

Please follow the instructions for each section of the exam. Show your work on all mathematical problems. Provide answers with the correct units and significant figures. Be concise in your answers to discussion questions.

Part 0: Warmup. 4 points each

1. When 10.0 g zinc and 8.0 g sulfur are allowed to react, all of the zinc is consumed and 15.0 g zinc sulfide is produced. The mass of unreacted sulfur remaining is:
- 2.0 g
 - 3.0 g
 - 5.0 g
 - Impossible to predict from this information alone.

Answer b

2. Which of the following have roughly the same mass:
- a proton and an electron
 - an electron and a neutron
 - a neutron and a proton
 - a proton and a bowling ball

Answer c

3. Thallium has two stable isotopes, ^{203}Tl and ^{205}Tl . Given that the atomic mass of thallium is 204.383 amu, which isotope must have the larger natural abundance?
- ^{203}Tl
 - ^{205}Tl
 - Both have the same natural abundance.
 - Not enough information to make this determination.

Answer b

Part I: Complete all of problems 4-10

4. Define the following using a maximum of two sentences for each definition. (4 points)
- accuracy: **The proximity of a data point to the "true value"**
 - precision: **The reproducibility of a measurement or set of data.**

5. A solution consisting of 8.50% ethanol and 91.50% water by mass has a density of 0.9867 g/mL. What mass of ethanol, in kg, is present in 7.50 L of the solution? (8 pts)

$$7500 \text{ mL} \times \frac{0.9867 \text{ g-soln}}{\text{mL}} \times \frac{8.50 \text{ g ethanol}}{100 \text{ g-soln}} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = \mathbf{0.629 \text{ kg ethanol}}$$

6. Complete the following table. (12 points)

Symbol	$^{40}\text{Ca}^{2+}$	^{75}As	$^{32}\text{S}^{2-}$
# of protons	20	33	16
# of neutrons	20	42	16
# of electrons	18	33	18
Charge	+2	0	-2
Name	calcium-40 ion	arsenic-75	sulfide-32 ion

7. Name the following compounds or provide the correct formula for the given names. (12 pts)

- a. iron (III) sulfate $\text{Fe}_2(\text{SO}_4)_3$
- b. CaF_2 calcium fluoride
- c. N_2O_5 dinitrogen pentoxide
- d. diphosphorous tetrafluoride PF_4
- e. aluminum carbonate $\text{Al}_2(\text{CO}_3)_3$
- f. $\text{Cr}(\text{PO}_4)_2$ chromium (VI) phosphate

8. How many copper-65 atoms are in a piece of copper weighing 215 μg ? The percent natural abundance of copper-65 is 30.83%. (8 points)

$$215 \mu\text{g Cu} \times \frac{10^{-6} \text{ g}}{1 \mu\text{g}} = 2.15 \times 10^{-4} \text{ g Cu}$$

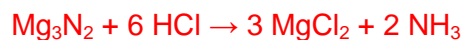
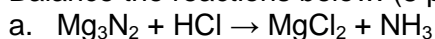
$$2.15 \times 10^{-4} \text{ g Cu} \times \frac{1 \text{ mol Cu}}{63.546 \text{ g Cu}} \times \frac{6.02 \times 10^{23} \text{ atoms Cu}}{1 \text{ mol Cu}} = 2.037 \times 10^{17} \text{ Cu atoms}$$

$$2.037 \times 10^{17} \text{ atoms Cu} \times \frac{30.83 \text{ atoms } ^{65}\text{Cu}}{100 \text{ atoms Cu}} = 6.28 \times 10^{17} \text{ } ^{65}\text{Cu atoms}$$

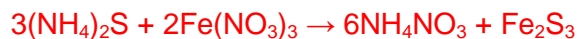
9. The atomic mass of silver is 107.868 amu and silver exists as two isotopes with nearly equal abundance. If you were able to pick up a single silver atom, what is the chance that you would get one with a mass of 107.868 amu? No calculations are needed, but you must clearly justify your answer. (8 points)

There is zero chance of finding an atom of mass 107.868 amu. Because 107.868 amu must be the "weighted average" of the masses of individual isotopes, and because there are only two isotopes, neither can have mass 107.868 amu. One isotope must have a mass greater than 107.868 amu and one must have a mass smaller than 107.868 amu

10. Balance the reactions below: (8 points)



- b. ammonium sulfide and iron(III) nitrate react to form ammonium nitrate and iron(III) sulfide



Part II. Answer three (3) of problems 11-14. Clearly mark the problem you do not want graded. 10 points each.

11. While Dalton's atomic theory is still the foundation for our understanding of basic chemical principles, our ability to better characterize atoms and compounds has identified a few shortcomings or errors in the theory. Identify the four key tenets of Dalton's theory and describe at least one shortcoming or error in the theory.

The four key points are

1. All matter is made of atoms, which are indivisible.
2. All atoms of a given element are identical
3. Compounds are the result of a combination of two or more different kinds of atoms
4. Chemical reactions involve the combination, separation or rearrangement of atoms

The key shortcoming is that Dalton's theory does not account for the presence of isotopes, which are atoms of the same element that are not identical because they have different numbers of neutrons.

We also now know that atoms can be split into smaller components (protons, neutrons, electrons and smaller).

12. Silicon has three stable isotopes, ^{28}Si , ^{29}Si , and ^{30}Si with masses of 27.98 amu, 28.98 amu, and 29.77 amu, respectively. If the natural abundance of ^{28}Si is 92.23%, what are the percent abundances of the other two isotopes?

The total abundance of ^{29}Si , and ^{30}Si must be: $100 - 92.23 = 7.77\%$

So: $f_{29} + f_{30} = 0.0777$ where f_x is the fractional abundance of the isotope with mass # x.

And: $(0.9223 \times 27.98) + 28.98f_{29} + 29.77f_{30} = 28.0855$ (This is our definition of atomic mass)

Now we need to find f_{29} and f_{30} :

$$\begin{aligned}f_{30} &= 0.0777 - f_{29} \\28.98f_{29} + 29.77f_{30} &= 28.0855 - (0.9223 \times 27.98) = 2.2795 \\28.98f_{29} + 29.77(0.0777 - f_{29}) &= 2.2795 \\28.98f_{29} - 29.77f_{29} &= 2.2795 - (29.77 \times 0.0777) = -0.03363 \\-0.79f_{29} &= -0.03363 \\f_{29} &= 0.04257 \\So, f_{30} &= 0.0777 - 0.04257 = 0.03513\end{aligned}$$

So, the percent abundance for ^{29}Si is 4.26% and the percent abundance for ^{30}Si is 3.51%

13. One of the reasons that methamphetamine is such a problem is that it is a relatively small molecule that is fairly easy to synthesize. A molecule of methamphetamine contains only carbon, hydrogen, and nitrogen and has a molar mass of 149.2 g/mol. If methamphetamine is 80.48% C and 9.39% N by mass, what is its molecular formula?

So, the percent H must be: $100 - 80.48 - 9.39 = 10.13\% \text{H}$

There are several ways to solve this problem. Here is one:

$$\frac{149.2 \text{ g-meth}}{1 \text{ mol meth}} \times \frac{80.48 \text{ g-C}}{100 \text{ g-meth}} \times \frac{1 \text{ mol C}}{12.011 \text{ g-C}} = \frac{9.997 \text{ mol C}}{1 \text{ mol meth}}$$

$$\frac{149.2 \text{ g-meth}}{1 \text{ mol meth}} \times \frac{9.39 \text{ g-N}}{100 \text{ g-meth}} \times \frac{1 \text{ mol N}}{14.0067 \text{ g-N}} = \frac{1.000 \text{ mol N}}{1 \text{ mol meth}}$$

$$\frac{149.2 \text{ g-meth}}{1 \text{ mol meth}} \times \frac{10.13 \text{ g-H}}{100 \text{ g-meth}} \times \frac{1 \text{ mol H}}{1.00794 \text{ g-H}} = \frac{14.995 \text{ mol H}}{1 \text{ mol meth}}$$

So, the likely formula is $\text{C}_{9.997}\text{H}_{14.995}\text{N}_{1.000}$ or, $\text{C}_{10}\text{H}_{15}\text{N}$. Is this really the molecular formula?

