**Q1.**

| | | | | |
|---|---|---|---|---|
| 2 | (a) | speck of light | B1 | |
| | | that moves haphazardly/randomly/jerkily/etc. | B1 | [2] |
| | (b) | randomness of collisions would be 'averaged out' | B1 | |
| | | so less (haphazard) movement | B1 | [2] |
| | | (do not allow 'more massive so less movement') | | |

**Q2.**

| | | | | |
|---|---|---|---|---|
| 3 | (a) | sum of (random) kinetic and potential energies | M1 | |
| | | of the atoms/molecules of the substance | A1 | [2] |
| | (b) (i) | potential energy unchanged as atoms remain in same positions | M1 | |
| | | *allow 'reduced because atoms slightly closer together'* | | |
| | | vibrational kinetic energy reduced because temperature lower | M1 | |
| | | so internal energy less | A1 | [3] |
| | (ii) | potential energy increases because separation increases | M1 | |
| | | kinetic energy unchanged because temperature unchanged | M1 | |
| | | so internal energy increases | A1 | [3] |

**Q3.**

| | | | | |
|---|---|---|---|---|
| 4 | (a) | mass per unit volume (*ratio idea must be clear, not units*) | B1 | [1] |
| | (b) (i) | pressure is same at the surface of mercury | | |
| | | because at same horizontal level | B1 | [1] |
| | (ii) | $h\rho g$ is same for both | B1 | |
| | | $53 \times 10^{-2} \times 1.0 \times 10^{3} \times g = 71 \times 10^{-2} \times \rho \times g$ | C1 | |
| | | $\rho = 7.5 \times 10^{2}$ kg m$^{-3}$ | A1 | [3] |

**Q4.**

| | | | | |
|---|---|---|---|---|
| 3 | (a) | mass / volume (ratio idea essential) | B1 | [1] |
| | (b) (i) | mass = $Ah\rho$ | B1 | [1] |
| | (ii) | pressure = force/area | B1 | |
| | | weight (of liquid)/force (on base) = $Ah\rho g$ | B1 | |
| | | pressure = $h\rho g$ | A0 | [2] |
| | (c) (i) | ratio = 1600 or 1600:1 | A1 | [1] |
| | (ii) | ratio = $\sqrt[3]{1600}$ | C1 | |
| | | = 11.7 (*allow 12*) | A1 | [2] |

| | | | | |
|---|---|---|---|---|
| **(d)** | **(i)** | density of solids and liquids are (about) equal | B1 | [1] |
| | **(ii)** | strong forces: fixed volume<br>rigid forces: retains shape / does not flow / little deformation<br>*(allow 1 mark for fixed volume, fixed shape)* | B1<br>B1 | [2] |

**Q5.**

| | | | | |
|---|---|---|---|---|
| **4** | **(a)** | **(i)** solid has fixed volume and fixed shape/incompressible | B1 | [1] |
| | | **(ii)** gas fills any space into which it is put | B1 | [1] |
| | **(b)** | atoms/molecules have (elastic) collisions with the walls (of the vessel)<br>momentum of atom/molecule changes<br>so impulse (on wall)/force on wall<br>random motion/many collisions (per unit time) gives rise to (constant) force/pressure | B1<br>B1<br>B1<br>B1 | [4] |
| | **(c)** | spacing (much) greater in gases than in liquids/about ten times<br>*either* spacing depends on $1/\sqrt[3]{\rho}$<br>*or* ratio of spacings is about 8.8 | C1<br>A1 | [2] |

**Q6.**

| | | | | |
|---|---|---|---|---|
| **6** | **(a)** | any two of:<br>large number of molecules / atoms / particles<br>molecules in random motion<br>no intermolecular forces<br>elastic collisions<br>time of collisions much less than time between collisions<br>volume of molecules much less than volume of containing vessel | B1 + B1 | [2] |
| | **(b)** | molecules collide with the walls<br>change in momentum of molecules implies force (on molecules)<br>molecules exert equal and opposite force on wall<br>pressure is averaging effect of many collisions<br>(*any three statements, 1 each*) | B3 | [3] |

