**ACTIVITY: Using radiocarbon carbon dioxide data**

**Activity idea**

In this activity, students interpret graphs from a long-term study of carbon dioxide in the atmosphere of New Zealand. They explore how the interval between samples affects the conclusions we are able to make.

By the end of this activity, students should be able to:

* draw and/or interpret simple line graphs
* think critically about the information data and graphs can provide
* understand the need for the careful planning of experiments
* understand long-term changes in radiocarbon carbon dioxide in the atmosphere

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**Introduction/background**

This activity involves real data from a long-running project studying radiocarbon carbon dioxide in the atmosphere. Students use the data to make some observations about changing levels of this gas. They also look at different sampling intervals to help them understand how this affects what we can learn from the data. They will come to realise that a poorly planned experiment could provide misleading results.

The instructions for this activity assume that students draw the graphs themselves, but teachers may prefer interpreting graphs that are supplied already drawn (worksheets for both approaches are supplied).

***Radiocarbon carbon dioxide (14CO2)***

Atoms of the element carbon come in several forms, called isotopes. Most carbon has a nucleus with 6 neutrons and 6 protons, written 12C.

About one in a trillion carbon atoms have 8 neutrons and 6 protons, written 14C. This isotope is radioactive and is often called radiocarbon. The radioactivity of 14C means that it can be detected amongst all the non-radioactive 12C. There is also a 13C, which is not radioactive.

Most of the carbon in the atmosphere is in carbon dioxide made from 12C, but small amounts of 14C carbon dioxide (14CO2) also occur naturally. In the late 1950s and early 1960s, humans added a lot more radioactive 14C to the atmosphere through the testing of nuclear weapons. One good thing came of this – scientists have been able to study the carbon cycle by following what happens to the 14C.

***Link to New Zealand research***

This activity uses real data from a long running atmospheric 14CO2 study at Baring Head. NIWA scientist Dr Kim Currie is involved in the project, which she combines with her research into ocean CO2 to help understand the way ocean and atmosphere interact in the carbon cycle.

**What you need**

* Copies of or online access to the article [Carbon dioxide in the atmosphere](https://www.sciencelearn.org.nz/resources/684-carbon-dioxide-in-the-atmosphere)
* Copies of worksheets for pairs A, B, C and D (with or without the graph drawn) and the whole group worksheet

**What to do**

1. As a class, read and discuss the article [Carbon dioxide in the atmosphere](https://www.sciencelearn.org.nz/resources/684-carbon-dioxide-in-the-atmosphere). Reinforce that radiocarbon carbon dioxide measurements have been collected from the air near Wellington since 1954 (firstly at Makara, now at Baring Head) – this is the longest continuous record of its kind in the world. When collecting data over time like this, it is important to choose how often to take a sample. A sample at Baring Head takes 2 days to collect, and then it is sent to the Rafter Radiocarbon Laboratory at GNS Science for analysis. This means daily sampling is not possible – even weekly is impractical and expensive – so samples in this study are collected each month. Discuss these questions:

* When you plan an experiment that involves change over time, do you want to make a measurement once every minute? Once an hour? Every 2 hours? Once a day? Once a year? (Of course it depends what you are measuring and what you hope to find out.)
* If you want to know how quickly someone’s pulse returns to normal after exercise, how often would you need to take their pulse? (You’d need to take your measurements at least twice a minute for just a few minutes. In a healthy person, pulse settles down quite quickly after exercise.)
* If you want to measure someone’s increase in height over time, how often would take measurements? (You’d probably choose once a week or month, even once a year. You know that people don’t normally grow fast enough to notice a difference between one day and the next.)

1. Divide the class into groups of 8, each with 4 pairs of students – pairs A, B, C and D. Explain that these pairs will work independently to start with to analyse data on radiocarbon carbon dioxide measurements, then the whole group will get together to share results and observations. Give each pair in a group the appropriate worksheet (with or without the graph completed) and have them work through it. Sometimes it may not be possible to answer the question or at least not accurately – that is part of the point of the activity.
2. Have the group of 8 get together and share information using the whole group worksheet, then consider more questions.

