# Unit 7 · States of Matter

**ANSWER KEY · FOR TEACHERS**

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

## 1 Key words

1. Boyle's law
2. absolute zero
3. partial pressure
4. Graham's law
5. vapor pressure
6. surface tension
7. viscosity
8. deliquescent

K · 4

Each carries 0.5 mark.

## 2 Label the diagram

1. $H_2O_2 + MnO_2$
2. oxygen + water vapor
3. water
4. shelf

K · 2

Each carries 0.5 mark.

## 3 Multiple choice

**i.** **b.** the pressure and the amount of gas — K · 1

Charles's law: V ∝ T for a fixed amount of gas (n) at constant **pressure**.

**ii.** **c.** 4 — K · 1

8 corners × ⅛ + 6 faces × ½ = 1 + 3 = **4**. Each corner atom is shared by eight cells, each face atom by two, so 14 atoms touch the cell but only 4 belong to it.

**iii.** **d.** diethyl ether — U · 1

The weaker the forces between a liquid's molecules, the more escape and the higher its vapor pressure. Diethyl ether has no O–H group to hydrogen bond, so its molecules escape most easily. Glycerol, with three O–H groups, has the lowest.

**iv.** **a.** 1 : 4 — A · 1

$\frac{r_{O_2}}{r_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}} = \frac{1}{4}$. Oxygen, 16 times as heavy, diffuses 4 times as slowly.

**v.** **c.** 327 °C — A · 1

Work in kelvin: 27 °C = 300 K. V ∝ T, so doubling V doubles T: 600 K = 600 − 273 = **327 °C**. Doubling the Celsius number, 54 °C, is the usual slip.

## 4 Short answers

**a.** MARKING SCHEME — U · 2

- ✓ Washing soda: efflorescent, loses water of crystallization to the air.
- ✓ Caustic soda: deliquescent, absorbs water from the air and dissolves in it.

**b.** MARKING SCHEME — U · 2

- ✓ A state that flows like a liquid with its molecules lined up like a crystal.
- ✓ A voltage turns the molecules and controls the light through each part of the screen.



Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

**c.** MARKING SCHEME A · 3

✓ $M_r = 172$.
✓ 20.9% water.
✓ 6.8 g of $CaSO_4$.

## 5 Long answer

ANSWER U · 4

**Postulates** (any four):

- A gas is made of a very large number of tiny particles whose own volume is negligible compared with the volume of the container.
- The particles move all the time, randomly, in straight lines, in all directions.
- They collide with each other and with the walls elastically (no kinetic energy is lost); their collisions with the walls are the gas's pressure.
- There are no forces of attraction or repulsion between the particles.
- Their average kinetic energy is proportional to the absolute temperature.

**Boyle's law**: at constant temperature, the particles keep the same average speed. If the volume is halved, the same particles are crowded into half the space, so they hit each square centimeter of wall twice as often: the pressure doubles. So $P \propto 1/V$, or PV is constant.

MARKING SCHEME

✓ Two postulates.
✓ Two more postulates.
✓ At constant temperature the particles' average speed stays the same.
✓ Less volume, more collisions with each part of the wall, so more pressure: $P \propto 1/V$.

## 6 Numerical problems

**a.** ANSWER A · 4

i. $n = \frac{PV}{RT} = \frac{1.5 \times 3.0}{0.0821 \times 300} = \mathbf{0.183\ mol}$.
ii. $0.183 \times 28 = \mathbf{5.1\ g}$.
iii. $0.183 \times 22.4 = \mathbf{4.1\ L}$ (or by $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$: $3.0 \times 1.5 \times 273 \div 300 = 4.1$ L).
iv. Fixed volume, so $P \propto T$: $1.5 \times 400 \div 300 = \mathbf{2.0\ atm}$.

MARKING SCHEME

✓ n = 0.183 mol.
✓ 5.1 g.
✓ 4.1 L at STP.
✓ 2.0 atm at 400 K.

**b.** ANSWER A · 4

i. He: $4.0 \div 4 = 1.0$ mol; $O_2$: $16.0 \div 32 = 0.50$ mol; 1.5 mol in all. $P = \frac{nRT}{V} = \frac{1.5 \times 0.0821 \times 300}{10.0} =$ **3.69 atm**.
ii. $pHe = \frac{1.0}{1.5} \times 3.69 = \mathbf{2.46\ atm}$; $p_{O_2} = \frac{0.50}{1.5} \times 3.69 = \mathbf{1.23\ atm}$ (they add up to 3.69 atm).
iii. $\frac{rHe}{r_{O_2}} = \sqrt{\frac{32}{4}} = \sqrt{8} = \mathbf{2.83}$ times as fast.

MARKING SCHEME

✓ Moles 1.0 and 0.50; total pressure 3.69 atm.
✓ p(He) = 2.46 atm.
✓ $p(O_2) = 1.23$ atm.
✓ Helium 2.83 times as fast (Graham's law).


Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

## 7 Think

**ANSWER** HA · 3

Floating has nothing to do with it: gas leaks out through tiny pores in the rubber in every direction, by **effusion**. At the same temperature all gas molecules have the same average kinetic energy, ½mv$^2$, so the lighter helium atoms move faster and pass through the pores more often.

By Graham's law, $\frac{rHe}{r_{N_2}} = \sqrt{\frac{28}{4}} = \sqrt{7} \approx$ **2.6** times as fast.

**MARKING SCHEME**

- ✓ The gas escapes through pores by effusion, not by floating.
- ✓ Same average kinetic energy, so lighter helium atoms move faster.
- ✓ Graham's law: about 2.6 times as fast.

## 8 Activity: A shrinking bottle

(not marked)

**WHAT STUDENTS SHOULD FIND**

The capped bottle **crumples inwards** as it cools; the open one doesn't change. In the capped bottle the amount and volume of warm air are fixed at first, so as it cools its **pressure falls** ($P \propto T$ at constant volume, Gay-Lussac's or the pressure law); some of the water vapor also condenses. The air outside, at a higher pressure, pushes the bottle in. With the cap off, air flows in as the inside cools, so the pressures stay equal.

| Marks by level | Knowledge | Understanding | Application | Higher ability | Total |
|---|---|---|---|---|---|
| **Marks** | 8 | 9 | 13 | 3 | **33** |



Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking