Hashtable Analysis

In writing a hashtable with doubling, I wanted to test that my understanding of amortized complexity was correct, and that the table was functioning as intended. To do this I captured three datasets into a single file. I measured how fast the hashtable could perform insertions, retrievals and deletions of n elements, where n doubled for each measurement. The resolution of this measurement was in milliseconds, so I started with 2^{14} elements and finished with 2^{28}. Any fewer and the whole batch of operations took less than one millisecond – already a good sign for the performance of this library!

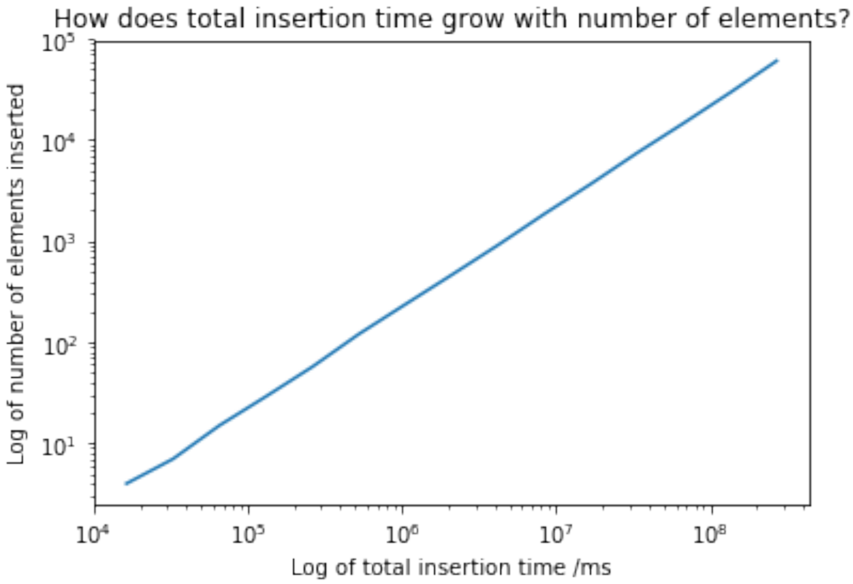
In [40]:
```
import re
from numpy import array


def next_number(file):
    return int(re.search("\d+", next(f)).group())


data = []


with open("data.txt") as f:
    while f:
        try:
            number_elements = next_number(f)
            insert_ms = next_number(f)
            retrieve_ms = next_number(f)
            delete_ms = next_number(f)
            data.append((number_elements, insert_ms, retrieve_ms, d
elete_ms))
        except StopIteration:
            break


sizes, insert_times, retrieve_times, delete_times = map(array, zip(
*data))
```

Linear Relationships

In the following three graphs I demonstrate that the time taken to insert, retrieve and delete all the elements in the hashtable is a *linear* function of the number of elements in the hashtable. For example, inserting a hundred elements will take one hundred times as long as inserting only one element.

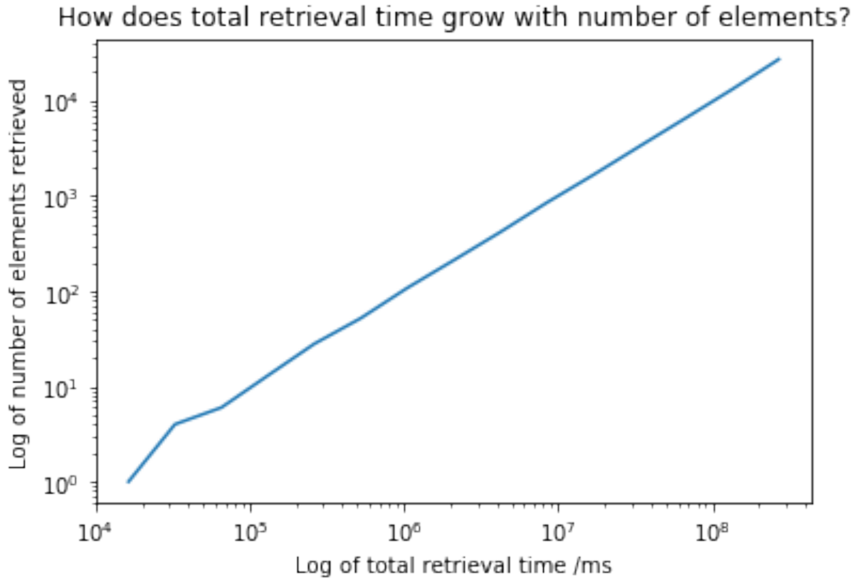
In [98]:
```
from matplotlib import pyplot as plt
from numpy import log, polyfit

chart, *_ = plt.loglog(sizes, insert_times)
slope, _ = polyfit(log(sizes), log(insert_times), 1)
print(f"The slope of this graph is {slope:.4f} (~1), indicating a l
inear relationship.")
plt.title("How does total insertion time grow with number of elemen
ts?")
plt.xlabel("Log of total insertion time /ms")
plt.ylabel("Log of number of elements inserted")
plt.show()
```

```
The slope of this graph is 0.9965 (~1), indicating a linear relati
onship.
```



