

Unit 3

Problems

Problems based on Chromium

Chromium(III) picolinate, which contains Cr^{3+} ions, is an over-the-counter dietary supplement for the treatment of Type-2 diabetes. Chromium-52 is the most abundant isotope of chromium in a naturally occurring sample.

Problem 3.1

A $^{52}\text{Cr}^{3+}$ ion contains _____ protons, _____ electrons and _____ neutrons.

Answer

For a neutral atom of Cr-52, i.e., ^{52}Cr , we note that $A = 52$ and $Z = 24$, since the atomic number of Cr is 24. We can also write it as $^{52}_{24}\text{Cr}$. Thus, an atom of $^{52}_{24}\text{Cr}$ has 24 protons and 24 electrons. The number of protons and neutrons add up to the mass number 52; hence, the number of neutrons equals $(52 - 24) = 28$.

For a $^{52}_{24}\text{Cr}^{3+}$ ion, the number of protons and neutrons are the same as a neutral $^{52}_{24}\text{Cr}$ atom.

In a $^{52}_{24}\text{Cr}^{3+}$ ion, the **positive** charge results because of the **loss of 3 electrons** from a neutral atom of $^{52}_{24}\text{Cr}$. Therefore, the number of electrons in an ion of $^{52}_{24}\text{Cr}^{3+}$ is 21.

Thus, a $^{52}_{24}\text{Cr}^{3+}$ ion has 24 protons, 21 electrons and 28 neutrons.

Problem 3.2

There are four stable isotopes of chromium (symbol Cr). Complete the table below.

Isotope	Number of electrons	Number of Protons	Number of Neutrons
$^{50}_{24}\text{Cr}$			
$^{52}_{24}\text{Cr}$			
$^{53}_{24}\text{Cr}$			
$^{54}_{24}\text{Cr}$			

Answer

Strategy: For a neutral atom of iron, ^A_ZCr ,

Atomic number (Z) = Number of protons = Number of electrons

Mass number (A) = Number of protons + Number of neutrons

We note that the atomic number of chromium is 24, which equals the number of protons and electrons for each of the isotopes.

Number of neutrons = Mass number (A) - Number of protons. For example, for $^{52}_{24}\text{Cr}$,

Number of neutrons = $52 - 24 = 28$

The answers are summarized in the table below.

Isotope	Number of electrons	Number of Protons	Number of Neutrons
$^{50}_{24}\text{Cr}$	24	24	26
$^{52}_{24}\text{Cr}$	24	24	28
$^{53}_{24}\text{Cr}$	24	24	29
$^{54}_{24}\text{Cr}$	24	24	30

Problem 3.3

The symbol for the alkaline earth metal with the lowest atomic number is _____.

Answer

Elements in Group 2A of the periodic table are called alkaline earth metals. These are beryllium, magnesium, calcium, etc. The one with the lowest atomic number is beryllium. The symbol is Be.

Problem 3.4

Halogens have _____ valence electrons.

Answer

Elements in Group 7A of the periodic table are called halogens, whose electron configurations are of the form [Rare gas] ns^2np^5 . Halogens have 7 valence electrons.

Problem 3.5

Selenium is a micronutrient and an anti-oxidant. It is found in certain nuts; Brazil nuts are particularly rich in selenium. Write the electron configuration of selenium, using the rare gas notation.

Answer

Selenium is in Group 6A of the periodic table with an atomic number of 34. Its ground state electron configuration is $[\text{Ar}]4s^23d^{10}4p^4$.

Problem 3.6

Early studies showed that vanadium (V) normalized blood sugar levels in animals with type 1 and type 2 diabetes. When people with diabetes were given vanadium, they had a modest increase in insulin sensitivity and were able to lower their need for insulin. (From WebMd). What is the ground state electron configuration for V and V^{2+} ?

Answer

V: $[\text{Ar}]4s^23d^3$

The 4s electrons are removed first to form the ion V^{2+}

Thus, the ground state electron configuration for V^{2+} is $[\text{Ar}]3d^3$

Problem 3.7

Calculate the average mass of chromium atoms, based on the data given below for naturally occurring chromium.

