Section A: Principles of Chemistry

A1 States of Matter

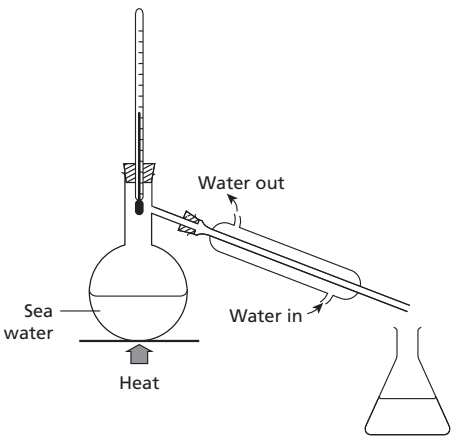
No.	Answers	Further explanations
1	C	
2	D	$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$ The concentrated ammonia solution gives off ammonia gas and the concentrated hydrochloric acid gives off hydrogen chloride gas, shown by the state symbols (g). The particles of both gases diffuse along the tube, collide and react to form a white ring composed of solid white ammonium chloride particles, shown by the state symbol (s).
3	A	Ammonia molecules diffuse faster than hydrogen chloride molecules. Ammonia molecules are smaller and lighter than hydrogen chloride molecules, so they diffuse faster along the tube, and the particles of the two gases collide and react closer to the source of the hydrogen chloride.
4	C	
5	A	Increased in length and become rigid The paw-paw strip is composed of living cells. Each cell is surrounded by a differentially permeable membrane and contains cytoplasm containing about 80% water. By osmosis, water enters each cell causing it to swell slightly. This causes the strip to increase in length and become rigid.
6	B	Moved down The 20% sucrose solution inside the thistle funnel contains more water than the 40% sucrose solution in the beaker. By osmosis, water moves out of the solution in the thistle funnel through the differentially permeable membrane into the solution in the beaker. This decreases the volume of the solution in the thistle funnel which causes the meniscus to move down.

No.	Answers	Further explanations
7	A	I only **I:** Sodium chloride preserves meat by drawing water out of the cells of the meat by osmosis. This prevents decay because there is then no water available in the cells of the meat to enable chemical reactions that cause decay to take place. **II:** Sodium chloride is not toxic to bacteria and fungi. **III:** Sodium chloride inhibits the growth of microorganisms by causing water to leave their cells by osmosis, not enter their cells.
8	D	
9	B	
10	B	Substance II The boiling point of substance II is –10 °C. At room temperature, that is, 25 °C, Substance II would have boiled.
11	C	Substance III A substance composed of slow moving particles would be in the liquid state. The melting point of substance III is –65 °C and its boiling point is 97 °C. At room temperature, that is, 25 °C, substance III would have melted, but not boiled, so would be in a liquid state.
12	A	
13	D	Heating iodine crystals. Iodine crystals sublime directly to a gas when heated without passing through the liquid state, so cannot be boiled since this occurs when a liquid changes to a gas.
14	D	At the surface of a liquid Evaporation can occur at any temperature, not just when the boiling point of the liquid has been reached, and heat does not need to be applied to the liquid for it to occur. It occurs at the surface of a liquid because some of the particles at the surface possess enough kinetic energy to overcome the forces of attraction between them, and so they are able to leave the liquid and become a vapour.
15	B	

No.	Answers	Further explanations
16	C	
17	C	
18	A	Gaining kinetic energy and moving faster. Substance X has finished melting at point T, so as heat continues to be added the particles gain more and more kinetic energy and move faster and faster until substance X starts to boil at point U.

A2 Mixtures and Separations

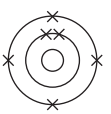
No.	Answers	Further explanations
1	B	
2	A	
3	A	
4	D	
5	D	
6	C	$KClO_3$ At 35 °C, $KClO_3$ is the compound with the lowest mass saturating 100 g of water.
7	D	KNO_3 As the temperature increases, the solubility of KNO_3 increases to the greatest extent.
8	C	21 g One small square on the solubility scale represents a solubility of 2 g per 100 g water and one small square on the temperature scale represents 2 °C. At 64 °C, 26 g $KClO_3$ saturates 100 g of water At 12 °C, 5 g $KClO_3$ saturates 100 g of water ∴ mass of crystals forming = 26 – 5 g = 21 g

No.	Answers	Further explanations
9	B	II and IV only **II:** Since liquid Y is floating above liquid Z, Y must be less dense than Z. **IV:** Since the liquids do not mix they must be immiscible. **I:** From the diagram it cannot be deduced that Y is oil. **III:** From the diagram it cannot be deduced that Y has a lower boiling point than Z.
10	B	
11	A	
12	A	
13	C	 The bulb of the thermometer must be in line with the side arm of the distillation flask to ensure that the temperature of the steam entering the condenser remains at 100 °C. This ensures that the distillate produced is pure water. The water must enter the condenser from the bottom and leave from the top to create a permanently cold surface on which the steam can condense.
14	C	II and III only **II:** Lime is added to neutralise the acidic cane juice which then prevents the sucrose breaking down into glucose and fructose when the juice is heated. **III:** Lime causes impurities to flocculate and precipitate out so they can be removed by filtration. **I:** Lime is alkaline, so cannot make the juice more acidic.

No.	Answers	Further explanations
15	B	Q: Bagasse R: Filtration S: Crystallisation During crushing, the dilute cane juice is squeezed out of the pieces of cane leaving the cane fibre or bagasse behind. After precipitation, the muddy impurities are separated from the cane juice by filtration. After vacuum distillation, the concentrated juice or syrup enters the vacuum pan where sugar crystals form in it by crystallisation.

A3 Atomic Structure

No.	Answers	Further explanations
1	B	The electrons orbiting around the nucleus of an atom make up most of the mass of the atom. The electrons orbiting around the nucleus of an atom contribute very little to the mass of the atom since the mass of each electron is 1/1840 the mass of a proton or a neutron.
2	D	
3	D	
4	B	A chromium atom has 24 protons, 28 neutrons and 24 electrons. The mass number of chromium, $^{52}_{24}Cr$, is 52 and the atomic number is 24. This means that a chromium atom has a total of 52 protons and neutrons, and 24 protons. It therefore has 28 neutrons, that is, 52 – 24, and 24 electrons since the number of electrons is equal to the number of protons.
5	B	31 The mass number of an element is the total number of protons and neutrons in one atom of the element, that is, 15 + 16.

No.	Answers	Further explanations
6	C	II and III only **II:** The mass number of silver, $^{108}_{47}Ag$, is 108. **III:** The atomic number of silver is 47, therefore a silver atom has 47 protons and, since the number of electrons is equal to the number of protons, a silver atom has 47 electrons. **I:** A silver atom has 61 neutrons, that is, 108 – 47, not 47. **IV:** The atomic number of silver is 47, not 61.
7	A	29 An atom of copper has a mass number of 64, therefore has 64 protons and neutrons in total. Since it has 35 neutrons, it must have 29 protons, that is, 64 – 35.
8	A	2,7 A fluorine atom, $^{19}_{9}F$, has an atomic number of 9. It therefore has 9 protons, so it must have 9 electrons. 2 electrons go into the first shell which leaves 7 electrons to go into the second shell.
9	D	 Because the atom has an atomic number of 6, it has 6 protons, therefore 6 electrons. 2 electrons go into the first shell which leaves 4 electrons to go into the second shell. The electrons in the second shell are shown singly and not paired since the shell contains fewer than 5 electrons.
10	C	The chemical properties of Z are very similar to those of aluminium, $^{27}_{13}Al$. Element Z has 11 electrons, therefore 11 protons and, since it has 12 neutrons, it has a mass number of 23. The chemical properties of an element are mainly determined by the number of valence electrons it has. Aluminium, $^{27}_{13}Al$, has 13 protons, therefore 13 electrons with a configuration of 2,8,3. Aluminium has 3 valence electrons and Z has 1 valence electron, so their chemical properties are not very similar.
11	A	

No.	Answers	Further explanations
12	B	Chemical properties The chemical properties of an element are determined by the number and arrangement of electrons in its atoms. Isotopes of an element have the same number of electrons, so have the same electronic configuration which gives them the same chemical properties.
13	C	${}^{y}_{x}R$ and ${}^{y+2}_{x}R$ Isotopes have the same atomic number, x, but different mass numbers, y and y + 2.
14	A	24.1 Average mass number of T $= \left\{\frac{90}{100} \times 24\right\} + \left\{\frac{10}{100} \times 25\right\}$ $= 24.1$
15	D	
16	D	

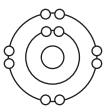
A4 Periodic Table and Periodicity

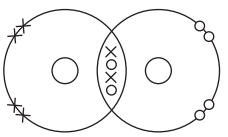
No.	Answers	Further explanations
1	C	
2	B	
3	C	II and III only **II** and **III:** The modern periodic table organises elements into groups and periods on the basis of their chemical properties and on the basis of the electronic configuration of their atoms. **I:** The modern periodic table organises elements on the basis of their increasing atomic number, not their increasing relative atomic mass.
4	D	
5	A	

No.	Answers	Further explanations
6	C	
7	A	5 occupied electron shells and 4 valence electrons The period number and the number of occupied electron shells in an atom are the same, that is, 5. The group number and number of valence electrons are the same, that is, 4.
8	B	Be a non-metal The element would have 7 protons, therefore 7 electrons with an electronic configuration of 2,5. The element has 5 valence electrons so would be in Group V of the periodic table making it a non-metal.
9	C	Elements with atomic numbers of 11, 14 and 17. Element I has 11 electrons with a configuration of 2,8,1. Element II has 14 electrons with a configuration of 2,8,4. Element III has 17 electrons with a configuration of 2,8,7. All three elements have 3 occupied electron shells placing them all in Period 3.
10	D	I, II and III **I:** Element Z has 2 valence electrons, so is in Group II. **II:** Element Z has 1 more electron shell than magnesium which has an electronic configuration of 2,8,2, so ionises more readily than magnesium making it more reactive than magnesium. **III:** All elements in Group II react with hydrochloric acid.
11	D	Strontium Calcium, strontium and barium are all in Group II so have similar chemical properties. Calcium is above strontium in the group, and strontium is above barium. Strontium is, therefore, closer to calcium in the group, so is closer to calcium in its reactivity.
12	A	
13	D	Colourless to brown Chlorine is more reactive than iodine, so would displace the iodide ions from the colourless potassium iodide solution producing iodine which would dissolve forming a brown solution.

No.	Answers	Further explanations
14	C	X is more reactive than Y The ease of ionisation decreases going down Group VII as the atomic radius increases, therefore the reactivity of elements decreases going down the group. X is below Y, so is less reactive than Y, not more reactive.
15	B	X ionises more readily than Z The atomic radius decreases moving from left to right across Period 3, so X has a smaller atomic radius than Z. Since Z and X are both non-metals that ionise by gaining electrons into their valence shell, X, being smaller, would gain valence electrons more readily than Z.
16	A	R is more reactive than T R and T are in the same period. The atomic radius decreases moving from left to right across the period, therefore R in Group I has a larger radius than T in Group II. Since R and T are in Groups I and II respectively, they are both metals, so they ionise by losing electrons. R, having a larger radius than T, ionises more readily making it more reactive than T.

A5 Structure and Bonding

No.	Answers	Further explanations
1	B	
2	A	23 An Fe atom has an atomic number of 26, so it has 26 protons. An Fe^{3+} ion has the same number of protons as the atom, 26, but since it has a charge of 3+ it has 3 more protons than electrons. An Fe^{3+} ion therefore has 23 electrons.
3	C	 Fluorine has 9 protons, therefore 9 electrons with a configuration of 2,7. Fluorine ionises by gaining 1 electron, giving a fluoride ion an electronic configuration of 2,8.

No.	Answers	Further explanations
4	A	Bond to form an ionic compound The element with atomic number 12 has 12 protons, therefore 12 electrons with a configuration of 2,8,2. The element is in Group II so is a metal. The element with atomic number 17 has 17 protons, therefore 17 electrons with a configuration of 2,8,7. The element is in Group VII so is a non-metal. When a metal bonds with a non-metal, an ionic compound is formed.
5	D	R_3T_2 R has 2 valence electrons, so has a valency of 2. T has 5 valence electrons, so has a valency of 3. Swapping valencies gives a formula of R_3T_2.
6	D	
7	B	 An oxygen atom has an atomic number of 8, therefore has 8 protons and 8 electrons with a configuration of 2,6. Each oxygen atom needs 2 electrons to fill its valence shell, so 2 oxygen atoms share 2 pairs of electrons between them. The other 4 valence electrons of each atom remain in pairs, with the pairs equally spaced around the valence shells.
8	C	An anion Particle Q has 2 more electrons than protons giving it a negative charge.
9	A	DE_3 Element D is in Group III, so has a valency of 3. Element E is in Group VII, so has a valency of 1. Swapping valencies gives a formula of DE_3.
10	B	
11	B	I and IV Atom I has 4 valence electrons so is a non-metal. Atom IV has 6 valence electrons so is also a non-metal. When 2 non-metals bond they do so by sharing electrons to form a covalent compound.

No.	Answers	Further explanations
12	D	II and IV Atom II has 3 valence electrons which it would lose when it ionises forming an ion with an electronic configuration of 2,8. Atom IV has 6 valence electrons, so it would gain 2 electrons when it ionises to form an ion with an electronic configuration of 2,8.
13	D	
14	C	
15	B	P: Na^+ Q: Cl^- R: Na^+ An Na^+ ion must be bonded to a Cl^- ion, and 2 Na^+ ions or 2 Cl^- ions cannot be bonded together. Since Q is bonded to the Na^+ ion, Q must be a Cl^- ion. Since there is 1 ion between the Na^+ ion and P, P must be an Na^+ ion. There is also 1 ion between P and R, so R must also be an Na^+ ion.
16	D	
17	A	
18	D	
19	B	
20	C	

A6 The Mole Concept (1)

No.	Answers	Further explanations
1	A	
2	B	84 Atom X has 3 valence electrons, therefore has a valency of 3. Atom Y has 7 valence electrons, therefore has a valency of 1. Switching valencies, the formula of the compound is XY_3. Relative atomic mass of X = 13 + 14 = 27 Relative atomic mass of Y = 9 + 10 = 19 Relative formula mass of XY_3 = 27 + (3 × 19) = 84
3	D	149 g mol^{-1} Molar mass of $(NH_4)_3PO_4$ = (3 × 14) + (12 × 1) + 31 + (4 × 16) g mol^{-1} = 149 g mol^{-1}
4	B	0.3 mol Mass of 1 mol Na_2CO_3 = (2 × 23) + 12 + (3 × 16) g = 106 g ∴ number of moles in 31.8 g = $\frac{31.8}{106}$ mol = 0.3 mol
5	B	I and III only Avogadro's constant = 6.0×10^{23}, and 1 mol of any substance contains 6.0×10^{23} particles of the substance. **I:** Mass of 1 mol Mg = 24 g ∴ 24 g Mg is equivalent to 1 mol which contains 6.0×10^{23} Mg atoms **III:** Mass of 1 mol $CuSO_4$ = 64 + 32 + (4 × 16) g = 160 g ∴ 160 g $CuSO_4$ is equivalent to 1 mol which contains 6.0×10^{23} $CuSO_4$ formula units **II:** Mass of 1 mol N_2 = 2 × 14 g = 28 g ∴ 14 g N_2 is equivalent to 0.5 mol which contains 3.0×10^{23} N_2 molecules

No.	Answers	Further explanations
6	C	4.8×10^{22} aluminium ions 1 mol Al_2O_3 contains 6.0×10^{23} Al_2O_3 formula units $\therefore$ 0.04 mol Al_2O_3 contains $0.04 \times 6.0 \times 10^{23}$ Al_2O_3 formula units $= 2.4 \times 10^{22}$ Al_2O_3 formula units 1 Al_2O_3 formula unit contains 2 Al^{3+} ions $\therefore$ 2.4×10^{22} Al_2O_3 formula units contain $2 \times 2.4 \times 10^{22}$ Al^{3+} ions $= 4.8 \times 10^{22}$ Al^{3+} ions
7	C	17g of ammonia 12 g of carbon-12 is equivalent to 1 mol which contains 6.0×10^{23} atoms **C:** Mass of 1 mol NH_3 = 17 g $\therefore$ 17 g NH_3 contains 6.0×10^{23} NH_3 molecules 1 NH_3 molecule contains 4 atoms $\therefore$ 6.0×10^{23} NH_3 molecules contain $4 \times 6.0 \times 10^{23}$ atoms $= 2.4 \times 10^{24}$ atoms **A:** Mass of 1 mol H_2 = 2 g $\therefore$ 1 g H_2 is equivalent to 0.5 mol which contains 3.0×10^{23} H_2 molecules 1 H_2 molecule contains 2 atoms $\therefore$ 3.0×10^{23} H_2 molecules contain $2 \times 3.0 \times 10^{23}$ atoms $= 6.0 \times 10^{23}$ atoms **B:** 56 g Fe is equivalent to 1 mol which contains 6.0×10^{23} Fe atoms **D:** 20 g Ne is equivalent to 1 mol which contains 6.0×10^{23} Ne atoms
8	D	6.0 dm^3 Volume of 1 mol SO_2 at rtp = 24 dm^3 $\therefore$ volume occupied by 0.25 mol = 0.25×24 dm^3 = 6.0 dm^3

No.	Answers	Further explanations
9	C	0.48 g Volume of 1 mol O_2 at stp = 22 400 cm^3 $\therefore$ number of moles in 336 cm^3 = $\frac{336}{22\,400}$ mol = 0.015 mol Mass of 1 mol O_2 = 2 × 16 g = 32 g $\therefore$ mass of 0.015 mol O_2 = 0.015 × 32 g = 0.48 g
10	A	Contains the same number of molecules as 2.1 g of nitrogen Mass of 1 mol CO_2 = 12 + (2 × 16) g = 44 g $\therefore$ number of moles in 3.3 g = $\frac{3.3}{44}$ mol = 0.075 mol Mass of 1 mol N_2 = 2 × 14 g = 28 g $\therefore$ number of moles in 2.1 g = $\frac{2.1}{28}$ mol = 0.075 mol Since 1 mol of all substances contain the same number of particles of the substance, 0.075 mol of both CO_2 and N_2 contain the same number of molecules.
11	A	$FeSO_4.7H_2O$ Mass of 1 mol $FeSO_4$ = 152 g $\therefore$ number of moles in 15.2 g = $\frac{15.2}{152}$ mol = 0.1 mol Mass of 1 mol H_2O = (2 × 1) + 16 g = 18 g $\therefore$ number of moles in 12.6 g = $\frac{12.6}{18}$ mol = 0.7 mol The sample of hydrated iron(II) sulfate is composed of 0.1 mol $FeSO_4$ and 0.7 mol H_2O $\therefore$ mole ratio of $FeSO_4$ to H_2O = 1 mol $FeSO_4$: 7 mol H_2O
12	C	W_3Z Number of moles of element W = $\frac{41.55}{23}$ mol = 1.8 mol Number of moles of element Z = $\frac{8.45}{14}$ mol = 0.6 mol Simplest mole ratio = 3 mol W : 1 mol Z Empirical formula = W_3Z

No.	Answers	Further explanations
13	A	NH_4NO_3 **A:** Mass of 1 mol NH_4NO_3 = 14 + (4 × 1) + 14 + (3 × 16) g = 80 g Mass of N in 1 mol NH_4NO_3 = 2 × 14 g = 28 g Proportion by mass of N = 28 : 80 = 0.35 : 1 **B:** Mass of 1 mol $(NH_4)_2SO_4$ = (2 × 14) + (8 × 1) + 32 + (4 × 16) g = 132 g Mass of N in 1 mol $(NH_4)_2SO_4$ = 2 × 14 g = 28 g Proportion by mass of N = 28 : 132 = 0.21 : 1 **C:** Mass of 1 mol $(NH_4)_3PO_4$ = (3 × 14) + (12 × 1) + 31 + (4 × 16) g = 149 g Mass of N in 1 mol$(NH_4)_3PO_4$ = 3 × 14 g = 42 g Proportion by mass of N = 42 : 149 = 0.28 : 1 **D:** Mass of 1 mol $Al(NO_3)_3$ = 27 + (3 × 14) + (9 × 16) g = 213 g Mass of N in 1 mol $Al(NO_3)_3$ = 3 × 14 g = 42 g Proportion by mass of N = 42 : 213 = 0.20 : 1

A7 The Mole Concept (2)

No.	Answers	Further explanations
1	D	
2	A	
3	B	$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$ The Cu^{2+} and the OH^- ions are the ones that take part in the reaction. They react to form an insoluble precipitate of copper(II) hydroxide. The NO_3^- and the Na^+ ions are the spectator ions which remain unchanged in the solution.

No.	Answers	Further explanations
4	C	55.6 g Mass of 1 mol NaCl = 23 + 35.5 g = 58.5 g $\therefore$ number of moles in 23.4 g = $\frac{23.4}{58.5}$ mol = 0.4 mol 2 mol NaCl produce 1 mol $PbCl_2$ $\therefore$ 0.4 mol NaCl produces 0.2 mol $PbCl_2$ Mass of 1 mol $PbCl_2$ = 207 + (2 × 35.5) g = 278 g $\therefore$ mass of 0.2 mol = 0.2 × 278 g = 55.6 g
5	D	3.6 dm^3 Mass of 1 mol CaO = 40 + 16 g = 56 g $\therefore$ number of moles in 4.2 g = $\frac{4.2}{56}$ mol = 0.075 mol 1 mol CaO produces 2 mol NH_3 $\therefore$ 0.075 mol CaO produces 0.15 mol NH_3 Volume of 1 mol NH_3 at rtp = 24 dm^3 $\therefore$ volume of 0.15 mol = 0.15 × 24 dm^3 = 3.6 dm^3
6	C	560 cm^3 Mass of 1 mol H^+ ions = 1 g Number of moles in 0.05 g = 0.05 mol 2 mol H^+ ions produce 1 mol H_2 $\therefore$ 0.05 mol H^+ ions produce 0.025 mol H_2 Volume of 1 mol H_2 at stp = 22 400 cm^3 $\therefore$ volume of 0.025 mol H_2 = 0.025 × 22 400 cm^3 = 560 cm^3
7	C	

No.	Answers	Further explanations
8	D	38.0 g dm^{-3} 250 cm^3 $MgCl_2$(aq) contains 0.1 mol $MgCl_2$ $\therefore$ 1000 cm^3 $MgCl_2$(aq) contains $\frac{0.1}{250} \times 1000$ mol $MgCl_2$ $= 0.4$ mol $MgCl_2$ Mass of 1 mol $MgCl_2 = 24 + (2 \times 35.5)$ g = 95 g $\therefore$ mass of 0.4 mol $MgCl_2 = 0.4 \times 95$ g = 38.0 g Molar concentration of the solution = 38.0 g dm^{-3}
9	B	3.2 g 1000 cm^3 NaOH(aq) contains 0.4 mol NaOH $\therefore$ 200 cm^3 NaOH(aq) contains $\frac{0.4}{1000} \times 200$ mol NaOH $= 0.08$ mol NaOH Mass of 1 mol NaOH = 23 + 16 + 1 g = 40 g $\therefore$ mass of 0.08 mol = 0.08 × 40 g = 3.2 g
10	A	1.335 g 1000 cm^3 HCl(aq) contains 0.6 mol HCl $\therefore$ 50 cm^3 HCl(aq) contains $\frac{0.6}{1000} \times 50$ mol HCl = 0.03 mol HCl 3 mol HCl form 1 mol $AlCl_3$ $\therefore$ 0.03 mol HCl forms 0.01 mol $AlCl_3$ Mass of 1 mol $AlCl_3 = 27 + (3 \times 35.5)$ g = 133.5 g $\therefore$ mass of 0.01 mol $AlCl_3 = 0.01 \times 133.5$ g = 1.335 g

A8 Acids, Bases and Salts (1)

No.	Answers	Further explanations
1	C	
2	B	
3	D	

No.	Answers	Further explanations
4	A	1 Hydrochloric acid is a strong acid which fully ionises when dissolved in water so it has a very low pH.
5	C	H_2CO_2 H_2CO_2 is the molecular formula of methanoic acid, HCOOH, which ionises to produce 1 H^+ ion per acid molecule when it dissolves in water, that is, it forms two ions, the $HCOO^-$ ion and the H^+ ion.
6	D	
7	A	
8	B	$CO_3^{2-}(aq) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$ The actual reaction occurring is between the CO_3^{2-} ions in the sodium carbonate and the H^+ ions in the hydrochloric acid to form carbon dioxide and water. For the equation to balance, 2 H^+ ions are needed for every 1 CO_3^{2-} ion. The Na^+ and Cl^- ions remain in solution as spectator ions and do not take part in the reaction.
9	B	
10	A	
11	D	Blue Aqueous ammonia is a weak alkali so would have a pH in the region of 9 or 10.
12	D	$Ca(OH)_2(s) + (NH_4)_2SO_4(s) \longrightarrow CaSO_4(s) + 2NH_3(g) + 2H_2O(l)$ The reaction between a base and an ammonium salt produces a salt, ammonia and water. Calcium hydroxide and calcium sulfate are both almost insoluble in water, so neither could be in the aqueous state.
13	A	Aluminium oxide X dissolves in both hydrochloric acid and aqueous sodium hydroxide because it reacts with both to form a soluble salt. X must, therefore, be amphoteric and not basic.
14	C	

A9 Acids, Bases and Salts (2)

No.	Answers	Further explanations
1	A	
2	D	
3	D	
4	C	$NaHPO_4$ Phosphoric acid can form 3 different salts. When 1 H^+ ion in each acid molecule is replaced it forms salts with the $H_2PO_4^-$ ion in them, for example, NaH_2PO_4. When 2 H^+ ions in each acid molecule are replaced it forms salts with the HPO_4^{2-} ion in them, for example, Na_2HPO_4. When all 3 H^+ ions in each acid molecule are replaced it forms salts with the PO_4^{3-} ion in them, for example, Na_3PO_4. The HPO_4^- ion does not exist.
5	C	Magnesium sulfate The method could be used to prepare any soluble salt except a potassium, sodium or ammonium salt. Calcium carbonate is insoluble, so could not be prepared by the method, and the most suitable method to prepare anhydrous aluminium chloride is direct combination, not the method illustrated.
6	A	Calcium nitrate A titration can only be performed using two solutions. When making a salt, one of the two solutions must be an alkali or carbonate solution to supply the cations of the salt. Calcium hydroxide is only very slightly soluble and calcium carbonate is insoluble, so neither could be made into solutions to be used in a titration to supply Ca^{2+} ions. A titration can only be used to make a potassium, sodium or ammonium salt.
7	B	II and III only **II** and **III:** Copper(II) chloride can be prepared by adding copper(II) oxide or copper(II) carbonate to hydrochloric acid since both copper(II) compounds are insoluble and react with the acid. **I** and **IV:** Copper(II) chloride could not be made by adding copper or copper(II) nitrate to hydrochloric acid because neither copper nor copper(II) nitrate reacts with the acid.

No.	Answers	Further explanations
8	B	
9	C	$40\ cm^3$ Equation for making the normal salt: $2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$ [1] Equation for making the acid salt: $NaOH(aq) + H_2SO_4(aq) \longrightarrow NaHSO_4(aq) + H_2O(l)$ or $2NaOH(aq) + 2H_2SO_4(aq) \longrightarrow 2NaHSO_4(aq) + 2H_2O(l)$ [2] Comparing equations [1] and [2], when the same volume of sodium hydroxide solution is used it would require twice the volume of acid to make the acid salt as was required to make the normal salt.
10	C	
11	B	
12	B	$10.4\ cm^3$ The neutralisation point is the point where the two straight lines intersect and 1 small square is equivalent to $0.4\ cm^3$ of hydrochloric acid having been added to the sodium hydroxide solution.
13	D	
14	A	3 mol X : 1 mol Y $1000\ cm^3$ alkali X contains 1.5 mol X $\therefore$ $30\ cm^3$ alkali X contains $\frac{1.5}{1000} \times 30$ mol X = 0.045 mol X $1000\ cm^3$ acid Y contains 1.0 mol Y $\therefore$ $15\ cm^3$ acid Y contains $\frac{1.0}{1000} \times 15$ mol Y = 0.015 mol Y 0.045 mol X neutralises 0.015 mol Y $\therefore$ 3 mol X neutralise 1 mol Y

No.	Answers	Further explanations
15	B	0.25 mol dm^{-3} $2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$ 1000 cm^3 NaOH(aq) contains 0.4 mol NaOH $\therefore$ 25 cm^3 NaOH(aq) contains $\frac{0.4}{1000} \times 25$ mol NaOH = 0.01 mol NaOH 2 mol NaOH neutralise 1 mol H_2SO_4 $\therefore$ 0.01 mol NaOH neutralises 0.005 mol H_2SO_4 20 cm^3 H_2SO_4(aq) contains 0.005 mol H_2SO_4 $\therefore$ 1000 cm^3 H_2SO_4(aq) contains $\frac{0.005}{20} \times 1000$ mol H_2SO_4 $= 0.25$ mol H_2SO_4

A10 Oxidation-reduction Reactions

No.	Answers	Further explanations
1	D	
2	B	
3	A	
4	D	The conversion of sulfur atoms to sulfide ions Reduction is the gain of electrons by an element in its free state or an element in a compound. To convert a sulfur atom, S, to a sulfide ion, S^{2-}, the sulfur atom has to gain 2 electrons.
5	A	I only **I:** The charge on the aluminium ion is 3+ and the oxidation number of a monatomic ion is always the same as the charge on the ion, that is, +3. **II:** The oxidation number of oxygen in hydrogen peroxide, a covalent compound, is –1, not –2. **III:** The oxidation number of magnesium in its free, uncombined state is zero, not +2.

No.	Answers	Further explanations
6	C	+5 (oxidation number of Cl) + 3(oxidation number of O) = –1 (oxidation number of Cl) + 3(–2) = –1 oxidation number of Cl = –1 + 6 = +5
7	C	
8	A	$S(g) + O_2(g) \longrightarrow SO_2(g)$ **A**: When sulfur is converted to sulfur dioxide, its oxidation number increases from 0 to +4. **B**: When sulfur dioxide is converted to sulfur trioxide, the oxidation number of sulfur increases from +4 to +6. **C**: When hydrogen sulfide is converted to sulfur, the oxidation number of sulfur increases from –2 to 0. **D**: When iron(II) sulfide is converted to hydrogen sulfide the oxidation number of sulfur remains as –2.
9	B	
10	A	$KOH(aq) + HCl(aq) \longrightarrow KCl(aq) + H_2O(l)$ There is no change in oxidation number of any of the elements.
11	B	Potassium bromide Oxidation is an increase in oxidation number of an element in its free state or in a compound. The oxidation number of the each Br^- ion in the potassium bromide has increased from –1 to 0.
12	D	

No.	Answers	Further explanations
13	C	II and III only **II:** If a colourless reducing agent is added to acidified potassium dichromate(VI) solution, the solution changes colour from orange to green. **III:** If a colourless reducing agent is added to acidified potassium manganate(VII) solution, the solution changes colour from purple to colourless. **I:** If a colourless reducing agent is added to acidified hydrogen peroxide solution there is no visible colour change, the solution remains colourless.
14	C	
15	D	I, II and III Acidified hydrogen peroxide acts as an oxidising agent unless it is reacting with a stronger oxidising agent than itself, in which case it acts as a reducing agent. **I:** It acts as an oxidising agent when it reacts with potassium iodide, a reducing agent. **II:** It acts as a reducing agent when it reacts with acidified potassium manganate(VII), a stronger oxidising agent than itself. **III:** It acts as an oxidising agent when it reacts with iron(II) sulfate, a reducing agent, and oxidises the green Fe^{2+} ion to the yellow Fe^{3+} ion.
16	C	Sulfuric acid is the oxidising agent. An oxidising agent causes an increase in the oxidation number of an element in its free state or in a compound. The sulfuric acid caused the oxidation number of the magnesium to increase from 0 to +2.

A11 Electrochemistry

No.	Answers	Further explanations
1	B	Y is higher in the electrochemical series than hydrogen. Metal Y reacts with hydrochloric acid, so is able to displace the H^+ ions from the acid; to do this Y must be above hydrogen in the electrochemical series.
2	C	$Mg(s) + Zn(NO_3)_2(aq) \longrightarrow Mg(NO_3)_2(aq) + Zn(s)$ Magnesium is closest to zinc in the electrochemical series, therefore displaces the Zn^{2+} ions in the zinc nitrate solution the least easily.
3	C	
4	A	Aqueous hydrochloric acid Hydrochloric acid is a strong acid which is fully ionised when dissolved in water, so is a strong electrolyte. Ethanoic acid is a weak acid and ammonia is a weak alkali, so both are weak electrolytes. Glucose does not ionise when dissolved in water so its solution is a non-electrolyte.
5	D	
6	B	
7	C	
8	B	
9	D	
10	A	P: Oxygen Q: Hydrogen The ions present in dilute sodium chloride solution are Na^+, Cl^-, H^+ and OH^-. The Cl^- and OH^- move towards P, the anode. The electrolyte is dilute, so the OH^- ions are preferentially discharged because they are lower in the electrochemical series and their discharge forms oxygen. The Na^+ and H^+ ions move towards Q, the cathode. The H^+ ions are discharged because they are lower in the electrochemical series and their discharge forms hydrogen.

