Half-Life Pennies Activity

TEACHER NOTES

The objective of this activity is to help your students to gain a better understanding of the process of radioactive decay through modeling. This activity could be used to support NGSS HS-PS1.8.

It will be necessary for your students to understand the basic concepts of unstable isotopes and half-life. Have them write the definitions in the boxes (see the KEY).

Each group will need about 25 to 35 pennies. You don't need to count- just throw them in a cup. It is good to give each group a slightly different number of pennies to really drive home the point later that the quantity does not change the half-life! If you don't have pennies, use whatever coins you have...but for fair tests a group's coins should all be the same type.

I give each group a tray or plate so that when they dump the pennies out, they are contained a little bit!

Read through the first few directions with the class. Each group needs to count their total number of pennies as their "Start" number before beginning! All "Start" boxes for Tables 1, 2, 3, and 4 can be filled in right then.

Then, let them have fun following the directions to dump and count ONLY the TAILS-UP pennies. The heads-up pennies should be placed to the side after each dump. They will not use all 10 spaces on the data table just because of the nature of half-life!

After all groups have completed Trials 1, 2, and 3, they will be AVERAGING their data for EACH DROP. See the Sample Data as an example. They should use whatever method of averaging numbers that they like and then round to the nearest whole number.

Now pair up the groups to SUM their averaged data from Table 4. I make a quick Excel spreadsheet on the front screen at this point with the summed data from the paired groups (I have each group read across their Table 5 aloud). For example, I have 8 groups, so I have 4 pairs of groups and my spreadsheet on the front screen would have 4 data tables:

0	1	2	3	4	5	6	7	8	9	10
55	25	10	5	3	2	0	0	0	0	0

0	1	2	3	4	5	6	7	8	9	10
56	39	21	12	5	1	0	0	0	0	0

0	1	2	3	4	5	6	7	8	9	10
55	25	13	6	2	1	1	1	0	0	0

0	1	2	3	4	5	6	7	8	9	10
50	26	16	7	6	3	1	1	0	0	0

This will make Table 6 a breeze to fill in for your students... you need to SUM the SMALL GROUP SUMS in the Excel spreadsheet. So using my examples above, I pop the function =SUM(select the cells for drop __) into the next row of cells:

0	1	2	3	4	5	6	7	8	9	10
216	115	60	30	16	7	2	2	0	0	0

There are blank graphs on the student sheet so that they can easily graph their 3 sets of data (Tables 4, 5, and 6). They will need to rotate their paper horizontally. Remind them to label their axes and label the Y-axis with to accommodate each respective data set. For example, for their individual group data, they would need to label incrementally up to around 30 pennies. For their small group summed data, they may need up to 60, and for the large group sum they may need up to 240.

What they will discover is that regardless of the number of pennies, the graph has the SAME SHAPE! It's always an exponential graph! In theory, they should be able to lay their graphs on top of one another on clear transparency sheets and have the exact same graph. This is half-life!

After they graph, have students answer the follow-up questions, which ask about the graphs and then ask students to apply the learning to new scenarios including the concept of radiocarbon dating.

The answer keys are on pages 3 through 6 and the student sheets are on pages 7 through 10!

Thank you very much for your purchase! If this product has met your needs, please consider leaving feedback under your My Purchases at TeachersPayTeachers.com. I read all feedback and I appreciate it very much! You may also feel free to email me at SunriseScienceTPT@gmail.com with any questions or concerns!

Name ___KEY___ Class ________ Date __________

Half-Life Pennies Activity

The objective of this activity is to gain a better understanding of the process of radioactive decay through modeling. It will be necessary to understand the basic concepts of unstable isotopes and half-life. Write the definitions in the boxes:

unstable isotope	half-life
Isotopes are atoms of an element with different numbers of neutrons. Some isotopes are unstable because of the magnetic repulsion of too many protons in the nucleus. These isotopes are unstable and therefore, radioactive.	The amount of time it takes for half of an unstable isotope to decay into a different element (radioactive decay causes transmutation).

