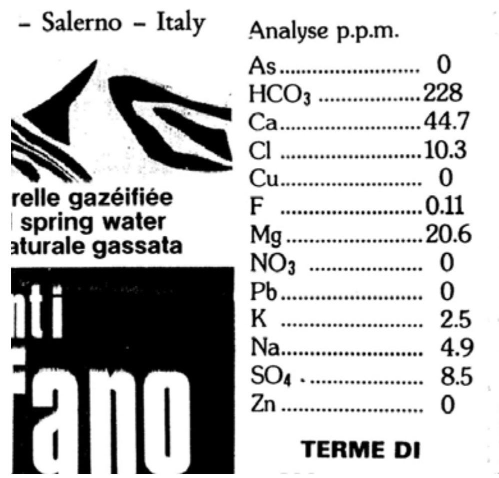
COMPETENCY 2 Making the Most of Scientific Knowledge

1. For some unknown reason, a few bottled water companies list the results of water analysis without including the ionic charges.

Using the charges of **polyatomic ions** and metal ions from the list shown, write the **empirical formulas** and **names** of any **four** compounds that can be created from these ions, if they were all present in sufficient quantities.



For example, if Li and OH had been listed,

We would first include the charges:

Li^+ (charge is positive one)
Polyatomic = OH^- (charge is negative one)

One of the four answers would have been:

- Empirical formula : LiOH
- Name: lithium hydroxide

Here are the charges for the polyatomic ions: HCO_3^-, NO_3^-, SO_4^{-2},

1. SOLUTION

The students will recognize the ions listed in the first two columns:

METAL IONS (those recognized by students from main groups studied)	POLYATOMICS	FORMULAE (any four of these are acceptable)	NAMES
Ca^{2+}	HCO_3^-	$Ca(HCO_3)_2$	calcium hydrogen carbonate
		$Ca(NO_3)_2$	calcium nitrate
		$CaSO_4$	calcium sulfate
Mg^{2+}	NO_3^-	$Mg(HCO_3)_2$	magnesium hydrogen carbonate
		$Mg(NO_3)_2$	magnesium nitrate
		$MgSO_4$	magnesium sulfate
K^+	SO_4^{2-}	$KHCO_3$	potassium hydrogen carbonate
		KNO_3	potassium nitrate
		K_2SO_4	potassium sulfate
Na^+		$NaHCO_3$	sodium hydrogen carbonate
		$NaNO_3$	sodium nitrate

		Na_2SO_4	**sodium sulfate**

2. Sodium benzoate is a preservative used in acidic foods such as jams and salad dressings.

- Sodium benzoate's toxic dose is 500 mg/kg of body weight.
- The greatest amount of sodium benzoate allowed in every 100 grams of jam is 0.10 g. This is the legal limit.

One day, something went wrong at a jam factory, and ten times the legal limit of sodium benzoate was added.

In theory, how many 454 gram-jars of jam would a 50 kg child have to eat to experience the toxic dose?

2. SOLUTION:

$$\frac{500\text{ mg of sodium benzoate}}{\text{kg of body weight}} = \frac{0.500\text{ g of sodium benzoate}}{\text{kg of body weight}}$$

$$50\text{ kg body weight}\left[\frac{0.500\text{ g sodium benzoate}}{\text{kg body weight}}\right] = 25\text{ g of sodium benzoate would be toxic.}$$

$$\text{Ten times the legal limit} = \frac{10 * 0.10\text{g sodium benzoate}}{100\text{ g of jam}} = \frac{1.0\text{g sodium benzoate}}{100\text{ g of jam}}$$

$$25\text{ g of sodium benzoate}\left[\frac{100\text{g of jam}}{1.0\text{ g sodium benzoate}}\right] = 2500\text{ g of jam}$$

2500g/(454 g/jar) = 5.5 jars would contain a toxic dose.

Other methods showing reasoning and the correct answer are also acceptable.

3. Isotopes of oxygen have been crucial in understanding the history of climate change. Of the three stable isotopes of oxygen, the pair that provide insight into past temperatures are ^{18}O and ^{16}O.

From the point of view of protons, neutrons, chemical properties, and physical properties, list two similarities and two differences between ^{18}O and ^{16}O.

3. SOLUTION

Similarities	Differences		
• They each have 8 protons per atom • They have similar chemical properties	^{18}O	Each atom has 10 neutrons.	Has a higher mass and density. (Water containing ^{18}O will evaporate more slowly.)
	^{16}O	Each neutron has 8 neutrons.	Has a lower mass and density.