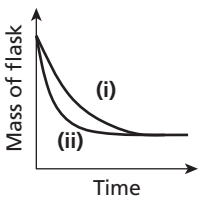
No.	Answers	Further explanations
11	C	II and III only **II:** The copper anode is active therefore it ionises and Cu^{2+} ions enter the electrolyte causing the anode to decrease in size. **III:** Cu^{2+} and H^+ ions move towards the cathode. The Cu^{2+} ions are preferentially discharged because they are lower in the electrochemical series, and their discharge forms pink copper around the cathode. **I:** The electrolyte remains blue, it does not become paler, because the same number of moles of Cu^{2+} ions entering the electrolyte at the anode is discharged at the cathode.
12	B	
13	D	$4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$ Anions are discharged at the anode. The electrolyte contains two types of anion, SO_4^{2-} and OH^-, which both move towards the anode. The OH^- ions are preferentially discharged because they are lower in the electrochemical series.
14	B	$25.0\ cm^3$ Equation for the reaction occurring at the anode, T: $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$ Equation for the reaction occurring at the cathode next to the gas syringe: $2H^+(aq) + 2e^- \longrightarrow H_2(g)$ or $4H^+(aq) + 4e^- \longrightarrow 2H_2(g)$ For every 4 mol of electrons, 1 mol of oxygen and 2 mol of hydrogen are produced. Half the volume of oxygen is produced at the anode, T, compared with the volume of hydrogen produced at the cathode.

No.	Answers	Further explanations
15	B	2.56 g Time current flows = (51 × 60) + 28 s = 3088 s ∴ quantity of electricity flowing = 2.5 × 3088 C = 7720 C $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ 2 mol electrons form 1 mol copper ∴ 2 × 96 500 C form 1 mol copper that is, 193 000 C form 1 mol Cu ∴ 7720 C form $\frac{1}{193\,000} \times 7720$ mol Cu = 0.04 mol Cu Mass of 1 mol Cu = 64 g ∴ mass of 0.04 mol Cu = 0.04 × 64 g = 2.56 g
16	C	28 950 C $Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$ 3 mol electrons forms 1 mol Cr that is, 3 × 96 500 C form 1 mol Cr ∴ 289 500 C form 1 mol Cr and 28 950 C form 0.1 mol Cr
17	A	X^{2+}, Y^+ The ions are discharged at the cathode so must be cations. 96 500 C or 1 mol electrons produced 0.5 mol X ∴ 2 mol electrons produced 1 mol X X must have a charge of 2+ 96 500 C or 1 mol electrons produced 1.0 mol Y ∴ 1 mol electrons produced 1 mol Y Y must have a charge of +
18	D	

No.	Answers	Further explanations
19	B	I and II only **I:** Electrolysis is used to increase the thickness of the aluminium oxide layer on aluminium saucepans which protects them against corrosion. **II:** Electrolysis is used to extract aluminium from its ore, bauxite, since aluminium is fairly high in the electrochemical series. **III:** Electrolysis cannot be used to coat a steel spoon with aluminium because aluminium is above hydrogen in the electrochemical series, so the H^+ ions in the electrolyte would be preferentially discharged at the cathode, not the Al^{3+} ions. Only metals below hydrogen can be used for electroplating.
20	A	

A12 Rates of Reaction

No.	Answers	Further explanations
1	B	I and III only The reaction between calcium carbonate and hydrochloric acid produces calcium chloride, carbon dioxide and water. **I:** Since the carbon dioxide is a gas, it is lost from the reaction vessel causing a decrease in mass over time which can be measured. **III:** If the carbon dioxide is collected in a gas syringe, its increase in volume over time can be measured. **II:** Any decrease in volume of the reactants over time is negligible and cannot be measured.
2	D	
3	C	
4	B	
5	A	
6	D	

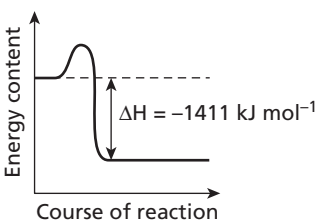
No.	Answers	Further explanations
7	C	
8	C	Finely divided flour particles can ignite spontaneously if temperatures are too high. Flour is flammable and finely divided flour particles have a very large surface area, so temperatures in flour mills must be kept as low as possible so that the flour particles don't spontaneously start to react with the oxygen in the air, resulting in a fire.
9	A	I and III only **I:** When the temperature increases, the particles gain kinetic energy. **III:** As the particles gain kinetic energy their speed of movement increases. **II:** As the particles start to move faster they collide more frequently, not less frequently. **IV:** As the particles gain kinetic energy they collide with more energy, not less energy.
10	A	 The mass of the limiting reactant, magnesium, is unchanged, therefore the overall decrease in mass of the two experiments is the same. Experiment (i) uses magnesium ribbon and experiment (ii) uses magnesium powder which has a larger surface area than the ribbon. Experiment (ii), therefore, occurs at a faster rate than experiment (i), so the gradient of the curve for (ii) is steeper.
11	D	
12	C	Sulfur forms at the same rate. No change is made to the sodium thiosulfate solution nor to the concentration of the hydrochloric acid. As a result, the frequency of collision of the particles does not change, so the rate at which sulfur forms does not change. Increasing the volume of the acid has no effect on the frequency of collision of the particles.

No.	Answers	Further explanations
13	B	
14	B	$2.83\ cm^3\ s^{-1}$ Volume of gas produced after 60 s = $170\ cm^3$ $\therefore$ average rate of reaction in the first minute = $\frac{170}{60}\ cm^3\ s^{-1} = 2.83\ cm^3\ s^{-1}$
15	C	0.02 mol $CaCO_3(g) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$ Total volume of gas produced in the reaction = $240\ cm^3$ Volume of 1 mol CO_2 at rtp = $24\ 000\ cm^3$ $\therefore$ number of moles in $240\ cm^3 = \frac{240}{24\ 000}$ mol = 0.01 mol 2 mol HCl form 1 mol CO_2 $\therefore$ 0.02 mol HCl form 0.01 mol CO_2

A13 Energetics

No.	Answers	Further explanations
1	A	I only **I:** In any chemical reaction, bonds have to break in the reactants and energy is absorbed from the surroundings to break these bonds. **II:** Forming new bonds in the product releases energy to the surroundings, so is an exothermic process, not an endothermic one. **III:** The amount of energy involved in breaking bonds can be more or less than the amount involved in forming bonds in the products.
2	D	
3	B	Photosynthesis During photosynthesis, chlorophyll in the chloroplasts of a green plant absorbs energy from the surroundings of the plant in the form of sunlight energy.

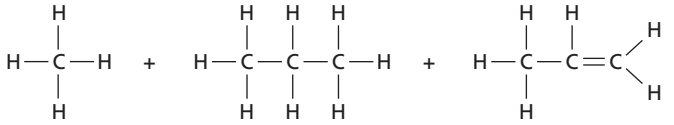
No.	Answers	Further explanations
4	D	The temperature of the reaction decreases ΔH is negative indicating that the reaction is exothermic. An exothermic reaction produces heat energy causing the reaction and its surroundings to become hotter, so its temperature increases, not decreases.
5	A	ΔH is positive The energy profile diagram shows that the reactants have less energy than the products, so the reaction is endothermic and absorbs energy form its surroundings. Its enthalpy change is, therefore, positive.
6	C	
7	A	
8	C	
9	B	I and II only **I:** Since an endothermic reaction absorbs energy from the environment, a calorimeter is used to prevent heat from being absorbed whilst the temperature change is being measured. **II:** When measuring enthalpy change, the reactants are placed in a calorimeter. **III:** An endothermic reaction does not give off heat to the environment, so a calorimeter is not used to prevent heat loss.
10	C	I and III only **I:** When any chemical substance dissolves in water, energy is absorbed to break the intermolecular forces between the water molecules. **III:** When sodium hydroxide dissolves in water, energy is released as the Na^+ and OH^- ions are attracted to the polar water molecules. **II:** The Na^+ and OH^- ions have ionic bonds between them, not intermolecular forces, so energy is not absorbed to break intermolecular forces between ions.