**Discussion questions**

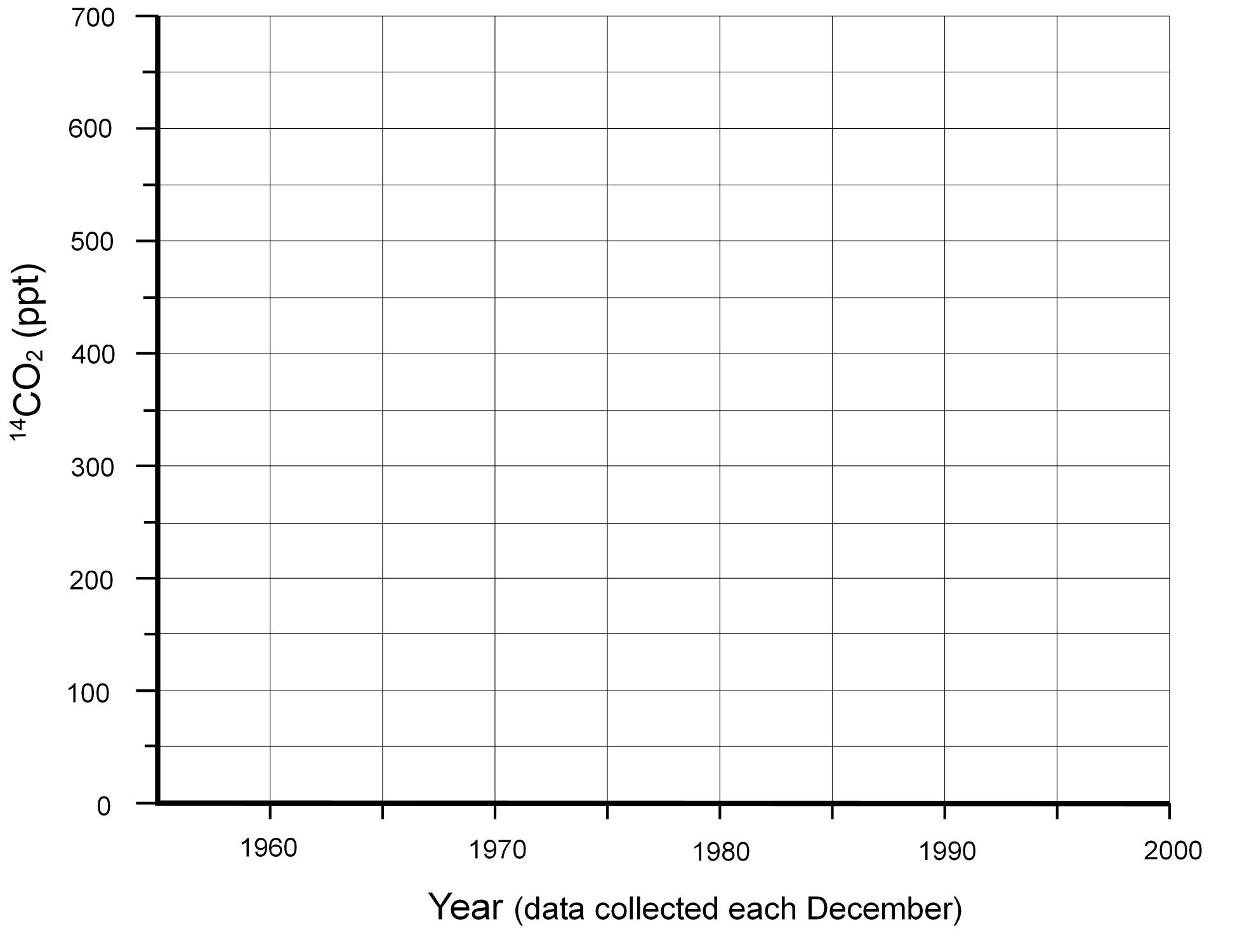
* + What might have caused the peak in 14CO2 levels?
  + What might have happened to cause the drop in 14CO2 since then?
  + Several countries started testing nuclear weapons in the atmosphere in the late 1950s and early 1960s. Get students to use their graphs to discuss when they think the testing of nuclear weapons stopped.

There was a Test Ban Treaty in 1963, but France carried on testing until 1968, China until 1980 (in the northern hemisphere). The 14Chas become part of the natural carbon cycle. Most of it has ended up in the ocean, some in plants and soil on land. Because 14C is radioactive, it will eventually decay to 12C, but not for thousands of years.

Students may mention all the CO2 added to the atmosphere through the burning of fossil fuels as a possible reason for the increase in 14CO2. However, fossil fuels do not contain 14C because it all decayed away long ago. The addition of lots of 12CO2 to the atmosphere, including from volcanoes, dilutes the 14CO2, so is one of the reasons levels of 14CO2 have gone down.

**Pair A worksheet: 14CO2 collected every 10 years between 1960 and 2000**

|  |  |
| --- | --- |
| **Year (in December)** | **14CO2 (parts per thousand – ppt)** |
| 1960 | 194 |
| 1970 | 496 |
| 1980 | 269 |
| 1990 | 163 |
| 2000 | 97 |

