is 12.01 g

Handwritten notes:  
 $^{12}\text{C} \approx 12$  exactly  
 $N_A$  of  $^{12}\text{C}$ , mass 13.00335 g  
 One  $^{13}\text{C}$ , mass 13.00336 u  
 $= 13.00336 \times 1.66054 \times 10^{-24} \text{ g}$

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Chemist's dozen: mole  $\rightarrow$  counting by weighing

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## Mole: Count by weighing

The mass in g of 1 mol of any element is called its **molar mass**

Number of particles in 1 mol is  $N_A = 6.02214076 \times 10^{23}$

Each of these **amounts** contains the **same number** of atoms



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[TP] Which contains the most molecules?

0% 1. 1 g of  $H_2$

6% 2. 45 g of  $Cl_2$

10% 3. 28 g of  $N_2$

84% 4. 24 g of  $CH_4$

molar mass of each substance

16 g of  $CH_4$  contains  $N_A$  of  $CH_4$  molecules

$$24 g \times \frac{1 \text{ mole}}{16 g} = 1.5 \text{ mole}$$

$$0.5 \text{ moles} = 1 g \times \frac{1 \text{ mole}}{2 g} \times N_A \text{ molecules}$$

$$0.7 \text{ moles} = 45 g \times \frac{1 \text{ mole}}{71 g} \times N_A \text{ molecules}$$

$$1 \text{ mole} = 28 g \times \frac{1 \text{ mole}}{28 g} \times N_A \text{ molecules}$$

$$1.5 \text{ moles} = 24 g \times \frac{1 \text{ mole}}{16 g} \times N_A \text{ molecules}$$

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## Mass to molecules

Which contains the most molecules?

$$1 \text{ g of } H_2: 1 g \times \frac{\text{mol}}{2 g} = 0.5 \text{ mol}$$

$$45 \text{ g of } Cl_2: 45 g \times \frac{\text{mol}}{(2 \times 35) g} = 0.64 \text{ mol}$$

$$28 \text{ g of } N_2: 28 g \times \frac{\text{mol}}{(2 \times 14) g} = 1.0 \text{ mol}$$

$$24 \text{ g of } CH_4: 24 g \times \frac{\text{mol}}{(12 + 4 \times 1) g} = 1.5 \text{ mol}$$

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[TP] Which of the following contains the **smallest** number of atoms?

54% 1. 187 g of liquid mercury, Hg  
 27% 2. 1400 u of uranium, U  
 15% 3.  $6 \times 10^{24}$  atoms of sodium, Na  
 5% 4. 2 mol of hydrogen gas, H<sub>2</sub>

Handwritten calculations:  
 $187 \text{ g} \times \frac{1 \text{ mol}}{201 \text{ g}} \times \frac{6 \times 10^{23} \text{ atoms}}{1 \text{ mol}} \approx 6 \times 10^{23} \text{ atoms}$   
 $1400 \text{ u} \times \frac{1 \text{ atom}}{238 \text{ u}} \approx 6 \text{ atoms}$   
 $12 \text{ g of } ^{12}\text{C} \text{ is } N_A \text{ atoms}$   
 $12 \text{ u of } ^{12}\text{C} \text{ is one atom}$   
 $238.03 \text{ u of U, I have } 6 \times 10^{23} \text{ atoms of U}$   
 $238.03 \text{ u of U, I have just a single atom of U}$

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

3% 1. 187 g of liquid mercury, Hg  
 1% 2. 1400 u of uranium, U  
 84% 3.  $6 \times 10^{24}$  atoms of sodium, Na  
 12% 4. 2 mol of hydrogen gas, H<sub>2</sub>

Handwritten calculations:  
 $201 \rightarrow 1 \text{ mol}$   
 $238 \rightarrow 10 \text{ mols}$   
 $2 \rightarrow 4 \text{ mols of H}_2$   
 $12 \text{ C} = 12 \text{ u}$   
 $13 \text{ C} \neq 13 \text{ u}$   
 $\frac{g}{N_A} = 1 \text{ u}$   
 $\frac{12 \text{ g}}{546319} = \frac{g}{N_A} = 1 \text{ u}$

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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>30</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.

Handwritten calculations:  
 # mol of A<sub>2</sub> with the same # of atoms as 1 mol of A  
 $\# \text{ of atoms in A} = 1.000 \text{ mol} \times \frac{N_A \text{ molecules}}{1 \text{ mol}} \times \frac{51 \text{ atoms}}{1 \text{ molecule}}$   
 $= 1.000 \times 51 \times N_A \text{ atoms}$   
 $\# \text{ of atoms in A}_2 = x \text{ mol} \times \frac{N_A \text{ molecules}}{1 \text{ mol}} \times \frac{49 \text{ atoms}}{1 \text{ molecule}}$   
 $= x \text{ mol} \times 49 \times N_A \text{ atoms}$   
 $x \times 49 \times N_A \text{ atoms} = 1.000 \times 51 \times N_A \text{ atoms}$   
 $x = 1.000 \times \frac{51}{49}$

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