We will be using pennies to represent the nuclei of two isotopes of a fictitious elements!

→ The 'tails up' pennies will represent unstable isotopes (radioactive) of an element called 'Pennium'

→ The 'heads up' pennies will represent stable isotopes (not radioactive) of an element called 'Lincolnium'

Materials needed:

- o a cup of pennies
- o the data tables
- o the blank graphs

Trial 1 Procedure:

1. Pour all pennies out of the cup. Count them. Write this number in the "Start" column of all four data tables. This represents all of the nuclei of the element 'Pennium', a radioactive isotope.
2. Put all of the nuclei back in the cup. Cover and shake the cup.
3. Pour all of the nuclei onto the tray.
4. Separate the nuclei into two piles: one with the HEADS side up and the other with the TAILS side up.
5. Count the number of nuclei in each pile. On data table 1 under drop 1, record the number of "radioactive nuclei," which are the TAILS-up pennies. The pennies that landed with the HEADS side up represent atoms of a more stable element "Lincolnium".
6. *Return only the Pennium (TAILS side up) to your cup. These nuclei are still radioactive. The heads-up pennies should be put to the side.
7. Again, shake the cup and pour the Pennium nuclei back onto the tray.
8. Separate the nuclei into the two piles and count and record the number of radioactive nuclei (TAILS-up) under drop 2 of table 1.
9. Repeat steps 6 through 8 until all atoms have converted to Lincolnium (Number of Pennium atoms = 0). You may not need all of the spaces on the data table.

Trial 2 Procedure:

10. Repeat steps 2 through 9, recording your data on data table 2.

Trial 3 Procedure:

11. Repeat steps 2 through 9, recording your data on data table 3.

SAMPLE DATA

Data Table 1:

Number of Pennium Isotope (TAILS up)	Start	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
	35	16	7	4	2	1	1	1	0	0	0

Data Table 2:

Number of Pennium Isotope (TAILS up)	Start	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
	35	18	10	5	3	1	0	0	0	0	0

Data Table 3:

Number of Pennium Isotope (TAILS up)	Start	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
	35	17	9	5	3	2	1	0	0	0	0

12. Calculate the **average** number of Pennium isotopes for each drop and record in **Table 4.** Round the numbers to the nearest whole number.

Data Table 4:

Average of Pennium Isotope for Each Drop	Start	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
	35	17	9	5	3	1	1	0	0	0	0

13. Add up the **averaged** number of Pennium isotopes for each drop (Table 4) with the table next to yours. Record in **Table 5.**

Data Table 5:

Summed Averages for Small Group	Start	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
	69	34	17	9	5	2	1	0	0	0	0

13. Add up the **averaged** number of Pennium isotopes for each drop (Table 4) with all of the other averages in the class. Record in **Table 6.**

Data Table 6:

Summed Averages for Large Group	Start	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
	212	105	52	26	14	7	4	1	0	0	0

SAMPLE DATA

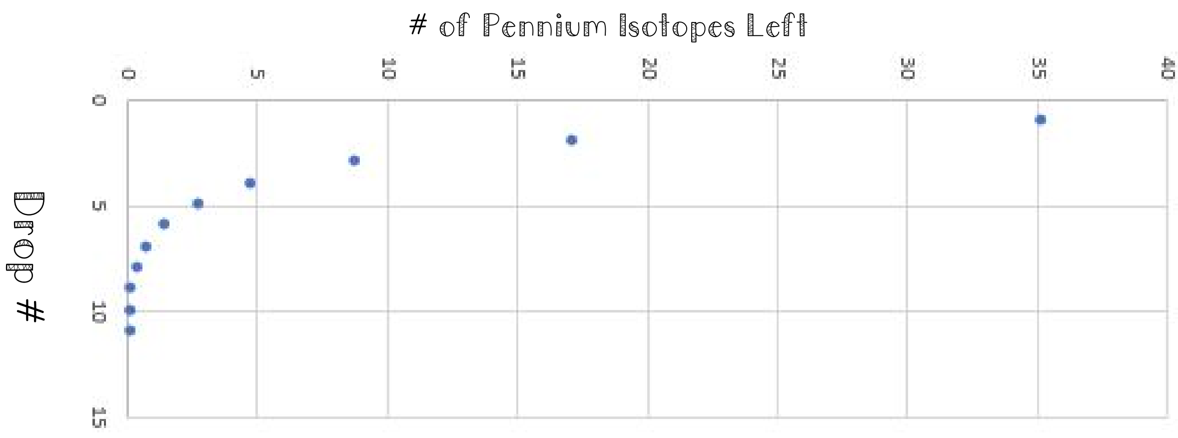
Name ________________________ Class ____________ Date ____________

