Worksheet: Thermodynamic Temperature and Molecular Speeds

Q1: Five bicyclists are riding at the following speeds: 5.40 m/s, 5.70 m/s, 5.80 m/s, 6.00 m/s, and 6.50 m/s.

Question Video

- What is their average speed?

A 5.33 m/s

B 4.96 m/s

C 5.88 m/s

D 4.69 m/s

E 5.66 m/s

- What is their root mean square (rms) speed?

A 5.33 m/s

B 4.98 m/s

C 5.89 m/s

D 4.69 m/s

E 5.65 m/s

Q2: Typical root-mean-square speeds of molecules in gases are large, even at low temperatures. Find the root-mean-square speed for helium atoms at a temperature of 5.00 K.

A 82.2 m/s

B 158 m/s

C 49.3 m/s

D 177 m/s

E 126 m/s

Q3: Find the temperature at which the average speed of carbon dioxide molecules is 510 m/s. Use a value of 44.0 g/mol for the molar mass of carbon dioxide.

A 507 K

B 541 K

C 570 K

D 514 K

E 535 K

Q4: The root-mean-square speed of carbon dioxide molecules in a flame is found to be 1 350 m/s. Find the temperature of the flame. Use a value of 44.0 g/mol for the molar mass of carbon dioxide molecules.

Question Video

A 3.16×10^3 K

B 3.09×10^3 K

C 3.22×10^3 K

D 3.31×10^3 K

E 3.38×10^3 K

Q5: How many times greater is the average translational kinetic energy of a nitrogen molecule at a temperature of 300 K to the gravitational potential energy of a nitrogen molecule-Earth system at the ceiling of a 3.00 m tall room with respect to the same system with the molecule at the floor?

A 5.86×10^4

B 4.86×10^4

C 5.82×10^4

D 4.60×10^4

E 4.54×10^4

Q6: Find the temperature at which hydrogen molecules have a root-mean-square velocity v_{rms} equal to the Moon's escape velocity. Use a value of 2.38 km/s for the escape velocity from the Moon and use a value of 2.016 g/mol for the molar mass of hydrogen molecules.

A 477 K

B 481 K

C 458 K

D 464 K

E 470 K

Q7: The isotopes ^{235}U and ^{238}U are chemically identical, differing only in their atomic masses. The difference in the atomic masses of the isotopes makes it possible to separate them due to the difference between the diffusion speeds of UF_6 gas containing these isotopes.

The molar masses of the ^{235}U and ^{238}U isotopes of UF_6 are 349.0 g/mol and 352.0 g/mol, respectively. What is the ratio of their typical root-mean-square speeds?

A 1.006

B 1.100

C 1.002

D 1.008

E 1.004

At what temperature would the root-mean-square speeds of the ^{235} U and ^{238} U isotopes of UF_6 differ by 1.00 m/s?

A 630 K

B 844 K

C 577 K

D 785 K

E 704 K

Q8: A refrigerator holds a volume 22.0 ft^3 of air. The air contains 5.71 moles of oxygen. Given a molar mass of oxygen of 32.0 g/mol and a root-mean-square speed of oxygen molecules of 465 m/s, what is the partial pressure of the oxygen in the refrigerator?

A 21.1 kPa

B 20.8 kPa

C 21.7 kPa

D 22.0 kPa

E 22.5 kPa

Q9: What is the total translational kinetic energy of the air molecules in a room that has a volume of 41 m^3 if the pressure is 1.3×10^5 Pa and the temperature is 27°C?

A 4.2×10^7 J

B 2.2×10^6 J

C 1.3×10^6 J

D 1.3×10^7 J

E 1.7×10^7 J

Q10: Nuclear fusion can occur when appropriate nuclei are brought very close together. The mutual Coulomb repulsion of the nuclei must be overcome to bring nuclei sufficiently near each other for fusion to occur. Nuclei can be brought to very small separations using the kinetic energy of high-temperature gas ions or by accelerating nuclei toward one another.

Calculate the potential energy of two nuclei separated by a distance of 1.00×10^{-12} m. Each nucleus has the same charge as a proton.

A 2.03×10^{-16} J

B 1.39×10^{-16} J

C 2.60×10^{-16} J

D 1.72×10^{-16} J

E 2.30×10^{-16} J

At what temperature will atoms in a gas have an average kinetic energy equal to the potential energy of two protons separated by a distance of 1.00×10^{-12} m?

