Separate Science (Chemistry) Unit 5 Energy changes – mark scheme

Foundation

Question number	Description	Marks	Page number
4.5.1 Exothermic and endothermic reactions			
1	Use of endothermic reaction, multiple choice reaction profile, exothermic gap fill, name apparatus to measure temperature, read thermometer scale and calculate temperature change	7	3
2	Compound formula and bonding multiple choice, reaction profile multiple choice, (4.2.1 dot and cross bonding for water)	8	4
7	Energy changes experiment – choosing thermometer from diagram with resolution of 0.1^{O}C, error type multiple choice, giving equipment used rather than glass beaker, plot results and draw line of best fit, extend line of best fit to determine y-axis intercept, reason for anomalous multiple choice	11	5
4.5.2 Chemical cells and fuel cells			
4	Control variables in chemical cells experiment, ordering metals used as electrode in reactivity, predict the voltage of a cell with copper as electrode and give reason, advantage and disadvantage of hydrogen fuel cells	10	6
10	Combination of electrode metals and electrolyte to give 0V, why alkaline batteries eventually stop working, why can alkaline batteries not be recharged, evaluate the use of hydrogen fuel cells compared with rechargeable lithium ion batteries using data in a table (6 marks)	11	8

Common content

Question number	Description	Marks	Page number
4.5.1 Exothermic and endothermic reactions			
1	(4.2.1 dot and cross bonding for hydrogen chloride), balanced symbol equation between hydrogen and chlorine, reaction	10	10

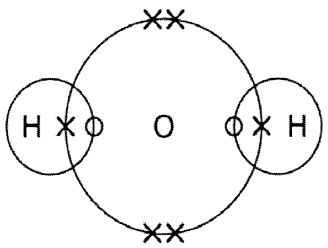
	profile diagram answers, how reaction profile shows exothermic, explain why hydrogen chloride gas doesn't conduct electricity but hydrochloric acid does.		
2	Describing method to investigate temperature changes when different masses of ammonium nitrate are dissolved in water	6	12

Higher

Question number	Description	Marks	Page number
4.5.1 Exothermic and endothermic reactions			
3	Label activation energy on reaction profile, determine energy change from reaction profile with scale, (4.2.1 dot and cross bonding in oxygen molecule), calculate energy change in reaction	8	13
5	(4.2.1 dot and cross bonding in ammonia, limitation of dot and cross diagram to represent ammonia molecule, 4.2.2 explain why ammonia has a low boiling point), calculate overall energy change in reaction, explain why reaction is exothermic, complete reaction profile	14	16
7	(4.1.2 name products formed in Halogen displacement, explain why chlorine is more reactive than iodine, explain why hydrogen chloride is gas at room temperature), calculate bond energy for a bond in displayed formulae for reaction when overall energy change is given	11	19
9	Reason for using polystyrene cup in temperature change practical, plotting results on graph and line of best fir, extending line of best fit to read value on graph, determine overall temperature change from graph, **calculate concentration of compound in mol/dm^3 and g/dm^3 from values in question and balanced symbol equation (6 marks)**	14	21
4.5.2 Chemical cells and fuel cells			
6	Suggesting control variables for investigation method, using results table on voltage for different metal electrode to order metals in reactivity and give justification, suggest why trains run on hydrogen fuel cells are "new steam trains"	9	24

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.1	sports injury pack		1	AO1 5.5.1.1
01.2	B		1	AO1 5.5.1.2
01.3	C		1	AO1 5.5.1.2
01.4	lower than		1	AO1 5.5.1.2
01.5	thermometer		1	AO1 5.5.1.2
01.6	27.4 (°C) (27.4–14.3 =) 13.1 (°C)	allow values in the range 27.2–27.5 (°C) allow correct subtraction of incorrect temperature reading	1 1	AO2 5.5.1.1
Total			**7**	