Half-Life Pennies Graphs

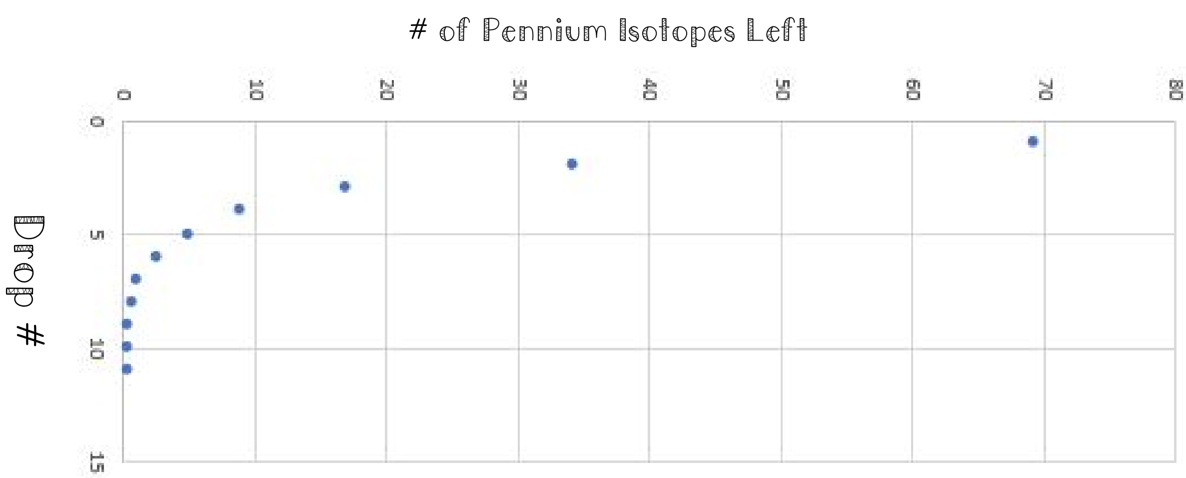
Results:

Graph the results from Tables 4, 5, and 6 on the three graphs below. You will need to rotate the paper horizontally. Graph Drops on the X-axis and Number of Pennium Isotopes on the Y-axis. The Y-axis must be labeled to accommodate the respective data for that graph! Then, complete the questions on the next page.

