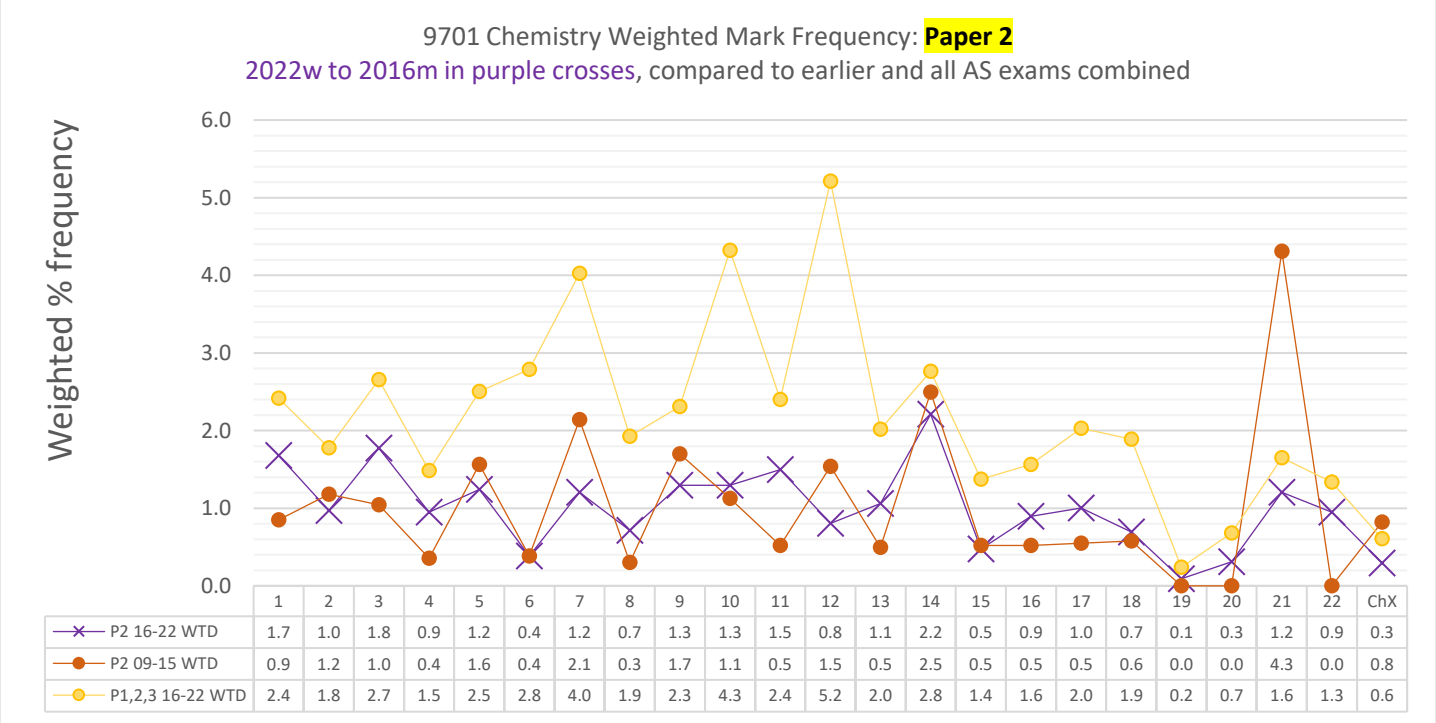
Name: Class: Date:

ALvl Chem 4 EQ P2 22w to 09s Paper 2 States of matter 65marks

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than one minutes to complete.

Paper 2 Topic 4 Checklist Tick each task off as you go along	RANK:	P1 Noob	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	P1[1] Winner	P1 Hero	P1 Legend
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	65		7	7	16	26	33	49	65
Time @75s/mark (minutes)	81		8	8	20	33	41	61	81



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	ChX
P2 16-22 WTD	1.7	1.0	1.8	0.9	1.2	0.4	1.2	0.7	1.3	1.3	1.5	0.8	1.1	2.2	0.5	0.9	1.0	0.7	0.1	0.3	1.2	0.9	0.3
P2 09-15 WTD	0.9	1.2	1.0	0.4	1.6	0.4	2.1	0.3	1.7	1.1	0.5	1.5	0.5	2.5	0.5	0.5	0.5	0.6	0.0	0.0	4.3	0.0	0.8
P1,2,3 16-22 WTD	2.4	1.8	2.7	1.5	2.5	2.8	4.0	1.9	2.3	4.3	2.4	5.2	2.0	2.8	1.4	1.6	2.0	1.9	0.2	0.7	1.6	1.3	0.6

What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important goal from skillful action in study is being better at any important task, even if circumstances do not feel ideal.

