

2021 ASSESSMENT REPORT

PSC315118 – PHYSICAL SCIENCES

Overall, the paper was an effective assessment tool – providing a good spread of student results and again highlighting the wide cross-section of abilities of the candidates. The performance of students on Criterion 8 is concerning for students' future success in Chemistry in Year 12, as there were a significant number who could not display a sound knowledge of the underlying principles of stoichiometry, essential in further Chemistry studies.

An overall concern in this paper was the failure of a significant number of students to state the equation they were using to solve a problem and/or to show the values substituted into that equation. No credit can be given for a wrong value if no working is shown, but only 0.5 marks were subtracted for calculator errors when markers could see the student had used a suitable approach to solve the problem.

The word 'laden' in question 13 d) was not understood. In an exam there are often unfamiliar words and, as one student commented, 'I wish I had bought a dictionary along', advice regularly given to students by teachers. Dictionaries also can help answer questions, like 'define the term allotrope'.

Students continue to be exposed to a number of concepts in class outside the syllabus, such as ionisation energy, electronegativity and an antineutrino. Whilst this extension is not to be discouraged, frequently students were unable to use these concepts correctly. Markers encourage teachers to make it clear to their students when topics are outside the syllabus.

The cut-offs for each section are given below:

Cut-offs	C	B	A
Criterion 4	13	21	25
Criterion 5	13	21.5	25.5
Criterion 6	13	22	26
Criterion 7	10	20	24
Criterion 8	10	20	24

General Comments

An overall concern in this paper was that a significant number of students did not state the equation they were using to solve a problem and/or to show the values substituted into that equation. No credit can be given for a wrong value if no working is shown, but only 0.5 marks were subtracted for calculator errors when markers could see the student had used a suitable approach to solve the problem.

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Part 1

Criterion 4

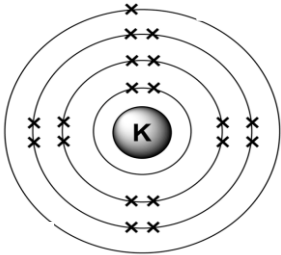
General Comments

The Criterion 4 section of the paper was accessible to most students and there was a good spread of results.

Question 1

Question 1 was well done by most students, with a mark of 4/6 or more being quite common.

Question	Answer	Mark Allocation			Comment
1a /2		No. of p	No. of n	No. of e ⁻	19 – 0.5 20 – 0.5 40 – 0.5 K ⁺ – 0.5 Few students gained full marks, with most students not reading that the second species was a potassium ion. Part marks were given for attributing the 18 electrons as being a neutral atom of argon as long as they assigned the correct mass number, using error carried forward (ECF).
	${}^{39}_{19}\text{K}$	19	20	19	
	${}^{40}_{19}\text{K}^+$	19	21	18	

Question	Answer	Mark Allocation	Comment
1b /2	 <p>Group 1 – 1 electron in the outer shell</p> <p>Period 4 – 4 occupied electron shells</p>	Diagram – 1 0.5 0.5	Whilst the electron shell diagram earned students 1 mark, very few students gained the 2 marks because most did not specify that the potassium atom has four shells occupied by electrons. Marks were not deducted marks for not pairing electrons in the electron shells.
1c /2	$\text{RAM} = \frac{39 \times 93.26 + 41 \times 6.73}{100} = 39.13$ <p>Or $\text{RAM} = 39 \times 0.9326 + 41 \times 0.0673 = 39.13$</p>	Equation – 1 Answer – 1	This question was well done. Pleasingly, most students gave the relevant equation before solving it. Significant figures were not a major issue. No units were expected, as RAM is relative; no marks were deducted for incorrect units.

Question 2

Again, this question 2 was reasonably well done. Most students scored over half marks.

Question	Answer	Mark Allocation	Comment
2a /2	<p>Elements in modern PT have similar physical properties, but in the shaded column of the 1865 periodic table Fe conducts electricity, whereas oxygen and sulfur do not.</p> <p>Modern PT elements in same group have same valency whereas valency of iron is (+)2 or (+)3 and S and O are both (-)2.</p> <p>Other possible physical properties could have been discussed – e.g. MP, BP, lustre, malleability, ductility.</p>	1 1	Even though this question was reasonably well done, not many students received full marks. Many confused the term valency with valence electrons (credit given where possible), and a surprising number incorrectly stated that iron had a full outer shell of electrons. Too many students stated O and S were gases, but Fe was a metal, incorrectly implying 'gases' and 'metals' are opposite terms. A small number misread the question and spoke about the periodic table as a whole, rather than just the shaded region.

Question	Answer	Mark Allocation	Comment
2b i /1	Atomic number is the number of protons in the nucleus of an atom.	1	This question was well done.
2b ii /1	It is unique to an element. Or no two different elements have the same atomic number, unlike RAM.	1	Many students discussed the number of electrons, reactivity, mass and/or trends, rather than the uniqueness of the atomic number of an element.
2c /3	Atoms of F (Z= 9) and O (Z = 8) each have 2 occupied electron shells. F has one more proton in the nucleus compared with O. Therefore, the valence electrons are attracted to the nucleus by electrostatic forces more. So, F atom is a bit smaller than O atom. From 9 (F) to 11 (Na) there is an extra, occupied electron shell, making the radius of the atom larger. This extra shell also reduces the electrostatic attraction between the nucleus and the valence electron hence Na is much bigger.	0.5 0.5 1 1	Most students addressed the question, with only a few giving general answers about the relevant trends. Most did not mention that O and F each have 2 occupied electron shells, and many incorrectly attributed the increased electrostatic force of attraction to the extra electron, rather than the extra proton in the nucleus. No marks were deducted for omitting the term 'occupied' in this question. The irrelevant terms 'electromagnetic' and 'electronegative' appeared sometimes. 'Shielding' was used correctly, but is not expected in this course.

Question 3

Question 3 proved very challenging for most students as the process of alpha particle ionisation is not well understood.

Question	Answer	Mark Allocation	Comment
3 /1	${}^1_1\text{H}$ contains 1 proton in the nucleus and 1 electron. When it loses an e^- it becomes positive ion, H^+ and consists of 1 proton	0.5 0.5	Most answers were too vague, correctly identifying a hydrogen ion as containing 1 proton in the nucleus but making no reference to the absence of an electron or a neutron.
3b /1	${}^1_1\text{H}^+$ and ${}^4_2\text{He}^{2+}$	0.5 each	This question was not answered well. Most students did not read the term 'exact chemical nature' and just rewrote the elemental symbols, not adding the charge, or incorrectly rewrote the isotopic mass as RAM.

