Chemistry for Earth Scientists
Practical 1: Atomic Theory and Stoichiometry
(Worked Solutions)

Use the unit-factor method to solve all of these problems (no matter how easy!)

1. How many seconds in a year?

Solution:

$$1\text{ year} \times \frac{365\text{ days}}{\text{year}} \times \frac{24\text{hours}}{\text{day}} \times \frac{60\text{ min}}{\text{hour}} \times \frac{60\text{ secs}}{\text{min}} = 3.1536 \times 10^{7}\text{ seconds}$$

2. How many inches are in a kilometer? There are 5280 feet/mile, 12 inches/foot and 0.62 miles/km.

$$1\text{ km} \times \frac{0.62\text{ mile}}{\text{km}} \times \frac{5280\text{ ft}}{\text{mile}} \times \frac{12\text{ inches}}{\text{foot}} = 3.9 \times 10^{4}\text{ inches}$$

3. You are having a party and want to invite 15 people. Each person will need 4 slices of pizza. Each pizza costs £16 and has 12 slices. How much will this cost?

Solution:

$$15\text{ people} \times \frac{4\text{ slices}}{\text{person}} \times \frac{1\text{ Pizza}}{12\text{ slices}} \times \frac{£16}{\text{Pizza}} =$$

4. A rock contains 20 ppm Au. This is the same as 20 mg Au per kg of rock. How many kg of rock are needed to get 1 g of Au?

$$1\text{ g Au} \times \frac{1\text{ kg rock}}{20\text{ mg Au}} \times \frac{1000\text{ mg}}{1\text{ g}} =$$

5. An ore contains 10 g Au per 1000 kg. Gold is worth $1500 an ounce. How many kg of ore must be mined to get £1,000,000? There are 28 g/ounce and $1.6/£.

Solution:

$$£1{,}000{,}000 \times \frac{1\text{ oz Au}}{\$1500} \times \frac{28\text{ g Au}}{\text{oz Au}} \times \frac{\$1.6}{£} \times \frac{1000\text{ kg Ore}}{10\text{ g Au}} =$$

6. Petrol costs £1.50 per litre. There are 4.5 litres/gallon (imperial). How many euros will it cost you to drive 800 kilometers given that your car gets 30 miles to the gallon and there are 1.45 euros/ £. There are 1.6 km/mile.

Solution:

$$800\text{ km} \times \frac{1\text{ mile}}{1.6\text{ km}} \times \frac{1\text{ gallon}}{30\text{ miles}} \times \frac{4.5\text{ litres}}{\text{gallon}} \times \frac{£1.50}{\text{litre}} \times \frac{1.45\text{ euros}}{£} =$$

7. There are 300 “calories” (actually, kcal) per pint of beer. Upon coming to Bristol, Fred is starting to drink, on average, two pints a day. A rule of thumb is that if he consumes 3500 excess calories, he will generate 1 pound of excess body fat. How much weight will Fred gain in his first year of University?

$$1\text{ year} \times \frac{365\text{ days}}{\text{year}} \times \frac{2\text{ beers}}{\text{day}} \times \frac{300\text{ kcal}}{\text{beer}} \times \frac{1\text{ lb fat}}{3500\text{ kcal}} = 63\ lbs$$

(Note: he doesn’t gain this much because, as is weight increases, is calorie needs increase)

8. How many ng of Pb are in 1.0×10^{-9} moles of lead? The atomic mass of lead is 208.0 grams/mole.

Solution:

$$1.0 \times 10^{-9}\text{ moles Pb} \times \frac{208\text{ g Pb}}{\text{mol Pb}} \times \frac{1\text{ ng}}{10^{-9}\text{ g}} = 208\text{ ng}$$

9. A solution contains 100 mg Pb/kg water. What is the concentration of Pb in moles Pb/kg water? Again, there are 207.2 grams Pb/mole Pb.

$$\frac{100.\text{ mg Pb}}{\text{kg water}} \times \frac{1\, molePb}{207.2\text{ g Pb}} \times \frac{1\, g}{1000\text{ mg}} = 4.83\ x\ 10^{-4}\text{molesPb/kgwater}$$