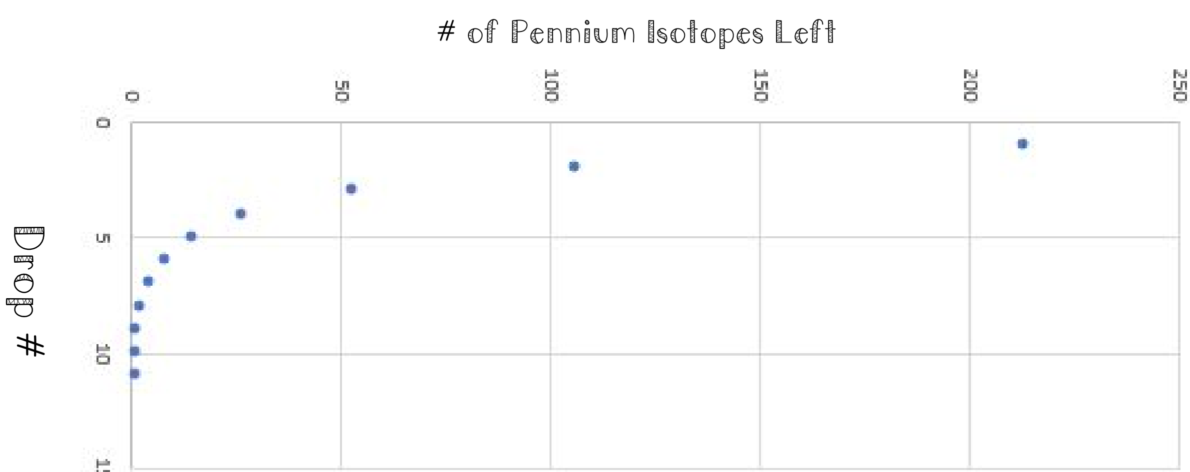
Your Average Data



Small Group Summed Data



Large Group Summed Data



Name KEY Class ________ Date __________

Half-Life Pennies Questions

1. What similarities do you notice about the three graphs from the Half-Life Pennies Activity?

   All three graphs have the same shape- an exponential curve!

2. Is half-life dependent upon the number of atoms present? Explain.

   No- half life does not depend on the number of atoms. We proved this because it didn't matter how large or small the sample size was (whether it was 24 pennies or 240 pennies)- the rate at which ½ of the pennies changed to 'stable' was the same!

3. I'm going to give you $1,000 (dream on!) but you must spend only ½ of it in the first year, ½ of the balance the second year, etc. One year thus represents one half-life of the $1,000.

   1. If you spend the maximum allowed each year, at the end of what year would you have $31.25 left? Show work.

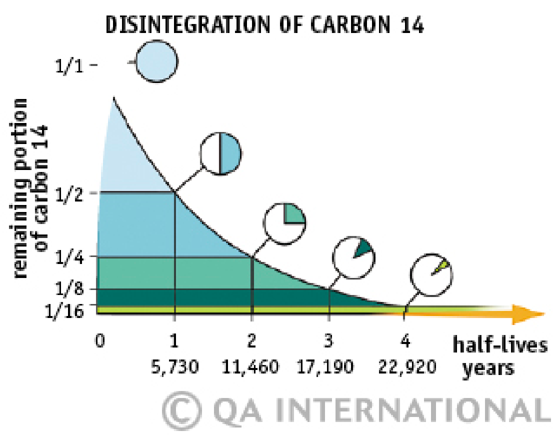
# of ½ lives (years)	0	1	2	3	4	5	6	7	8	9	10
Amount of $	$1000	$500	$250	$125	$62.50	$31.25	$15.63	$7.81	$3.91	$1.95	$0.97

   2. How much would be left after 10 half-lives?

      You would have about 97₵ left after 10 half lives had passed.

4. How long is a half-life for carbon-14?

   5,730 years (we know this because on the graph, ½ of the original amount is gone after 5,730 years).



5. If only 25% of the carbon-14 remains, how old is the material containing the carbon-14?

   11,460 years (we know this because on the graph, only ¼ of the original amount remains after 11,460 years).

6. If a sample originally had 120 atoms of carbon-14, how many atoms will remain after 17,190 years?

# of ½ lives (years)	0	1 (5,730)	2 (11,460)	3 (17,190)
# of C-14 atoms	120	60	30	15

7. If a sample known to be about 11,460 years old has 400 carbon-14 atoms, how many atoms were in the sample when the organism died?

Years old (# of ½ lives)	11,460 (2)	5,730 (1)	Now
# of C-14 atoms	1600	800	400

(start from present and work backwards)

Isotope	Half-Life
Uranium-238	4.5 billion years
Thorium-234	24 days
Protactinium-234	1.2 minutes
Uranium-234	240,000 years
Thorium-230	75,000 years
Radium-226	1,600 years
Radon-222	3.8 days
Polonium-218	3.1 minutes
Lead-214	27 minutes
Bismuth-214	20 minutes
Lead-210	22 years
Bismuth-210	5 days
Polonium-210	138 days

