Radiochemistry: from half-lives to saving lives

Student Handbook

Website: https://moodle.cinch-project.eu/course/view.php?id=85

This Section is to be completed BEFORE CLASS

Isotopes

Isotopes are atoms with the same number of ____________ but a different number of _____________.

Isotopes of an element share the same chemical ______________.

Radioactive isotopes (radionuclides)

A radioisotope is an _____________ that has ___________ nuclei.

This instability causes them to undergo changes in the nucleus in order to increase their stability, this process is known as ___________________. In doing so they emit radiation in the form of alpha, beta and gamma (α, β or γ) or a combination of them.

Q. Calculate the number of protons, neutrons and electrons for the following isotopes of potassium.

$_{19}$K	^{39}K	^{40}K	^{41}K
Protons			
Neutrons			
Electrons			

Medical radioisotopes

Yttrium-90 (^{90}Y) is an important radioisotope that can be used to treat _______________.

^{90}Y is formed when strontium-90 (^{90}Sr) undergoes _______________________ decay, which in turn undergoes β^- decay to form stable zirconium-90 (^{90}Zr).

$$^{90}_{38}Sr \xrightarrow{t_{1/2} = 29\ years}$$

$$\xrightarrow{t_{1/2} = 64\ hours}$$

The short _______________ of ^{90}Y means that it can be implanted in the cancer and deliver a high dose of radiation in a relatively short time period. The microspheres also block the blood vessels surrounding the cancer, starving the cancer of its ______________________ – thereby killing it.

Q. Why does ^{90}Sr accumulate in bones? (Hint: what other ions have similar properties to Sr^{2+}?)

____

____

Column Chromatography

Chromatography is a technique used to ____________ ___________ and ____________ components in a mixture.

Q. In gas chromatography, the mobile phase is an inert gas (e.g. helium). What is the mobile phase in column chromatography? ___________________

Q. What is the stationary phase? ____

Separation by column chromatography depends on the balance between _____________ in the moving phase and _______________ in the stationary phase.

Retention Factor (*k'*)

Complete the table below with the word "stationary" or "mobile" to describe the movement of the radionuclide in a given nitric acid concentration. One answer has already been provided.

Solvent	Sr-90	Y-90
3 M HNO_3		
0.0001 M HNO_3		mobile

Q. Based on the information above, how could you separate ^{90}Sr from ^{90}Y?

____

____

Experimental Procedure

Use your understanding of the theory to complete the experimental procedure.

Prepare the column

1. Open valve 3 (V3) to start the experiment.
2. Set the solvent flow rate to _____________________.
3. Select ____________________ solvent.
4. Click on "start solvent pump" to begin pumping the solvent onto the column. Use the camera feed to check that the pump is rotating and droplets of solvent are landing on the slide.
5. Allow the solvent to run for 5 minutes to ______________________ the entire column.
6. Whilst waiting, set up your measurement parameters by going to the measurement tab. Set the measurement time to 3600 seconds (the duration of your experiment, 1 hour) and the counting interval to 10 seconds (this is how often the Geiger counter will record the activity).
7. Click on "start measurement".
8. Make a note of the _____________________.

Separation of ^{90}Y from ^{90}Sr

9. After 5 minutes, stop the solvent pump.
10. Click on ______________. The syringe will administer the $^{90}Sr/^{90}Y$ solution onto the top of the column.
11. Start the solvent pump. Use the video to check that the solvent is flowing and that the measurement table is being filled.
12. Allow the first peak in the chromatogram to build up and return to the background count rate.
13. Select ________________________ solvent.
14. Allow the second peak to build up and return to the background count rate.
15. The experiment is now complete. Email the data and log book to your school email address.
16. Click on 'logout and exit'.

Missing words/phrases

background count rate	"inject activity!"	0.0001 M HNO_3
1 ml/minute	3 M HNO_3	'wet' the entire column

This Section is to be completed IN CLASS

What is Radiation?

Radiation is energy travelling as ______________ or _______________.

Q. What are the three main types of ionising radiation? ________________________________

Half-life (t½)

The quantity of material remaining after a given time, can be calculated using the equations below.

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

$$N_t = N_0 \, e^{-\lambda t}$$

λ = decay constant (s^{-1})
N_0 = initial quantity
N_t = remaining quantity after a time, t
t = time interval (s)
$t_{½}$ = half-life (s)

Q. Assuming a starting mass of 1.00 g, calculate the amount of ^{90}Y remaining after 5 days.

Beta minus decay (β^-)

β^- decay occurs when an isotope is ______________ because it has too many ________________.

To reach a more stable state, one of the _____________ decays into a _____________ and an ____________.

Q. Calculate how many protons, neutrons and electrons there are in ^{90}Sr, ^{90}Y and ^{90}Zr.

	^{90}**Sr**	^{90}**Y**	^{90}**Zr**
Protons	38		
Neutrons	52		
Electrons	38		

Questions

1. In your experiment, which component is the mobile phase and which is the stationary phase?

2. Why is it important to wet the column at the start of the experiment?

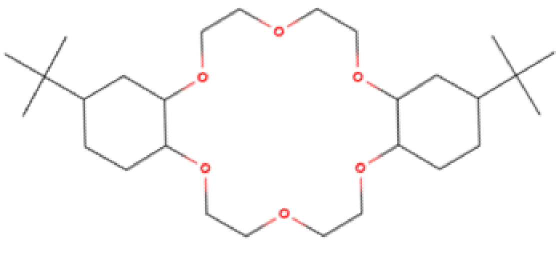
3. Draw and label a sketch of your results.

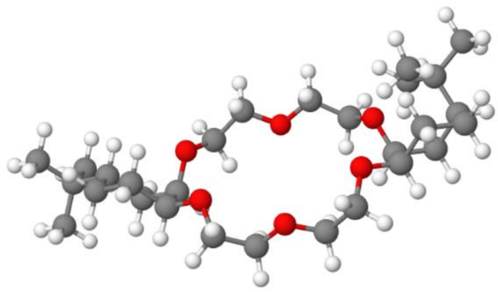
4. Using a noble gas core [Kr], complete the electron arrangement for the following:

   Sr

   Y

   Sr^{2+}





5. Go to the MolView website (http://molview.org). Use the left-hand panel to draw the crown ether used in this experiment. The chemical formula is $C_{28}H_{52}O_6$. Click on 2D to 3D to convert your diagram into a 3D shape. Use the right-hand panel to estimate the diameter of the resin's cavity (using the top panel, find "distance", then click between the atoms).

6. The ionic radius of Sr^{2+} and Y^{3+} is 1.40 Å and 1.16 Å respectively. Why do you think Y^{3+} shows very little affinity towards the crown ether resin?

7. What order did you add the acid solvent to the column and why?

8. What is the problem with storing ^{90}Y for too long before using it?

9. What hazards are associated with this experiment?

10. If you were carrying out this experiment in person, what precautions would you take?

11. How would you improve the design of the experiment?

12. Research another radioisotope and give an example of its application.