4. Gallium, which is replacing the toxic element mercury in fever thermometers, has an atomic mass is 69.723 amu.

The following table shows the relative abundance for each of gallium's two isotopes.

Isotope	**Relative Abundance**
^{69}Ga	60.1 %
???	39.9 %

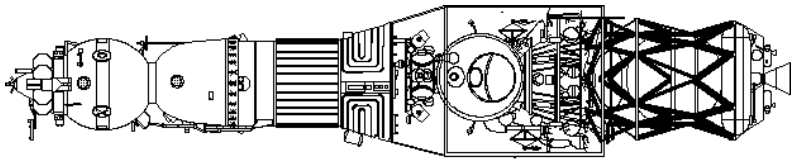
Calculate the mass number of the missing isotope.

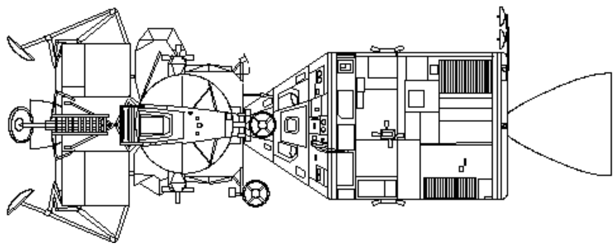
4. SOLUTION

69(0.601) + x (0.399) = 69.723.
0.399x + 41.469 = 69.723.
x = (69.723 - 41.469) /0.399
x = 70.81
The missing isotope is ^{71}Ga with a mass number of 71.

5. In space vehicles, CO_2(carbon dioxide) has to be removed to prevent it from becoming toxic to astronauts. This is done by inserting cylinders of LiOH in the cabin of the vehicles, and then the following reaction occurs:

$$2\ LiOH_{(s)} \quad + \quad CO_{2(g)} \rightarrow \quad Li_2CO_{3(s)} \quad + \quad H_2O_{(s)}$$





In a typical day, according to a study, a crew of four astronauts will exhale a total of 3600 grams of CO_2.

How many kg of LiOH are needed to absorb such an amount of CO_2?

5. SOLUTION

$$3600\ g\ CO_2 \left(\frac{mole}{12+2(16)\ g}\right) = \frac{3600}{44} moles = 81.818...moles\ CO_2$$

From the balanced equation, we observe that two moles of LiOH are needed to react with every 1 mole of CO_2:

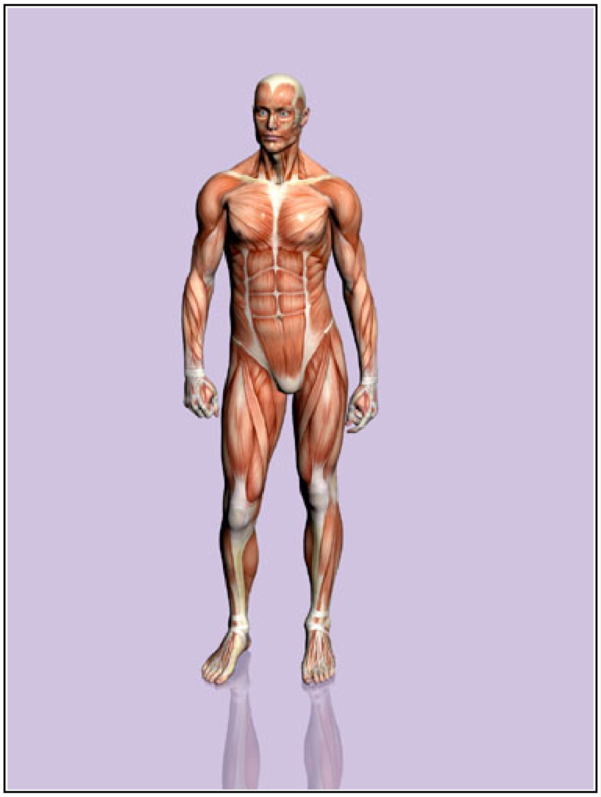
$$81.818\ moles\ CO_2 \left(\frac{2\ LiOH}{1 CO_2}\right) = 163.636\ldots moles\ LiOH$$

$$163.636\ldots moles\ LiOH \left(\frac{7+16+1 g}{mole}\right) = 3927\ g\ of\ LiOH$$

3927 g of LiOH = 3.9 kg

6. The following table gives the mass of each element found in a 75 kg human body.

ELEMENT	Mass % in the human body	Mass (g)
O	65	48750
C	18	13500
H	10	7500
N	3	2250
Ca	1.5	1125
P	1.2	900
K	0.2	150
S	0.2	150
Cl	0.2	150
Na	0.1	75
Mg	0.05	37.5
Fe	0.05	37.5



Use these numbers to calculate the **total number of atoms** in a 75 kg human body.

