CHURCHLANDS
SENIOR HIGH SCHOOL

CHEMISTRY
UNITS 1 & 2
2022

MARKING GUIDE

TIME ALLOWED FOR THIS PAPER
Reading time before commencing work: Ten minutes
Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Book

To be provided by the candidate:
Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: calculators satisfying the conditions set by the SCSA for this subject.

IMPORTANT NOTE TO CANDIDATES
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One Multiple-choice	25	25	50	25	25
Section Two Short answer	10	10	60	76	35
Section Three Extended answer	5	5	70	86	40
				Total	100

Section One: Multiple-choice **25% (25 marks)**

1	a ☐ b ☐ c ■ d ☐
2	a ☐ b ☐ c ☐ d ■
3	a ☐ b ■ c ☐ d ☐
4	a ☐ b ☐ c ■ d ☐
5	a ■ b ☐ c ☐ d ☐

6	a ☐ b ■ c ☐ d ☐
7	a ☐ b ☐ c ■ d ☐
8	a ☐ b ☐ c ☐ d ■
9	a ■ b ☐ c ☐ d ☐
10	a ☐ b ☐ c ■ d ☐

11	a ☐ b ☐ c ■ d ☐
12	a ☐ b ☐ c ☐ d ■
13	a ☐ b ☐ c ☐ d ■
14	a ☐ b ■ c ☐ d ☐
15	a ☐ b ☐ c ☐ d ■

16	a ■ b ☐ c ☐ d ☐
17	a ☐ b ■ c ☐ d ☐
18	a ■ b ☐ c ☐ d ☐
19	a ☐ b ■ c ☐ d ☐
20	a ☐ b ☐ c ■ d ☐

21	a ☐ b ☐ c ☐ d ■
22	a ☐ b ☐ c ■ d ☐
23	a ☐ b ■ c ☐ d ☐
24	a ■ b ☐ c ☐ d ☐
25	a ☐ b ■ c ☐ d ☐

Section Two: Short answer **35% (76 marks)**

Question 26 **(7 marks)**

(a) Calculate the relative atomic mass of this element, and thus state its identity. (2 marks)

Description	Marks
Ar = (78.99 x 24 + 10 x 25 + 11.01 x 26) / 100 = 24.32	1
Magnesium	1
Total	**2**

(b) Complete the table above. (4 marks)

Description	Marks

Species	Number of protons	Number of neutrons	Electron configuration	Mass number	Overall charge
W	11	**13**	**2, 8, 1**	24	0
X	**12**	14	2, 8	**26**	+2
Y	17	20	**2, 8, 8**	**37**	-1

Correct values for Species W	1
Correct values for Species X	1
Correct values for Species Y	1
Total	**3**

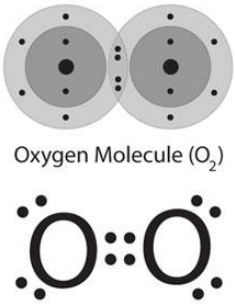
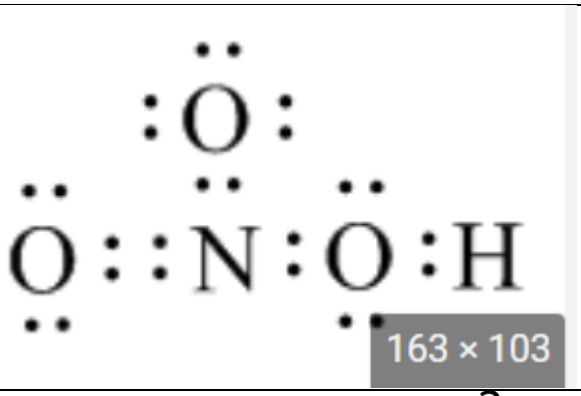
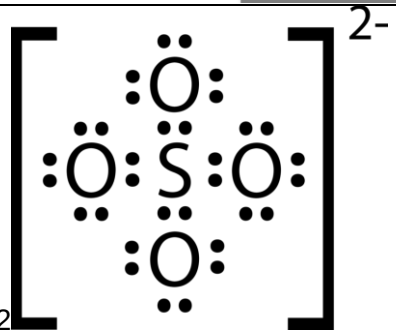
(c) Which of the species in the table represents particles of the same element that was analysed by mass spectrometry? (1 mark)

Description	Marks
Species X	1
Total	**1**

Question 27 **(9 marks)**

Complete the following table by;

- drawing an electron dot diagram
- predicting whether, when mixed with water, the compound would form a solution capable of conducting electricity.