Question	Answer	Mark Allocation	Comment
3c /2	An α particle has a (2+) charge so it needs to gain 2 electrons to become a stable He atom. When it comes near an oxygen atom, for example, the α particle will cause one of O's electrons to be detached and O will become O^+ , i.e. the O atom is ionised.	1 1	Disappointingly, few students could correctly answer this question. There were multiple misconceptions including students discussing the nuclear process of alpha decay, alpha bombardment of nuclei, and transferring of electrons resulting in ionic bonds.

Question 4

Question 4 answers showed that most students have a good basic understanding of nuclear radiation. One common misconception is that γ radiation is non-ionising and harmless.

Question	Answer	Mark Allocation	Comment
4a i /1	${}^{82m}_{35}\text{Br} \rightarrow {}^{82}_{35}\text{Br} + {}^0_0\gamma$	1 Each error – 0.5	This question was quite well answered, but too often the $m/^*$ symbol to indicate the metastable state of Br was either omitted or placed on the wrong side of the equation.
4a ii /2	Any two of the following were accepted: Br-82 produces gamma radiation, which is able to penetrate through the many metres of dirt to be detected above ground. It has a half-life long enough to allow for the buildup of radiation to be detected, but short enough that it will not be maintained the long term. Gamma radiation is weakly ionising, therefore, as this water may be ingested by people in their houses this is the safest type of radiation to use.	1 1	Whilst a pleasing number of students were able to correctly identify relevant properties of the emission of γ rays from Br-82 and attribute it to the scenario (e.g. detection at the surface), a disappointingly large number incorrectly stated that gamma radiation was non-ionising and harmless.

Question	Answer	Mark Allocation	Comment
4b i /2	Both have the 53 protons and electrons in a neutral atom. Iodine-131 has 78 neutrons and iodine-123 has 70 neutrons in the nucleus.	1 1	While most students understood this question, many did not receive full marks, as they were not specific to the given isotopes. Another common error was students comparing radioactivity and stability rather than atomic structure.
4b ii /2	${}^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^0_{-1}\text{e}$	1 – overall equation 1 – identify daughter isotope	The most common errors were either incorrectly balancing the equation or placing the beta particle on the wrong side. Both scenarios listed the daughter isotope as Te, the result of not using -1 in ${}^0_{-1}\text{e}$; both were awarded part marks.
4b iii /2	I-123 would be safer for patient. Beta particles are more strongly ionising than gamma. Ionisation causes mutations to DNA which can cause cancer.	0.5 0.5 1	While generally well done, often the preferred isotope was not given as the answer, only the type of radiation. That students unnecessarily discussed penetration of the rays surprised markers. Once again, a disappointingly large number of students incorrectly stated that gamma radiation was non-ionising and harmless.

Question 5

Question 5 contained straightforward, predictable questions, but, surprisingly, challenged students.

Question	Answer	Mark Allocation	Comment
5a /1	Background radiation from any 2 of e.g. building materials, rocks, people, cosmic rays	1	Many students just listed background radiation and were attributed part marks. Sources that were not accepted were forms of non-ionising radiation such as mobile phones, electrical equipment, microwaves.
5b /2	Background = 6 counts/30 sec Average count = $\frac{(222-6)+(178-6)+(194-6)}{3} = 192$ counts / 30 sec or 198 counts (unadjusted for background)	1 for background 1 for finding counts per sec	While generally well done, many students did not consider background radiation, determining the count rate as 6.6 counts/sec, too many students equated this to the given value of 6.4. The question did not use the

Question	Answer	Mark Allocation	Comment
	Counts/sec = $192/30 = 6.4$ or $(198-6)/30 = 6.4$		words 'about 6.4'.
5c /1	Mobile phones produce electromagnetic radiation not nuclear/ionising radiation thus the GM counter detected nothing.	1	This was answered well.
5d /2	Readings: $6.4 \rightarrow 3.2$ (1 half life) $\rightarrow 1.6$ after 2 $\rightarrow 0.8$ after 3 $\rightarrow 0.4$ after 4 i.e. 4 half lives have passed, so $t_{1/2} = 24/4 = 6$ hours	1 No. of $t_{1/2}$ 1 Calculate $t_{1/2}$	While generally well answered, many students struggled to calculate how many half-lives had passed, with ECF regularly being used.

Part 2

Criterion 5

General Comments

The Criterion 5 section of the paper was generally well answered. Students are reminded to include appropriate units and directions when required. The best answers showed an equation and full working.

Question 6

Question 6 was a straight-forward question and was answered well by most students. Many students had marks for poor vector diagrams. It is suggested that students use a ruler and ensure arrows and appropriate scale is used.

Question	Answer	Mark Allocation	Comment
6a i /1	$3.20 + 4.50 = 7.70$ km	1	
6a ii /1	Time = $30 \text{ min} + 45 \text{ min} = 75 \text{ min} = 1.25 \text{ h}$ Speed = $\frac{\text{distance}}{\text{time}}$ $= 7.70/1.25$ $= 6.16 \text{ km h}^{-1}$	1	Common error was using time = 1.15 h

Question 7

Question 7 was quite well done. Many students did not read the scale of the graph correctly.

Question	Answer	Mark Allocation	Comment
7a /1	0 – 1000 s, 5500 – 8000 s and instantaneously at 12000s	1	Students frequently missed the scale of the graph.
7b /1	a = slope of line $= \frac{-1.2}{(1.5)(10^3)} = -0.8 \times 10^{-3} \text{ ms}^{-1} \text{ west (or } 0.8 \times 10^{-3} \text{ m s}^{-1} \text{ east)}$	1	– 0.5 if 10^3 not used The equation of motion $v = u + at$ could have been used, however, many students incorrectly used $t = 4.5$
7c /2	s = area under the curve = area travelled west – area travelled east $= (1.2 \times 3 \times 10^3) + \frac{1}{2} (1.2 \times 1.5 \times 10^3) - (1.5 \times 4 \times 10^3)$ $= -1500 \text{ m west or } 1500 \text{ m east}$	2	Many students incorrectly used 4×10^3 as the length of the first rectangle. It was pleasing that most students knew to subtract the area below the time axis. It is suggested that students shade and label the areas to be found.