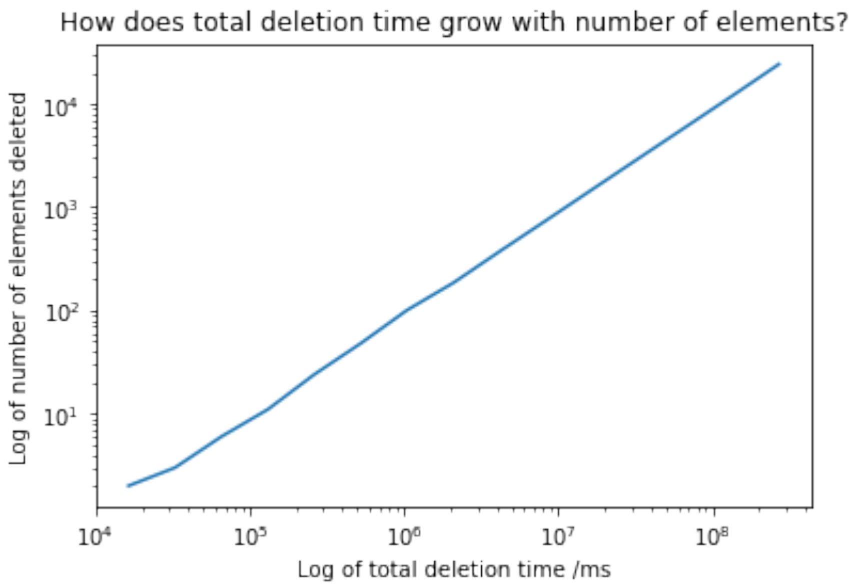
In [97]:
```
chart, *_ = plt.loglog(sizes, retrieve_times)
slope, _ = polyfit(log(sizes), log(retrieve_times), 1)
print(f"The slope of this graph is {slope:.4f} (~1), indicating a l
inear relationship.")
plt.title("How does total retrieval time grow with number of elemen
ts?")
plt.xlabel("Log of total retrieval time /ms")
plt.ylabel("Log of number of elements retrieved")
plt.show()
```

```
The slope of this graph is 1.0121 (~1), indicating a linear relati
onship.
```



In [96]:
```
chart, *_ = plt.loglog(sizes, delete_times)
slope, _ = polyfit(log(sizes), log(delete_times), 1)
print(f"The slope of this graph is {slope:.4f} (~1), indicating a l
inear relationship.")
plt.title("How does total deletion time grow with number of element
s?")
plt.xlabel("Log of total deletion time /ms")
plt.ylabel("Log of number of elements deleted")
plt.show()
```

```
The slope of this graph is 0.9884 (~1), indicating a linear relati
onship.
```



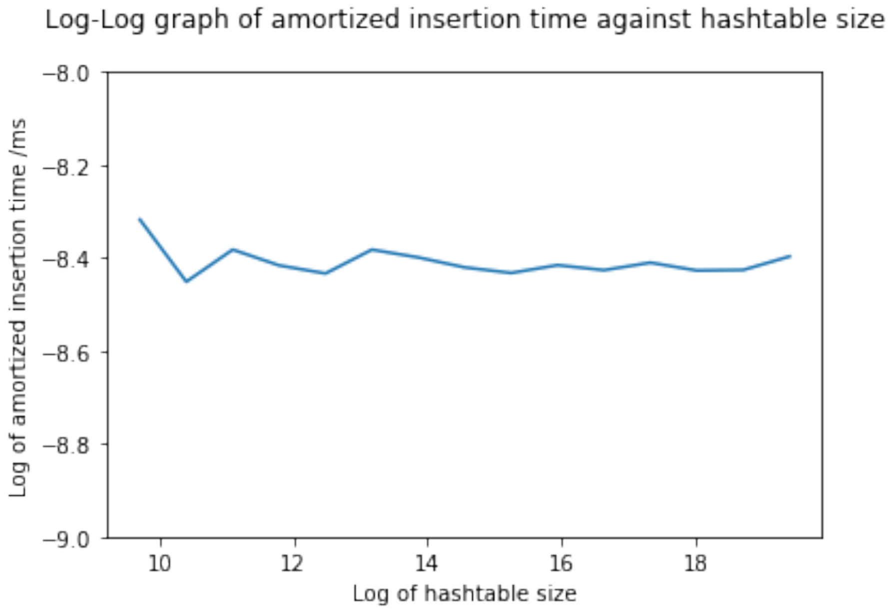
Amortized Complexities

Here I demonstrate that the amortized complexity of insertion, retrieval and deletion is O(1) (or in other words, does not grow meaningfully with the number of elements in the hashtable).