Question 2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	H_2O_2		1	AO2 4.1.1.1 4.2.1.4
02.2	covalent		1	AO1 4.2.1.4
02.3	transition metals		1	AO1 4.1.3.2
02.4	B		1	AO1 4.5.1.2
02.5	A		1	AO2 4.5.1.2
02.6	exothermic		1	AO1 4.5.1.1
02.7	 1 bonding pair of electrons in the right hand overlap 4 non-bonding electrons on oxygen	 scores **2** marks allow dots, crosses, circles or $e^{(-)}$ for electrons do **not** accept any change to the number of electrons in the left hand overlap do **not** accept non-bonding electrons on hydrogen ignore inner shell electrons drawn on oxygen	 1 1	AO1 4.2.1.4
Total			**8**	

Question 7

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.1	sports injury pack		1	AO1 4.5.1.1
07.2	D		1	AO1 4.5.1.1
07.3	systematic error		1	AO1 4.5.1.1
07.4	polystyrene cup	allow other insulating containers	1	AO1 4.5.1.1
07.5	all six points plotted correctly line of best fit line extrapolated correctly to y-axis	allow a tolerance of ± ½ a small square allow **1** mark for at least 3 points plotted correctly ignore extrapolation to y-axis	2 1 1	AO2 4.5.1.1
07.6	20.4 (°C)	allow ecf from question **07.5** allow a tolerance of ± ½ a small square	1	AO2 4.5.1.1
07.7	the mixture was not stirred too little sulfuric acid was added		1 1	AO3 4.5.1.1
Total			**11**	

Question 4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.1	concentration (of solution / electrolyte) temperature (of solution / electrolyte)	 ignore room temperature allow volume (of solution / electrolyte) allow size of electrodes allow distance between electrodes do **not** accept electrode **X** unqualified do **not** accept (measured) voltage	1 1	AO3 4.5.2.1
04.2	(most reactive) magnesium zinc (least reactive) cobalt	allow Mg allow Zn allow Co	1	AO3 4.4.1.2 4.5.2.1
04.3	0 (volts) two different metals are needed to produce a voltage	 dependent on voltage being given as 0 volts allow the two electrodes are the same metal allow there is no difference in reactivity (between the electrodes)	1 1	AO3 4.5.2.1
04.4	connect cells (in series) use $\left(\frac{12}{1.5} =\right)$ 8 cells	ignore putting cells together	1 1	AO1 AO2 4.5.2.1
04.5	electric toy		1	AO3 4.5.2.1 4.5.2.2

Question 4 continued

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.6	(advantage) any **one** from: • faster to refuel (than recharging) • can travel further (before refuelling) • hydrogen can be renewable • produces a constant voltage • no toxic chemicals released after disposal (disadvantage) any **one** from: • hydrogen is made from fossil fuels • hydrogen is made from non-renewable resources • hydrogen is difficult to store • hydrogen is flammable / explosive • costs more to refuel (than recharging) • costs more to manufacture • not many hydrogen filling stations	allow lasts longer allow hydrogen is renewable allow the only product is water ignore no emissions ignore expensive unqualified	1 1	AO3 4.5.2.1 4.5.2.2
Total			**10**	

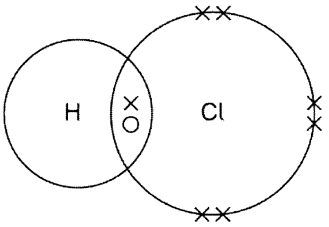
Question	Answers	Extra information	Mark	AO / Spec. Ref.
10.1	copper, zinc, sodium chloride solution		1	AO2 4.5.2.1
10.2	a reactant is used up	allow the reaction stops allow electrolyte / electrode / ions / metal / metal hydroxide / alkali for reactant	1	AO1 4.5.2.1
10.3	the reaction is not reversible		1	AO1 4.5.2.1
10.4	$2H_2 + O_2 \rightarrow 2H_2O$	allow fractions / multiples allow **1** mark for O_2	2	AO1 AO2 4.1.1.1 4.5.2.2