As you are moving through your studies you can learn more about yourself by trying out new ways to manage yourself, and analysing how effective those new techniques were. In this reflective process not only will you get better at working positively and productively to deliver ambitious and successful outcomes, but you will be working towards one aspect of life's highest pursuit, summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each page or group of 10-20 marks, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. Multiple choice questions, done carefully where you explain and show yourself your thinking using written notes as you move through each question, can be more useful than just Paper 2 for students aiming for a C or B grade. Paper 2 should be the larger focus for students aiming for A and A* grades, however.
4. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are NOT using the marking scheme correctly; your correct answer might not be fully complete for all the marks you are awarding. The marks easiest to miss rely on providing the largest amount of detail.

[1] **DO NOT** work on these higher levels of completion in your AS year unless you have also achieved at least a "**Silver**" (25%) in the same topic in **Paper 1**, which tend also to be easier questions, as well as ""**Silver**" (25%) in the same topic, if it exists, in Paper 3.

4 States of matter

4.1 The gaseous state: ideal and real gases and $pV = nRT$

Learning outcomes

Candidates should be able to:

1 explain the origin of pressure in a gas in terms of collisions between gas molecules and the wall of the container

2 understand that ideal gases have zero particle volume and no intermolecular forces of attraction

3 state and use the ideal gas equation $pV = nRT$ in calculations, including in the determination of M_r

4.2 Bonding and structure

Learning outcomes

Candidates should be able to:

1 describe, in simple terms, the lattice structure of a crystalline solid which is:
   (a) giant ionic, including sodium chloride and magnesium oxide
   (b) simple molecular, including iodine, buckminsterfullerene C_{60} and ice
   (c) giant molecular, including silicon(IV) oxide, graphite and diamond
   (d) giant metallic, including copper

2 describe, interpret and predict the effect of different types of structure and bonding on the physical properties of substances, including melting point, boiling point, electrical conductivity and solubility

3 deduce the type of structure and bonding present in a substance from given information

Q# 94/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 Carbon monoxide gas, CO(g), and nitrogen gas, N_2(g), are both diatomic molecules.

(c) Both carbon monoxide and nitrogen are gases at room temperature and pressure.

They both behave like ideal gases under certain conditions.

(i) State the **two** conditions necessary for these two gases to approach ideal gas behaviour.

.....

..... [1]

(ii) Explain why N_2(g) behaves more like an ideal gas than CO(g) does at 20.0 °C and 101 kPa.

.....

.....

..... [2]

(d) Calculate the amount, in mol, of pure nitrogen gas which occupies 100 cm^3 at 101 kPa and 20.0 °C.

Use relevant information from the *Data Booklet*. Show your working.

Assume nitrogen behaves as an ideal gas.

..... mol
[3]

[Total: 11]

Q# 95/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1 The rate of chemical reactions is affected by changes in temperature and pressure.

(ii) 2.00 g of krypton gas, Kr(g), is placed in a sealed 5.00 dm^3 container at 120 °C.

Calculate the pressure, in Pa, of Kr(g) in the container.
Assume Kr(g) behaves as an ideal gas.

Show your working.

pressure = ... Pa [3]

(iii) State and explain the conditions at which krypton behaves most like an ideal gas.

.....

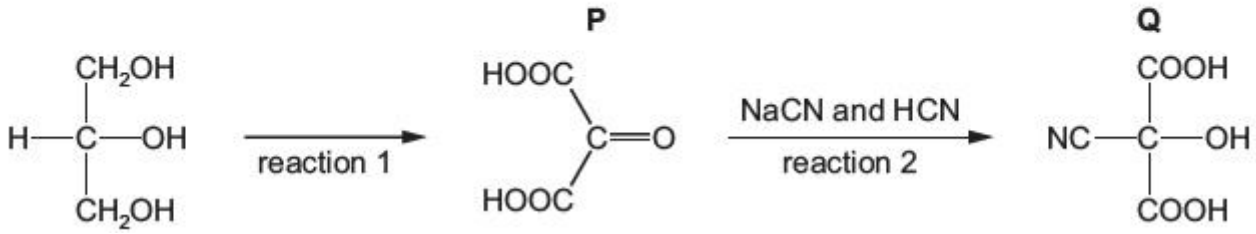
.....

