Week 1 PSET: #1: Thermite

The thermite reaction, used to weld rails together in the building of railroads, occurs when Fe_2O_3 reacts with Al to produce Al_2O_3 and Fe.

Write a balanced equation for this reaction:

$$\_\,Fe_2O_3 + \_\,Al \rightarrow \_\,Al_2O_3 + \_\,Fe$$

$$1\,Fe_2O_3 + 2\,Al \rightarrow 1\,Al_2O_3 + 2\,Fe$$

... with lowest possible whole number coefficients:

$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$$

Calculate the mass of iron metal (in grams) that can be prepared from 150 g Al and 250 g Fe_2O_3:

Molar masses:

Al	27
Fe_2O_3	157
Fe	~~56~~ 55.8

$$150\text{ g Al} \cdot \frac{1\text{ mole}}{27\text{ g}} \cdot \frac{1}{2} = 2.7\text{ reaction units.}$$

$$250\text{ g }Fe_2O_3 \cdot \frac{1\text{ mole}}{157\text{ g}} \simeq 1.59\ \cancel{\text{moles}}\text{ reaction units}$$

Fe_2O_3 is the limiting reactant. $2 \cdot 1.59$ moles Fe will be produced.

$$2 \cdot 1.59 \cdot \frac{\cancel{27}\text{ g}}{55.8} = \cancel{85}.\ 177.4$$

#2: Decomposition of ammonium nitrate

Solid NH_4NO_3 decomposes on heating to 400°C into N_2O gas and H_2O gas.

Write a balanced chemical equation:

$$\_\,NH_4NO_3 \rightarrow N_2O + \_\,H_2O$$

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

Calculate the number of grams of H_2O that will form on decomposition of 0.1 mole NH_4NO_3.

$$0.1 \cdot 2 = 0.2 \text{ moles } H_2O \cdot \frac{18\,g}{\text{mole}} = 3.6\,g\ H_2O$$

#3: Kinetic Energy

Select the objects with thee same kinetic energy associated with them.

Recall: $K = \frac{1}{2} m v^2$

A	mass 0.5	velocity 1	$KE = \frac{1}{4}$
B	1	2	$= 2$
C	1	1	$= \frac{1}{2}$
D	2	1	$= 1$
E	3	1	$= \frac{3}{2}$
F	4	1	$= 2$

B and F have the same KE

#4 Chlorine Isotopes

Chlorine ~~isotopes~~ has two isotopes, ^{35}Cl and ^{37}Cl. For the anion $^{37}Cl^-$, specify the following:

\# protons: 17

\# neutrons: 20

\# electrons: 18

Cl has constant proton number 17.
This Cl has $17-(-1)$ electrons.
This Cl has $37-17$ neutrons.

#5: Zirconium

Metallothermic production of zirconium would involve the reaction of Na with $ZrCl_4$ to produce Zr and NaCl.

Write a balanced chemical equation:

$$\_Na + \_ZrCl_4 \rightarrow \_Zr + \_NaCl$$

$$4Na + ZrCl_4 \rightarrow Zr + 4NaCl$$

Calculate the amount of zirconium produced (in kg) if a reactor were charged with 491.0 kg $ZrCl_4$ and 49.0 kg Na.

Begin by dividing all masses by 1000; we'll multiply 1000 back in at the end.

$$491.0\,g \cdot \frac{1}{233.04} = 2.11 \text{ reaction units}$$

$$49\,g \cdot \frac{1}{23} = 2.13 \text{ reaction units;}$$

thus $ZrCl_4$ is the limiting reactant.

$$2.11 \cdot 91.22 = 192.47 \text{ grams}$$

$$\cdot 1000$$

$$192.47 \text{ kg.}$$

I forgot to multiply by $\frac{1}{4}$ when finding the reaction units Na.

$$49 \cdot \frac{1}{23} \cdot \frac{1}{4} = 0.532 \text{ reaction units}$$

$$0.532 \cdot \frac{91.22\,g}{\text{mole Zr}} =$$

This still isn't right, so let's do this in a simpler way.
Recall that: $4Na + ZrCl_4 \rightarrow Zr + 4NaCl$.

Then for every mole $ZrCl_4$ there must be 4 moles Na.

$$491\text{ kg} \cdot \frac{1000\,g}{kg} \cdot \frac{1\text{ mole } ZrCl_4}{91.22\text{ grams}} = 5382\text{ moles } ZrCl_4$$

$$49\text{ kg} \cdot \frac{1000\,g}{kg} \cdot \frac{1\text{ mole Na}}{22.99\,g} = 2131\text{ moles Na.}$$

We conclude that Na is the limiting reactant. For 4 moles of Na, 1 mole of Zr is produced.

$$2131 \cdot \frac{1}{4} = 532.75\text{ moles Zr} \cdot \frac{0.09122\text{ kg}}{\text{mole}}$$

$$= 48.6\text{ kg Zr.}$$

I had the right answer with the first method, but I was checking against the wrong solution

#6: Atomic Weight

Calculate the atomic weight (in amu) of an element X given the following data:

^{24}X : 24 amu at 0.7870 fractional abundance
^{25}X : 25 amu at 0.1017 ''
^{26}X : 26 amu at 0.1113 ''

$$\frac{(24\cdot 0.787 + 25 \cancel{0.1071}\cdot 0.1017 + 26\cdot 0.1113)}{1}$$

||

24.32 amu

#7: Mercury atoms

How many atoms are in 14.0 cm^3 of mercury (at room temperature)?

$$14\ cm^3\ Hg \cdot \frac{13.53\ g}{cm^3} = 189.42\ g\ Hg \cdot \frac{1\ mole}{200.59\ g} = 0.94\ moles\ Hg$$

$$0.94\ moles\ Hg \cdot \frac{\text{Avogadros number}}{mole} = 5.66 \cdot 10^{23}\ atoms\ Hg$$