<table>
<tr><th>Question</th><th>Answers</th><th>Mark</th><th>AO / Spec. Ref.</th></tr>
<tr><td rowspan="5">10.5</td><td>Level 3: A judgement, strongly linked and logically supported by a sufficient range of correct reasons, is given.</td><td>5–6</td><td>AO3</td></tr>
<tr><td>Level 2: Some logically linked reasons are given. There may also be a simple judgement.</td><td>3–4</td><td>AO3</td></tr>
<tr><td>Level 1: Relevant points are made. This is not logically linked.</td><td>1–2</td><td>AO2</td></tr>
<tr><td>No relevant content</td><td>0</td><td></td></tr>
<tr><td colspan="2">Indicative content

reasons why fuel cells could be judged as better

<table><tr><th>from the table</th><th>from other knowledge</th></tr><tr><td>• time for refuelling a fuel cell is faster than recharging
or
a fuel cell does not need to be recharged
• a fuel cell has a greater range</td><td>• hydrogen can be renewable if made by electrolysis using renewable energy
• lithium-ion batteries can catch fire
• produces only water
or
no pollutants produced
• lithium-ion batteries may release toxic chemicals on disposal
• lithium-ion batteries (eventually cannot be recharged so) have a finite life</td></tr></table>
reasons why the lithium-ion battery could be judged as better

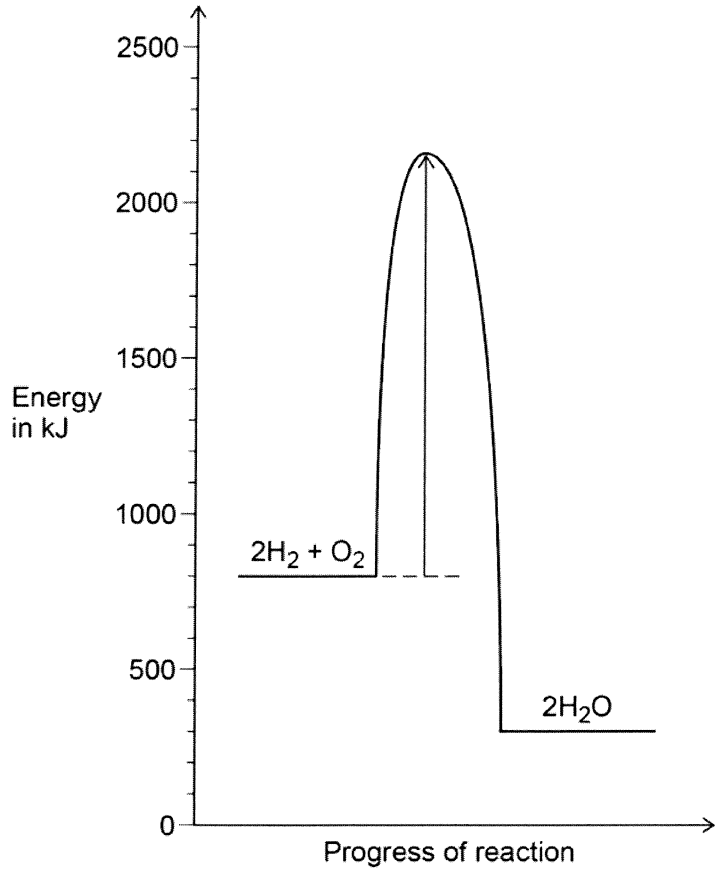
<table><tr><th>from the table</th><th>from other knowledge</th></tr><tr><td>• lithium-ion uses energy more efficiently
• cost of lithium-ion car much less
• cost of recharging much less than refuelling with hydrogen</td><td>• hydrogen is often made from fossil fuels so is not renewable
• charging points are more widely available than hydrogen filling stations
• hydrogen takes up a lot of space
or
is difficult to store
• hydrogen can be highly flammable / explosive
• no emissions produced
• (catalyst in the hydrogen fuel-cell eventually becomes poisoned so) have a finite life</td></tr></table></td><td></td><td>4.4.3.4
4.5.2.1
4.5.2.2</td></tr>
<tr><td>Total</td><td colspan="2"></td><td>11</td></tr>
</table>