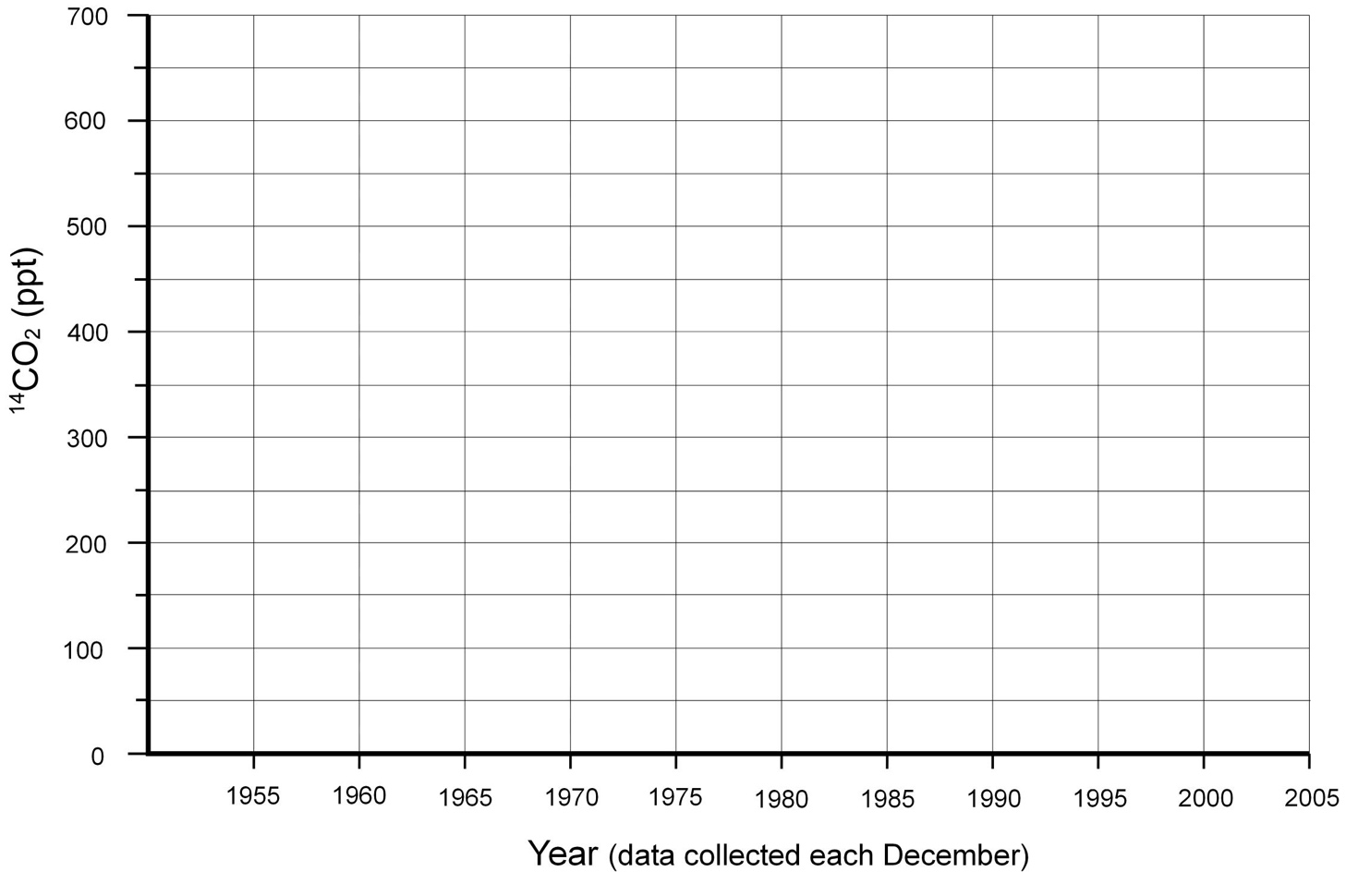


|  |  |  |
| --- | --- | --- |
| In which year was 14CO2 at its highest level? | |  |
| In which month was 14CO2 at its highest level? | |  |
| How much 14CO2 was there in | 1965 |  |
|  | 1970 |  |
|  | 1975 |  |

(No samples were taken in 1965 and 1975, so you will need to estimate the figures using the graph.)