No.	Answers	Further explanations
11	D	It takes more energy to break ionic bonds than intermolecular forces. Heat of solution does not measure the quantity of energy required to break ionic bonds or intermolecular forces only, it measures the energy change occurring when bonds break between the solute particles and between the solvent particles, and bonds form between the solute and solvent particles during solvation.
12	D	$\frac{50 \times 4.2 \times 6.5}{1000}$ kJ Heat change for the reaction = $\frac{\text{mass of solution} \times \text{specific heat capacity} \times \text{temperature change}}{1000}$ kJ It is assumed that the solution has the same density as water, 1 g cm^{-3} $\therefore$ mass of the solution = 25 + 25 g = 50 g
13	C	2 mol sodium hydroxide react with 2 mol nitric acid The equation shows that 57 kJ of energy is released when 1 mol of water is produced in the reaction between 1 mol NaOH and 1 mol HNO_3. Therefore, 114 kJ of energy, that is, 2 × 57 kJ, would be released when 2 mol of water are produced in the reaction between 2 mol NaOH and 2 mol H_2SO_4.
14	B	II and III only The volumes and concentrations of all alkalis and acids in the question are the same, so the number of moles of all alkalis and acids reacting is the same. Sodium hydroxide and potassium hydroxide are strong alkalis, and hydrochloric acid and nitric acid are strong, monobasic acids, so when the same number of moles of either alkali reacts with the same number of moles of either acid, the reactions all produce the same quantity of energy. Ethanoic acid is a weak acid and ammonia solution is a weak alkali, so their reactions do not produce as much energy.
15	B	 ΔH is negative and this indicates that the reaction is exothermic, so the energy content of the reactants is greater than the products. The correct unit for ΔH is kJ mol^{-1}.

Section B: Organic Chemistry

B1 Sources of Hydrocarbon Compounds

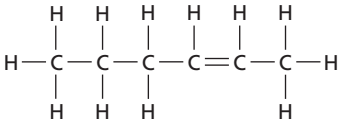
No.	Answers	Further explanations
1	A	
2	D	Boiling points The components of crude oil are separated by fractional distillation in a fractionating tower. The different components condense at different levels within the tower based on their different boiling points.
3	A	
4	B	
5	C	
6	A	
7	C	II and III only **II:** The temperature at the top of a fractionating tower is about 20 °C and the boiling point of X is 10 °C, so it would still be in the gaseous state at the top of the tower. **III:** Having a boiling point of 10 °C suggests that X is composed of very small molecules and having a boiling point of 420 °C suggests that Y is composed of very large molecules. The fractions composed of small molecules are most likely to be used as fuels. **I:** The boiling point of X is lower than the boiling point of Y, so the molecules of X must be smaller than those of Y, not larger.
8	C	
9	B	

No.	Answers	Further explanations
10	D	 CH_4, C_3H_8 and C_3H_6 could not be produced by cracking the hydrocarbon with the formula C_7H_{16} since the products contain a total of 7 carbon atoms and 18 hydrogen atoms, not 7 carbon atoms and 16 hydrogen atoms.

B2 Organic Chemistry – An Introduction

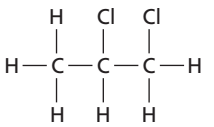
No.	Answers	Further explanations
1	C	
2	B	
3	D	Quadruple bonds between adjacent carbon atoms To form a quadruple bond between adjacent carbon atoms, the adjacent atoms would have to share all four of their valence electrons and neither atom would have any unshared valence electrons to bond with other carbon atoms.
4	A	III only **III:** A homologous series is a group of organic compounds which all possess the same functional group. **I:** The molecular formula of each member of a series differs from the member directly before it or after it by CH_2, so the members cannot have the same molecular formula. **II:** The physical properties of members of a series show a gradual change as the number of carbon atoms increases, so the physical properties are not the same.
5	B	
6	A	
7	A	

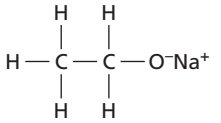
No.	Answers	Further explanations
8	C	Alcohol series Mass of 1 mol C = 12 g $\therefore$ number of moles in 36 g = $\frac{36}{12}$ mol = 3.0 mol Mass of 1 mol H = 1 g $\therefore$ number of moles in 8 g = $\frac{8}{1}$ mol = 8.0 mol Mass of 1 mol O = 16 g $\therefore$ number of moles in 16 g = $\frac{16}{16}$ mol = 1.0 mol The empirical formula of the compound is C_3H_8O. This can be written as C_3H_7OH, therefore it is an alcohol.
9	D	I, II and III **I:** Removing the H atom of the –COOH functional group and including it with the other H atoms in the general formula of an alkanoic acid, $C_nH_{2n+1}COOH$, the general formula could be rewritten as $C_nH_{2n+2}CO_2$. **II:** The general formula of the alkanoic acid series is usually written as $C_nH_{2n+1}COOH$. **III:** Removing the H atom of the –COOH functional group and including it with the other H atoms in the general formula $C_nH_{2n+1}COOH$, and removing the C atom of the functional group and including it with the other C atoms, the general formula could be rewritten as $C_{n+1}H_{2n+2}O_2$.
10	B	
11	D	
12	A	Propanoic acid The total number of carbon atoms in the C_2H_5COOH molecule is 3, therefore when naming the compound the prefix prop- is used.
13	C	
14	D	III and IV Both III and IV have the methyl group attached to carbon atom number 2, so they are both 2-methylpentane.

No.	Answers	Further explanations
15	D	
16	B	
17	C	2,3-dimethylbutane The compound has two methyl groups, one attached to carbon atom number 2 and the other attached to carbon atom number 3, so the name begins with '2,3-dimethyl-'. The longest continuous chain of carbon atoms is 4, so the next part of the name is '-but-'. The general formula of the compound is C_nH_{2n+2}, therefore it belongs to the alkane series, so the name ends with '-ane'.
18	C	 To be drawn correctly, hex-2-ene must have the double bond between carbon atoms 2 and 3, and convention states that the longest continuous chain of carbon atoms must be drawn horizontally.

B3 Reactions of Carbon Compounds (1)

No.	Answers	Further explanations
1	B	
2	C	H_2 Methane and chlorine undergo a slow substitution reaction in dim light during which one hydrogen atom in the methane molecule is replaced by one chlorine atom at a time. Each replaced hydrogen atom bonds with the remaining chlorine atom from each chlorine molecule to form hydrogen chloride and never bonds with another hydrogen atom to form hydrogen.
3	D	

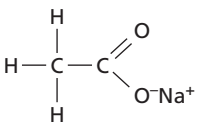
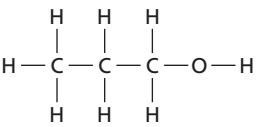
No.	Answers	Further explanations
4	D	C_2H_2 C_2H_2 has the highest ratio of carbon to hydrogen atoms in its molecules, that is, 1 carbon to 1 hydrogen, so not all of the carbon is converted to carbon dioxide and the unreacted carbon remains, giving the flame the smokiest appearance.
5	C	 One of the bonds in the carbon-carbon double bond breaks and one chlorine atom is added to each carbon atom at either side of the original double bond.
6	A	
7	C	
8	B	
9	D	
10	C	
11	B	I and III only **I:** Natural gas has a high heat of combustion, so it releases large amounts of heat energy when burnt. **III:** Natural gas is mainly methane. Its molecules have a low ratio of carbon to other atoms, so it burns with a clean blue flame which does not contain polluting soot. **II:** The fact that natural gas is a fossil fuel does not contribute to it being a good fuel.
12	A	
13	B	

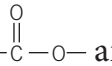
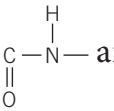
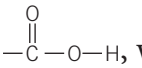
No.	Answers	Further explanations
14	C	 CH_3CH_2OH is ethanol, and when ethanol reacts with sodium, the sodium displaces the hydrogen atom in the –OH group forming sodium ethoxide, which has the formula CH_3CH_2ONa. Sodium ethoxide is ionic, so the structural formula shows the Na^+ ion separately from the ethoxide ion, $CH_3CH_2O^-$, and not bonded to it with a covalent bond.
15	A	Q When ethanol, CH_3CH_2OH, is heated with concentrate sulfuric acid at 170 °C, the ethanol is dehydrated, that is, water is removed from each molecule leaving ethene, C_2H_4. Ethene is an alkene whose molecules each contain a carbon-carbon double bond, so it is an unsaturated compound.
16	A	
17	D	
18	C	Fractional distillation After a week, the fermentation mixture would contain mainly water together with no more than about 14% ethanol, any unfermented glucose and yeast cells, so its boiling point would be slightly above 100 °C, the boiling point of its main component, water. The boiling point of ethanol is 78 °C, and the method used to separate miscible liquids with boiling points that are close together is fractional distillation.
19	B	Aerobic bacteria had entered the mixture and had started to oxidise the ethanol to ethanoic acid If the concentration of ethanol in a mixture is not too high, aerobic bacteria oxidise the ethanol to ethanoic acid which is a weak acid, and weak acids have pH values of 5 or 6.