Description			Marks
	Electron dot diagram	Electrical conductivity in aqueous solution ('yes' or 'no')	
O_2		no	
HNO_3		yes	
$Al_2(SO_4)_2$	 $2[Al]^{3+}$ 2	yes	
Correct structure for O_2			2
Correct structure for HNO_3			2
Correct electron arrangement for $Al_2(SO_4)_2$			1
Square brackets and charges shown for $Al_2(SO_4)_2$			1
Correct electrical conductivities			3
		Total	**9**

Question 28 **(7 marks)**

(a) State the function of a catalytic converter. (1 mark)

Description	Marks
To (catalyse reactions which) reduce the amount of harmful gases (e.g. carbon monoxide, unburnt petrol and nitrogen oxides) emitted by a vehicle.	1
Total	**1**

(b) Explain why the use of nanoparticles has greatly reduced the amount of precious metals used to construct a catalytic converter. (3 marks)

Description	Marks
Nanoparticles have a very large surface area (to mass ratio).	1
This increases the frequency of collisions between the catalyst and the gases.	1
Therefore less material is required (compared to the bulk) to provide an equivalent surface area / to function effectively.	1
Total	**3**

(c) Calculate the number of palladium atoms you could purchase for $1. (3 marks)

Description			Marks
m(Pd for $1)	=	1 / 110	1
	=	9.091×10^{-3} g	
n(Pd)	=	0.00909 / 106.4	1
	=	8.544×10^{-5} mol	
N(Pd)	=	$8.544 \times 10^{-5} \times 6.022 \times 10^{23}$	1
	=	5.15×10^{19} atoms	
Total			**3**

Question 29 **(9 marks)**

(a) Explain, in terms of intermolecular forces, why the vapour pressure of hexane is much higher than the other two liquids. (3 marks)

Description	Marks
Hexane is non-polar and exhibits only dispersion forces.	1
Water and ethanol exhibit strong hydrogen bonds (in addition to dipole-dipole and dispersion forces).	1
Thus the sum of intermolecular forces is lower in hexane, allowing vapour to form/evaporation to occur/molecules to escape the liquid more easily.	1
Total	**3**

(b) Which of these liquids has the highest boiling point? Justify your answer. (3 marks)

Description	Marks
Water	1
Either of the following justifications: • Boiling occurs when the vapour pressure equals the atmospheric pressure, • thus a lower vapour pressure indicates a larger amount of heat is required before boiling will occur. **or** • A lower vapour pressure indicates stronger intermolecular forces are present, • therefore a larger amount of heat is required to disrupt the bonding.	2
Total	**3**

(c) Explain, in terms of the kinetic theory, why the vapour pressure of water increases with increasing temperature. (3 marks)

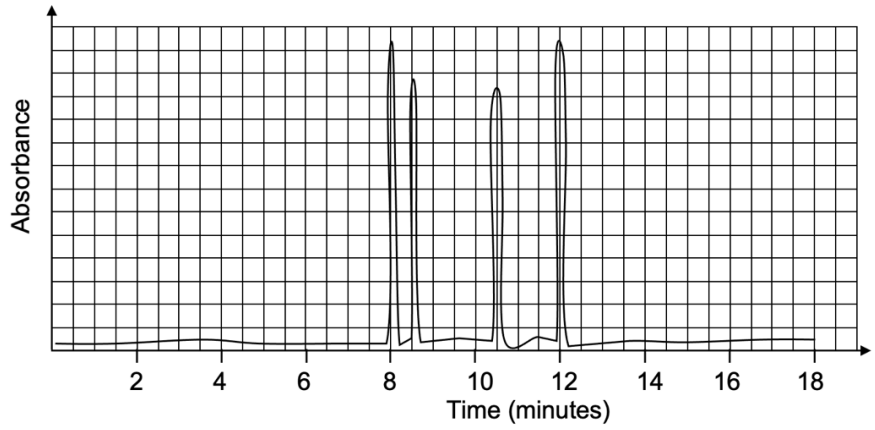
Description	Marks
An increase in temperature increases the average kinetic energy of the particles.	1
This would increase the rate of evaporation. **or** This would allow a higher proportion of molecules to evaporate.	1
Resulting in increased collisions between the vapour and the container.	1
Total	**3**