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.1	shared electron pair	allow electrons drawn as dots, crosses, circles or $e^{(-)}$	1	AO1 4.6.2.4
	1 hydrogen electron and 7 chlorine electrons drawn on outer shells	ignore inner shell electrons drawn on chlorine an answer of  scores **2** marks	1	
01.2	correct symbols and formulae	an answer of $H_2 + Cl_2 \rightarrow 2HCl$ scores **2** marks	1	AO2 4.5.2.1 4.5.1.5
	correct balancing of equation containing HCl	allow correct multiples	1	
01.3	A activation energy		1	AO1 4.7.4.4
	B (overall) energy change		1	
01.4	energy of products is less than the energy of the reactants		1	AO2 4.7.4.4

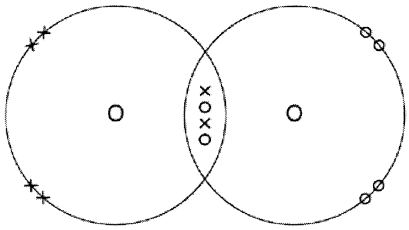
Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.5	hydrogen chloride molecules do not have an overall electric charge	allow hydrogen chloride does not contain ions	1	AO1 AO2 4.6.2.3 4.6.2.5
	hydrochloric acid contains ions		1	
	(which) are free to move so charge can flow	do **not** accept reference to delocalised electrons	1	
Total			**10**	

Question	Answers	Mark	AO/ Spec. Ref
02.6	**Level 3:** The design/plan would lead to the production of a valid outcome. All key steps are identified and logically sequenced.	5–6	AO3 AO2
	Level 2: The design/plan would not necessarily lead to a valid outcome. Most steps are identified, but the plan is not fully logically sequenced.	3–4	5.5.1.1
	Level 1: The design/plan would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.	1–2	
	No relevant content	0	
	Indicative content **Steps** • use a suitable container eg test tube • use insulation • add water • measure the initial water temperature (with a thermometer) • add stated mass eg 1g **or** 1 spatula • stir (to dissolve the solid) • measure the final (allow lowest or highest) temperature of the solution • calculate the temperature difference **or** determine graphically • repeat with different masses • repeat with the same volume of water to access level 3 there must be an indication of how the temperature change is determined using different masses dissolved in the same quantity of water		

Total			14

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	line from reactants to top of curve (i.e. from 800 to 2160)  ignore arrowheads		1	AO1 5.5.1.2

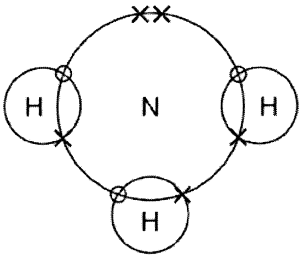
03.2		an answer of (–) 500 (kJ) scores **2** marks ignore sign		AO2 AO3 5.5.1.2
	reads levels of reactants (800 kJ) and products (300 kJ)		1	
	(800 – 300) = 500 (kJ)	allow correct subtraction of one incorrect value determined for the energy change	1	

03.3		allow combination of circles, dots, crosses or $e^{(-)}$		AO2 5.2.1.4
	two shared pairs in overlap		1	
	all non-bonding electrons in outer shell (4 electrons on each O atom)	ignore any inner shell electrons	1	
		 diagram scores 2 marks		

03.4	(bonds broken) ((4×463) + (2×138) =) **2128** (bonds made) ((4×463) + (496) =) **2348** (energy change = bonds broken – bonds made) (2128 – 2348 =) (–) **220** (kJ) **alternative approach:** (bonds broken) (2× (O–O) = (2×138) =) **276** (1) (bonds made) (1× (O=O) =) **496** (1) (energy change = bonds broken – bonds made) (276 – 496 =) (–) **220** (kJ) (1)	an answer of (–) 220 (kJ) scores **3** marks an incorrect answer for one step does **not** prevent allocation of marks for subsequent steps ignore energy change sign allow correct calculation using incorrect values from step 1 and/or step 2	1 1 1	AO2 5.1.1.1 5.5.1.1 5.5.1.3

