Lecture 2 CH131 Summer 1

Wednesday, May 22, 2019

- Summary: Isotopes → atomic weight
- Chemist's dozen: The mole
- Example problems

Next lecture: Complete ch2: Chemical formulas, equations, and reaction yields. Begin ch 3: Chemical bonding: The classical description

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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}C atom

A_r of ^{13}C is 13.00335 (unitless)

Atomic mass unit, u: 1/12 mass of one ^{12}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

Chemist's dozen: mole → counting by weighing

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 $N_A = 6.022140857 \times 10^{23}$

Each of these amounts contains the same number of atoms

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

27% 1. 187 g of liquid mercury, Hg
67% 2. 1400 u of uranium, U
7% 3. 6×10^{24} atoms of sodium, Na
0% 4. 2 mol of hydrogen gas, H_2

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

6% 1. 187 g of liquid mercury, Hg
0% 2. 1400 u of uranium, U
94% 3. 6×10^{24} atoms of sodium, Na
0% 4. 2 mol of hydrogen gas, H_2

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Problem: 7e 2.1; 8e 1.25

$N_A = 6.022\,141\,29 \times 10^{23}$

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 12 as the relative atomic mass of ^{12}C).

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Problem: 7e 2.3; 8e 1.27

3. Compute the relative molecular masses of the following compounds on the ^{12}C scale:
(a) P_4O_{10} (b) BrCl
(c) $Ca(NO_3)_2$ (d) $KMnO_4$
(e) $(NH_4)_2SO_4$

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Problem: 7e 2.7; 8e 1.31

7. The vitamin A molecule has the formula $C_{20}H_{30}O$, and a molecule of vitamin A_2 has the formula $C_{20}H_{28}O$. Determine how many moles of vitamin A_2 contain the same number of atoms as 1.000 mol vitamin A.

# of moles of $C_{20}H_{28}O$ with same # of atoms as 1 mol $C_{20}H_{30}O$

$$\#\text{ of atoms in A} = 1.000\text{ mol} \times \frac{N_A\text{ molecules}}{1\text{ mol}} \times \frac{51\text{ atoms}}{1\text{ molecule}} = 1.000\, N_A\, 51$$

$$\#\text{ of atoms in } A_2 = x\text{ mol} \times \frac{N_A\text{ molecule}}{1\text{ mol}} \times \frac{49\text{ atoms}}{1\text{ molecule}} = x\, N_A\, 49$$

$$x\, N_A\, 49 = 1.000\, N_A\, 51$$

$$x = 1.000 \times \frac{51}{49} = 1.041$$

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Problem: 7e 2.11; 8e 1.35

11. Aluminum oxide (Al_2O_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 g cm^{-3}. Calculate the number of atoms of aluminum in 15.0 cm^3 corundum.

$$\#\text{ atoms} = 15.0\text{ cm}^3 \times \frac{3.97\text{ g}}{\text{cm}^3} \times \frac{1\text{ mol } Al_2O_3}{M(g)} \times \frac{2\text{ mol Al}}{1\text{ mol } Al_2O_3} \times \frac{N_A\text{ atom Al}}{\text{mol Al}}$$

$$= \frac{15.0 \times 3.97 \times 2 \times N_A}{M(g)}$$

$$= \frac{15.0 \times 3.97 \times 2 \times 6.022 \times 10^{23}}{(2 \cdot 26.9815 + 3 \times 15.9994)}\text{ atoms}$$

$$= 7.04 \times 10^{23}$$

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Problem: 7e 2.33; 8e 2.21

g → mol H_2 → mol $NaBH_4$ → g

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

(a) $Mg + 2HCl \longrightarrow H_2 + MgCl_2$

(b) $2\ CuSO_4 + 4\ KI \longrightarrow 2\ CuI + I_2 + 2\ K_2SO_4$

(c) $NaBH_4 + 2\ H_2O \longrightarrow NaBO_2 + 4\ H_2$

g of $NaBH_4$ needed to form 1.000 g of H_2

$$\text{g of } NaBH_4 = 1.000\text{ g } H_2 \times \frac{\text{mol } H_2}{M(g)} \times \frac{1\text{ mol } NaBH_4}{4\text{ mol } H_2} \times \frac{M(g)}{1\text{ mol } NaBH_4}$$

$$= \frac{1.000}{(2 \times 1.0079)} \times \frac{1}{4} \times (22.9898 + 10.811 + 4 \times 1.0079)\text{ g}$$

$$= \frac{1.000 \times 37.831}{(2 \times 1.0079)4} = 4.691\text{ g}$$

4.692

22.9898
10.811
4.0316
37.831

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Problem: 7e 2.35, 8e 2.23

35. An 18.6-g sample of K_2CO_3 was treated in such a way that all of its carbon was captured in the compound $K_2Zn_3[Fe(CN)_6]_2$. Compute the mass (in grams) of this product.