Question 30 **(9 marks)**

(a) Which acidulant is likely to be the most polar? Justify your answer, making reference to the role of intermolecular forces. (4 marks)

Description	Marks
Oxalic acid	1
The mobile phase is polar.	1
Therefore components with highest polarity will dissolve more readily in the mobile phase.	1
Thus (they will move more quickly through the column) resulting in a lower retention time.	1
Total	**4**

(b) On the grid below, sketch the expected chromatogram for the white wine sample. Label both axes appropriately. (3 marks)

Description	Marks
	
Correct y-axis label	1
Correct x-axis label and scale	1
Four peaks shown at correct retention times (i.e. 8, 8.5, 10.5, 12 min)	1
Peaks at correct height from absorbance table	1
Total	**4**
Note: peaks may be any height and width, as long as retention times are accurate	

Question 31 **(8 marks)**

(a) Explain, in terms of structure and bonding, why this lump of iron now has the capacity to be drawn into a paperclip. (3 marks)

Description	Marks
Iron exhibits metallic bonding, which is characterised by positive metal ions surrounded by a sea of delocalised electrons.	1
This bonding (between the delocalised electrons and positive ions) is non-directional.	1
Thus if a force is applied, the iron can be shaped without disrupting the bonding (resulting in ductility/malleability).	1
Total	**3**

(b) Explain, in terms of structure and bonding, why the sand did not dissolve. (2 marks)

Description	Marks
Sand exhibits covalent network bonding. **or** Sand consists of a strong 3D network of covalent bonds.	1
These bonds are difficult to break / the network is resistant to chemical attack (and thus sand will not dissolve).	1
Total	**2**

(c) Name a separation technique by which the sand could now be removed from the mixture. (1 mark)

Description	Marks
Filtration	1
Total	**1**

(d) Name a separation technique that would allow the solid nickel chloride to be recovered. (1 mark)

Description	Marks
Distillation / Evaporation	1
Total	**1**

(e) Identify the physical property of the two remaining compounds that makes this separation possible. (1 mark)

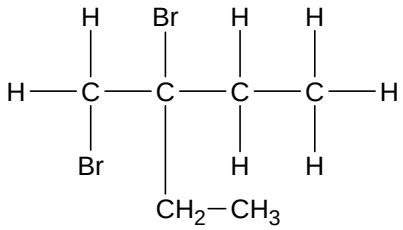
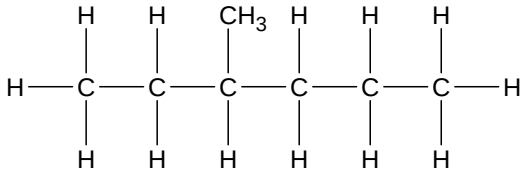
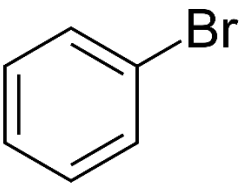
Description	Marks
Different boiling points	1
Total	**1**

Question 32 **(9 marks)**

Consider the three organic reactions which are partially summarised in the table below.

Complete this table by;

- drawing the structural formula for any missing organic reactants and products, and
- stating the IUPAC name for any missing organic reactants and products.