Question 8

Question 8 was a difficult question and very few students received full marks.

Question	Answer	Mark Allocation	Comment
8a /1	Terminal velocity is the constant speed which is reached by a falling object when the air resistance force is equal and opposite to the force due to gravity.	1	A common error was to state <i>when</i> terminal velocity occurs as opposed to actually defining it.
8b /2	The heavier skydiver will reach a higher terminal velocity. As their weight force is higher, it takes longer for the air resistance force to increase to the point that it is equal to the weight force, and thus the skydiver will be at a higher maximum velocity.	1 1	This was not answered well with many students stating that the acceleration experienced by the skydivers was constant (not taking into account the context of the question which was terminal velocity).

Question 9

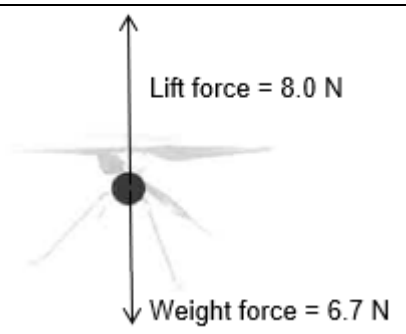
Question 9 was generally well answered. The calculation questions were well handled. There were a variety of explanations for question 9b.

Question	Answer	Mark Allocation	Comment
9a i /1	$\Delta p = m\Delta v$ $= (45 \times 10^{-3})(63 - 0)$ $= 2.84 \text{ kg m s}^{-1}$	1	
9a ii /1	$F = \frac{\Delta p}{t}$ $= \frac{2.84}{0.025}$ $= 114 \text{ N forward}$	1	No marks were deducted for missing direction, marks were deducted for missing units.
9b /2	When the arrow hits the target, the target exerts a horizontal force to stop the arrow and the arrow exerts a horizontal force on the target in accordance with Newton's third law. In order to stop the target from accelerating away from the arrow in accordance with Newton's second law, the horizontal brace provides a resisting horizontal force, which means the net force is zero and the target doesn't fall, in accordance with Newton's first law.	2	A variety of explanations were given full marks. However, many students did not show a deep understanding of Newton's Laws.
9c /1	$s_x = u_x t$ $t = \frac{s_x}{u_x}$ $= \frac{20}{63}$ $= 0.317 \text{ s}$	1	
9d /1	$v_y = u_y + a_y t$ $= (0) + (-9.81)(0.317)$ $= -3.11 \text{ m s}^{-1}$	1	Students were not penalised for using the value $t = 0.3$ s in this question.

Question	Answer	Mark Allocation	Comment
9e /2	$s_y = u_y t + \frac{1}{2} a_y t^2$ $= 0 + \frac{1}{2} (-9.81)(0.317)^2$ $= -0.494 \text{ m}$	1 1	A common error was using $u = 63 \text{ m/s}$ (or some other figure) rather than the correct 0 m/s figure.

Question 10

Question 10 was handled well, however, very few students received full marks for 10)e)ii). Force diagrams were not well constructed.

Question	Answer	Mark Allocation	Comment
10a /1	$F = mg$ $= (1.80)(3.72)$ $= 6.70 \text{ N down}$	1	Common error: units in kg rather than N.
10b /1		1	<p>Lift vector should be longer than weight vector. Arrows need to have arrowheads and be labelled. -0.5 for each error.</p> <p>Many students did not use the centre of mass on the diagram.</p>
10c /1	$F_{\text{net}} = 8.0 - 6.70 = 1.30 \text{ N (up)}$	1	Often the direction was missing.
10d /1	$a = \frac{F_{\text{net}}}{m}$ $= \frac{1.30}{1.80}$ $= 0.724 \text{ m s}^{-2} \text{ upwards}$	1	

Question	Answer	Mark Allocation	Comment
10a /1	$F = mg$ $= (1.80)(3.72)$ $= 6.70 \text{ N down}$	1	Common error: units in kg rather than N.
10e i /1	$v^2 = u^2 + 2as$ $= (0) + 2(0.724)(2.5)$ $v^2 = 3.62 \text{ m s}^{-1}$ $v = \sqrt{3.62}$ $v = 1.90 \text{ m s}^{-1} \text{ (up)}$	1	Errors included incorrect displacement and not using $u = 0 \text{ m/s}$ (initially stationary).
10e ii /2	$v^2 = u^2 + 2as$ $= (-1.90)^2 + 2(3.72)(3.0)$ up -, down + $= 5.09 \text{ m s}^{-1}$ As 5.09 > 4.8, the helicopter would not survive.	1.5 0.5	Very few correct responses. The most common error was using $u = 0 \text{ m/s}$ rather than using the value from part 1 of the qn. Most students were able to conclude whether the helicopter would survive based on the velocity they calculated.

Part 3

Criterion 6

General Comments

The Criterion 6 section of the paper was handled pleasingly well by students.

Question 11:

Question 11 was a good introductory question for criterion 6 and was generally well answered.

Question	Answer	Mark Allocation	Comment
11a /1	$E_p = mgh$ $= (3100)(9.81)(10)(0.75)$ $= 228000 \text{ J}$ $= 228 \text{ kJ}$	1	Many students did not incorporate the 10 from 10 seconds into their calculation

Question	Answer	Mark Allocation	Comment
11b /1	$P = \frac{\Delta E}{t}$ $= \frac{228}{10}$ $= 22.8 \text{ kW}$	1	This was answered well.
11c /1	While the motor provides 55 kW, some of this energy (27.2 kW) is lost by friction to heat.	1	Fewer students than expected explained that much of the power of the motor was converted into heat energy due to the effects of friction, though strangely many mentioned air resistance, which would have been a smaller concern. The word 'account' lead some students to apply maths to the problem, rather than a discussion.

