SCH3U3 Period # 2 / Room 311

“Using Electron to Identify Elements”

Given: Sept. 27, 2019

Due: Oct. 1, 2019

Lab Partners:

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Problem:

When trying to determine the chemical composition of a binary compound, the compound can be provided energy to excite its electrons to a higher energy state, as explained by the Bohr model of an atom. When the electrons jump down to a lower energy state, they release energy in the form of light. The colour of the released light can help to identify the metal of the compound. This lab explores an approach to excite the compound using a flame, and predicting the metal in a mystery compound from the colour the flame burns.

Materials:

- 2 250 mL beakers with 200mL of water
- 1 T-pin
- 1 Paper towel
- lead (II) nitrate
- lead(II) chloride
- potassium chloride
- potassium nitrate
- sodium chloride
- sodium sulfite
- sodium sulfate
- copper(II) sulfate
- copper(II) chloride
- strontium nitrate
- strontium chloride
- Mystery Compound 24
- Bunsen Burner
- Flint Striker

Procedure:

Please refer to the “Using Electrons to Identify Elements Lab” handout.

Observations:

Table 1.1

Compound Name	Compound Formula	Flame Colour
lead (II) nitrate	$Pb(NO_3)_2$	White, Orange
lead(II) chloride	$PbCl_2$	White, Orange
potassium chloride	KCl	Green, white, red, violet
potassium nitrate	KNO_3	Pink, Orange

sodium chloride	$NaCl$	Orange
sodium sulfite	Na_2SO_3	Orange
sodium sulfate	Na_2SO_4	Orange
copper(II) sulfate	$CuSO_4$	Green
copper(II) chloride	$CuCl_2$	Green, Blue
strontium nitrate	$Sr(NO_3)_2$	Red
strontium chloride	$SrCl_2$	Red
Mystery Compound 24	Mystery Compound 24	Red

Analysis:

2. What does each colour of each flame represent?

As seen in Table 1.1, there is a correlation between flame colours and the metal in the compound. The compound that made the flame burn white correlates to lead as the cation, orange correlates to sodium, green correlates to copper(II), and red correlates to strontium. Compounds containing potassium correlated to a wide array of colours, but the colours both potassium compounds burned was a shade of light purple. Since mystery compound 24 burned red, it is logical to consider that the metal in the compound is strontium. These results can be shown in this table:

Table 1.2

Metal Cation	Colour of Flame
lead(II)	White
potassium	Orange
sodium	Purple
copper(II)	Green
strontium	Red

3. Which has a larger wavelength, red light or blue light?

Red light has a longer wavelength than blue light since it has a lower frequency than blue light. Since red light has a frequency of $4.3 \times 10^{14}\ Hz$, its wavelength is calculated as follows:

$v = \lambda f$

$3.0 \times 10^{8}\ ms^{-1} = \lambda(4.3 \times 10^{14}\ Hz)$

$\lambda = \frac{3.0 \times 10^{8} ms^{-1}}{4.3 \times 10^{14} Hz}$

$\lambda = 6.98 \times 10^{-7} m$

Since blue light has a frequency of $6.40 \times 10^{14} Hz$, its wavelength is calculated as follows:

$v = \lambda f$

$3.0 \times 10^{8} ms^{-1} = \lambda(6.4 \times 10^{14} Hz)$

$\lambda = \frac{3.0 \times 10^{8} ms^{-1}}{6.40 \times 10^{14} Hz}$

$\lambda = 4.69 \times 10^{-7} m$

Therefore, red light, with a wavelength of $6.98 \times 10^{-7} m$, has a longer wavelength than blue light, with a wavelength of $4.69 \times 10^{-7} m$.

4. Which has a higher energy, red or blue light?

Energy is given by the equation $E = hf$, where E= energy, h = Planck's Constant, f = frequency.

For red light,

$E = hf$

$E = (6.626 \times 10^{-34} Js)(4.3 \times 10^{14} Hz)$

$E = 2.85 \times 10^{-19} J$

For blue light,

$E = hf$

$E = (6.626 \times 10^{-34} Js)(6.4 \times 10^{14} Hz)$

$E = 4.24 \times 10^{-19} J$

Therefore, blue light has a higher energy than red light.

5. Which has a higher energy, UV or IR radiation?

Energy is given by the equation $E = hf$, where E= energy, h = Planck's Constant, f = frequency. UV radiation has a frequency of $8 \times 10^{14} Hz$ and its energy is calculated as follows:

$E = hf$

$E = (6.626 \times 10^{-34} Js)(8 \times 10^{14} Hz)$

$E = 5.30 \times 10^{-19} J$

IR radiation has a frequency of $4.3 \times 10^{14} Hz$ and its energy is calculated as follows:

$E = hf$

$E = (6.626 \times 10^{-34} Js)(4.3 \times 10^{14} Hz)$

$E = 2.85 \times 10^{-19} J$

Therefore, UV radiation has a higher energy than IR radiation

6. Which has a higher frequency UV or IR?

The frequency of a wave is implicitly given by $v = \lambda f$, and is explicitly given by rearranging that equation: $f = \frac{v}{\lambda}$. The wavelength of UV and IR radiation is $3.75 \times 10^{-7}\ m$and $6.98 \times 10^{-7}\ m$, respectively.