10. 50 grams of NaCl are dissolved in 1 kg of water. What is the concentration of NaCl in moles/kg water? There are 58.0 g NaCl/mole NaCl.

$$\frac{50.\text{ g NaCl}}{\text{kg water}} \times \frac{1\, moleNaCl}{58.0\text{ g NaCl}} = 0.86\text{ moles NaCl/kgwater}$$

11. In the simple elemental gas phase, oxygen exists as the O_2 molecule. At 1 bar pressure, a mole of O_2 molecules has a volume of 22.4 litres. Given that there are 6.022×10^{23} O_2 molecules in a mole, how much volume in ($Å^3$)

is available for each O_2 molecule? Note that there are 1000 cm^3 in a liter and 10^8 Å/cm.

Solution:

$$\frac{22.4 \text{ liters}}{\text{mole}} \times \frac{1 \text{ mole}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{1000 \text{ cm}^3}{\text{liter}} \times \frac{(10^8 \text{Å})^3}{\text{cm}^3} = 3.72 \times 10^4 \text{Å}^3$$

12. How much biomass (CH_2O) in kg would be produced if we removed all the CO_2 from the atmosphere via photosynthesis:

$CO_2 + H_2O = CH_2O + O_2$

The concentration of CO_2 in the atmosphere is 200 mg/kg, the volume of the atmosphere is 8.14×10^{18} m^3 and the density of the atmosphere is about 0.5 kg/m^3.

Solution:

$$\frac{200 \text{ mg CO}_2}{\text{kg Atmos.}} \times \frac{0.5 \text{ kg Atmos.}}{\text{m}^3 \text{ Atmos.}} \times 8.14x10^{18} \text{m}^3 \text{Atmos.} \times \frac{1 \text{ mole CH}_2\text{O}}{1 \text{ mole CO}_2}$$

$$\times \frac{30\text{g CH}_2\text{O}}{\text{mole CH}_2\text{O}} \times \frac{1 \text{ mole CO}_2}{44 \text{ g CO}_2} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ kg}}{1000 \text{ g}} =$$

13. How many grams of CO_2 do we generate from burning 1 kg of coal (assume pure carbon). There are 12 grams of carbon in 44 g of CO_2.

$$1.0\text{kg C} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{44. \text{ g CO}_2}{12. \text{ g C}} = 3.7x10^3 \text{g CO}_2$$

14. Balance the following reaction for the weathering of feldspar (microcline):

$KAlSi_3O_8$ (microcline) + CO_2 + H_2O =

$Al_2Si_2O_5(OH)_4$ (kaolinite) + H_4SiO_4 + HCO_3^- + K^+

Now, calculate how many moles of CO_2 will be consumed by the weathering of 1 kg of microcline. The atomic masses of Si, Al, K and O are 28.0, 27.0, 39.1 and 16.0 grams/mole, respectively.

Solution:

$aKAlSi_3O_8$ (microcline) $+bCO_2 + cH_2O =$

$dAl_2Si_2O_5(OH)_4$ (kaolinite) $+ eH_4SiO_4 + fHCO_3^- + gK^+$

K: a =g
Al : a = 2d
Si: 3a = 2d + e
O: 8a + 2b + c = 9d + 4e + 3f
C: b = f
H: 2c = 4d + 4e + f

We have 7 unknowns and 6 equations. Set a = 1 to get g = 1 and d = ½ and e = 2. We then get 8 + c = 9/2 + 8 + f and 2c = 2 + 8 + f to give c = 11/2 and f=1 and b =1

$KAlSi_3O_8$ (microcline) $+CO_2 + 11/2\ H_2O =$

½ $Al_2Si_2O_5(OH)_4$ (kaolinite) $+ 2H_4SiO_4 + HCO_3^- + K^+$

$$1\text{kg Feld.} \times \frac{1 \text{ mole Feld}}{278.1 \text{ g Feld.}} \times \frac{1000\text{g Feld.}}{\text{kg Feld.}} \times \frac{1 \text{ moles } CO_2}{\text{mole Feld.}} = 3.6 \text{ moles } CO_2$$