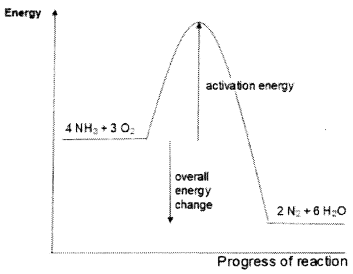
Total			**8**

Question 5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1		 scores **2** marks allow dots, crosses, circles or $e^{(-)}$ for electrons		AO1 4.2.1.4
	1 bonding pair of electrons in each overlap		1	
	2 non-bonding electrons on nitrogen	do **not** accept non-bonding electrons on hydrogen ignore inner shell electrons drawn on nitrogen	1	
05.2	does not show the shape **or** only two-dimensional	allow is not three-dimensional	1	AO1 4.2.1.4
05.3	(ammonia has) small molecules	allow (ammonia has) a simple molecular (structure)	1	AO1 4.2.2.1 4.2.2.4
	(ammonia has) weak intermolecular forces	allow (ammonia has) weak intermolecular bonds do **not** accept weak covalent bonds	1	
	(so) little energy is needed to overcome the intermolecular forces	allow (so) little energy is needed to break the intermolecular bonds allow (so) little energy is needed to separate the molecules do **not** accept references to breaking covalent bonds	1	

05.4	Cr_2O_3		1	AO2 4.1.3.2
05.5	(for bonds broken) ((12 x 391) + (3 x 498) =) 6186 (for bonds made) ((2 x 945) + (12 x 464) =) 7458 (overall energy change = 6186-7458 =) (-)1272 (kJ)	an answer of (-)1272 (kJ) scores **3** marks allow correct calculation using incorrectly calculated values from step 1 and/or step 2	 1 1 1	AO2 4.5.1.3

Question 5 continued

05.6	7458 (kJ) (released in making bonds) is greater than 6186 (kJ) (used in breaking bonds) **or** the products have 1272 (kJ) less energy than the reactants	allow ecf from question **05.5** allow the (overall) energy change is -1272 (kJ)	1	AO2 4.5.1.3
	(so) energy is released (to the surroundings)	dependent on MP1 being awarded allow (so) heat is released (to the surroundings) if no values given, allow **1** mark for more energy released in making bonds than used in breaking bonds	1	
05.7	 scores **2** marks allow discontinuous lines ignore arrow heads		AO1 4.5.1.2
	activation energy labelled		1	
	(overall) energy change labelled		1	
Total			**14**	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.1	potassium chloride **and** iodine	either order allow KCl for potassium chloride and I_2 for iodine	1	AO1 4.1.2.6
07.2		allow converse statements allow energy levels for shells throughout		AO1 4.1.2.6
	(chlorine's) outer electrons / shell closer to the nucleus	allow chlorine has fewer shells allow chlorine atom is smaller than iodine atom ignore chlorine has fewer outer shells	1	
	(so) the chlorine nucleus has greater attraction for outer electrons / shell	allow chlorine has less shielding do **not** accept incorrect types of attraction	1	
	(so) chlorine gains an electron more easily	 **maxf 2** marks can be awarded if the answer refers to chloride / iodide instead of chlorine / iodine	1	
07.3	hydrogen chloride is made of small molecules	allow hydrogen chloride is simple molecular	1	AO1 4.1.2.6 4.2.1.4
	(so hydrogen chloride) has weak intermolecular forces	do **not** accept reference to bonds breaking unless applied to intermolecular bonds	1	4.2.2.4
	(intermolecular forces) require little energy to overcome		1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.4		an answer of 290 (kJ/mol) scores **4** marks an answer of 188 (kJ/mol) scores **3** marks an incorrect answer for one step does **not** prevent allocation of marks for subsequent steps		AO2 4.5.1.3
	(bonds broken = 4(412) + 193 =)1841		1	
	(bonds formed = 3(412) + 366 + **X** =) 1602 + **X**		1	
	−51 = 1841 − (1602 + **X**)	allow use of incorrectly calculated values of bonds broken and / or bonds formed from steps 1 and 2 for steps 3 and 4	1	
	(**X** =) 290 (kJ/mol)	allow a correctly calculated answer from use of −51 = bonds formed – bonds broken	1	
	OR alternative method ignoring the 3 unchanged C–H bonds (412 + 193 =) 605 (1) 366 + **X** (1) −51 = 605 − (366 + **X**) (1) (**X** =) 290 (kJ/mol) (1)			
Total			**11**	