In [99]:

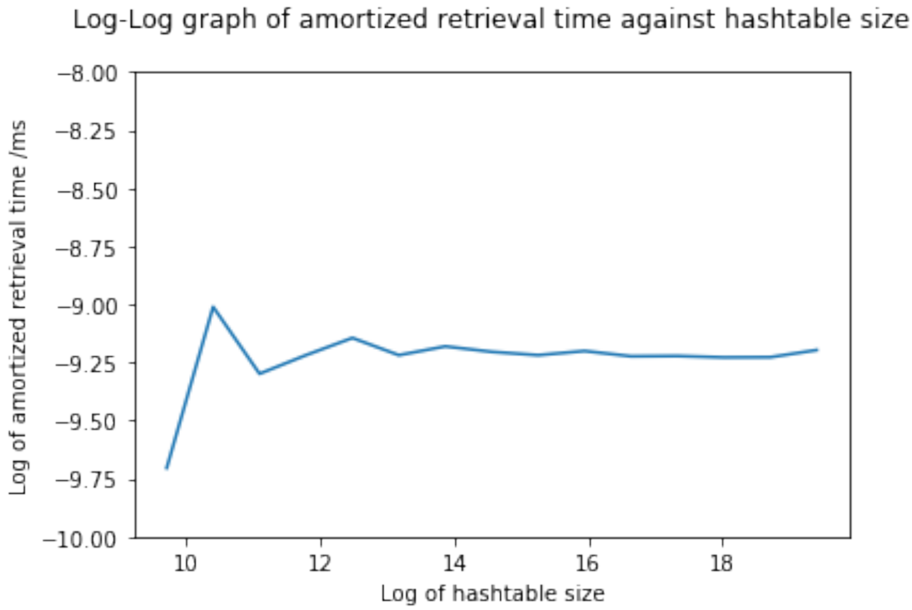
```
from numpy import exp
ylower, yupper = 9, 8

amortized_time = insert_times / sizes
slope, _ = polyfit(log(sizes), log(amortized_time), 1)
print(f"The slope of this graph is {slope:.4f} (~0), indicating a c
onstant relationship.")
print(f"The Y axis range here is effectively from {exp(-ylower) * 1
0**6:.0f}ns to {exp(-yupper) * 10**6:.0f}ns.\n",
      "(Faster == lower on the Y axis)")
plt.plot(log(sizes), log(amortized_time))
plt.ylim(-ylower, -yupper)
plt.ylabel("Log of amortized insertion time /ms")
plt.xlabel("Log of hashtable size")
plt.title("Log-Log graph of amortized insertion time against hashta
ble size\n")
plt.show()
```

```
The slope of this graph is -0.0035 (~0), indicating a constant rel
ationship.
The Y axis range here is effectively from 123ns to 335ns.
 (Faster == lower on the Y axis)
```



In [100]:
```
from numpy import exp
ylower, yupper = 10, 8

amortized_time = retrieve_times / sizes
slope, _ = polyfit(log(sizes), log(amortized_time), 1)
print(f"The slope of this graph is {slope:.4f} (~0), indicating a c
onstant relationship.")
print(f"The Y axis range here is effectively from {exp(-ylower) * 1
0**6:.0f}ns to {exp(-yupper) * 10**6:.0f}ns.\n",
      "(Faster == lower on the Y axis)")
plt.plot(log(sizes), log(amortized_time))
plt.ylim(-ylower, -yupper)
plt.ylabel("Log of amortized retrieval time /ms")
plt.xlabel("Log of hashtable size")
plt.title("Log-Log graph of amortized retrieval time against hashta
ble size\n")
plt.show()
```

```
The slope of this graph is 0.0121 (~0), indicating a constant rela
tionship.
The Y axis range here is effectively from 45ns to 335ns.
 (Faster == lower on the Y axis)
```



In [102]:

```
from numpy import exp
ylower, yupper = 10, 8

amortized_time = delete_times / sizes
slope, _ = polyfit(log(sizes), log(amortized_time), 1)
print(f"The slope of this graph is {slope:.4f} (~0), indicating a constant relationship.")
print(f"The Y axis range here is effectively from {exp(-ylower) * 10**6:.0f}ns to {exp(-yupper) * 10**6:.0f}ns.\n",
      "(Faster == lower on the Y axis)")
plt.plot(log(sizes), log(amortized_time))
plt.ylim(-ylower, -yupper)
plt.ylabel("Log of amortized deletion time /ms")
plt.xlabel("Log of hashtable size")
plt.title("Log-Log graph of amortized deletion time against hashtable size\n")
plt.show()
```

```
The slope of this graph is -0.0116 (~0), indicating a constant relationship.
The Y axis range here is effectively from 45ns to 335ns.
 (Faster == lower on the Y axis)
```