8. Starting with 50 grams of Radium-226, how many grams of Radium-226 are left after 3,200 years?

# of ½ lives (years)	0	1 (1,600)	2 (3,200)
grams of Radium-226	50 g	25 g	12.5 g

9. After 4 half-lives, a sample of Polonium-218 weighs 12 g. What was the original weight of the sample?

# of ½ lives	0	1	2	3	4
grams of Po-218	192 g	96 g	48 g	24 g	12 g

(start from half life #4 and work backwards)

Name ____ Class ________ Date ___________

Half-Life Pennies Activity

The objective of this activity is to gain a better understanding of the process of radioactive decay through modeling.
It will be necessary to understand the basic concepts of unstable isotopes and half-life. Write the definitions in the boxes:

unstable isotope	half-life

We will be using **pennies** to represent the nuclei of two isotopes of a fictitious elements!

→ The '**tails up**' pennies will represent unstable isotopes (**radioactive**) of an element called 'Pennium'

→ The '**heads up**' pennies will represent stable isotopes (**not radioactive**) of an element called 'Lincolnium'

Materials needed:

- o a cup of pennies
- o the data tables
- o the blank graphs

Trial 1 Procedure:

1. Pour all pennies out of the cup. **Count them.** Write this number in the "Start" column of **all four** data tables. This represents all of the nuclei of the element 'Pennium', a radioactive isotope.
2. Put all of the nuclei back in the cup. Cover and shake the cup.
3. Pour all of the nuclei onto the tray.
4. Separate the nuclei into two piles: one with the HEADS side up and the other with the TAILS side up.
5. Count the number of nuclei in each pile. On **data table 1** under **drop 1**, record the number of "radioactive nuclei," which are the TAILS-up pennies. The pennies that landed with the HEADS side up represent atoms of a more stable element "Lincolnium".
6. ***Return only the Pennium** (TAILS side up) to your cup. These nuclei are **still radioactive**. The heads-up pennies should be put to the side.
7. Again, shake the cup and pour the Pennium nuclei back onto the tray.
8. Separate the nuclei into the two piles and count and record the number of radioactive nuclei (TAILS-up) under **drop 2** of table 1.
9. Repeat steps 6 through 8 until all atoms have converted to Lincolnium (Number of Pennium atoms = 0). You may not need all of the spaces on the data table.

Trial 2 Procedure:

10. Repeat steps 2 through 9, recording your data on **data table 2**.

Trial 3 Procedure:

11. Repeat steps 2 through 9, recording your data on **data table 3**.

Data Table 1:.

Number of Pennium Isotope (TAILS up)	**Start**	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10

Data Table 2:.

Number of Pennium Isotope (TAILS up)	**Start**	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10

Data Table 3:.

Number of Pennium Isotope (TAILS up)	**Start**	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10

12. Calculate the **average** number of Pennium isotopes for each drop and record in **Table 4.** Round the numbers to the nearest whole number.

Data Table 4:.

Average of Pennium Isotope for Each Drop	**Start**	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10

13. Add up the **averaged** number of Pennium isotopes for each drop (Table 4) with the table next to yours. Record in **Table 5.**

Data Table 5:.

Summed Averages for Small Group	**Start**	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10

13. Add up the **averaged** number of Pennium isotopes for each drop (Table 4) with all of the other averages in the class. Record in **Table 6.**

Data Table 6:.

Summed Averages for Large Group	**Start**	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10

Name ________________ Class ________ Date ________

Half-Life Pennies Graphs

Results:

Graph the results from Tables 4, 5, and 6 on the three graphs below. You will need to rotate the paper horizontally. Graph Drops on the X-axis and Number of Pennium Isotopes on the Y-axis. The Y-axis must be labeled to accommodate the respective data for that graph! Then, complete the questions on the next page.