g K_2CO_3 → mol K_2CO_3 → mol C → mol product → g product

$$18.6\text{ g} \times \frac{\text{mol } K_2CO_3}{M(K_2CO_3)} \times \frac{1\text{ mol C}}{\text{mol } K_2CO_3} \times \frac{1\text{ mol product}}{12\text{ mol C}} \times \frac{M(\text{product})}{\text{mol product}}$$

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Problem: 7e 2.39, 8e 2.27

39. Cryolite (Na_3AlF_6) is used in the production of aluminum from its ores. It is made by the reaction

$$6\ NaOH + Al_2O_3 + 12\ HF \longrightarrow 2\ Na_3AlF_6 + 9\ H_2O$$

Calculate the mass of cryolite that can be prepared by the complete reaction of 287 g Al_2O_3.

$$287\text{g } Al_2O_3 * \frac{\text{mol } Al_2O_3}{M(Al_2O_3)} * \frac{2 \text{ mol } Na_3AlF_6}{1 \text{ mol } Al_2O_3} * \frac{M(Na_3AlF_6)}{\text{mol } Na_3AlF_6}$$

$$= \frac{287 * 2 * M(Na_3AlF_6)}{M(Al_2O_3)}$$

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Problem: 7e 2.47, 8e 2.35

47. When ammonia is mixed with hydrogen chloride (HCl), the white solid ammonium chloride (NH_4Cl) 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?

$NH_3 + HCl \rightarrow NH_4Cl$

	NH_3	HCl	NH_4Cl
I	10.0g	10.0g	0
I	0.587	0.274	
C	−0.274	−0.274	+0.274
F	0.313	0	0.274

$10.0\text{g } NH_3 * \frac{\text{mol}}{(14.007+3*1.0079)\text{g}} = 0.587\text{ mol}$

$10.0\text{g } HCl * \frac{\text{mol}}{(1.0079+35.453)\text{g}} = 0.274\text{ mol}$

$0.313 \text{ mol } NH_3 * \frac{M(NH_3)}{1 \text{ mol } NH_3} = 5.33\text{g}$

$0.274 \text{ mol } NH_4Cl * \frac{M(NH_4Cl)}{1 \text{ mol } NH_4Cl} = 14.7\text{g}$

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Problem: 7e 2.49, 8e 2.37

49. The iron oxide Fe_2O_3 reacts with carbon monoxide (CO) to give iron and carbon dioxide:

$$Fe_2O_3 + 3\ CO \longrightarrow 2\ Fe + 3\ CO_2$$

The reaction of 433.2 g Fe_2O_3 with excess CO yields 254.3 g iron. Calculate the theoretical yield of iron (assuming complete reaction) and its percentage yield.

	Fe_2O_3	CO	Fe
I	433.2g	−	0
I	2.713 mol		0
C	−2.713 mol		+5.426
F	0		5.426

$433.2\text{g} * \frac{\text{mol}}{(2*55.845+3*15.9994)\text{g}} = 2.713\text{ mol}$

$2.713 \text{ mol } Fe_2O_3 * \frac{2 \text{ mol Fe}}{1 \text{ mol } Fe_2O_3}$

max mol Fe = 5.426 mol

actual mol Fe = $254.3\text{g} * \frac{1 \text{ mol}}{55.845\text{g}}$ = 4.554 mol

$\%\text{yield} = 100\% * \frac{\text{actual}}{\text{max}} = 100\% * \frac{4.554 \text{ mol}}{5.426 \text{ mol}} = 83.93\%$

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General limiting reagent recipe

2 A + 3 B → C + 2 D, 7.00 mol of A and 10.00 mol of B react with 52 % yield. How much A, B, C, and D at the end of the reaction?

		2A	3B	C	2D
	I	7.00	10.00	0	0
100%	C		−10.00	+3.33	6.67

① For each reactant, calculate how much of one product

$7.00 \text{ mol A} * \frac{1 \text{ mol C}}{2 \text{ mol A}} = 3.50 \text{ mol C}$

$10.00 \text{ mol B} * \frac{1 \text{ mol C}}{3 \text{ mol B}} = 3.33 \text{ mol C}$

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