Isotope	Abundance	Isotopic mass (amu)
^{50}Cr	0.04345	49.9460464
^{52}Cr	0. 83789	51.9405098
^{53}Cr	0.09501	52.9406513
^{54}Cr	0.02365	53.9388825

Answer

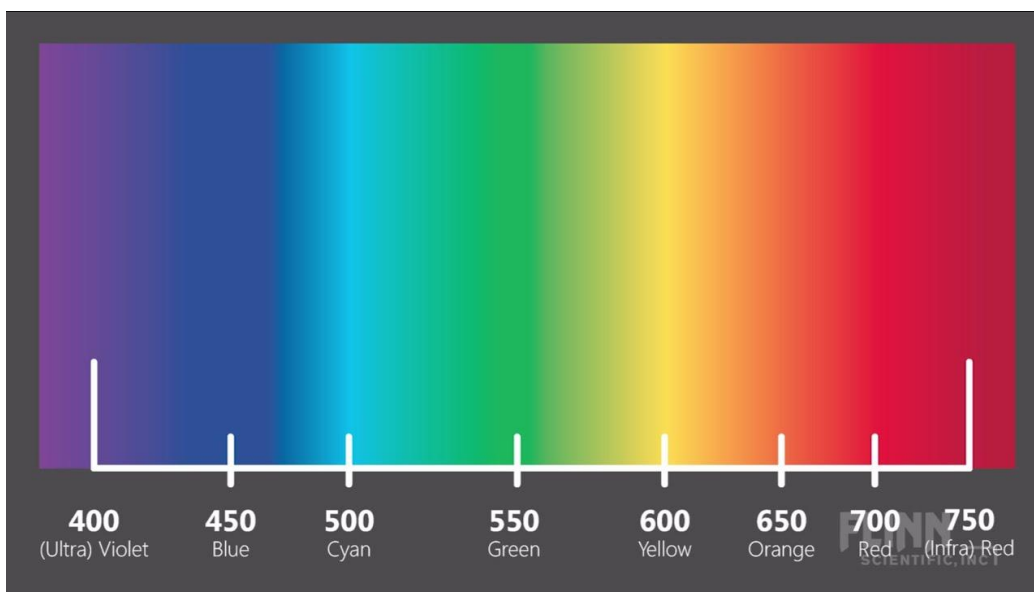
We apply the formula given below, using the numbers provided in the Table above.

$$\text{Average Mass} = \sum_i (\text{Fractional Abundance} \times \text{Isotopic Mass})_i$$

Thus, the average mass = $(0.04345 \times 49.9460464 \text{ amu}) + (0. 83789 \times 51.9405098 \text{ amu}) +$
 $+ (0.09501 \times 52.940 \text{ amu}) + (0.02365 \times 53.9388825 \text{ amu})$

$$= 51.996 \text{ amu.}$$

Please note that this matches the average mass 52.00 amu in common periodic tables.



Problem 3.8

The visible region for the human eye is given above. Which traffic light corresponds to the lowest energy (per photon)? An explicit calculation is not needed.

Answer

Strategy:

The key equations are:

$$E = h\nu$$

$$c = \nu\lambda$$

Thus,

$$E = \frac{hc}{\lambda}$$

where

E = energy

h = Planck's constant

ν = frequency

c = velocity of light

λ = wavelength

We note that E depends on $1/\lambda$. The **higher** the value of λ , **lower the energy**. Thus, comparing green (550 nm), yellow (600 nm) and red light (700 nm), red light corresponds to the lowest energy per photon.

Problem 3.9

Calculate the energy and wavelength for the transition $n = 5 \rightarrow n = 2$ in a H atom.