Your Average Data

Small Group Summed Data

Large Group Summed Data

Name ______________________________ Class ________ Date __________

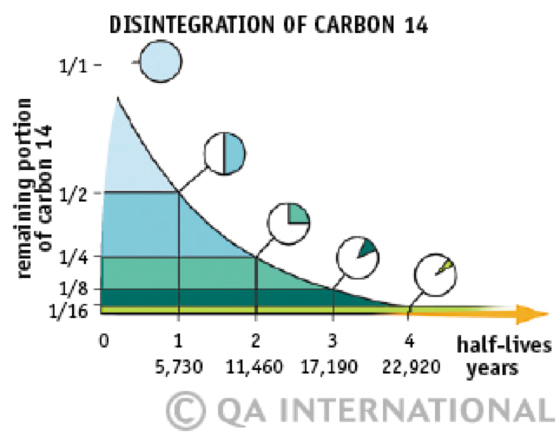
Half-Life Pennies Questions

1. What similarities do you notice about the three graphs from the Half-Life Pennies Activity?

2. Is half-life dependent upon the number of atoms present? Explain.

3. I'm going to give you $1,000 (dream on!) but you must spend only ½ of it in the first year, ½ of the balance the second year, etc. One year thus represents one half-life of the $1,000.
   1. If you spend the maximum allowed each year, at the end of what year would you have $31.25 left? Show work.
   2. How much would be left after 10 half-lives?

4. How long is a half-life for carbon-14?



5. If only 25% of the carbon-14 remains, how old is the material containing the carbon-14?

6. If a sample originally had 120 atoms of carbon-14, how many atoms will remain after 17,190 years?

7. If a sample known to be about 11,460 years old has 400 carbon-14 atoms, how many atoms were in the sample when the organism died?

8. Starting with 50 grams of Radium-226, how many grams of Radium-226 are left after 3,200 years?

9. After 4 half-lives, a sample of Polonium-218 weighs 12 g. What was the original weight of the sample?

Isotope	Half-Life
Uranium-238	4.5 billion years
Thorium-234	24 days
Protactinium-234	1.2 minutes
Uranium-234	240,000 years
Thorium-230	75,000 years
Radium-226	1,600 years
Radon-222	3.8 days
Polonium-218	3.1 minutes
Lead-214	27 minutes
Bismuth-214	20 minutes
Lead-210	22 years
Bismuth-210	5 days
Polonium-210	138 days

TERMS OF USE

Thank you for your purchase! The **original** purchaser of this document/product is granted permission to reproduce the pages in needed quantities for the purchaser's classroom/home use only. By purchasing this resource, you are agreeing that the contents are the property of Sunrise Science and **licensed to you only for classroom/personal use as a single user**. I retain the copyright, and reserve all rights to this product.

YOU MAY:

- Use items (free and purchased) for your own classroom students, or your own personal use.
- Reference this product in blog posts, at seminars, professional development workshops, or other such venues PROVIDED there is both credit given to myself as the author and a link back to my TPT store is included in your post/presentation.
- Distribute and make copies of **free items only** to other teachers PROVIDED there is credit given to Sunrise Science and a link back to my TPT store.

YOU MAY NOT:

- Claim this work as your own, alter the files in any way (unless this has been advertised as an editable resource), or remove/attempt to remove the copyright/watermarks.
- Sell the files or combine them into another unit for sale/free.
- Post this document for sale/free elsewhere on the internet (this includes public classroom websites and Google Doc links on blogs).
- Make copies of purchased items to share with others is strictly forbidden and is a violation of the Terms of Use, along with copyright law.
- Obtain this product through any of the channels listed above.

Thank you for abiding by universally accepted codes of professional ethics while using this product.

If you encounter an issue with your file, notice an error, or are in any way experiencing a problem, please contact me at SunriseScienceTPT@gmail.com and I will be more than happy to help sort it out!

Thank you ☺ Karla @ Sunrise Science

/SunriseSciences @SunriseScience @SunriseScienceClassroom

I use Fonts and Graphics from these amazing artists: kimberly geswein fonts, KB3 Teach Fonts, Carrie Stephens, Kate Hadfield Designs, Kelly B.'s Clipart, Glitter meets glue designs, Sarah Pecorino Illustration, GW Fonts