A 1.23×10^{7} K

B 9.31×10^{6} K

C 1.40×10^{7} K

D 1.04×10^{7} K

E 1.11×10^{7} K

Q11: Temperature varies greatly at different parts of the Sun. A location on the Sun's surface has a temperature of 5.5×10^{3}°C and a location in a region of the Sun's core has a temperature of 15×10^{6}°C.

What is the average kinetic energy of helium atoms at the location on the Sun's surface?

A 1.9×10^{-19} J

B 1.4×10^{-19} J

C 2.5×10^{-19} J

D 3.3×10^{-19} J

E 1.2×10^{-19} J

What is the average kinetic energy of helium atoms at the location in the region of the Sun's core?

A 2.5×10^{-16} J

B 1.2×10^{-16} J

C 3.6×10^{-16} J

D 3.3×10^{-16} J

E 3.1×10^{-16} J

Q12: The product of the pressure and volume of a sample of hydrogen gas at 0.00°C is 80.0 J.

How many moles of hydrogen are present?

A 0.0320 mol

B 0.0288 mol

C 0.0395 mol

D 0.0433 mol

E 0.0325 mol

What is the average translational kinetic energy of the hydrogen molecules?

A 5.81×10^{-21} J

B 5.54×10^{-21} J

C 6.04×10^{-21} J

D 6.22×10^{-21} J

E 5.65×10^{-21} J

What is the value of the product of pressure and volume at 200°C?

A 150 J

B 145 J

C 157 J

D 161 J

E 139 J

Q13: Nuclear fusion reactions between hydrogen nuclei require the nuclei to approach each other at very great speeds. What temperature of a hydrogen plasma is needed to ensure that the hydrogen nuclei in the plasma have average kinetic energies of 6.73×10^{-14} J?

A 2.52×10^{9} K

B 3.25×10^{9} K

C 3.33×10^{9} K

D 1.54×10^{9} K

E 4.98×10^{9} K

Q14: A bullet of mass 12 g is traveling horizontally at 350 m/s when it strikes and embeds in a pendulum bob of mass 4.2 kg.

- How much mechanical energy is dissipated in the collision?

A 710 J

B 730 J

C 650 J

D 850 J

E 770 J

Assuming that the value of the molar heat capacity at constant volume C_v for the bob plus the bullet is $3R$, calculate the temperature increase of the system due to the collision. Take the molecular mass of the system to be 220 g/mol.

A 0.58°C

B 1.5°C

C 0.55°C

D 2.9°C

E 1.3°C

Q15: A person is in a closed racquetball court that has a volume of 435 m^3. The person is hitting a ball that has a mass of 52.5 g in random directions around the room. The ball always collides elastically with the surfaces of the court and returns to the person who then immediately hits it again. The average kinetic energy of the ball during this process is 3.20 J.

During the ball's motion, the velocity v of the ball varies. Determine the average value of v^2.

A 122 m^2/s^2

B 111 m^2/s^2

C 89.0 m^2/s^2

D 21.0 m^2/s^2

E 6.67 m^2/s^2

Determine the average pressure on the surface of the racquetball court due to the impacts of the racquetball.

A 4.90×10^{-3} Pa

B 4.63×10^{-3} Pa

C 2.25×10^{-3} Pa

D 51.1×10^{-3} Pa

E 1.47×10^{-3} Pa

Q16: The most probable speed for molecules of a gas at a temperature of 315 K is 271 m/s. What is the molar mass of the gas?

A 33.4 g/mol

B 13.2 g/mol

C 1.08 g/mol

D 71.3 g/mol

E 7.03 g/mol

Q17: Nitrogen molecules with a molar mass of 28.0 g/mol are in a gas at a temperature of 295 K.

- Find the most probable speed of the molecules.

A 459 m/s

B 419 m/s

C 436 m/s

D 403 m/s

E 500 m/s

- Find the average speed of the molecules.

A 459 m/s

B 472 m/s

C 436 m/s

D 403 m/s

E 500 m/s

- Find the root-mean-square speed of the molecules.

A 459 m/s

B 513 m/s

C 436 m/s

D 403 m/s

E 500 m/s

Q18: Determine the temperature at which nitrogen molecules have a root-mean-square speed equal to the escape velocity of Earth. Use a value of 11.1 km/s for Earth's escape velocity and use a value of 28.0 g/mol for the molar mass of nitrogen molecules.

A 1.92×10^5 K

B 2.04×10^5 K

C 1.33×10^5 K

D 1.38×10^5 K

E 1.74×10^5 K