**Q7.**

| | | | | |
|---|---|---|---|---|
| 7 | (a) | density in solids and liquids similar | M1 | |
| | | spacing in solids and liquids about the same | A1 | |
| | | density in gases much less as spacing in gases much greater | B1 | [3] |
| | (b) | density = mass / volume | C1 | |
| | | mass = $1.67 \times 10^{-27}$ kg and volume = $4/3\ \pi\ r^3$ | C1 | |
| | | density = $(1.67 \times 10^{-27}) / 4/3 \times \pi \times (1.0 \times 10^{-15})^3$ | | |
| | | = $3.99 \times 10^{17}$ kg m$^{-3}$ | A1 | [3] |
| | (c) | atoms / molecules composed of large amount of empty space / nucleus has very small volume compared to volume of atom / space between atoms in a gas is very large | B1 | [1] |

**Q8.**

| | | | | |
|---|---|---|---|---|
| 3 | (a) | $V = h \times A$ | | |
| | | $m = V \times \rho$ | B1 | |
| | | $W = h \times A \times \rho \times g$ | B1 | |
| | | $P = F / A$ | B1 | |
| | | $P = h\rho g$ | | |
| | | $P$ is proportional to $h$ if $\rho$ is constant (and $g$) | B1 | [4] |
| | (b) | density changes with height | B1 | |
| | | hence density is not constant with link to formula | B1 | [2] |

**Q9.**

| | | | | |
|---|---|---|---|---|
| 4 | (a) | pressure = force / area (normal to force) | A1 | [1] |
| | (b) | molecules/atoms/particles in (constant) random/haphazard motion | B1 | |
| | | molecules have a change in momentum when they collide with the walls | M1 | |
| | | (force exerted on molecules) therefore force on the walls | A1 | |
| | | reference to average force from many molecules/many collisions | A1 | [4] |
| | (c) | elastic collision when kinetic energy conserved | B1 | |
| | | temperature constant for gas | B1 | [2] |

**Q10.**

| | | | | |
|---|---|---|---|---|
| 4 | (a) | apparatus: cell with particles e.g. smoke (container must be closed) | B1 | |
| | | diagram showing suitable arrangement with light illumination and microscope | B1 | [2] |
| | (b) | specks / flashes of light | M1 | |
| | | in random motion | A1 | [2] |
| | (c) | cannot see what is causing smoke to move hence molecules smaller than smoke particles | (B1) | |
| | | continuous motion of smoke particles implies continuous motion of molecules | (B1) | |
| | | random motion of particles implies random motion of molecules | (B1) | |
| | | | max. 2 | [2] |

**Q11.**

| | | | | | |
|---|---|---|---|---|---|
| 5 | (a) | | metal: crystalline / lattice / atoms in regular pattern | B1 | |
| | | | (atoms in regular) pattern that repeats itself (within crystal) | B1 | [2] |
| | | | polymer: long chains of atoms / molecules | B1 | |
| | | | chain consists of 'units' that repeat themselves | B1 | [2] |
| | (b) | (i) | e.g. latex is soft / not strong / flows / ductile | B1 | |
| | | | elastic limit easily exceeded | B1 | [2] |
| | | | (*allow any two sensible comments, 1 each*) | | |
| | | (ii) | more solid / does not flow / stronger / higher ultimate tensile stress | | |
| | | | more brittle | | |
| | | | elastic limit much higher | | |
| | | | increased toughness | | |
| | | | (*any two, 1 each*) | B2 | [2] |

**Q12.**

| | | | | | |
|---|---|---|---|---|---|
| 5 | (a) | | haphazard / random / erratic / zig-zag movement | M1 | |
| | | | of (smoke) particles (*do not allow molecules / atoms*) | A1 | [2] |
| | (b) | | motion is due to unequal / unbalanced collision rates (on different faces) | B1 | |
| | | | (unequal collision rate due to) random motion of (gas) molecules / atoms | B1 | [2] |
| | (c) | *either* | collisions with air molecules average out | M1 | |
| | | | this prevents haphazard motion | A1 | [2] |
| | | *or* | particle is more massive / heavier / has large inertia (M1) | | |
| | | | collisions cause only small movements / accelerations (A1) | | |