6. **<u>SOLUTION</u> (in the answer booklet, you can include this table without the formulae mentioned in the headings and without the answers, needless to say!)**

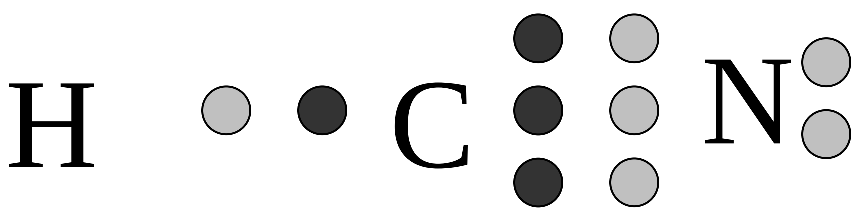
ELEMENT	Mass % in the human body	Mass (g)	Molar mass (g/mole)	Moles = mass/molar mass	Atoms = moles *6.02 X 10^{23}
O	65	48750	16	3046.875	
C	18	13500	12	1125	
H	10	7500	1	7500	
N	3	2250	14	160.7143	
Ca	1.5	1125	40	28.125	
P	1.2	900	31	29.03226	
K	0.2	150	39	3.846154	
S	0.2	150	32	4.6875	
Cl	0.2	150	35.5	4.225352	
Na	0.1	75	23	3.26087	
Mg	0.05	37.5	24	1.5625	
Fe	0.05	37.5	56	0.669643	
			total	11908	7.2 X10^{27} atoms

COMPETENCY 3 Communicating With the Language of Science

7. The seed within a peach pit contains a small amount of cyanogenic glucosides, compounds that react with stomach acid to produce the poison hydrogen cyanide, HCN.

   Draw a Lewis dot structure for HCN and find the total number of covalent chemical bonds in one molecule of this poisonous compound.

7. SOLUTION



There are four pairs of shared electrons, equivalent to four covalent bonds.
Or student can write: one triple bond and one single bond.

Check:

Element	Valence	Bonds needed
H	1	2 - 1 = 1
C	4	8 – 4 = 4
N	5	8 – 5 = 3

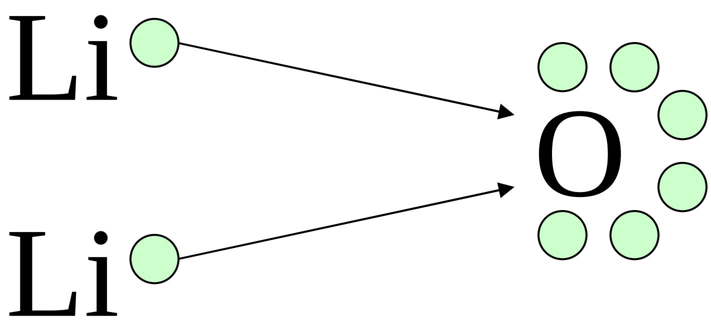
Bonds = total of 8 / 2 electrons per bond = 4.

8. To prevent the oxidation of lithium metal before it is placed in long-lasting batteries, it has to be stored in Vaseline jelly. If stored in oil, as is done with the rest of its group's members, lithium floats to the top and still reacts with oxygen.

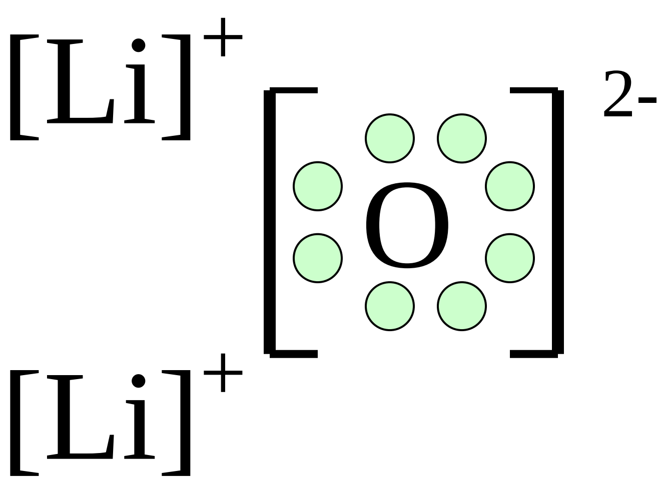
a) Use Lewis dot structures to reveal how oxygen (O) reacts with lithium (Li).
b) Then also draw a diagram to represent the product of this reaction.

8. SOLUTION

a) REACTION
(each dot represents a valence electron)



b) IONIC PRODUCT



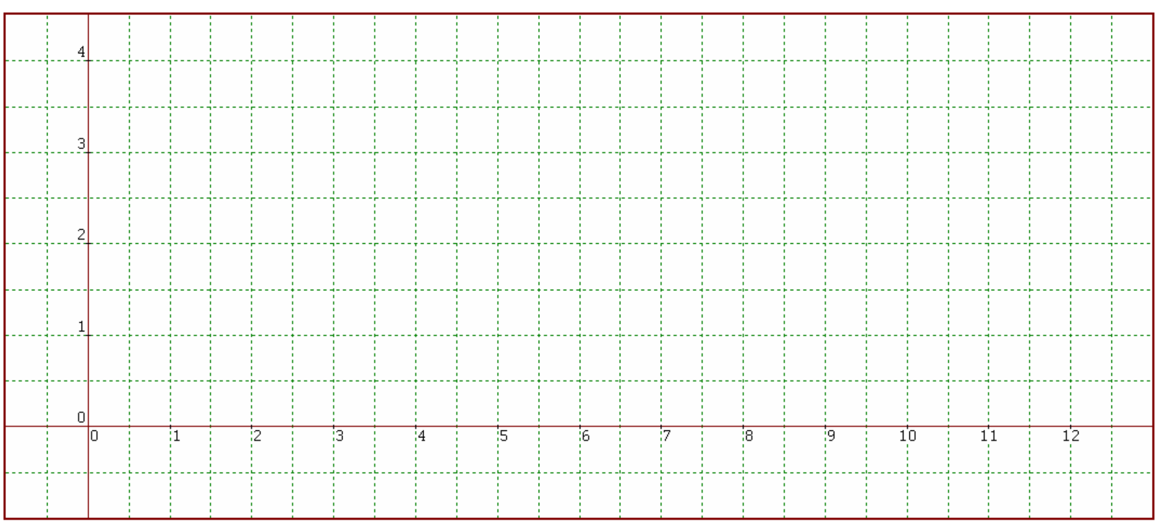
9. On the Cartesian plane provided, plot the electronegativity of the elements lithium through magnesium versus their atomic numbers.

The electronegativities of the elements are listed in the table below in increasing order.

To correctly match the electronegativities with their respective atomic numbers, you have to use your knowledge of the electronegativity trends within a period and within a group(family).

Correctly label both axes and label the graph with an appropriate title.

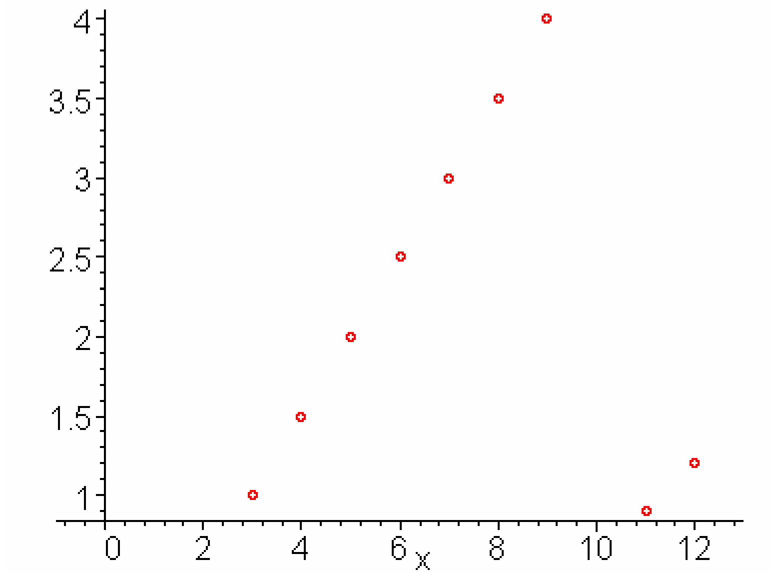
Electronegativity values for elements 3→12 (Paulings = unit)
0.9
1
1.2
1.5
2
2.5
3
3.5
4
cannot be measured



9. SOLUTION

ELECTRONEGATIVITY VERSUS ATOMIC NUMBER

Electronegativity (Paulings)