Answer

The key equations are:

$$\Delta E = -2.179 \times 10^{-18} J \left(\frac{1}{n_{final}^2} - \frac{1}{n_{initial}^2} \right)$$

$$\lambda = \frac{hc}{\Delta E}$$

where

ΔE = difference between energy levels

h = Planck's constant

c = velocity of light

λ = wavelength

Thus,

$$\Delta E = -2.179 \times 10^{-18} J \left(\frac{1}{2^2} - \frac{1}{5^2} \right) = -4.5759 \times 10^{-19} J$$

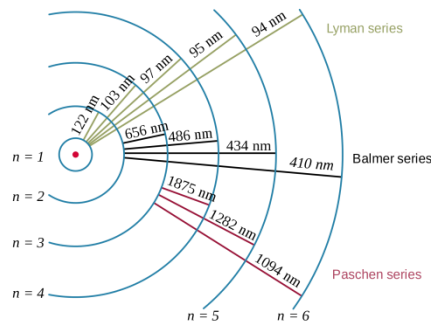
The negative sign corresponds to emission. We have also retained an extra digit for the next step.

$$\lambda = \frac{hc}{\Delta E} = \frac{(6.626 \times 10^{-34} J \cdot s)(2.998 \times 10^8 \frac{m}{s})}{4.5759 \times 10^{-19} J} = 4.341 \times 10^{-7} m$$

We convert this to nm, to compare with the figure given below.

$$\lambda = (4.341 \times 10^{-7} m) \left(\frac{10^9 nm}{1m} \right) = 434.1 nm$$

This matches (essentially) with the figure below. Please note that a negative value of ΔE simply represents emission, and wavelengths, even for emitted light, is reported as a positive number.



Problem 3.10

<https://www.thoughtco.com/liquid-nitrogen-facts-608504#:~:text=Liquid%20Nitrogen%20Uses&text=The%20freezing%20and%20transporting%20of,cryotherapy%20to%20remove%20skin%20abnormalities>

Liquid nitrogen is used for freezing and transporting of food products and the cryopreservation of biological samples, such as sperm, eggs, and animal genetic samples. In liquid nitrogen, nitrogen (N_2) molecules are held together by _____.

- (a) ion-ion interactions
- (b) ion-dipole interactions
- (c) dipole-dipole interactions
- *(d) London dispersion forces

Answer

Nitrogen molecules are nonpolar. The forces between molecules are London dispersion forces.

Problem 3.11

For which of the following, the ONLY intermolecular forces are London dispersion forces?

- (a) Ammonia (NH_3)
- (b) Water (H_2O)
- (c) Hydrochloric acid (HCl)
- *(d) Methane (CH_4)

Answer

EXCEPT methane, these molecules are all polar. Thus, in ammonia, water and hydrochloric acid, BOTH London dispersion forces and dipole-dipole forces exist. We also note that H-bonding is present in water and ammonia.

Problem 3.12

In which of the following substances do hydrogen bonds form?

- (a) Hydrogen, H_2
- (b) Methane, CH_4
- *(c) Ethanol (CH_3CH_2OH)
- (d) Phosphine (PH_3)

Answer

For hydrogen bonding, H must be bonded to one of the following atoms, F, O or N. Thus, hydrogen bonding is found in ethanol.

Problem 3.13

Which one of the following has the HIGHEST normal boiling point?

- *(a) HF
- (b) HCl
- (c) HBr
- (d) HI

Solution

The presence of hydrogen bonds in HF results in the highest normal boiling point, although London dispersion forces are the highest in HI.

Problem 3.14

Of the following substances, _____ has the HIGHEST normal boiling point.

- *(a) NaCl
- (b) HCl
- (c) CH_2Cl_2
- (d) CH_3Cl

Solution

The compounds HCl, CH_2Cl_2 and CH_3Cl are all polar, while NaCl is ionic.

Problem 3.15

Hand sanitizers contain ethanol (CH_3CH_2OH). What are the intermolecular forces present in a sample of **pure ethanol**? Hint: There are multiple correct answers; please select all answers that are applicable.

- (a) ion-ion interactions
- (b) ion-dipole interactions
- *(c) dipole-dipole interactions
- *(d) H-bonding
- *(d) London dispersion forces

Solution

Ethanol is a polar molecule. In a molecule of ethanol, a H atom is attached to an atom of oxygen; thus, inter-molecular H-bonding is present. London dispersion forces are present in all molecules. Therefore, the forces present are: London dispersion forces, dipole-dipole interactions and H-bonding. Since no ions are present, ion-ion interactions and ion-dipole interactions don't exist.