Description	Marks
Reactant shaken with bromine water, $Br_2(aq)$	
	2
1,2-dibromo-2-ethylbutane 3-bromo-3-bromomethylPentane	1
Reactant shaken with chlorine water, $Cl_2(aq)$, in the presence of UV light	
	2
3-methylhexane	1
Reactant shaken with iodine water, $Br_2(aq)$, in the presence of $AlBr_3(s)$	
	2
bromobenzene	1
Total	**9**

Note:

- one mark may be allocated for structural formulae, in the case of a minor error, such as a missing H atom
- follow through marks may be awarded if the IUPAC name correctly matches an incorrectly drawn structure

Question 33 **(9 marks)**

(a) Define a 'supersaturated' solution. (1 mark)

Description	Marks
A greater amount of solute than maximum has been dissolved in a solvent (at a given temperature). **or** The concentration of a solution is greater than that predicted using solubility data/tables.	1
Total	**1**

(b) Calculate the mass of $KNO_3(s)$ crystals that would form. Show all workings. (3 marks)

Description	Marks
Maximum amount of KNO_3 dissolved in 100 g at 30 °C = 45 g	1
Therefore maximum amount KNO_3 dissolved in 210 g at 30 °C = 94.5 g	1
Mass of KNO_3 crystals that would form = 125 – 94.5 = 30.5 g	1
Total	**3**

(c) Classify this solution as ‘unsaturated’, ‘saturated’ or ‘supersaturated’. (1 mark)

Description	Marks
Unsaturated	1
Total	**1**

(d) Describe how the student could use a flame test to distinguish these solutions. (2 marks)

Description	Marks
Spray a sample of each solution in a flame. **or** Dip a wire loop in each solution and then hold in a flame.	1
The solutions would produce different flame colours, allowing them to be distinguished. **or** The KNO_3 would produce a purple/coloured flame whilst the $Mg(NO_3)_2$ would appear white.	1
Total	**2**

Question 34 **(8 marks)**

(a) Describe how the student could use these indicators to identify which liquid was in each beaker. (2 marks)

Description	Marks
Add methyl orange indicator to a sample of each, the solution that turns red is HNO_3.	1
Add phenolphthalein to a sample of the remaining two solutions, the pink one is KOH / the colourless one is water.	1
Total	**2**
Note: these tests may be performed in a different order or a slightly different method may be used; award one mark each time an observation based on indicator colour is clearly linked to the identity of a solution	

(b) Complete this table, by including the distinguishing observation for test tube C. (1 mark)

Description		Marks
Test tube C	Pungent colourless gas formed	1
	Total	**1**

(c) Write a balanced ionic equation for the reaction occurring in test tube C. (2 marks)

Description	Marks
$NH_4Cl(s) + OH^-(aq) \rightarrow H_2O(l) + NH_3(g) + Cl^-(aq)$	
Correct species	1
Correct balancing	1
Total	**2**
Note: state symbols are not required for full marks.	

(d) Complete this table, by including the distinguishing observation for test tube A. (1 mark)

Description		Marks
Test tube A	Colourless (odourless) gas formed	1
Total		**1**

(e) Write a balanced ionic equation for the reaction occurring in test tube A. (2 marks)

Description	Marks
$MgCO_3(s) + 2\ H^+(aq) \rightarrow H_2O(l) + CO_2(g) + Mg^{2+}(aq)$	
Correct species	1
Correct balancing	1
Total	**2**
Note: state symbols are not required for full marks.	

Question 35 **(7 marks)**

(a) Calculate the amount of energy that would be released in the combustion of one full tank of petrol. (3 marks)

Description			Marks
$m(C_8H_{18})$	=	48.18×10^3 = 48180 g	1
$n(C_8H_{18})$	=	48180 / 114.224 = 421.803 mol	1
E(released)	=	421.803 / 2 x 10920 = 2303043 kJ = 2.303×10^6 kJ	1
		Total	**3**

(b) Calculate the volume of hydrogen gas, stored at STP, that would be required to produce this same amount of energy. (2 marks)

Description			Marks
$n(H_2)$	=	2303043 / 564 x 2 = 8166.82 mol	1
$V(H_2)$	=	22.71 x 8166.82 = 185468 L = 1.855×10^5 L	1
		Total	**2**
Note: follow through marks may be awarded if correct calculation method is shown based on an incorrect value in part (a)			