For UV radiation, its frequency is calculated as follows:

$$f = \frac{v}{\lambda}$$

$$f = \frac{3.0 \times 10^{8}}{3.75 \times 10^{-7}}$$

$$f = 8.0 \times 10^{14}$$

For IR radiation, its frequency is calculated as follows:

$$f = \frac{v}{\lambda}$$

$$f = \frac{3.0 \times 10^{8}}{6.98 \times 10^{-7}}$$

$$f = 4.3 \times 10^{14}$$

Therefore, UV radiation has a higher frequency than IR radiation.

7. What kind of radiation is used in TV remotes?

TV remotes use short bursts of IR radiation to communicate with your TV, with a short burst and a pause encoding a 1 and 0, respectively. Moreover, remotes also send out a short code of IR radiation to specify the device for which the instruction applies.

8. What is the mathematical relationship between energy of a radiation and wavelength?

The energy of a radiation is proportional to its wavelength, and is given by $E = hf$, where E = energy, h = Planck's Constant, and f = frequency.

9. What is the relation between frequency and wavelength?

Frequency is inversely proportional to wavelength, and is given by $f = \frac{v}{\lambda}$, where f = frequency, v = velocity, and v = wavelength. This also explains why EM radiation with a higher frequency, like UV radiation, have a shorter wavelength than radiation with a lower frequency, like IR radiation.

10. Which travels faster, red light or blue light?

Light, in a vacuum, travels at the same speed, regardless of its wavelength, frequency, polarization, or other characteristics. However, in certain materials, light travels differently depending on its velocity. The speed at which light travels through a material is described by a refractive index, which is inversely proportional to the speed of light through a material. The refractive index is calculated using $n = \frac{c}{v}$, where n = refractive index, c = speed of light in a vacuum, and v = velocity of light. Since the velocity of light is given by $v = \lambda f$, where v = velocity, λ = wavelength, and f = frequency, the refractive index is inversely proportional to the light's frequency and wavelength. This is further supported by calculations of the velocities of red and blue light as follows, given that the frequencies and wavelengths of red and blue light, respectively, are: $4.3 \times 10^{14} Hz$,$7.0 \times 10^{-9} m$, $6.7 \times 10^{14} Hz$,$4.5 \times 10^{-9} m$.

$v_{red} = \lambda f$

$v_{red} = (7.0 \times 10^{-9})(4.3 \times 10^{14})$

$v_{red} = 3.01 \times 10^{6} ms^{-1}$

$v_{blue} = \lambda f$

$v_{blue} = (4.5 \times 10^{-9})(6.7 \times 10^{14})$

$v_{blue} = 3.02 \times 10^{6} ms^{-1}$

Given that the velocities of red and blue light are $3.01 \times 10^{6} ms^{-1}$ and $3.02 \times 10^{6} ms^{-1}$ respectively, their refractive indices are calculated as follows:

$n_{red} = \frac{c}{v}$

$n_{red} = \frac{3\times10^{8}}{3.01\times10^{6}}$

$n_{red} = 9.97 \times 10^{2}$

$n_{blue} = \frac{c}{v}$

$n_{blue} = \frac{3\times10^{8}}{3.02\times10^{6}}$

$n_{blue} = 9.93 \times 10^{2}$

As the calculations show, for light with a smaller wavelength, it travels slower through materials as its refractive index is larger. Therefore, red light travels faster than blue light in certain materials.

11.Fireworks display beautiful colours why?

Fireworks hold a combination of the metals in this lab and others to create their beautiful colours, as an additional discovery in this lab was that burning multiple chemicals together causes the flame to burn in a combination of the colours that the flame burned for each ion individually. Fireworks that hold a combination of these metals are able to create combinations of these colours, and holding the metals in separate canisters can create many different colours.

Conclusion:

As seen in Table 1.2, certain metal cations cause the flame to burn a different colour; lead(II) burned white, potassium burned orange, sodium burned light purple, copper(II) burned green, and strontium burned red. Mystery compound 24 burned red, implying that the metal cation in the compound was strontium. The colours each metal cation causes the flame to burn was a result of the metal's electrons jumping down to a lower energy state, releasing energy in the form of light, its colour determined by its wavelength. Three possible sources of error include: the T-pin used to burn each compound could have collected residue of previous metals that did not come off through the rinse, wash, and dry process, producing a number of different colours when the T-pin is placed in the flame again. This source of error may have contributed to the multitude of colours seen when burning potassium chloride in the original experiment. Furthermore, different colours of the flame that could have come from a chemical burning at a higher temperature were unobserved because each chemical was burned at a fixed temperature that may not have been hot enough to achieve those reactions. Finally, it is nearly impossible for the contents of each bottle to be completely comprised of the compound on the bottle's label - the tiny impurities in the chemicals may have contributed to the colour the flame burned from each chemical, causing the flame to burn colours other than the colour fire burns when burning only that compound.