**Pair B worksheet: 14CO2 collected every 5 years between 1955 and 2005**

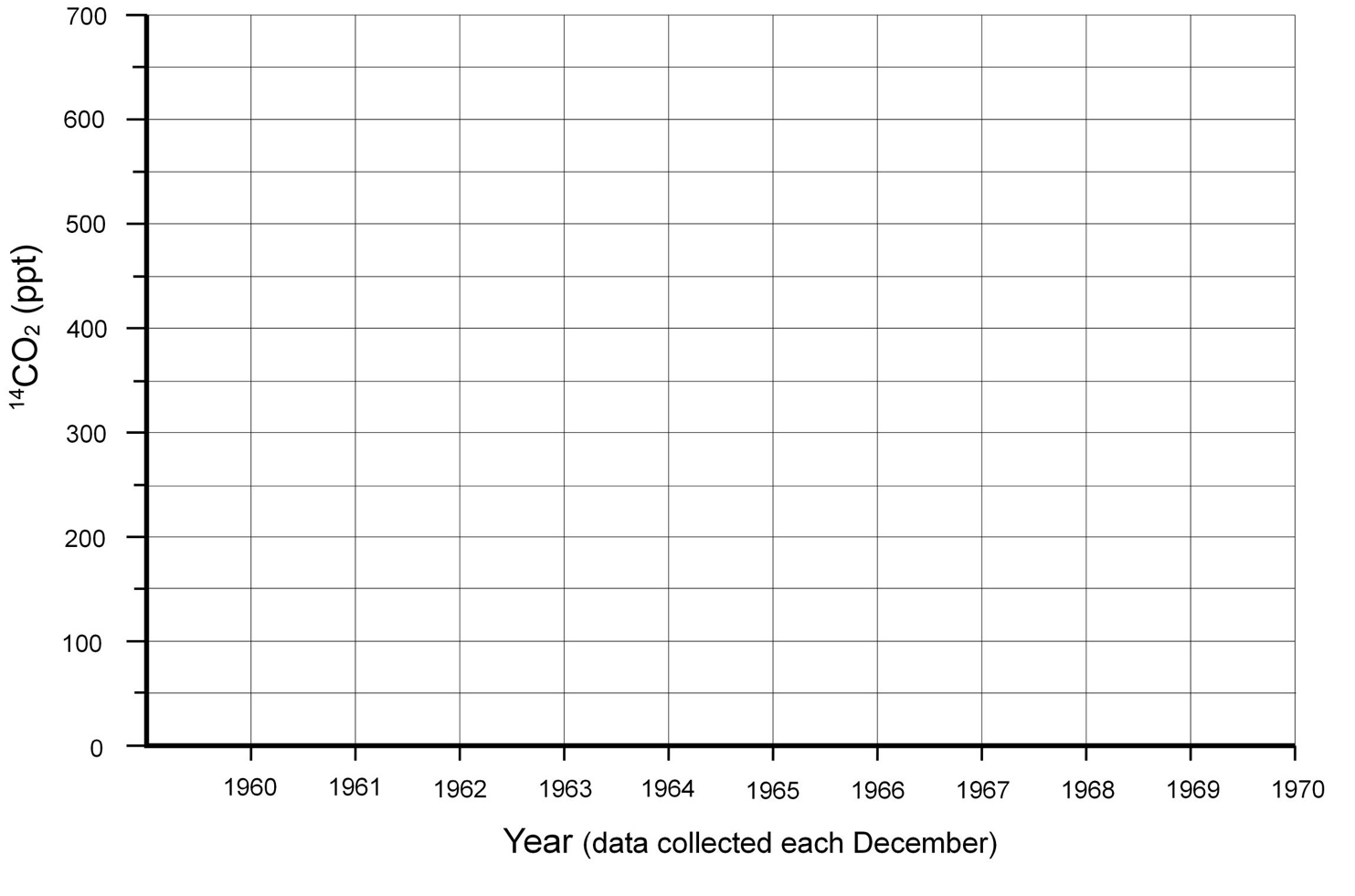
|  |  |
| --- | --- |
| **Year (in December)** | **14CO2 (parts per thousand – ppt)** |
| 1955 | 0.1 |
| 1960 | 194 |
| 1965 | 634 |
| 1970 | 496 |
| 1975 | 371 |
| 1980 | 269 |
| 1985 | 205 |
| 1990 | 163 |
| 1995 | 107 |
| 2000 | 97 |
| 2005 | 70 |



|  |  |  |
| --- | --- | --- |
| In which year was 14CO2 at its highest level? | |  |
| In which month was 14CO2 at its highest level? | |  |
| How much 14CO2 was there in | 1965 |  |
|  | 1970 |  |
|  | 1975 |  |

**Pair C worksheet: 14CO2 collected once a year from December 1960–December 1970**

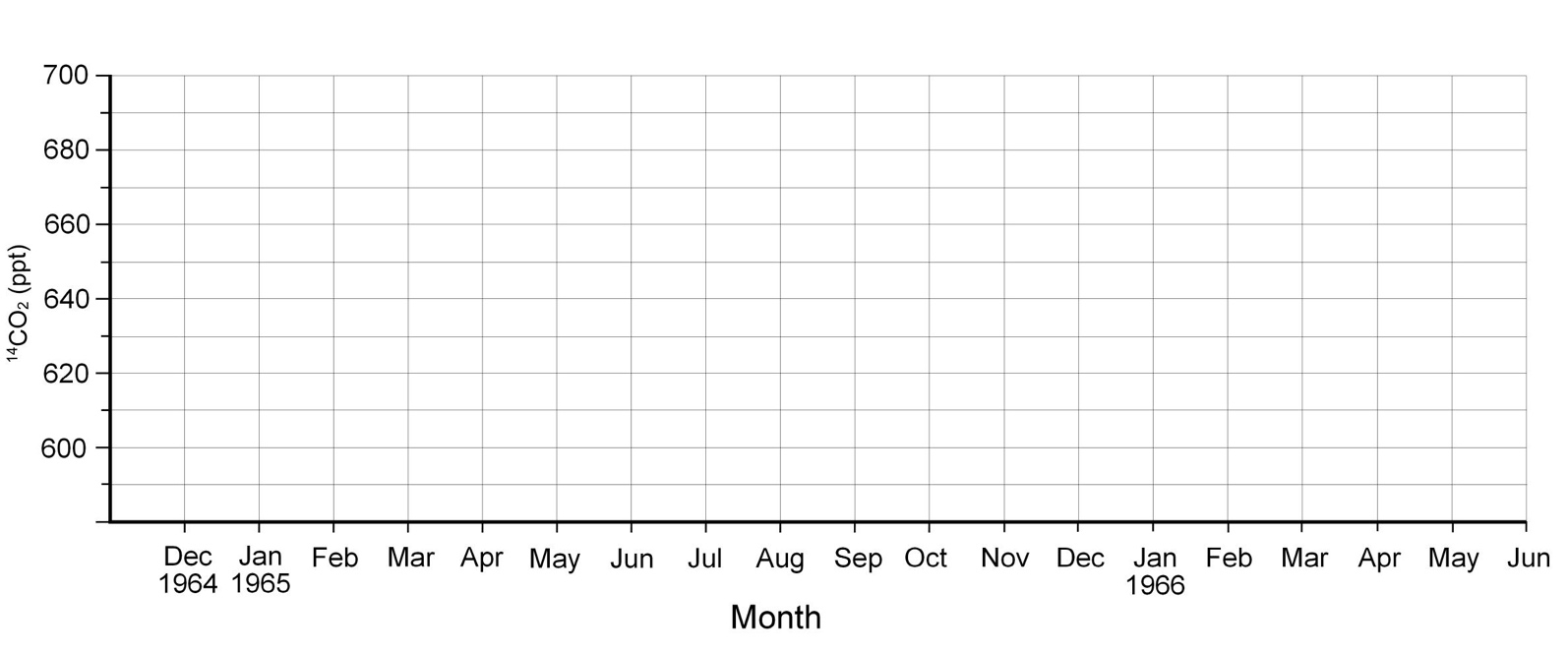
|  |  |
| --- | --- |
| **Year (in December)** | **14CO2 (parts per thousand – ppt)** |
| 1960 | 194 |
| 1961 | 227 |
| 1962 | 267 |
| 1963 | 430 |
| 1964 | 616 |
| 1965 | 634 |
| 1966 | 628 |
| 1967 | 580 |
| 1968 | 540 |
| 1969 | 510 |
| 1970 | 496 |