**Q13.**

2 (a) (i) e.g. (phase) change from liquid to gas / vapour
thermal energy required to maintain constant temperature ..... B1 [1]
(*do not allow 'convert water to steam'*)

(ii) e.g. evaporation takes place at surface ..... B1
boiling takes place in body of the liquid ..... B1
e.g. evaporation occurs at all temperatures ..... B1
boiling occurs at one temperature ..... B1 [4]

(b) (i) volume = $(\frac{48}{4.5} =)$ 10.7 $cm^3$ ..... A1 [1]

(ii) **1** volume = $10.7 / (6.0 \times 10^{23})$
= $1.8 \times 10^{-23}$ $cm^3$ ..... A1 [1]
**2** separation = $\sqrt[3]{(1.8 \times 10^{-23})}$
= $2.6 \times 10^{-8}$ cm ..... A1 [1]

**[Total: 8]**

**Q14.**

2 crystalline: atoms / ions / particles in a regular arrangement / lattice
long range order / orderly pattern
(lattice) repeats itself (1) B1
polymer: long chain molecules / chains of monomers B1
some cross-linking between chains / tangled chains (1)
amorphous: disordered arrangement of molecules / atoms / particles B1
any ordering is short-range (1)
(*three 'B' marks plus any other 2 marks*) B2 [5]

**Q15.**

1 (a) density = mass / volume B1 [1]

(b) density of liquids and solids same order of spacing similar / to about 2× B1
density of gases much less as spacing much more
or density of gases much lower hence spacing much more B1 [2]

(c) (i) density = $68 / [50 \times 600 \times 900 \times 10^{-9}]$ C1
= 2520 (allow 2500) kg $m^{-3}$ A1 [2]

(ii) $P = F / A$ C1
$= 68 \times 9.81 / [50 \times 600 \times 10^{-6}]$ C1
$= 2.2 \times 10^{4}$ Pa A1 [3]

**Q16.**

| | | | | |
|---|---|---|---|---|
| 3 | (a) | pressure = force / area | B1 | [1] |
| | (b) | molecules collide with object / surface and rebound | B1 | |
| | | molecules have change in momentum hence force acts | B1 | |
| | | fewer molecules per unit volume on top of mountain / temperature is less hence lower speed of molecules | B1 | |
| | | hence less pressure | A0 | [3] |
| | (c) (i) | $\rho = m / V$ | C1 | |
| | | $W = V\rho g = 0.25 \times 0.45 \times 9.81 \times 13600$ | C1 | |
| | | $= 15000$ (15009) N | A1 | [3] |
| | (ii) | $p = W / A$ (or using $p = \rho gh$) $= 15009 / 0.45$ | | |
| | | $= 3.3 \times 10^4$ Pa | A1 | [1] |
| | (iii) | pressure will be greater due to the air pressure (acting on the surface of the liquid) | B1 | [1] |

**Q17.**

| | | | | |
|---|---|---|---|---|
| 3 | (a) | metal: regular / repeated / ordered arrangement / pattern / lattice or long range order (of atoms / molecules / ions) | B1 | |
| | | polymer: tangled chains (of atoms / molecules) or long chains (of atoms / molecules / ions) | B1 | |
| | | amorphous: disordered / irregular arrangement or short range order (of atoms / molecules / ions) | B1 | [3] |
| | (b) | metal: straight line or straight line then curving with less positive gradient | B1 | |
| | | polymer: curve with decreasing gradient with steep increasing gradient at end | B1 | [2] |

**Q18.**

| | | | | |
|---|---|---|---|---|
| 1 | | volume = $\pi (14 \times 10^{-3})^2 \times 12 \times 10^{-3}$ ($=7.389 \times 10^{-6}$ m$^3$) | C1 | |
| | | density = mass / volume [any subject] | C1 | |
| | | mass = $6.8 \times 10^3 \times 7.389 \times 10^{-6} = 0.0502$ | | |
| | | weight = $mg$ | C1 | |
| | | $= 0.0502 \times 9.81 = 0.49$ N (mark not awarded if not to **two** s.f.) | A1 | [4] |