Solutions

Each answer shows the steps, then the **result**.

2.1

- any two: many identical molecules in **random motion**; molecular **volume negligible**; **no forces** except during collisions; collisions are **elastic**; collision time negligible

2.2

- molecules collide with the walls and **change momentum** (rebound)
- this exerts a **force** on the wall; force over the wall area is the **pressure**

2.3

- the **square root of the mean of the squared speeds** of the molecules ($\sqrt{\langle c^2 \rangle}$)

2.4

- the product of pressure and volume equals **one third** of (the number of molecules × molecular mass × mean-square speed)

3.1 B

- mean kinetic energy of a molecule is $\frac{3}{2}kT$
- **A** is kT; **C** is a speed formula, not the mean KE; **D** is RT, which is for a mole, not one molecule

3.2

- $E = \frac{3}{2}kT$

$$E = \tfrac{3}{2}(1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}})(300\ \mathrm{K}) = \mathbf{6.2 \times 10^{-21}}\ \mathrm{J}$$

3.3

- $\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT \Rightarrow \langle c^2 \rangle = 3kT/m$

$$c_{\mathrm{r.m.s.}} = \sqrt{\frac{3(1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}})(300\ \mathrm{K})}{5.3 \times 10^{-26}\ \mathrm{kg}}} = \mathbf{4.8 \times 10^{2}}\ \mathrm{m\ s^{-1}}$$

3.4

- heating raises the **mean KE / mean speed** of the molecules
- they hit the walls **harder and more often**, so the pressure rises (volume fixed)

3.5

(a) the **sum of the random kinetic and potential energies** of all the molecules

- "random" means the motion has no overall direction — the whole container moving does not count

(b) in an ideal gas the molecules exert **no forces** on one another except during collisions, so the total **potential** energy is zero and the internal energy is entirely kinetic

- the mean kinetic energy of a molecule is $\frac{3}{2}kT$, i.e. proportional to T, so the total is proportional to T as well

(c) internal energy is proportional to T, so at T it is U, at $3T$ it is $3U$ and at $2T$ it is $2U$

process	**work done on the gas**	**thermal energy supplied**	**increase in internal energy**
compression to $3T$	W	$2U - W$	$+2U$
cooling to $2T$	0	$-U$	$-U$

- $+2U$; $-U$; the zero work; both thermal-energy entries, from $\Delta U = q + w$

(d) at **constant volume** the gas neither expands nor is compressed, so no work is done on or by it