|  |  |
| --- | --- |
| In which year was 14CO2 at its highest level? |  |
| In which month was 14CO2 at its highest level? |  |

**Pair D worksheet: 14CO2 collected once a month from December 1964–June 1966**

|  |  |
| --- | --- |
| **Month and year** | **14CO2 (parts per thousand – ppt)** |
| Dec 1964 | 616 |
| Jan 1965 | 689 |
| Feb 1965 | 634 |
| Apr 1965 | 634 |
| May 1965 | 615 |
| Jul 1965 | 695 |
| Aug 1965 | 614 |
| Sept 1965 | 634 |
| Nov 1965 | 626 |
| Dec 1965 | 634 |
| Feb 1966 | 647 |
| Mar 1966 | 647 |
| Apr 1966 | 632 |
| May 1966 | 622 |
| Jun 1966 | 612 |



|  |  |
| --- | --- |
| In which year was 14CO2 at its highest level? |  |
| In which month was 14CO2 at its highest level? |  |

**Whole group worksheet**

Each pair fill in their row of the table:

|  |  |  |  |
| --- | --- | --- | --- |
| **Pair** | **Year 14CO2 was at its highest level** | **Highest level of 14CO2** | **Month 14CO2 was at its highest level** |
| A |  |  |  |
| B |  |  |  |
| C |  |  |  |
| D |  |  |  |

Did all pairs find the highest level in the same year? Why or why not?

Did each pair record the same value for the highest level of 14CO2? Why or why not?

Decide on the best or most accurate answers:

The year in which 14CO2 was at its highest level was

The highest level of 14CO2 was

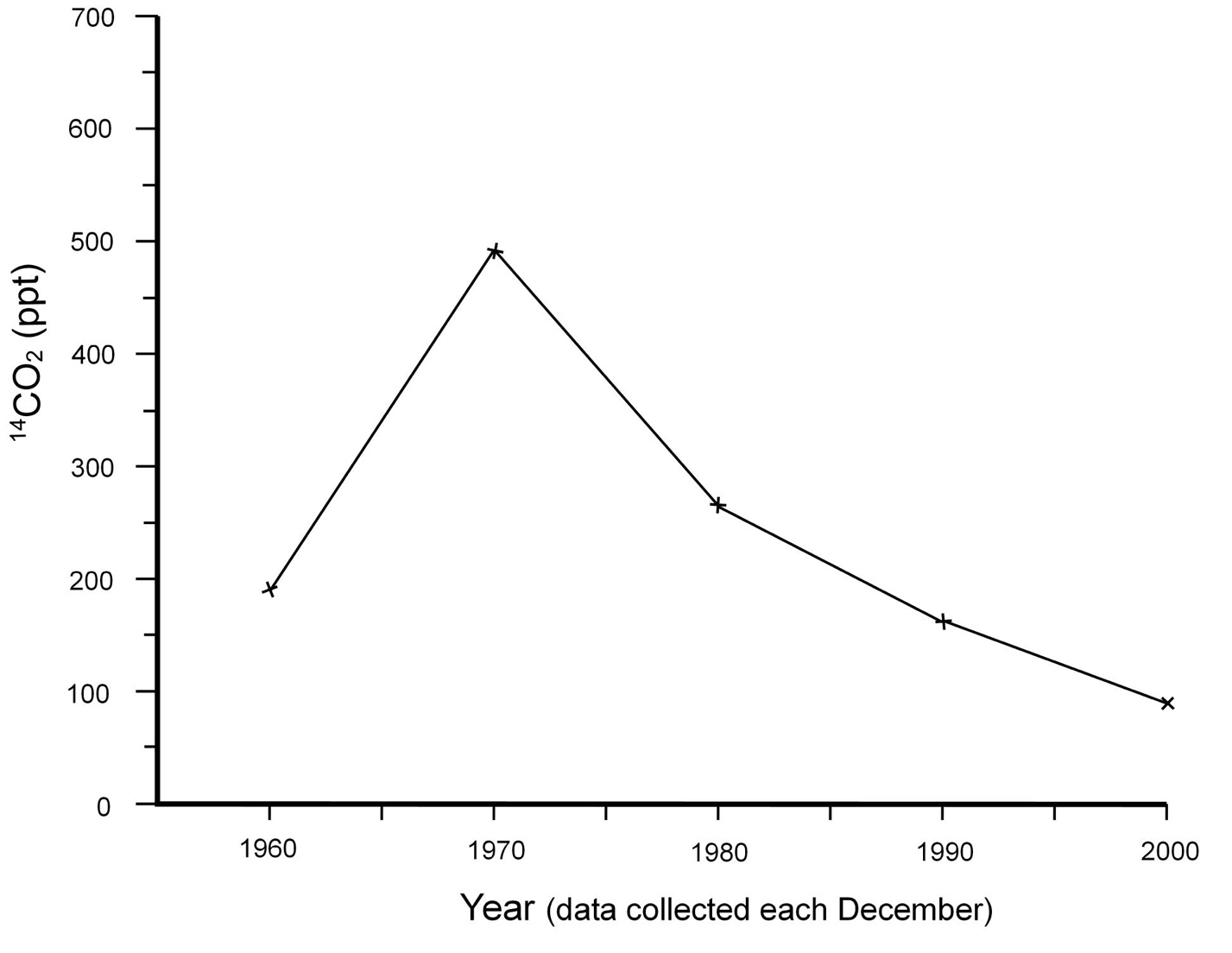
The month in which 14CO2 was at its highest level was

