

**Passage II**

Carbon monoxide gas (CO) is toxic in air at concentrations above 0.1% by volume. Cars are the major source of atmospheric CO in urban areas. Higher CO levels are observed during colder weather. A group of students proposed that cars emit more CO at colder air temperatures than at warmer air temperatures during the first 15 minutes after they are started. The students did the following experiments to investigate this hypothesis.

*Experiment 1*

A hose was connected to the tailpipe of a car. The engine was started and the exhaust was collected in a plastic bag. A 1 mL sample of the exhaust was taken from the bag with a syringe and injected into a *gas chromatograph*, an instrument that separates a mixture of gases into its individual components. Comparisons of the exhaust with mixtures of known CO concentrations were made to determine the percent by volume of CO in the exhaust. Exhaust was collected at 2-minute intervals. Samples of exhaust from each of 4 cars were tested at an external temperature of  $-9^{\circ}\text{C}$ . The results are shown in Table 1.

Time after starting (min)	Percent of CO in the exhaust at $-9^{\circ}\text{C}$ :			
	1978 Model X	1978 Model Y	1996 Model X	1996 Model Y
1	3.5	3.2	1.2	0.3
3	4.0	3.7	1.0	1.2
5	4.5	7.5	1.5	2.5
7	3.6	10.0	1.0	3.0
9	3.2	9.1	0.5	2.6
11	3.1	8.0	0.5	2.0
13	3.0	7.0	0.5	2.0
15	2.9	7.0	0.4	1.8

*Experiment 2*

The same 4 cars were tested at a temperature of  $20^{\circ}\text{C}$  using the procedure from Experiment 1. The results are shown in Table 2.

Time after starting (min)	Percent of CO in the exhaust at $20^{\circ}\text{C}$ :			
	1978 Model X	1978 Model Y	1996 Model X	1996 Model Y
1	2.0	0.8	0.3	0.2
3	2.8	2.0	0.5	1.0
5	3.4	6.0	0.5	1.5
7	1.5	7.0	0.3	0.8
9	1.3	7.0	0.3	0.5
11	1.0	6.5	0.1	0.3
13	1.0	5.0	0.1	0.3
15	0.9	4.8	0.1	0.2

6. Do the results from Experiment 1 support the hypothesis that, at a given temperature and time, the exhaust of newer cars contains lower percents of CO than the exhaust of older cars?
  - F. Yes; the highest percent of CO was in the exhaust of the 1996 Model Y.
  - G. Yes; both 1996 models had percents of CO that were lower than those of either 1978 model.
  - H. No; the highest percent of CO was in the exhaust of the 1978 Model Y.
  - J. No; both 1978 models had percents of CO that were lower than those of either 1996 model.

7. A student, when using the gas chromatograph, was concerned that  $\text{CO}_2$  in the exhaust sample may be interfering in the detection of CO. Which of the following procedures would best help the student investigate this problem?
  - A. Filling the bag with  $\text{CO}_2$  before collecting the exhaust
  - B. Collecting exhaust from additional cars
  - C. Injecting a sample of air into the gas chromatograph
  - D. Testing a sample with known amounts of CO and  $\text{CO}_2$

8. Based on the results of the experiments and the information in the table below, cars in which of the following cities would most likely contribute the greatest amount of CO to the atmosphere in January? (Assume that the types, numbers, and ages of cars used in each city are approximately equal.)

City	Average temperature ( $^{\circ}\text{F}$ ) for January
Minneapolis	11.2
Pittsburgh	26.7
Seattle	39.1
San Diego	56.8

- F. Minneapolis
- G. Pittsburgh
- H. Seattle
- J. San Diego

9. In Experiment 1, which of the following factors varied?
  - A. The method of sample collection
  - B. The volume of exhaust that was tested
  - C. The year in which the cars were made
  - D. The temperature at which the engine was started



10. Many states require annual testing of cars to determine the levels of their CO emissions. Based on the experiments, in order to determine the maximum percent of CO found in a car's exhaust, during which of the following times after starting a car would it be best to sample the exhaust?
- F. 1–3 min
  - G. 5–7 min
  - H. 9–11 min
  - J. 13 min or longer
11. How would the results of the experiments be affected, if at all, if the syringe contents were contaminated with CO-free air? (The composition of air is 78% N<sub>2</sub>, 21% O<sub>2</sub>, 0.9% Ar, and 0.1% other gases.) The measured percents of CO in the exhaust would be:
- A. higher than the actual percents at both  $-9^{\circ}\text{C}$  and  $20^{\circ}\text{C}$ .
  - B. lower than the actual percents at  $-9^{\circ}\text{C}$ , but higher than the actual percents at  $20^{\circ}\text{C}$ .
  - C. lower than the actual percents at both  $-9^{\circ}\text{C}$  and  $20^{\circ}\text{C}$ .
  - D. the same as the actual percents at both  $-9^{\circ}\text{C}$  and  $20^{\circ}\text{C}$ .