Question 12

Question	Answer	Mark Allocation	Comment
12a /2	Bottle has kinetic energy initially and, as it gains height, gravity does work converting kinetic energy progressively into gravitational potential energy. At max height it has no E_k ($v = 0$) and E_p is at a maximum. As it falls E_p is transformed back into E_k .	1 0.5 0.5	Relatively few students described the energy changes starting with the bottle's E_k being converted to gravitational E_p as it rose and slowed due to gravitational force. Instead, students resorted to $E_k \rightarrow E_p \rightarrow E_k$. This is not describing the energy changes, and conveys little to the marker (e.g. When is E_p at a maximum?); this answer was given very little credit.
12b /2	As all E_k is transformed into E_p : $\Delta E_p = \Delta E_k$ $mgh = \frac{1}{2}mv^2$ Rearranged: $h = \frac{v^2}{2g}$ $= \frac{10^2}{2(9.81)}$ $= 5.10 \text{ m}$	1 1	Many students did not follow the instruction to use the conservation of energy. This should have led them to equate change in potential energy to change in kinetic energy and obtain the solution, and instead used equations of motion. The non-inclusion of a mass in the data given so far in the question may be the reason for this approach.

Question	Answer	Mark Allocation	Comment
12c i /1	$u = 0$ therefore $p = 0$	1	There were many faults with part c) caused by a failure to comprehend that the mass of the bottle after all the water had exited was 85 grams, whilst the mass of the water and cork was 200 grams - despite all this being clearly stated in the question. Surprisingly, some students did not change grams into kilograms.
12c ii /1	$p_{\text{bottle}} = mv$ $= (0.085)(10)$ $= 0.85 \text{ kg m s}^{-1}$ upwards	1	
12c iii /1	Total momentum = 0 $\therefore p_{\text{water + cork}} = - p_{\text{bottle}}$ $0.200 v = 0.85 \text{ kg m s}^{-1}$ downwards $\therefore v = \frac{0.85}{0.2} = 4.25 \text{ m s}^{-1}$ down	0.5 0.5	

Question 13

Question 13 was generally better answered.

Question	Answer	Mark Allocation	Comment
13a /2	$v = \frac{100}{3.6}$ $= 27.8 \text{ m s}^{-1}$ $E_k = \frac{1}{2}mv^2$ $= \frac{1}{2}(1560)(27.8)^2$ $= 602000 \text{ J} = 602 \text{ kJ}$	1 1	Some students were unable to correctly change km/h into m/s.
13b /1	$W = Fs$ Rearranged: $s = \frac{W}{F}$ $= \frac{602000}{7500}$ $= 80.2 \text{ m}$	1	
13c /2	At bottom, $E_{\text{total}} = E_k = 602000 \text{ J}$ 10 m up, $E_p = mgh = (1560)(9.81)(10)$	1	Many students obtained the correct potential energy, but some did not then subtract it from the answer

Question	Answer	Mark Allocation	Comment
	$= 153000 \text{ J}$ $E_k = E_{\text{total}} - E_p$ $= 602000 - 153000$ $= 449 \text{ kJ}$	1	obtained in part a) to find the remaining kinetic energy. Some added it instead.
13d /2	<p>The heavily laden car's brakes would be hotter than the unladen car.</p> <p>As the heavy car (i.e. greater mass) has more kinetic energy, more work was done by the brakes to stop the car and more energy converted to heat through friction. (Assume the stopping distance is about the same.)</p>	1 1	Few students managed to give a complete answer by stating that the heavier vehicle would have hotter brakes, clearly explaining that the heavier car's greater mass meant it had greater E_k , and thus more work was done by the brakes to stop the car, which implied that, as a by-product, more energy was changed into heat energy due to friction. Some students appeared to not know what "laden" meant and the word 'brakes' was often misspelt as "breaks", despite it being given in the question.

Question 14

This question was generally well done, although the markers had to use 'error carried forward' quite often. 6/6 was not an uncommon score.

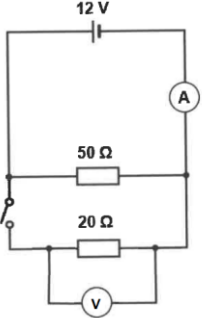
Question	Answer	Mark Allocation	Comment
14a /1	$q = It$ $= (500 \times 10^{-3})(5)(60)$ $= 150 \text{ C}$	1 (0.5 if not SI units)	Generally well done, as long as students correctly converted both mA to A and minutes to seconds. Markers saw too many calculations involving 500,000 amps.
14b /1	$\text{Number of electrons} = \frac{q}{e}$ $= \frac{150}{1.6 \times 10^{-19}}$ $= 9.4 \times 10^{20} \text{ electrons}$	1	The vast majority of students identified -1.6×10^{-19} as relevant and most saw it as a divisor. A few students did not realise that. Whereas the initial negative related to charge, the question was about number.
14c /1	A non-ohmic resistor is one that does not have a constant resistance at all applied voltages.	1	A variety of 'definitions' were acceptable: - 'non-linear relationship between current and voltage', 'does not have a constant resistance', anything appropriate

Question	Answer	Mark Allocation	Comment
			graphically. Many responses did not clarify the relationship between resistance, current and voltage.
14d /2	$P = I^2R = (500 \times 10^{-3})^2 (200)$ $= 50 \text{ W or } 5 \times 10^{-2} \text{ kW}$	1	Generally well done as long as students remembered to square the value for I in $P = I^2R$, as well as include it in the formula. A few students took the long route of calculating V first, using $V = IR$, then using $P = VI$.
14e /2	$t = 40 \times 5 \times 2 = 400 \text{ h}$ $E = Pt = (5 \times 10^{-2})(400) = 20 \text{ kWh}$ $\text{Cost} = (20)(26.587) = 532 \text{ cents or } \5.32	1 for 1 any correct step 1.5 for 2	Surprisingly well done, although the instruction to 'Give your answer to the nearest cent' was often overlooked. Many students managed to get two of the three quantities correct, but neglected the third, and which two were included varied widely. A very common error was assuming the time needed to be converted to seconds. Some students clearly had no concept of what a reasonable answer could be. Answers ranged from a fraction of a cent to multiple millions of dollars.

Question 15

While not as well done as Question 14, this question still provided a good number of high scores. The implications of the switch being 'open' or 'closed' was misunderstood by a significant number who tended to reverse them, perhaps equating 'open' with 'on'.