Group D’s graph showed a pattern of highs and lows during 1965. Discuss if the same pattern might be seen every year. How would you find out?

Describe what happened to the level of 14CO2 between 1955 and 2005.

**Pair A worksheet (graph drawn): 14CO2 collected every 10 years between 1960 and 2000**

|  |  |
| --- | --- |
| **Year (in December)** | **14CO2 (parts per thousand – ppt)** |
| 1960 | 194 |
| 1970 | 496 |
| 1980 | 269 |
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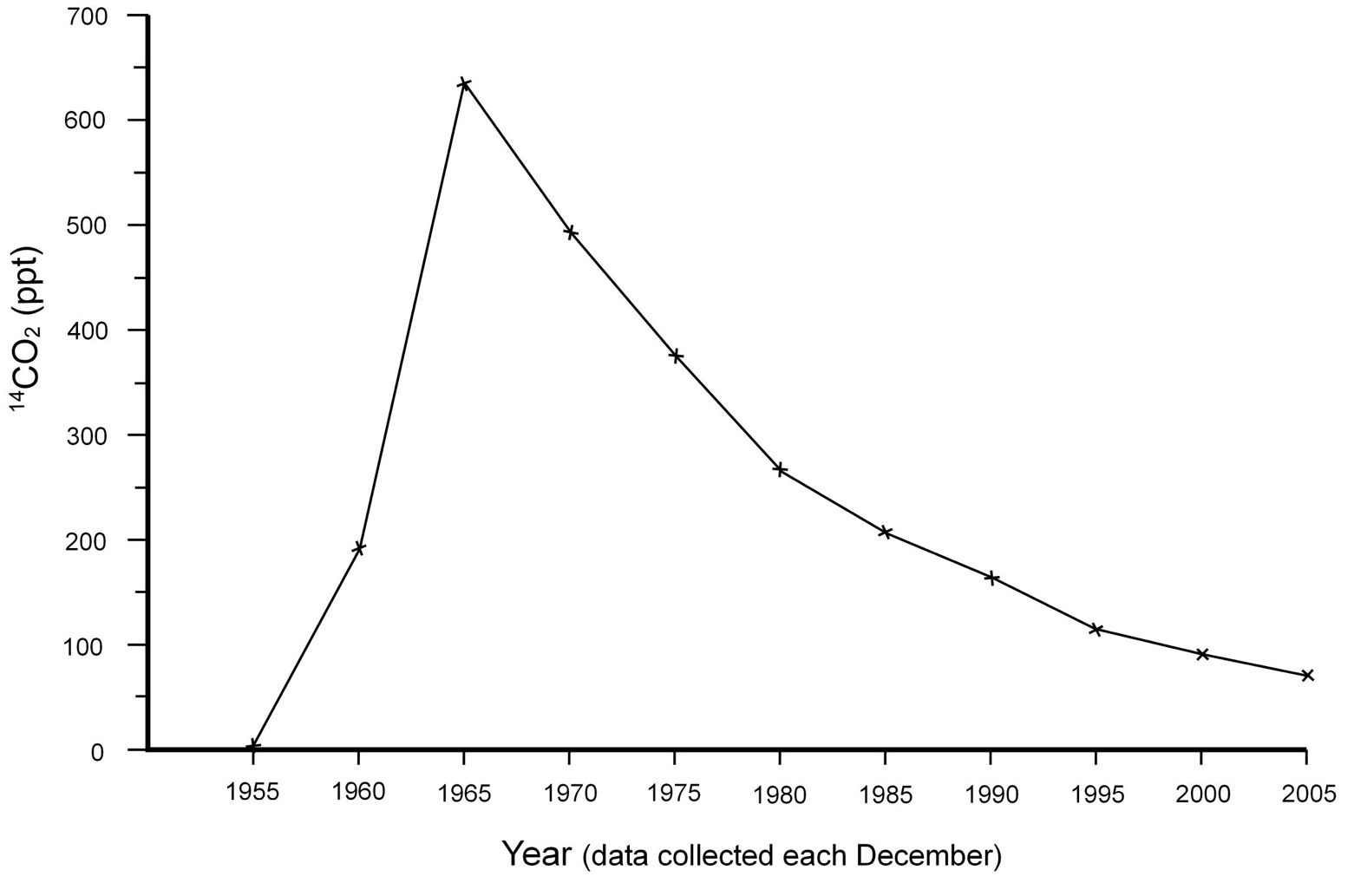