.....

..... [2]

3 Glycerol, $CH_2(OH)CH(OH)CH_2OH$, is widely used in the food industry and in pharmaceuticals.

(a) A series of reactions starting from glycerol is shown.



(b) Glycerol can be used as a starting material in the manufacture of nitroglycerine, $C_3H_5N_3O_9$.

Nitroglycerine decomposes rapidly on heating to form a mixture of gases.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

A sample of nitroglycerine decomposes, releasing 1.06 dm^3 of $O_2(g)$ at 850 K and 1.00×10^5 Pa.

(i) Calculate the mass of nitroglycerine that decomposes.

mass of nitroglycerine = ... g [3]

(ii) Calculate the total volume of gas released by this decomposition at 850 K and 1.00×10^5 Pa.

total volume of gas = ... dm^3 [1]

(iii) $Cl_2(g)$ does **not** behave as an ideal gas under these conditions.

Explain why $Cl_2(g)$ behaves even **less** ideally at:

- very high pressures

.....

.....

.....

- very low temperatures.

.....

.....

.....

[2]

[Total: 11]

Q# 98/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

(c) HOF is the only known molecule that contains only the elements hydrogen, oxygen and fluorine.

(d) Interhalogen compounds, such as $BrCl$ or IF_5, contain two or more different halogen atoms that are covalently bonded.

D is an interhalogen compound that contains only chlorine and fluorine.

At 0 °C and 101 325 Pa, 1 dm^3 of **D** has a mass of 4.13 g.

(i) Use the general gas equation to calculate the relative molecular mass, M_r, of **D**.

M_r = ...

[3]

(ii) Use your answer to **(i)** to determine the molecular formula of **D**.

If you were unable to calculate the M_r in **(i)**, assume that the M_r is 130.5. This is **not** the correct value.

molecular formula of **D** = ...
[1]

Q# 99/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2 Carbon and silicon are elements in Group 14.

(a) C_{60} and diamond are allotropes of carbon.

(i) Describe the lattice structure of solid C_{60}.

.....

.....

.....

..... [2]

(ii) C_{60} sublimes (turns directly from solid to gas) at about 800 K. Diamond also sublimes but only above 3800 K.

Explain why C_{60} and diamond sublime at such different temperatures.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(b) C_{60} forms hydrocarbons with similar chemical properties to those of alkenes. One such hydrocarbon is $C_{60}H_{18}$.

(i) State what is meant by the term *hydrocarbon*.

.....

..... [1]

(ii) Describe a test to indicate the presence of double bonds between carbon atoms in $C_{60}H_{18}$. Give the result of the test.

test .....

.....

result .....

.....

[2]

(c) 0.144 g of C_{60} was placed in a 100 cm^3 container of hydrogen gas at 20 °C and 1.00×10^5 Pa.

The container was heated to make the C_{60} and hydrogen gas react.

The reaction occurred as shown in the equation.

$$C_{60}(s) + xH_2(g) \rightarrow C_{60}H_{2x}(s)$$

After the reaction, the container was allowed to cool to 20 °C. The pressure decreased to 2.21×10^4 Pa. All of the C_{60} had reacted.

(i) Name the type of reaction that occurred.

..... [1]

(ii) Calculate the amount, in moles, of C_{60} that reacted.

amount of C_{60} = ... mol [1]

(iii) Calculate the amount, in moles, of hydrogen gas that reacted with the C_{60}.

amount of hydrogen gas = ... mol [2]

(iv) Use your answers from **(ii)** and **(iii)** to deduce the molecular formula of the hydrocarbon, $C_{60}H_{2x}$.

If you were unable to calculate the amount of hydrogen gas, assume that 0.00240 mol of hydrogen gas reacted. This is **not** the correct value for the amount of hydrogen gas that reacted.

molecular formula = ... [2]

(d) Silicon shows the same kind of bonding and structure as diamond.

(i) State the type of bonding and structure shown by silicon.

.....

.....

..... [2]

Q# 100/ ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 Structure and bonding can be used to explain many of the properties of substances.