Atomic Number

RATIONALIZATION FOR TEACHERS (if needed)

- **Neon(10) has no electronegativity because it does not bond.**
- **From Li(3) to F(9) electronegativities increase across the period**
- **$_{11}$Na 's value has to be lower than $_{3}$Li's because electronegativities decrease as you increase atomic number within a group.**
- **$_{12}$Mg 's value has to be lower than $_{4}$Be 's for the same reason (group trend).**
- **At the same time, Mg's value has to be higher than Na's because of the trend across the period**

COMPETENCY 1 (Seeking Solutions to Scientific Problems)

10. According to the environmental protection agency (EPA), sulphate (SO_4^{-2}) is a substance that occurs naturally in drinking water. But health concerns regarding sulphate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of this ion.

The following is the basic test for checking levels of sulphate (SO_4^{-2}).

(1) Add 25.0 ml of deionized (purified with filter) water to a plastic cup.
(2) Take a 2.0 ml sample of the drinking water you are testing and add it to the plastic cup.
(3) Then while swirling, add REAGENT 1 from the sulphate testing kit.
(4) With more swirling, add REAGENT 2 from the kit.
(5) After 1 minute, the solution will turn cloudy if the sulfate ion is present in the drinking water. If no sulfate ion is present, then the solution will remain clear

A scientist tests a sample of water, observes some cloudiness but wants to check if the drinking water is indeed the only source of sulphate being detected in the test.

Modify the above procedure so the scientist could use it to check whether or not the deionized water was also contributing some sulphate ion.

10. SOLUTION

(1) Add 25.0 ml of deionized (purified with filter) water to a plastic cup.
(2) Take a 2.0 ml sample of the same deionized water and add it to the the plastic cup.
(3) Then while swirling, add REAGENT 1 from the sulphate testing kit.
(4) With more swirling, add REAGENT 2 from the kit.
(5) After 1 minute, the solution will remain clear if the deionized water truly contained no sulphate.

11. A technician wants to use electricity to ionize four different elements: sulfur(S), chlorine(Cl), potassium(K) and sodium(Na). Each is in its own sealed tube.

In hoping to eject electrons from each of these elements, she gradually applies voltage. She knows when she will be successful because, in each case, a characteristic light will be emitted.

- Use your knowledge of periodic trends to form a hypothesis about which element will ionize first and which will ionize last.
- In your hypothesis, mention why you are making that prediction.

11. **SOLUTION**

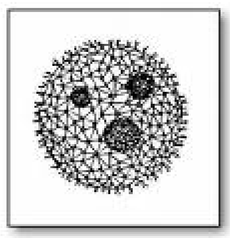
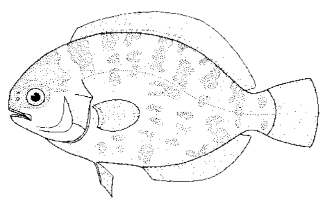
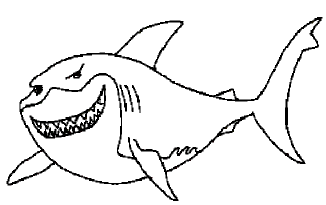
Metals have ionization energies that are lower than those of non-metals. Within a group, ionization energy decreases with atomic number, so potassium should ionize more easily than sodium and be the first to produce light.

Ionization energy increases within a period, so it is more difficult to ionize chlorine than it is to ionize sulphur, which is to chlorine's left in the periodic table.

Summary of hypothesis: We should see potassium ionize first and see chlorine ionize last.

12. The following table reveals concentrations of mercury found in water and in various organisms in the Gulf of Mexico in the year 2000.

Form a hypothesis about why algae have more mercury than the water itself, and why different fish have various concentrations of mercury.

		Eating habits	Concentration of mercury(ppm)
sea water			< 0.001
microscopic algae		Plant-like; makes its own food; serves as food for small fish	0.032
butterfish		The butterfish feeds on small fish, squid	0.058
white shark		Fish, marine mammals, who in turn eat fish	0.988

Source:http://www.cfsan.fda.gov/~frf/sea-mehg.html

12. <u>SOLUTION</u>

The rate at which algae excrete mercury is lower than their intake rate. In other words, algae filter the mercury and *<u>bioconcentrate</u>* it because organic compounds within their cells bond to the toxic metal. When small fish feed on algae, the fish continue to accumulate the poison by a similar mechanism. Out of the three organisms, the shark is the highest on the food chain, so it *<u>bioaccumulates</u>* the most mercury.