No.	Answers	Further explanations
20	D	$Mg(s) + 2CH_3COOH(aq) \longrightarrow (CH_3COO)_2Mg(aq) + H_2(g)$ Magnesium reacts with ethanoic acid to produce magnesium ethanoate and hydrogen. The magnesium displaces the hydrogen atom in the functional group of ethanoic acid, so the formula for magnesium ethanoate is most correctly written as $(CH_3COO)_2Mg$. All ethanoates are soluble in water, so magnesium ethanoate is given the state symbol (aq).

B4 Reactions of Carbon Compounds (2)

No.	Answers	Further explanations
1	B	I and II only **I:** When ethanoic acid reacts with ethanol a water molecule is lost, so the reaction is a condensation reaction. **II:** The specific reaction between an alkanoic acid and an alcohol is known as esterification. **III:** The reaction forms two products, not one, so it is not an addition reaction.
2	D	To bring about the reaction The concentrated sulfuric acid acts as a catalyst to speed up the reaction, and it increases the yield of ester by removing the water produced in the reaction which favours the forward reaction. The reaction occurs slowly at room temperature without the sulfuric acid, so it is not needed to bring about the reaction.
3	D	Methyl ethanoate The second part of the molecule comes first in the name. The second part of the molecule, $-OCH_3$, has one carbon atom, so came from the alcohol, methanol, and is called methyl. The first part of the molecule comes second in the name. The first part of the molecule, CH_3CO-, has two carbon atoms, so came from the acid, ethanoic acid, and is called ethanoate.
4	B	$C_2H_5COOC_2H_5$ Propanoic acid has the formula C_2H_5COOH and the part from the acid, C_2H_5CO-, comes first in the formula. Ethanol has the formula C_2H_5OH and the part from the alcohol, $-OC_2H_5$, comes second in the formula.

No.	Answers	Further explanations
5	C	Butanoic acid and methanol Acid hydrolysis produces the alkanoic acid and alcohol from which the ester was formed, and the first part of the ester's name is derived from the alcohol and the second part is derived from the acid. Methyl must have been derived from methanol, and butanoate must have been derived from butanoic acid.
6	A	 and  The ester was formed from ethanoic acid and propanol. Alkaline hydrolysis would form the sodium salt of the acid, sodium ethanoate, CH_3COONa, and propanol, C_3H_7OH. Since sodium ethanoate is ionic, the ethanoate and sodium ions are drawn to show their charges and cannot be shown as if they have a covalent bond between.
7	A	
8	C	The detergent does not form a precipitate in hard water. A soapless detergent does not form a precipitate in hard water so the statement is true, and a soapy detergent does form a precipitate in hard water so the statement is untrue.
9	D	
10	C	
11	B	
12	A	I and III Both compounds undergoing condensation polymerisation must have two functional groups other than carbon-carbon double bonds.
13	C	II and IV only Any compound undergoing addition polymerisation must have a carbon-carbon double bond.
14	C	

No.	Answers	Further explanations
15	C	II and III only **II:** The ester linkage has the formula  and this linkage is present. **III:** The amide linkage has the formula  and this linkage is present. **I:** The hydroxyl functional group has the formula – OH and this group is not present and must not be confused with the carboxyl functional group,  , which is present.
16	B	
17	D	
18	A	

Section C: Inorganic Chemistry

C1 Characteristics of Metals

No.	Answers	Further explanations
1	A	I only **I:** When any metal ionises it does so by losing electrons to form positive cations. **II:** The very unreactive metals do not react with oxygen in the air. **III:** The metal, mercury, is a liquid at room temperature, so not all metals are solid.
2	C	
3	D	Behave as reducing agents When a metal reacts it ionises by losing electrons to the other reactant, thereby causing the other reactant to gain electrons, that is, to be reduced.
4	D	

No.	Answers	Further explanations
5	B	I and II only **I:** Zinc reacts with hydrochloric acid to form the ionic compound, zinc chloride, which contains Zn^{2+} ions. **II:** When heated, zinc reacts with oxygen in the air to form the ionic compound, zinc oxide, which contains Zn^{2+} ions. **III:** Zinc does not react with cold water, it only reacts with steam.
6	A	
7	C	
8	B	
9	B	Metal X: Iron Metal Y: Aluminium Metal Z: Sodium Metal X must form a basic oxide, so could be calcium, iron or magnesium. Metal Y must form an amphoteric oxide, so could be zinc or aluminium. The hydroxide of metal Z must be a hydroxide of sodium or of a metal higher than sodium in the reactivity series, so Z must be potassium or sodium.
10	C	III and IV only **III:** When heated, all nitrates decompose releasing oxygen. **IV:** Since oxygen is released when any nitrate is heated, the mass of the nitrate decreases. **I:** Brown fumes of nitrogen dioxide are only released when the nitrates of calcium and below in the reactivity series are heated, so not all nitrates produce nitrogen dioxide when heated. **II:** Some nitrates and the nitrite or oxide produced when they are heated have the same colour, so some nitrates do not change colour when heated.
11	D	$Na_2CO_3(s) \xrightarrow{heat} Na_2O(s) + CO_2(g)$ Sodium carbonate is stable, so it does not decompose into sodium oxide and carbon dioxide when heated, making this equation incorrect.

C2 Reactivity and Extraction of Metals

No.	Answers	Further explanations
1	B	
2	D	Metal X, magnesium, metal Y, copper Magnesium is above copper in the reactivity series, and metal X must be more reactive than magnesium since magnesium burns easily, but not vigorously, when heated in air. Metal Y must be less reactive than magnesium since it will only burn if heated very strongly. Metal Y must be more reactive than copper since copper does not burn when heated.
3	A	II only **II:** Calcium hydroxide decomposes when heated to form calcium oxide and water in the form of steam. **I:** Potassium nitrate does decompose on heating to form potassium nitrite and oxygen. **II:** Going down the reactivity series of metals, the more readily their carbonates decompose. Magnesium is higher than zinc in the reactivity series, so magnesium carbonate would decompose less readily than zinc carbonate, not more readily.
4	C	U, T, R, S Both T and U are more reactive than R and S because they both react with hydrochloric acid, and R and S do not react. Since a precipitate forms when U is added to an aqueous salt of T, U must displace T from the salt, so U is higher than T in the reactivity series. Since R occurs in nature as compounds and S does not, R must be higher in the series than S.
5	C	

No.	Answers	Further explanations
6	B	Tubes I and IV **Tube I:** Copper is higher than silver in the reactivity series so displaces the silver ions in the silver nitrate solution forming solid silver. **Tube IV:** Iron is higher in the reactivity series than copper so displaces the copper(II) ions in the copper(II) sulfate solution forming solid copper. **Tube II:** Copper is lower than zinc in the reactivity series so does not displace the zinc ions in the zinc sulfate solution. **Tube III:** Iron is lower than magnesium in the reactivity series so does not displace the magnesium ions in the magnesium sulfate solution.
7	A	
8	D	
9	A	
10	C	I and II only Carbon would displace a less reactive metal from its compounds, but not a more reactive metal. **I:** Copper is below zinc in the reactivity series, so would be displaced from its ores by reacting the ores with carbon. **II:** Iron is below zinc in the reactivity series, so would be displaced from its ores by reacting the ores with carbon. **III:** Magnesium is above aluminium in the reactivity series, so would not be displaced from its ores by reacting the ores with carbon.
11	D	
12	A	
13	A	Carbon monoxide Raw materials are the basic materials from which products are made and which have not been processed in any way. Carbon monoxide is produced during the extraction process, so is not a raw material.