(c) Identify one (1) advantage and one (1) disadvantage of hydrogen powered vehicles. (2 marks)

Description	Marks
Many possible advantages, including; • water is the only product • carbon emissions are reduced • $CO_2(g)$ is not produced • greater sustainability • greener alternative	1
Many possible disadvantages, including; • very large storage capacity required • storage and transport of $H_2(g)$ for cars is not yet practical • most $H_2(g)$ is currently produced using fossil fuels • this technology is expensive / buying a new car is expensive • this technology requires further development / is not currently available	1
Total	**2**

Section Three: Extended answer **40% (86 marks)**

Question 36 **(15 marks)**

(a) Identify the type of bonding present in these minerals, and explain, in terms of structure and bonding, why they are hard and brittle. (5 marks)

Description	Marks
Ionic	1
Ionic compounds consists of a rigid 3D lattice composed of cations and anions.	1
The strong electrostatic attraction between these ions results in the substance being hard.	1
When a force is applied, like charges align and repel,	1
causing the lattice to shatter (and thus are regarded as brittle).	1
Total	**5**

(b) Calculate the percentage by mass of iron in jarosite, and suggest a reason for the different shade of red produced by this mineral. (3 marks)

Description	Marks
M(jarosite) = 500.818	1
% Fe = (3 x 55.85) / 500.818 x 100 = 33.46%	1
Different shade may be due to a much lower percentage of iron.	1
Total	**3**

(c) Calculate the volume of $CO_2(g)$, measured at STP, that would be produced, if all the huntite underwent decomposition. State your answer to the appropriate number of significant figures. (6 marks)

Description			Marks
$m(Mg_3Ca(CO_3)_4)$	=	3.82 / 100 x 5.75	1
	=	0.21965 kg	
$m(Mg_3Ca(CO_3)_4)$	=	0.21965×10^3	1
	=	219.65 g	
$n(Mg_3Ca(CO_3)_4)$	=	219.65 / 353.05	1
	=	0.62215 mol	
$n(CO_2)$	=	4 x 0.62215	1
	=	2.4886 mol	
$V(CO_2)$	=	22.71 x 2.4886	1
	=	56.516 L	
	=	56.5 L (3 SF)	1
		Total	**6**

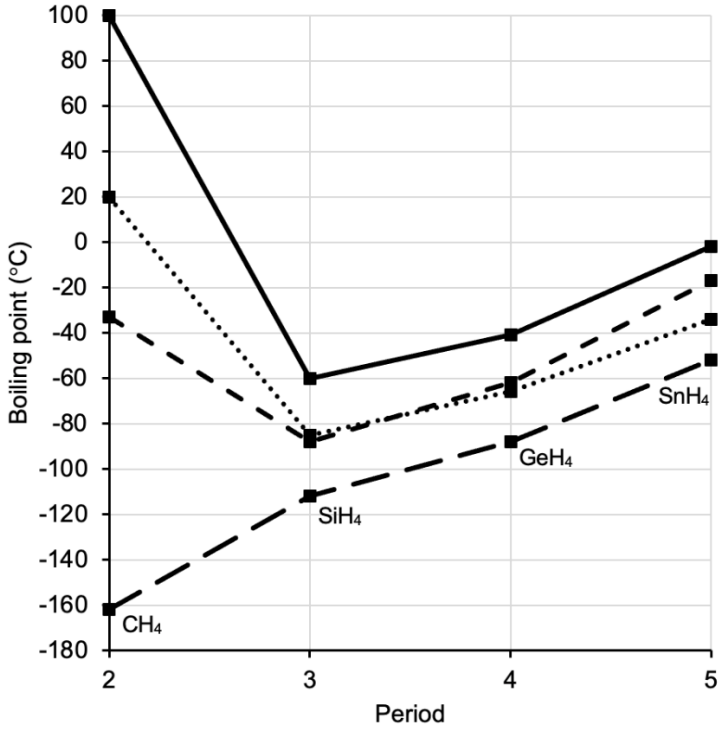
(d) Calculate the quantity of heat that would have been absorbed. (1 mark)