|  |  |  |
| --- | --- | --- |
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| In which month was 14CO2 at its highest level? | |  |
| How much 14CO2 was there in | 1965 |  |
|  | 1970 |  |
|  | 1975 |  |

(No samples were taken in 1965 and 1975, so you will need to estimate the figures using the graph.)

**Pair B worksheet (graph drawn): 14CO2 collected every 5 years between 1955 and 2005**

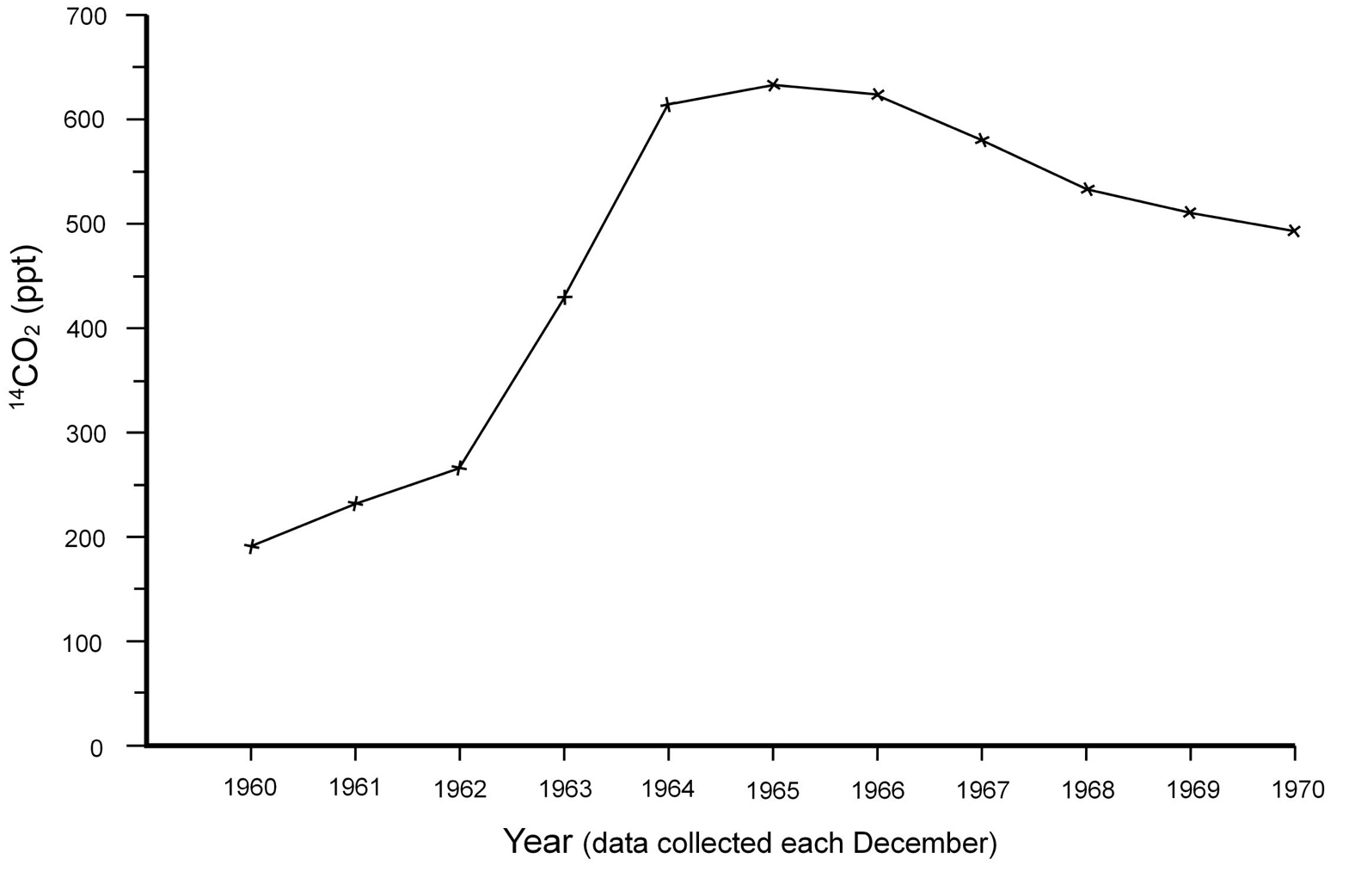
|  |  |
| --- | --- |
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| 1960 | 194 |
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|  |  |  |
| --- | --- | --- |
| In which year was 14CO2 at its highest level? | |  |
| In which month was 14CO2 at its highest level? | |  |
| How much 14CO2 was there in | 1965 |  |
|  | 1970 |  |
|  | 1975 |  |