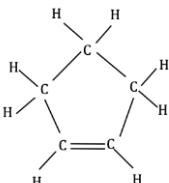
Question	Answer	Mark Allocation	Comment
15a /1	$I = \frac{V}{R} = \frac{12}{50}$ $= 0.24 \text{ A}$	1	Easily done, except by those who did not understand the diagram given showed an open switch, which led to an answer of 0.
15b /2	$R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{(20)(50)}{(20 + 50)}$ $= 14.3 \Omega$ $I = \frac{V}{R} = \frac{12}{14.3}$	1 1	Generally very well done. Most students both recognised that the resistors were in parallel and could correctly select and apply the appropriate formula. A few students did not group the denominator, hence calculating $(50 * 20)/50 + 20$ instead of $(50 * 20)/(50 +$

Question	Answer	Mark Allocation	Comment
	$= 0.84 \text{ A}$		20) and getting 40 instead of 14.3
15c /1		1	Very few students had marks deducted if they put the voltmeter in series in various positions.
15d /1	12 V	1	Markers were pleased with the number of correct responses. The question asked only for a value, and a good number of students used their time wisely by not giving any explanation or calculation. The most common error was $20 * 0.84 = 16.8$.
15e i /2	The voltmeter would need to have much greater resistance. This means that it would not draw much current as the current splits with a parallel branch, inversely proportional to the resistances (high R, low I).	1 1	All three options were common. The successful answer included some sort of reference to greater resistance leading to lower current or recognition that being in parallel was significant.
15e ii /2	When the switch is open, there are two resistors in the circuit: - the ammeter and the 50Ω resistor $R_T = R_1 + R_2 = 50 + 0.05$ $= 50.05 \Omega$ $I = \frac{V}{R} = \frac{12}{50.05}$ $= 0.240 \text{ A}$ Given the resistance without accounting for the resistor is 0.24 A, to three significant figures there is no difference.	0.5 – R_T 1 - Current 0.5 – final comparison	This was a difficult question, with many responses simply restating the question. The majority of responses included some sort of calculation, and most, but by no means all, involved current, which was what was specifically asked for. A small number of students mistakenly interpreted the circuit as having the ammeter in parallel with the resistors and then extended the parallel equation to three resistors $(R_1 R_2 R_3)/(R_1 + R_2 + R_3)$, inevitably ending in confusion.

Question 16

General Comments

- a) Too many students wrote 'nickel sulfate' and did not state the fact the salt was nickel (II) sulfate. Furthermore, the metal cation in an ionic salt does not require a prefix.
- b) The most common error was failing to use the table of common ions to recognize that thiosulfate ions have a 2⁻ charge, meaning there will need to be two (2) ammonium ions per thiosulfate ion.
- c) It was expected that some attempt must be made to show other bonded species (hydrogens), not just C–C bonds.
- d) Most students managed to correctly identify the main components of the systematic name, however common errors included failure to recognize the main (parent) chain was 4 carbons long as it must include the C=C bond.

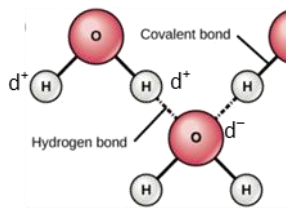
Question	Answer	Mark Allocation	Comment
16a /1	nickel(II) sulfate sodium thiosulfate	0.5 0.5	– 0.5 if not nickel(II) stated Not disodium
16b /1	N ₂ O ₅ (NH ₄) ₂ CO ₃	0.5 0.5	
16c /1		Cyclic double bond: 0.5 All H 0.5	No bonded H atoms (or dashes to indicate) – no marks
16d /2	4-bromo-2-methylbut-1-ene	4 chain: 0.5 Chain with from DB: 0.5	Ignore dashes (marking) If wrong direction for numbering answer must be

Question	Answer	Mark Allocation	Comment
		Numbering:0.5 Alphabetic:0.5	otherwise correct (for 1 mark): "1-bromo-3-methylbut-3-ene"

Question 17

General Comments:

- a) Many students were showing a hybrid structure between a Bohr and electron dot (Lewis) diagram. For the expected diagram, only the valence electrons are required (for all atoms present) and no circles are expected. Lines are not conventionally drawn but no marks were deducted. Many students drew a diagram with 2 oxygens and 1 hydrogen atom (water is H₂O not HO₂).
- b) The wording of the question implied a single water molecule so if correctly represented a full mark was awarded. Better diagrams showed polarity of water molecule and indicated intermolecular interactions. The polarity of the water molecule was often represented opposite to its actual polarity (the O atom end of the water molecule has the partial negative charge). The relationship between the energy required to disrupt intermolecular bonding and molecular polarity was important and often overlooked.

Question	Answer	Mark Allocation	Comment
17a /1	$ \begin{array}{c} \text{H} \\ \vdots \\ \text{H} : \text{C} : \text{H} \\ \vdots \\ \text{H} \end{array} $	8 electrons around C: 0.5 4 electrons pairs: 0.5	If full electron shells for C: 0.5 maximum Clear pairs of electrons between C and 4 H atoms 0.5
17b /3	<p>Water is a polar molecule whereas methane is non-polar:</p> <p>Stronger Intermolecular bonds (Hydrogen bonds) form between the H atoms (δ^+) and O atoms (δ^-) of adjacent molecules.</p> 	1 mark 1 mark	Statement of polarity for H ₂ O and CH ₄ ½ mark for water is polar Some labeling of diagram expected: With correct polarity 1 mark. No polarity – no marks

Question	Answer	Mark Allocation	Comment
17a /1	$ \begin{array}{c} \text{H} \\ \vdots \\ \text{H} : \text{C} : \text{H} \\ \vdots \\ \text{H} \end{array} $	8 electrons around C: 0.5 4 electrons pairs: 0.5	If full electron shells for C: 0.5 maximum Clear pairs of electrons between C and 4 H atoms 0.5
	These bonds take more energy to break than the weaker intermolecular (dispersion forces/Van der Waals) forces between the molecules of non-polar methane, hence the BP of methane is much lower than room temperature. Hence methane is a gas at room temperature and water is a liquid.	1 mark	Connection between energy required to break bonds (and hence B.P) and strength of intermolecular bonds.

Question 18

General Comments:

- a) Some students used only the information provided by the empirical formula (CH_2) and concluded the molecule was methene; it doesn't exist, in combination with the combustion information. The best responses indicated that the carbon chain must be 3 carbons long and have 6 hydrogen atoms. When combined with the observations from the reaction with bromine, the compound must be propene. There was some confusion between addition (for unsaturated) and substitution (for saturated) reaction observations.

Care must be taken when analysing information in a table. Student responses need to do more than just repeat what is in the table. For example, "Reacts rapidly with bromine" is not enough. "Reacts rapidly with bromine, hence has unsaturated bonds" is more appropriate.