Description			Marks
E(released)	=	0.62215 x 350	1
	=	218 kJ	
		Total	**1**
Note: follow through marks may be awarded if correct calculation method is shown based on an incorrect value from part c)			

Question 37 **(17 marks)**

Plot this boiling point data on the graph on the previous page. (1 mark)

(e)

Description	Marks
	
Points plotted correctly and joined by straight lines	1
Total	**1**

(a) Identify the molecular shape of each of the following groups of hydrides. (3 marks)

Description		Marks
Group 16 hydrides	v-shaped / bent	1
Group 17 hydrides	linear	1
Total		**2**

(b) State and explain the trend in electronegativity as you move down the Group 17 elements. (3 marks)

Description	Marks
The electronegativity decreases.	1
Moving down a group, the valence shell is further from the nucleus (and experiences increased shielding).	1
Therefore a lesser force is exerted by the nucleus on a (bonding pair of) electron(s).	1
Total	**3**

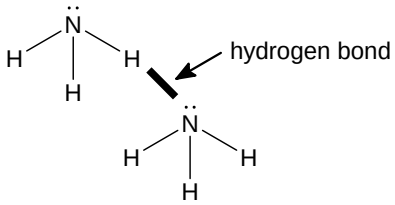
(c) Explain, using the concept of electronegativity, which of the Group 17 hydrides is the most polar. (2 marks)

Description	Marks
HF is the most polar	1
Hydrogen and fluorine have the largest difference in electronegativity. **or** Since fluorine has the highest electronegativity, the shared electron pair in HF is more strongly attracted to the F atom (compared with the other group 17 hydrides).	1
Total	**2**

(d) Identify the hydride which exhibits the strongest dispersion forces, and explain why this occurs. (3 marks)

Description	Marks
H_2Te	1
H_2Te has the largest molecular mass / greatest number of molecular electrons.	1
This results in; an increased likelihood that a temporary dipole will form. **or** an increased likelihood that a stronger temporary dipole will form.	1
Total	**3**

(f) Explain why the boiling points of H_2O, HF and NH_3 do **not** follow the same trend seen in the Group 14 hydrides. Support your answer with a diagram illustrating the predominant type of intermolecular interaction in NH_3. (5 marks)

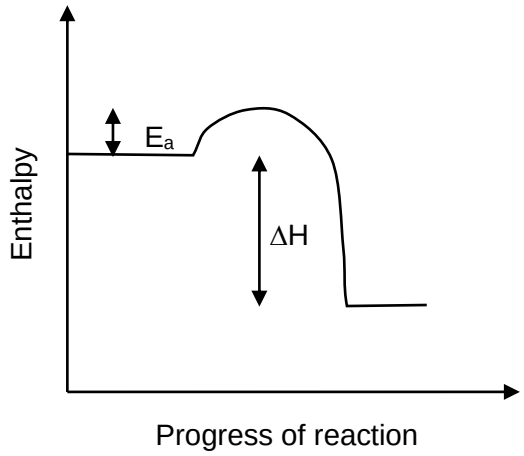
Description	Marks
The Group 14 hydrides exhibit only dispersion forces.	1
Whereas H_2O, HF and NH_3 all exhibit hydrogen bonding (in addition to dipole-dipole and dispersion forces).	1
Thus these compounds have a greater sum of intermolecular forces (and therefore higher boiling point).	1
	
Two molecules of NH_3 correctly shown	1
Hydrogen bond shown between a H atom of one molecule and the non-bonding electron pair of another	1
Total	**5**

Question 38 **(19 marks)**

(a) Define activation energy, and suggest what assumption can be made regarding the magnitude of the activation energy for this reaction. (2 marks)

Description	Marks
The minimum energy required for a collision to be successful.	1
Low activation energy (since it occurs rapidly at room temperature).	1
Total	**2**

(b) On the axes below, sketch an energy profile diagram for this reaction. Label the axes, activation energy and enthalpy change. (4 marks)

Description	Marks
	
Axes labelled correctly	1
Exothermic shape shown	1
Activation energy labelled correctly	1
Enthalpy change labelled correctly	1
Total	**4**