(a) Copper, ice, silicon(IV) oxide, iodine and sodium chloride are all crystalline solids.

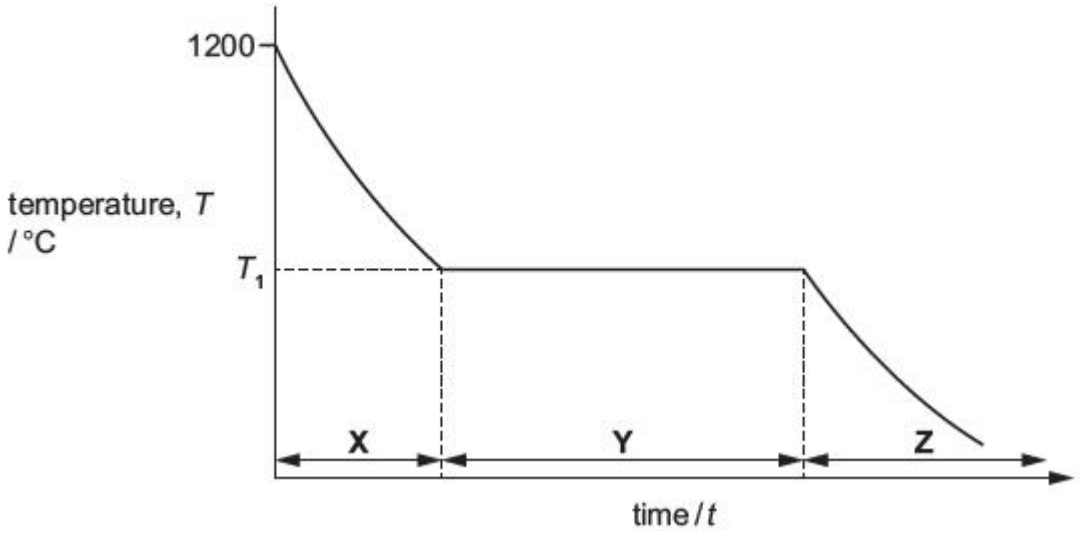
Complete the table with:

- the name of a type of bonding found in each crystalline solid,
- the type of lattice structure for each crystalline solid.

crystalline solid	type of bonding	type of lattice structure
copper		
ice		
silicon(IV) oxide		
iodine		
sodium chloride		

[5]

(c) The graph represents how the temperature of a sample of copper (melting point 1085 °C) changes as it is gradually cooled from 1200 °C.



(i) Identify the state(s) of matter present during each stage of the process shown in the graph.

X .....

Y .....

Z .....

[2]

(ii) State what is happening to the energy and movement of the particles in the copper during stage **X**.

.....

.....

..... [2]

(iii) Explain why the temperature stays constant at T_1 during stage **Y**.

.....

.....

.....

..... [2]

[Total: 15]

Q# 101/ ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1 This question is about Period 3 elements and their compounds.

(a) Give an explanation for each of the following statements.

(iii) Sodium is a better electrical conductor than phosphorus.

.....

.....

.....

..... [2]

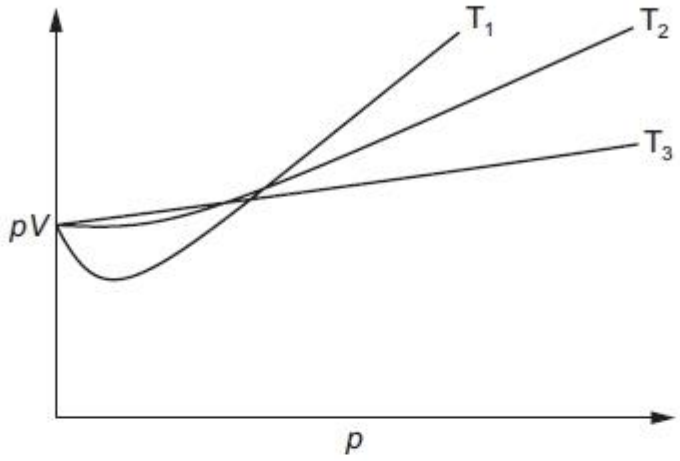
(iv) Magnesium is a better electrical conductor than sodium.

.....

..... [1]

2 The relationship $pV = nRT$ can be derived from the laws of mechanics by assuming ideal behaviour for gases.

(a) The graph represents the relationship between pV and p for a real gas at three different temperatures, T_1, T_2 and T_3.