- b) There was some common confusion about the products of alkane substitution.
- c) The most common error was stating that isomers have the same empirical formula (all members of a homologous series do!) rather than the same molecular formula. A small number of student responses incorrectly identified C_3H_6 and C_3H_8 as being isomers.

Question	Answer	Mark Allocation	Comment
18a /4	X is propene, C ₃ H ₆ It is an alkene since it reacts quickly via addition with bromine. It has 3 carbons: 6 H, from the combustion (burning) information Y is cyclopropane, C ₃ H ₆ Is an alkane since it won't react with Br ₂ immediately	1 0.5 0.5 1 1	Identifying C ₃ H ₆ and alkene (1 mark) – ½ for C ₃ H ₆
18b /2	$ \begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array} + \text{Br}_2 \rightarrow \begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{Br} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array} + \text{HBr} $	1 for products 1 for structures	Multiple substitutions acceptable, as is position of Br. If students write H ₂ as a product, maximum of 1 mark in total as both H atoms must be shown on structural formulae
18c /1	X and Y are isomers They have the same molecular formulae but different structures	0.5 0.5	ECF for identifying isomers

Question 19

General Comments:

- “Reactivity” could be interpreted as rate of reaction rather than formation of cation/anion so accepted answers for atoms with similar reactivity to Cl were both F and Li.
- Too many responses focused purely on the mechanics of ion formation rather than going on to describe the formation of an ionic compound through ionic bonding/electrostatic interaction between Li⁺ cations and H⁻ (hydride) anions.
- Too many responses indicated the bonding as “covalent molecular” – this is the classification of the substance based on its structure, the bonds being broken are intermolecular bonds (since it is a covalent molecular compound).

- d) Too many responses indicated that since lithium is a metal it is malleable. Too few described the structure of lithium and explained how this accounts for its malleability. The ability of the delocalized electrons to move and maintain structural integrity through electrostatic attraction between cations and electrons is key to the explanation.
- e) Many responses seemed to indicate that only carbon has allotropes, which is not true.
- f) Most student responses indicated knowledge of delocalized electrons carrying the charge. It was expected that students would discuss the number of valence electrons involved in bonding and hence the origin of the 1 delocalised electron per carbon atom. A surprising number of responses also seemed to infer that the tube-shape was the source of electrical conductivity.

Question	Answer	Mark Allocation	Comment																
19a /2	Na Either Mg ²⁺ or Be ²⁺ F Ar	0.5 0.5 0.5 0.5	Could use a Group 1 metal – Li or F																
19b /2	Li (2,1) donates one electron to H(1), so forming the Li ⁺ and H ⁻ ions. There is an electrostatic attraction between these ions, forming the ionic bonds within a 3-D lattice	0.5 0.5 1	Ion formation for correct charges on ions ionic bonding																
19c /2	<table border="1"> <thead> <tr> <th></th> <th>Lithium</th> <th>Lithium hydride</th> <th>Hydrogen</th> </tr> </thead> <tbody> <tr> <td>M P (°C)</td> <td>181</td> <td>692</td> <td>-259</td> </tr> <tr> <td>Force or bond overcome on melting</td> <td>Metallic</td> <td>Ionic bond</td> <td>Intermolecular (dispersion/ Van der Waals)</td> </tr> <tr> <td>Particles present</td> <td>Li⁺ and e⁻</td> <td>Li⁺ and H⁻</td> <td>H₂</td> </tr> </tbody> </table>		Lithium	Lithium hydride	Hydrogen	M P (°C)	181	692	-259	Force or bond overcome on melting	Metallic	Ionic bond	Intermolecular (dispersion/ Van der Waals)	Particles present	Li ⁺ and e ⁻	Li ⁺ and H ⁻	H ₂	0.5 each 0.5 each	Can say “molecules”, hydrogen molecules or H ₂ molecules but <u>not</u> “H molecules” “Cations and anions” or “+ and – ions” instead of Li ⁺ and H ⁻ were accepted
	Lithium	Lithium hydride	Hydrogen																
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Force or bond overcome on melting	Metallic	Ionic bond	Intermolecular (dispersion/ Van der Waals)																
Particles present	Li ⁺ and e ⁻	Li ⁺ and H ⁻	H ₂																

Question	Answer	Mark Allocation	Comment
19d /2	Li consists of Li ⁺ cations surrounded by a sea of delocalised valence electrons. When pressure/force is applied to make a sheet, the cations are forced to move relative to each other. The repulsion from this distortion of the lattice is overcome as the sea of delocalised electrons maintains electrostatic attraction between cations and electrons.	1 1	Structure description: Cationic lattice + delocalized electrons When distortion of the lattice occurs, the delocalized valence electrons are able to move and maintain structural integrity by maintaining electrostatic attraction
19e i /1	An allotrope is one form of an element that exists in a different physical form. OR Allotropes of an element contains the same type of atoms, but arranged differently.		The dictionary definition was accepted – maybe not as scientific, but legitimate.
19e ii /2	Each carbon in the fused hexagonal rings have 3 valence electrons localised in covalent bonds with three (3) other C atoms. The 4 th valence electron of each carbon atom is free to move when an electric field is applied.	1 1	 ½ mark for delocalised valence electrons conduct electricity

Question 20:

General Comments:

- Not understanding the likely reaction (formation of a precipitate) or lack of a reaction between the acid and salt was common.
- Extinguishing a flame was not accepted as a definitive test as gases other than CO₂ will also extinguish flames. Too many students' responses indicated pop tests, the use of trees or other esoteric qualitative tests.
- Net ionic equations require only the reacting ionic species (in this case) forming the precipitate.
- Connection to the observations for the differing tests used by Groups A and B was essential for full marks.

General Comments

The inclusion of both states and units is only penalised once in each half of the paper.

Question 21

Whilst students were told this question related to **two** different compounds involving potassium, sulfur and oxygen, many students assumed the calculations related to the one compound and arbitrarily changed a perfect answer of K_2SO_3 to K_2SO_4 in part b).