**Pair C worksheet (graph drawn): 14CO2 collected once a year from December 1960–December 1970**

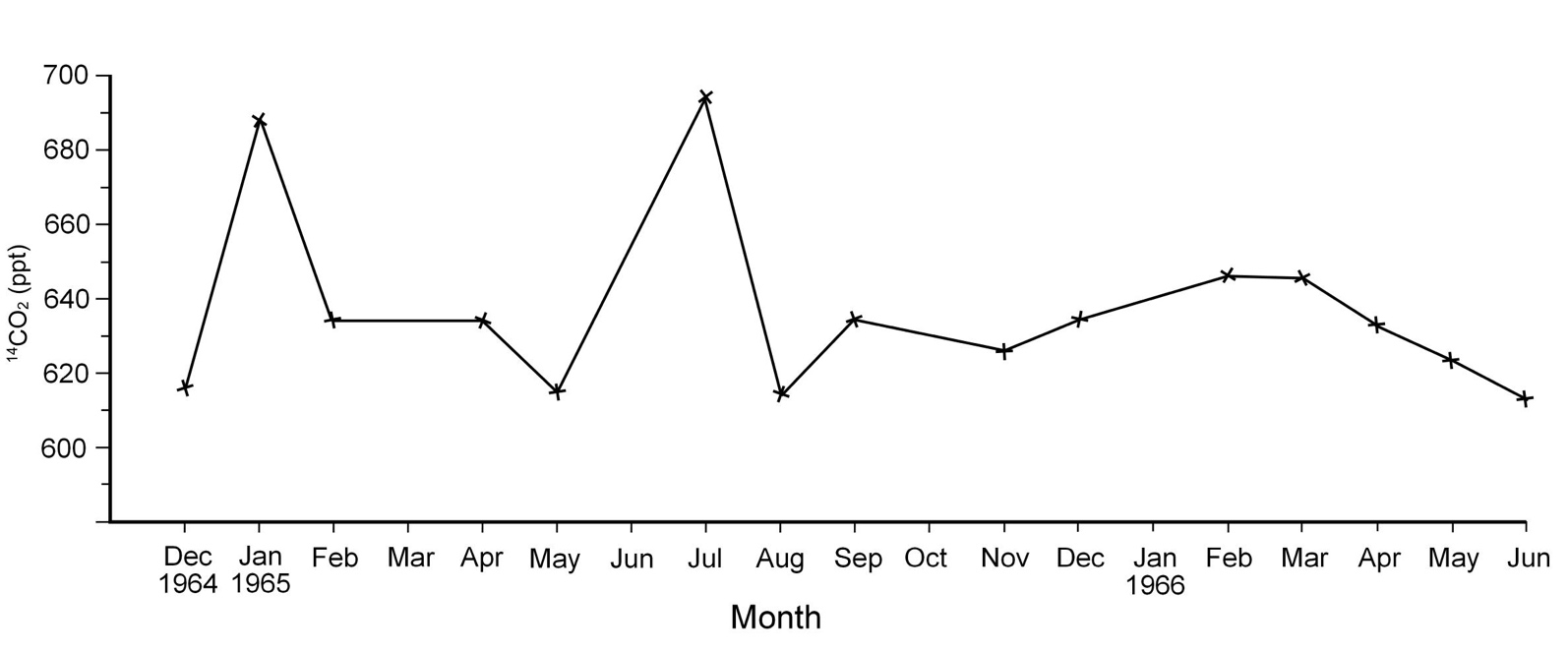
|  |  |
| --- | --- |
| **Year (in December)** | **14CO2 (parts per thousand – ppt)** |
| 1960 | 194 |
| 1961 | 227 |
| 1962 | 267 |
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|  |  |
| --- | --- |
| In which year was 14CO2 at its highest level? |  |
| In which month was 14CO2 at its highest level? |  |

**Pair D worksheet (graph drawn): 14CO2 collected once a month from December 1964–June 1966**

|  |  |
| --- | --- |
| **Month and year** | **14CO2 (parts per thousand – ppt)** |
| Dec 1964 | 616 |
| Jan 1965 | 689 |
| Feb 1965 | 634 |
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| Dec 1965 | 634 |
| Feb 1966 | 647 |
| Mar 1966 | 647 |
| Apr 1966 | 632 |
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| Jun 1966 | 612 |



|  |  |
| --- | --- |
| In which year was 14CO2 at its highest level? |  |
| In which month was 14CO2 at its highest level? |  |