(c) Suggest two (2) ways that the rate of this reaction could be measured. (2 marks)

	Description	Marks
1.	Measure the amount of $CaCO_3$ solid formed in a given time period / Measure how long it takes for an 'X' placed under the reaction vessel to be obscured	1
2.	Measure the amount of CO_2 gas formed in a given time period	1
	Total	**2**

(d) List two (2) variables that should be controlled in order to ensure the data collected by the student is valid. (2 marks)

Description	Marks
Any two (2) of the following; • volume of $NaHCO_3$ • volume of $CaCl_2$ • concentration of $NaHCO_3$ • concentration of $CaCl_2$ • size of beaker / reaction vessel used • whether the reaction mixture is stirred / swirled / left untouched etc	2
Total	**2**

(e) Predict the likely outcome of this investigation, using collision theory to support your answer. (4 marks)

Description	Marks
An increase in temperature will increase the reaction rate.	1
Increased temperature increases the average kinetic energy of particles.	1
This results in both an increased frequency of collisions, and	1
an increased proportion of successful collisions / increased proportion of particles with $E_k > E_a$.	1
Total	**4**

Question 39 **(21 marks)**

(a) (i) Name the type of forces indicated by the arrows (➡) on the diagram. (1 mark)

Description	Marks
Ion-dipole	1
Total	**1**

(ii) Explain how these forces form. (3 marks)

Description	Marks
Water molecules are (highly) polar (due to their asymmetry and the large difference in electronegativity between O and H).	1
The positive side / H atoms (δ^+) on the water are attracted to the anions.	1
The negative side / non-bonding electrons (δ^-) on the water are attracted to the cations.	1
Total	**3**

(b) Calculate the concentration of chloride ions in seawater, in moles per litre. (5 marks)

Description			Marks
$n(AgCl)$	=	0.264 / 143.35	1
	=	0.0018416 mol	
$n(Cl^-$ in 20 mL)	=	0.0018416 mol	1
$c(Cl^-$ dilute)	=	0.0018416 / 0.02	1
	=	0.092082 mol L^{-1}	
$n(Cl^-$ in 100 mL)	=	0.092082 x 0.1	1
	=	0.0092082 mol	
$c(Cl^-$ in seawater)	=	0.0092082 / 0.015	1
	=	0.614 mol L^{-1}	
		Total	**5**
Alternate working 1:			
$c(Cl^-$ dilute)	=	0.092082 mol L^{-1}	
$c(Cl^-$ concentrated)	=	$c(Cl^-$ dilute) x V(dilute) / V(concentrated)	
	=	(0.092082 x 0.1) / 0.015	
	=	0.614 mol L^{-1}	
Alternate working 2:			
$n(Cl^-$ in 20 mL)	=	0.0018416 mol	
$n(Cl^-$ in 100 mL)	=	0.0018416 x (100 / 20)	
	=	0.0092082 mol	
	=	$n(Cl^-$ in 15 mL seawater)	
$c(Cl^-$ in seawater)	=	0.0092082 / 0.015	
	=	0.614 mol L^{-1}	

(c) Calculate the concentration of silver ions in solution X (see diagram). (3 marks)

Description			Marks
$n(AgNO_3$ added)	=	0.1 x 0.02	1
	=	0.002 mol	
$n(Ag^+$ remaining)	=	0.002 – 0.0018416	1
	=	0.0001584 mol	
$c(Ag^+$ remaining)	=	0.0001584 / 0.04	1
	=	0.00396 mol L^{-1}	
		Total	**3**
Note: follow through marks may be awarded if correct calculation method is shown based on an incorrect value from part b)			

(d) (i) did the student add a large enough volume of silver nitrate solution to precipitate out all of the chloride ions present in the sample .