Question	Answer	Mark Allocation	Comment																																								
21a /1	$c(K^+) = 0.26 \text{ mol L}^{-1}$ $c(SO_4^{2-}) = 0.13 \text{ mol L}^{-1}$	0.5 0.5	This question was not answered well. There is a lack of understanding of dissociation of ions in solution. Common errors were using molar mass of potassium sulfate and calculating the number of ions using Avogadro's number. (No marks for reversal of values)																																								
21b /2	Consider 100 g sample <table style="margin-left: 40px; border-collapse: collapse;"> <tr> <td></td> <td style="text-align: center;">K</td> <td style="text-align: center;">S</td> <td style="text-align: center;">O</td> <td></td> </tr> <tr> <td>Mass (g)</td> <td style="text-align: center;">49.4</td> <td style="text-align: center;">20.3</td> <td style="text-align: center;">30.3</td> <td></td> </tr> <tr> <td>Mol</td> <td style="text-align: center;"><u>49.4</u></td> <td style="text-align: center;"><u>20.3</u></td> <td style="text-align: center;"><u>30.3</u></td> <td></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>39.10</u></td> <td style="text-align: center;"><u>32.06</u></td> <td style="text-align: center;"><u>16.0</u></td> <td></td> </tr> <tr> <td></td> <td style="text-align: center;">= 1.263</td> <td style="text-align: center;">= 0.633</td> <td style="text-align: center;">= 1.89</td> <td></td> </tr> <tr> <td>Mol ratio</td> <td style="text-align: center;"><u>1.263</u></td> <td style="text-align: center;"><u>0.633</u></td> <td style="text-align: center;"><u>1.89</u></td> <td></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>0.633</u></td> <td style="text-align: center;"><u>0.633</u></td> <td style="text-align: center;"><u>0.633</u></td> <td></td> </tr> <tr> <td></td> <td style="text-align: center;">= 2</td> <td style="text-align: center;">= 1</td> <td style="text-align: center;">= 3</td> <td></td> </tr> </table> Empirical formula is K_2SO_3		K	S	O		Mass (g)	49.4	20.3	30.3		Mol	<u>49.4</u>	<u>20.3</u>	<u>30.3</u>			<u>39.10</u>	<u>32.06</u>	<u>16.0</u>			= 1.263	= 0.633	= 1.89		Mol ratio	<u>1.263</u>	<u>0.633</u>	<u>1.89</u>			<u>0.633</u>	<u>0.633</u>	<u>0.633</u>			= 2	= 1	= 3		1 0.5 0.5	This question was generally well done. Most students showed a clear understanding of the process involved. Common errors included using P as the symbol for K (but still the molar mass for K) and obtaining the correct mole ratio but then writing the final answer as K_2SO_4 , relating it to part a. Students also reversed the ratio when working out the number of moles. Students must not round off too early in these problems; carrying 3 to 4 significant figures in the early parts of the calculations leads to far fewer errors.
	K	S	O																																								
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	= 2	= 1	= 3																																								

Question 22

Question 22 covered a range of topics from criterion 8, from balancing chemical equations to completing a calculation and to defining terms associated with acids and was completed with mixed success. Many students struggle to master these concepts which are the building blocks of Chemistry.

Question	Answer	Mark Allocation	Comment
22a /1	$\text{Fe}_2\text{O}_{3(s)} + 3\text{CO}_{(g)} \rightarrow 2\text{Fe}_{(l)} + 3\text{CO}_{2(g)}$	1 (– 0.5 each error.)	This question was not answered well or not attempted; it was a difficult equation to balance for 1 mark.
22b /2	$\text{CaCO}_{3(s)} + 2\text{HNO}_{3(aq)} \rightarrow \text{Ca}(\text{NO}_3)_{2(aq)} + \text{H}_2\text{O}_{(l)} + \text{CO}_{2(g)}$ OR $\text{CaCO}_{3(s)} + 2\text{H}^+_{(aq)} \rightarrow \text{Ca}^{2+}_{(aq)} + \text{H}_2\text{O}_{(l)} + \text{CO}_{2(g)}$	2 (– 0.5 each error, including forgetting states.)	This question was not answered well with confusion around the chemical formula for nitric acid. A few examples given as its formula were H_2SO_4 , HCl , NH_3 , and NaOH . Quite a few students thought it was an extension of part a) and used iron oxide instead of calcium carbonate. Generally, students did not recognise that it was an acid – carbonate reaction, instead rearranging it as a precipitation reaction.
22c /3	$M(\text{CO}_2) = 44 \text{ g mol}^{-1}$ $n(\text{CO}_2) = \frac{m}{M}$ $= \frac{2.50}{44}$ $= 0.0568 \text{ mol}$ $n(\text{H}_2\text{CO}_3) = n(\text{CO}_2)$ $= 0.0568 \text{ mol (from equation)}$ $\therefore c(\text{H}_2\text{CO}_3) = \frac{n}{v} = \frac{0.0568}{0.75}$ $= 0.076 \text{ mol L}^{-1}$	0.5 1 0.5 1	Generally well attempted with most students realising it required a calculation of moles of CO_2 and then a calculation of concentration. Common errors included using $M(\text{H}_2\text{CO}_3)$ instead of $M(\text{CO}_2)$ to calculate $n(\text{CO}_2)$ from the mass given. Students generally did not make reference to the mole ratio to show equivalence of moles of CO_2 and H_2CO_3 and did not change mL to L. Early rounding off errors caused the final answers to vary greatly; a few attempted to put the answer into scientific notation, not always correctly.
22d /2	Dilute: small amount of dissolved CO_2 per L (unit volume) of solution Weak: the acid only partially breaks down/ionises, producing $\text{H}^+_{(aq)}$ in water.	1 1	This is a common exam question but was not answered well. The idea of a weak acid was answered reasonably with key words like 'partial ionisation' included in most answers. The concept of dilute was not conveyed well, with most students stating just 'a low concentration' but not

Question	Answer	Mark Allocation	Comment
			relating it back to the acid. They also stated that it was watered down or just reiterated the word dilute. A good proportion of students stated that dilute was below a specific concentration value (e.g. 0.5 mol L ⁻¹).