Question 9

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.1	polystyrene is a better (thermal) insulator (so) reduces energy exchange (with the surroundings)	allow polystyrene is a poorer (thermal) conductor allow (so) reduces energy / heat loss (to the surroundings)	1 1	AO3 4.5.1.1
09.2	all six points plotted correctly line of best fit through points plotted from Table 6 both lines of best fit extrapolated correctly until they cross	allow a tolerance of ± ½ a small square allow **1** mark for at least 3 points plotted correctly	2 1 1	AO2 4.5.1.1
09.3	11 (cm^3)	allow ecf from question **09.2** allow answers in the range 10.75 to 11.25 (cm^3) allow a tolerance of ± ½ a small square	1	AO2 4.5.1.1
09.4	(27.5 – 18.9) = 8.6 (°C)	allow ecf from question **09.2** allow answers in the range 8.5 to 8.7 (°C) allow a tolerance of ± ½ a small square	1	AO2 4.5.1.1

Question 9 continued

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.5		an answer of 0.62 (mol/dm^3) for concentration in mol/dm^3 scores **4** marks an answer of 0.31 (mol/dm^3) for concentration in mol/dm^3 scores **3** marks		AO2/2 4.3.1.2 4.3.2.5 4.3.4 4.4.2.5
	(moles H_2SO_4 = 0.500 × $\frac{15.5}{1000}$) = 0.00775		1	
	(moles KOH = 2 x moles H_2SO_4 = 2 x 0.00775) = 0.0155	allow correct calculation using incorrectly calculated value of moles of H_2SO_4	1	
	(conc KOH = moles KOH x $\frac{1000}{25.0}$) = 0.0155 x $\frac{1000}{25.0}$	allow correct calculation using incorrectly calculated value of moles of KOH	1	
	= 0.62 (mol/dm^3)	allow correct answer using incorrectly calculated value of moles of KOH	1	
	(M_r KOH =) 56		1	
	(conc = M_r x conc in mol/dm^3 = 56 x 0.62) = 34.7 (g/dm^3)	allow 35 or 34.72 (g/dm^3) allow correct answer using incorrectly calculated value of concentration in mol/dm^3 and/or incorrect M_r	1	
	alternative approach for step 1 to step 4 $\frac{2}{1} = \frac{25 \times \text{conc KOH}}{15.5 \times 0.500}$ (2) (conc KOH) = $\frac{2 \times 15.5 \times 0.500}{25.0}$ (1) = 0.62 (mol/dm^3) (1)	allow **1** mark if mole ratio is incorrect		

Total			**14**

Question 6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	any **two** from: • temperature (of solution) • concentration of electrolyte / solution • compound / ions in electrolyte / solution	ignore room temperature allow volume of electrolyte / solution allow size of electrode allow distance between electrodes do **not** accept electrode **X** unqualified do **not** accept (measured) voltage	2	AO3 4.5.2.1
06.2	order: (most reactive) magnesium cobalt nickel tin copper (least reactive) silver justification: the higher the (positive) voltage, the more reactive (the metal) silver has a negative voltage because silver is less reactive than copper	allow **1** mark for magnesium, cobalt, nickel, tin in order at top allow **1** mark for copper and silver in order at the bottom allow the most reactive (metal) has the highest voltage	2 1 1	AO3 4.4.1.2 4.5.2.1
06.3	magnesium and tin		1	AO3 4.5.2.1

06.4	(in a fuel cell) hydrogen is oxidised (to produce water) water is produced / released as gas / vapour / steam	allow (in a fuel cell) hydrogen reacts with oxygen (to produce water) if no other mark awarded, allow **1** mark for fuel cells produce water	1 1	AO3 4.5.2.2
Total			**9**	