(i) Draw **one** line on the graph to show what the relationship should be for the same amount of an **ideal** gas. [1]

(ii) State and explain, with reference to the graph, which of T_1, T_2 or T_3 is the lowest temperature.

.....

..... [1]

(iii) Explain your answer to **(ii)** with reference to intermolecular forces.

.....

..... [1]

(iv) State and explain the effect of pressure on the extent to which a gas deviates from ideal behaviour.

.....

.....

.....

..... [2]

(b) A flask with a volume of 100 cm^3 was first weighed with air filling the flask, and then with another gas, **Y**, filling the flask. The results, measured at 26 °C and 1.00×10^5 Pa, are shown.

Mass of flask containing air = 47.930 g

Mass of flask containing **Y** = 47.989 g

Density of air = 0.00118 g cm^{-3}

Calculate the relative molecular mass, M_r, of **Y**.

M_r of **Y** = ... [4]

Q# 103/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1 Some intercontinental jet airliners use kerosene as fuel. The formula of kerosene may be taken as $C_{14}H_{30}$.

Bicycles may be carried on commercial airliners. When carried on airliners, bicycles are placed in the luggage hold. This is a part of the aircraft which, in flight, will have different temperatures and air pressures from those at sea level.

This question concerns the change in pressure in an inflated bicycle tyre from when it is at sea level to when it is in the hold of an airliner in flight.

(d) At sea level and a temperature of 20 °C an inflated bicycle tyre contains 710 cm^3 of air at an internal pressure of 6×10^5 Pa.

Use the general gas equation $PV = nRT$ to calculate the amount, in moles, of air in the tyre at sea level.

[2]

The same bicycle, with its tyres inflated at sea level as described in **(d)** above, is placed in the luggage hold of an airliner. At a height of 10 000 m, the temperature in the luggage hold is 5 °C and the air pressure is 2.8×10^4 Pa.

(e) Assuming the volume of the tyre does not change, use your answer to **(d)** to calculate the pressure inside the tyre at a height of 10 000 m.

[2]

Mark Scheme ALvl Chem 4 EQ P2 22w to 09s Paper 2 States of matter 65marks

Q# 94/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(c)(i)	high temperature AND low pressure	1
2(c)(ii)	**M1** CO is polar / has a permanent dipole OR N_2 is non-polar	1
	M2 IMF in CO are (more) significant / larger OR IMF in N_2 are smaller / less significant	1
	Alternative answer **M1** (Size of) N_2 smaller than CO OR volume of N_2 molecules / particles smaller	
	Alternative answer **M2** volume of N_2 molecules / particles is more negligible ORA	

2(d)	**M1** correct conversion to consistent units P = 101 000 V = 100 / 1 000 000 = (1×10^{-4}) T = 293	1
	M2 use of all values from M1 in correct relationship, n = PV / RT	1
	M3 calculation = 4.15×10^{-3} mol	1

Q# 95/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(b)(ii)	**M1:** moles of krypton = 2.00 ÷ 83.8 (= 0.0239 mol) **M2:** conversion of value into consistent units for $pV = nRT$ **M3:** $p = \frac{M1 \times 8.31 \times 393}{5.00 \times 10^{-3}} = 15600$ Pa	3
1(b)(iii)	**M1:** low pressure **AND** high temperature **M2:** Either of: • volume of particles is negligible (compared to volume of container) • VdW forces are insignificant (owing to high kinetic energy of particles)	2

Q# 96/ ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3(b)(i)	**M1** no. of mol $O_2 = \frac{1.00 \times 10^5 \times 1.06 \times 10^{-3}}{(8.31 \times 850)}$ **M2** no. of mol of nitroglycerine = $4 \times 0.0150 = 0.0600$ (mol) **M3** mass of nitroglycerine = $0.0600 \times 227 = 13.6(2)$ (g)	3
3(b)(ii)	$1.06 \times 29 = 30.7(4)$ dm^3	1

Q# 97/ ALvl Chemistry/2019/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3(d)(iii)	**M1** size / volume of **molecule** / **particle** becomes significant / non-negligible OR IMFs become significant / non-negligible	1
	M2 IMFs becomes significant / non-negligible / collisions are not elastic	1