Question 23

Question	Answer	Mark Allocation	Comment
23a /2	$3\text{Cl}_{2(g)} + 2\text{Al}_{(s)} \rightarrow 2\text{AlCl}_{3(s)}$	2 (- 0.5 each error)	Most students scored part marks, however, as they were given the product formula they manipulated the reactants to achieve this. The vast majority did not recognise that chlorine gas was a diatomic molecule. States of matter were required for full marks.
23b /2	$M_r(\text{AlCl}_3 \bullet 6\text{H}_2\text{O}) = 133.3 + 6 \times 18.016 = 241.4$ $\% \text{H}_2\text{O present} = \frac{6 \times 18.016}{241.4} = \frac{108.1}{241.4}$ $= 44.8\%$	0.5 1 0.5	Generally well done. Common errors included incorrectly calculating the molar mass of the water, as well as not adding this to 133.3 to obtain the molar mass of the hydrated aluminium chloride.
23c i /1	No. of units of AlCl_3 in molecule = $\frac{276}{133.3} = 2$ \therefore formula is Al_2Cl_6	0.5 0.5	Most students scored part marks, however, 'deduce' in the question required students to show how they came to their answer. Common errors included not incorporating the multiplier factor, 2, into the chemical formula, leaving it as a coefficient ie 2AlCl_3 instead of Al_2Cl_6 .
23c ii /2	$n(\text{Al}_2\text{Cl}_6) = \frac{m}{M}$ $= \frac{2 \times 10^{-3}}{267}$ $= 7.5 \times 10^{-6} \text{ mol}$ \therefore no of molecules = $n \times N_A$ $= 7.5 \times 10^{-6} \times 6.02 \times 10^{23}$ $= 4.5 \times 10^{18}$	1 1	Generally answered well. Most students recognised they had to firstly calculate moles and then use Avogadro's number. Common mistakes included using $M(\text{AlCl}_3)$ instead of $M(\text{Al}_2\text{Cl}_6)$ and not calculating the moles, instead using the mass in the equation: no of molecules = $n \times N_A$. Students also rounded too early or made simple calculator errors.

Question 24

Question	Answer	Mark Allocation	Comment
24a /1	The decrease in mass of the flask and its contents as a result of the reaction. OR Measure mass of flask and its contents at beginning and at end of reaction.	1	This question was not answered well. Markers were looking for a mass measurement before and after the reaction had gone to completion, but received a variety of responses, including measuring concentration and number of moles.
24b /2	$n(\text{Zn}) = 0.075 \text{ mol}$ From equation $n(\text{H}_2) = n(\text{Zn}) = 0.075 \text{ mol}$ $\therefore m(\text{H}_2) = 0.075 \times 2.016$ $= 0.151 \text{ g}$ $= 0.151 \times 1000 \text{ mg}$ $= 151 \text{ mg}$	0.5 1 0.5	The word 'calculate' implied that reading from the graph was not an acceptable response here and only received part marks. Students who used the mole ratio and then $m = n \times M$ were awarded full marks, as were those who calculated the relevant gradient of the graph and then found the mass using the equation of the line.
24c /1	$n(\text{HCl}) = cV$ $= 0.200 \times 1.20$ $= 0.24 \text{ mol}$		This was answered well.
24d /2	From the equation $n(\text{Zn}) = \frac{1}{2} n(\text{HCl})$ there is a maximum of 0.24 mol of $\text{HCl}_{(aq)}$ present, so there is a maximum of 0.12 mol of Zn that can react. If more Zn is added, there is no more acid to react Alternate – if 0.14 mol of Zn is added, it needs 0.28 mol of acid, which is not available.	0.5 1 0.5	Reasonably well done although full marks were only awarded if the mole ratio between the HCl and Zn was mentioned correctly.
24e /1	pH will increase The solution is becoming less acidic/ closer to neutral (pH 7) as the acid is reacting.	0.5 0.5	Some students related this to the question in part d); when clear, this was given part marks. Some confusion is still evident regarding the relationship between $[\text{H}^+]$ and pH.

Question 25

Question	Answer	Mark Allocation	Comment
25a /1	$n(\text{dilute H}_2\text{SO}_4) \text{ prepared} = 2 \times 0.103 = 0.206 \text{ mol}$ $\therefore n(\text{conc H}_2\text{SO}_4) \text{ needed} = 0.206$ $c = \frac{n}{V} \Rightarrow V = \frac{n}{c}$ $\therefore V = \frac{0.206}{1.42} = 145 \text{ mL}$ Using dilution: $n(\text{dilute H}_2\text{SO}_4) = n(\text{conc H}_2\text{SO}_4)$ $\therefore c_1V_1 = c_2V_2$ $\therefore 2 \times 0.103 = 1.42 \times V_2$ $\therefore V_2 = \frac{0.206}{1.42} = 145 \text{ mL}$	1	Generally well done, although occasionally the 2L was incorrectly attributed to the concentrated acid. This gave a volume required of 27 L, which should have been identified as far too large.
25b /2	$n(\text{H}_2\text{SO}_4) = 0.0202 \times 0.103$ $= 2.08 \times 10^{-3} \text{ mol}$ From equation $\frac{n(\text{XHCO}_3)}{n(\text{H}_2\text{SO}_4)} = \frac{2}{1}$ $\therefore n(\text{XHCO}_3) = 2 \times n(\text{H}_2\text{SO}_4)$ $= 2 \times 2.08 \times 10^{-3}$ $= 4.16 \times 10^{-3} \text{ mol}$	1 0.5 0.5	This was answered well. The mole ratio must be clear for full marks.
25c /2	$n(\text{XHCO}_3) \text{ in } 25 \text{ mL} = 4.16 \times 10^{-3} \text{ mol}$ $\therefore n(\text{XHCO}_3) \text{ in } 250 \text{ mL} = 4.16 \times 10^{-3} \text{ mol} \times 10$ $= 4.16 \times 10^{-2} \text{ mol}$ $n = \frac{m}{M} \Rightarrow M = \frac{m}{n}$ $\therefore M(\text{XHCO}_3) = \frac{3.49}{0.0416} = 83.87 \text{ g mol}^{-1}$	1 1	This question was not answered well, with many students trying to 'fudge' the answer. Full marks were awarded only if the markers could clearly see how the factor of 10 was used. When the calculated value of M was arbitrarily divided by 10 to make it fit with the approximate value given, without explanation, only part marks were awarded.
25d /2	$M(\text{HCO}_3^-) = 1.008 + 12 + 48 = 61.008 \text{ g mol}^{-1}$ $\therefore M(\text{X}) = 83.87 - 61.008 = 22.9 \text{ g mol}^{-1}$ Hence X is sodium	1 1	Reasonably well done although a variety of responses were provided. Markers were looking for a calculation leading to the determination that X was sodium for full marks.