Description	Marks
n(NaCl) = c x v = 21.2 x 0.025 = 0.53 moles	1
n(AgCl) = c x V = 3.2 x 0.150 = 0.48 moles	1
Mole ratio statement	1
Final statement – No they did not add enough	1
Total	**4**
Note: follow through marks may be awarded if correct calculation method is shown based on an incorrect value from part b)	

(ii)

Description	Marks
Mole ratio statement $AgNO_3$:AgCl 1:1 therefore 0.48 moles AgCl formed	1
m(AgCl) = n x M = 0.48 x 143.35 =68.8 grams	1
Total	**2**
Note: follow through marks may be awarded if correct calculation method is shown based on an incorrect value from part b)	

(e) Explain, with reference to the process of AAS, why a higher concentration of gold results in a higher absorbance reading. (3 marks)

Description	Marks
The light / wavelengths emitted (from the gold present in the hollow cathode lamp) is specific to gold.	1
Any gold present in the sample absorbs this light / these wavelengths (as electrons jump to a higher energy level).	1
The greater the concentration of gold in the sample, the greater the amount of light absorbed.	1
Total	**3**

(f) Give a reason that the presence of silver in seawater would **not** affect the AAS absorbance reading. (1 mark)

Description	Marks
Silver would not absorb the same wavelengths as gold. **or** Silver would not absorb the light emitted by the gold cathode.	1
Total	**1**

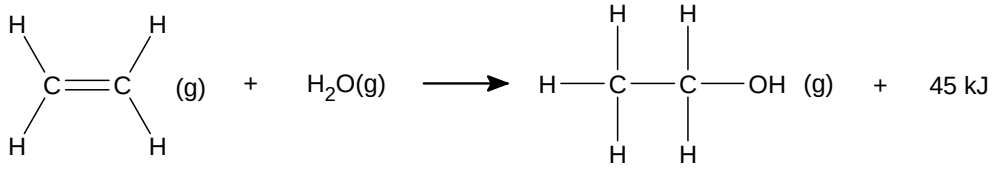
(g) Calculate the concentration of gold in seawater, in parts per million. (5 marks)

Description			Marks
From graph; c(Au)	=	5.4×10^{-11} mol L^{-1}	1
m(Au)	= =	$5.4 \times 10^{-11} \times 197$ 1.0638×10^{-8} g	1
m(Au)	= =	$1.0638 \times 10^{-8} \times 1000$ 1.0638×10^{-5} mg	1
m(1 L seawater)	=	1.0236 kg	1
c(Au in ppm)	= =	$1.0638 \times 10^{-5} / 1.0236$ 1.039×10^{-5} ppm	1
		Total	**5**

Note:
- accept absorbance readings from graph between 5.38×10^{-11} – 5.42×10^{-11} mol L^{-1}
- this gives a final concentration of between 1.035×10^{-5} – 1.043×10^{-5} ppm

Question 40 **(18 marks)**

(a) Write a balanced thermochemical equation for this reaction. Use full structural formulae for any organic substances and include state symbols. (5 marks)

Description	Marks
	
Correct species	1
Correct full structural formulae of ethene and ethanol used	1
Correct state symbols	1
Correct heat of reaction incorporated	1
Catalyst written above arrow	1
Total	**5**

(b) Name the type of reaction occurring. (1 mark)

Description	Marks
Addition / Hydration	1
Total	**1**

(c) Explain how this reaction conforms to the Law of Conservation of Energy, despite producing heat. (3 marks)

Description	Marks
Energy is absorbed when bonds are broken.	1
However, a greater amount of energy is released when bonds are formed.	1
The difference in energy between these processes is released as heat.	1
Total	**3**
Alternate response: • The enthalpy of the reactants is higher • than that of the products. • This difference in enthalpy is released as heat / transformed into heat energy.	

(d) Explain, in terms of the collision theory, how this would increase the rate of this reaction. (2 marks)

Description	Marks
A greater number of gas particles are found per unit volume / This results in a higher concentration of gas particles	1
This increases the frequency of collision (and thus the reaction rate)	1
Total	**2**

(e) Explain, in terms of the collision theory, the function of the phosphoric acid catalyst in this reaction. (3 marks)

Description	Marks
It will provide an alternate reaction pathway with a lower activation energy.	1
Therefore a greater proportion of particles will be able to overcome the activation energy / will have $E_k > E_a$.	1
This increases the reaction rate.	1
Total	**3**