Check the molar mass:

$$10(12.011) + 15(1.00794) + 14.0067 = 149.23$$

Therefore, $\text{C}_{10}\text{H}_{15}\text{N}$ must be the molecular formula!

14. Iron ore is impure Fe_2O_3 . When Fe_2O_3 is heated with carbon, metallic iron and carbon monoxide gas are formed. From a sample of ore weighing 895 g, 432 g of pure iron is obtained. What is the percent Fe_2O_3 , by mass, in the original ore sample? (molar masses (g/mol): $\text{Fe}_2\text{O}_3 = 159.6922$, carbon monoxide = 28.010)

From the formula and molar mass of iron oxide, we know there are $2(55.847) = 111.694 \text{ g Fe}$ per $159.6922 \text{ g Fe}_2\text{O}_3$. So if we ended up 432 g Fe , there must have been:

$$432 \text{ g-Fe} \times \frac{159.6922 \text{ g Fe}_2\text{O}_3}{111.694 \text{ g-Fe}} = 617.6 \text{ g Fe}_2\text{O}_3$$

Therefore, 617.6 grams of Fe_2O_3 must have been present in the original sample. In terms of percent, this corresponds to:

$$\frac{617.6 \text{ g Fe}_2\text{O}_3}{895 \text{ g ore}} \times 100\% = \mathbf{69.0\% \text{ Fe}_2\text{O}_3}$$

Note that you can get the same mass of Fe_2O_3 using the reaction stoichiometry:



$$432 \text{ g-Fe} \times \frac{1 \text{ mol-Fe}}{55.847 \text{ g-Fe}} \times \frac{1 \text{ mol-Fe}_2\text{O}_3}{2 \text{ mol-Fe}} \times \frac{159.6922 \text{ g Fe}_2\text{O}_3}{1 \text{ mol-Fe}_2\text{O}_3} = \mathbf{617.6 \text{ g Fe}_2\text{O}_3}$$

To save some calculation time, you may round all atomic masses to two (2) decimal points.

Possibly Useful Information

$D = m/v$
 $N_a = 6.02214 \times 10^{23} \text{ mol}^{-1}$

													13	14	15	16	17	18
													3A	4A	5A	6A	7A	8A
1 1A											2 2A						2 He	
1 H											1.00794						4.00260	
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
6.941	9.01218											10.811	12.011	14.0067	15.9994	18.9984	20.1797	
11 Na	12 Mg	3	4	5	6	7	8	9	10	11	12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
22.9898	24.3050	3B	4B	5B	6B	7B	8B		1B	2B	26.9815	28.0855	30.9738	32.066	35.4527	39.948		
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
39.0983	40.078	44.9559	47.88	50.9415	51.9961	54.9381	55.847	58.9332	58.693	63.546	65.39	69.723	72.61	74.9216	78.96	79.904	83.80	
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
85.4678	87.62	88.9059	91.224	92.9064	95.94	(98)	101.07	102.906	106.42	107.868	112.411	114.818	118.710	121.757	127.60	126.904	131.29	
55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
132.905	137.327	138.906	178.49	180.948	183.84	186.207	190.23	192.22	195.08	196.967	200.59	204.383	207.2	208.980	(209)	(210)	(222)	
87 Fr	88 Ra	89 †Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg								
(223)	226.025	227.028	(261)	(262)	(266)	(264)	(277)	(268)	(271)	(272)								
*Lanthanide series			58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
			140.115	140.908	144.24	(145)	150.36	151.965	157.25	158.925	162.50	164.930	167.26	168.934	173.04	174.967		
†Actinide series			90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		
			232.038	231.036	238.029	237.048	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(262)		

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