Q# 98/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2(d)(i)	$pV = nRT \therefore n = \frac{pV}{RT} = \frac{101\,325 \times 0.001}{8.31 \times 273} = 0.0447$ mol $\therefore M_r = \frac{m}{n} = \frac{4.13}{0.0447} = 92.4$ or 92.5 **M1** Use of $T = 273$ K, $V = 0.001$ m^3 and $p = 101325$ Pa **M2** correct use of $pV = nRT$ using values from M1 **M3** correct calculation of M_r using 4.13 ÷ moles from M2	3
2(d)(ii)	ClF_3	1

Q# 99/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2(a)(i)	simple molecular regular arrangement (of C_{60} molecules)	2
2(a)(ii)	C_{60} has (weak) intermolecular / VdW / London / dispersion / id–id forces (and covalent bonds) diamond has covalent bonds (diamond's) bonds are stronger more energy required / lots of energy to break (covalent bonds in diamond)	4
2(b)(i)	(a molecule / compound that is made up of) carbon and hydrogen (atoms) only	1
2(b)(ii)	add bromine (water) / Br_2(aq) (brown to) colourless / decolourised	2
2(c)(i)	addition	1
2(c)(ii)	(n_{C60} = 0.144 / 720 =) 2×10^{-4}	1
2(c)(iii)	$pV = nRT \quad \therefore \quad \Delta n = (p_1 - p_2)V / RT$ $\Delta n = (1.00 \times 10^5 - 2.21 \times 10^4).100 \times 10^{-6} / 8.31 \times 293$ = 0.00320	2
2(c)(iv)	(C_{60}:H_2 =) 2.00×10^{-4} : 0.00320 or 1:16 $\underline{C_{60}}H_{32}$	2
2(d)(i)	giant (molecular) (each Si has four) covalent (bonds)	2

Q# 100/ ALvl Chemistry/2017/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(a)

substance	type of bonding	type of lattice structure	
copper	metallic	giant/metallic	1
ice	covalent OR hydrogen(-bonding) / H(–bonding)	hydrogen-bonded / simple / molecular	1
silicon(IV) oxide	covalent	giant (molecular) / macromolecular	1
iodine	covalent	simple / molecular	1
sodium chloride	ionic	giant / ionic	1

2(c)(i)	X = liquid AND Z = solid	1
	Y = liquid and solid OR 'liquid / solid' OR 'liquid OR solid'	1
2(c)(ii)	(kinetic) energy reducing	1
	motion slowing *owtte*	1
2(c)(iii)	energy given out / released forming bonds / forming bonds exothermic	1
	compensates for / counteracts heat loss / cooling *owtte*	1
	Total:	15

Q# 101/ ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

(iii)	sodium has mobile / free electrons / electrons free (to move throughout the structure) phosphorus is simple/ covalent/ molecular	[1] [1]	[2]
(iv)	magnesium has <u>two</u> free /delocalised /outer / valence electrons per atom OR <u>more</u> free /delocalised/ <u>outer</u> electrons than sodium	[1]	[1]

Q# 102/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 (a) (i)	Straight line drawn horizontally from same intercept	[1]	[1]
(ii)	T_1 because it shows greatest deviation/furthest from ideal	[1]	[1]
(iii)	reducing T (reduces KE of particles) so intermolecular forces of attraction become more significant	[1]	[1]
(iv)	greatest deviation is at high pressure increasing pressure decreases volume so volume of particles becomes more significant ora	[1] [1]	[2]
(b)	Mass of air = 100×0.00118 = 0.118 g Mass of flask = 47.930 – 0.118 = **47.812** g Mass of Y = 47.989 – 47.812 = **0.177** g $pV = nRT = \frac{m}{M_r} RT$ $M_r = \frac{mRT}{pV} = \frac{0.177 \times 8.31 \times 299}{1 \times 10^5 \times 100 \times 10^{-6}}$ = **44.0** (43.979 to 2 or more sf)	[1] [1] [1] [1]	[4]

Q# 103/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) $n = \frac{PV}{RT} = \frac{6 \times 10^5 \times 710 \times 10^{-6}}{8.31 \times 293}$ (1)

$= 0.175$ (1) [2]

(e) $P = \frac{nRT}{V} = \frac{0.175 \times 8.31 \times 278}{710 \times 10^{-6}}$ (1)

$= 569410.5634$ Pa $= 5.7 \times 10^5$ (1)

allow ecf on (d) [2]

[Total: 10]