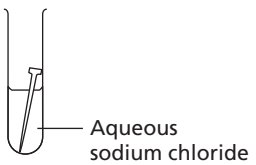
No.	Answers	Further explanations
14	C	
15	B	
16	D	

C3 Uses of Metals

No.	Answers	Further explanations
1	B	I and II only **I:** Wrought iron is almost pure iron, so nearly all of the atoms are of the same size making it malleable and ductile. **II:** Wrought iron is easily welded. **III:** Wrought iron is fairly resistant to corrosion, not extremely resistant.
2	C	
3	B	
4	A	
5	C	I and II only **I:** Because the atoms of the metals used to make alloys are usually of different sizes, the regular packing arrangement of the atoms in alloys is changed. This makes it harder for the atoms to slide over each other and makes the alloy stronger than the pure metals. **II:** When metals are alloyed with each other, the alloy produced is more resistant to corrosion than the pure metals. **III:** Alloying metals does not usually increase their ability to conduct electricity.

No.	Answers	Further explanations
6	B	II only **II:** Lead solder is an alloy of about 60% lead and 40% tin. **I:** Magnalium is an alloy of aluminium and magnesium, not aluminium and copper. **III:** Cast iron contains about 4% carbon whereas high carbon steel contain between about 0.25% and 1.5% carbon, so cast iron has a higher percentage of carbon, not a lower percentage.
7	D	
8	C	
9	A	
10	D	

C4 Impact of Metals on Living Systems and the Environment

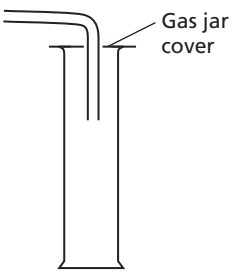
No.	Answers	Further explanations
1	B	 For the iron nail to rust, it must be exposed to both oxygen and water or water vapour. The process is speeded up by the presence of other chemicals, in this case sodium chloride.
2	D	
3	C	
4	B	
5	A	
6	B	
7	D	

No.	Answers	Further explanations
8	C	Planktonic plants ⟶ shrimp ⟶ mackerel ⟶ marlin Mercury becomes higher in concentration moving up a food chain. The lowest concentration given in the table is in planktonic plants, followed by shrimp, followed by mackerel and the highest concentration is in marlin. Since the rooted aquatic plants do not contain any mercury, they are not part of the food chain.
9	A	
10	C	

C5 Non-metals (1)

No.	Answers	Further explanations
1	A	I only **I:** When any non-metal ionises it gains electrons into its valence electron shell forming an anion. **II:** The non-metal, graphite, is a good conductor of electricity, so not all non-metals are poor conductors. **III:** Some non-metals do not react with reactive metals, for example, carbon, so not all non-metals react with reactive metals.
2	C	
3	B	Removes electrons from the metal atoms When a non-metal reacts with a metal, the non-metal atoms ionise by gaining electrons to form anions. The non-metal atoms gain these electrons by removing them from the metal atoms.

No.	Answers	Further explanations
4	A	I and III only **I:** The non-metal, bromine, causes the oxidation number of the I^- ion in the potassium iodide to increase from –1 to 0, therefore is behaving as an oxidising agent. **III:** The non-metal, nitrogen, causes the oxidation number of the magnesium atom to increase from 0 to +2, therefore is behaving as an oxidising agent. **II:** The non-metal, carbon, causes the oxidation number of the carbon atom in the carbon dioxide to decrease from +4 to +2, therefore is behaving as a reducing agent. **IV:** The non-metal, hydrogen, causes the oxidation number of the Pb^{2+} ion in the lead(II) oxide to decrease from +2 to 0, therefore is behaving as a reducing agent.
5	D	Hydrogen, sulfur, carbon, nitrogen Hydrogen, sulfur, carbon and nitrogen all react with oxygen to form non-metal oxides. Oxygen is a powerful oxidising agent, so the other non-metals all behave as reducing agents during the reactions. Chlorine and oxygen act as oxidising agents in all their reactions.
6	A	
7	A	W: Nitric acid X: Magnesium carbonate All the reactions produce carbon dioxide. When nitric acid and magnesium carbonate react they form soluble magnesium nitrate which dissolves. The reaction is rapid and it continues to produce carbon dioxide until the limiting reactant is used up. Sulfuric acid and calcium carbonate react to form insoluble calcium sulfate, and hydrochloric acid and lead(II) carbonate react to form insoluble lead(II) chloride. In both reactions the insoluble salt forms a coating around the carbonate and quickly stops the reaction. When yeast ferments glucose the reaction occurs slowly, so would not be very useful to produce a significant volume of carbon dioxide.

No.	Answers	Further explanations
8	B	I and II only **I and II:** Carbon dioxide does not react with either concentrated sulfuric acid or anhydrous calcium chloride, so both can be used to dry the gas. **III:** Carbon dioxide is an acidic oxide and calcium oxide is a basic oxide, so the carbon dioxide would react with the calcium oxide instead of being dried by it.
9	C	 Carbon dioxide is denser than air so would be collected by upward displacement of air.
10	A	
11	B	
12	C	

C6 Non-metals (2)

No.	Answers	Further explanations
1	D	
2	A	
3	B	
4	C	
5	C	II and III only **II** and **III:** Sulfur dioxide and nitrogen dioxide are acidic oxides, so they react with rainwater to form acidic solutions. **I:** Carbon monoxide is a neutral oxide that does not react with rainwater, so cannot form acid rain.

No.	Answers	Further explanations
6	B	
7	A	
8	C	
9	B	I and II only **I:** Because water has a high heat of vaporisation a lot of heat energy is required to change liquid water to water vapour. When an organism sweats and the water evaporates it removes a lot of heat energy from the organism. **II:** Because water dissolves many substances it can dissolve many harmful substances in the environment and become polluted. **III:** The melting point of water is 0 °C and the boiling point is 100 °C. At temperatures experienced on Earth, most water is in the liquid state, not the gaseous state.
10	D	Water has a maximum density at 4 °C When water is cooled below 4 °C it starts to expand and becomes less dense and this continues until it freezes at 0 °C. As a result, ice at 0 °C floats on the denser warmer water as it forms.
11	C	
12	A	
13	D	$Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$ To soften hard water the Ca^{2+} ions have to be removed. One way is to precipitate them out as insoluble calcium carbonate, and since calcium carbonate is insoluble it must be given the state symbol (s). The correct formulae for sodium zeolite and calcium zeolite are Na_2Z and CaZ respectively, and not NaZ and Ca_2Z.
14	D	
15	B	

C7 Qualitative Analysis

No.	Answers	Further explanations
1	D	R: $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$ S: $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$ A green precipitate of iron(II) hydroxide forms when sodium hydroxide solution is added to a solution containing green Fe^{2+} ions. A red-brown precipitate of iron(III) hydroxide forms when aqueous ammonia, that is, ammonium hydroxide solution, is added to a solution containing yellow Fe^{3+} ions.
2	A	P: Calcium nitrate Q: Lead(II) nitrate On adding sodium hydroxide solution to a solution containing Ca^{2+} ions a precipitate of calcium hydroxide forms which is basic and does not react with excess sodium hydroxide solution, so the precipitate remains in excess. On adding sodium hydroxide solution to a solution containing Pb^{2+} ions a precipitate of lead(II) hydroxide forms which is amphoteric and reacts with excess sodium hydroxide solution to form soluble sodium plumbate, so the precipitate dissolves.
3	C	
4	C	Al^{3+} ion The Al^{3+} ion reacts with aqueous sodium hydroxide to from a white precipitate of aluminium hydroxide which, being amphoteric, reacts with excess aqueous sodium hydroxide, so the precipitate dissolves. The Al^{3+} ion reacts with aqueous ammonia to from a white precipitate of aluminium hydroxide which does not react with excess aqueous ammonia, so the precipitate remains. The Al^{3+} ion does not react with aqueous potassium iodide, so no precipitate forms.
5	D	Ca^{2+} ion The Ca^{2+} ion reacts with aqueous sodium hydroxide to from a white precipitate of calcium hydroxide which, being basic, does not react with excess aqueous sodium hydroxide, so the precipitate remains. The Ca^{2+} ion does not react with aqueous ammonia or aqueous potassium iodide, so no precipitates form.

No.	Answers	Further explanations
6	C	I and II only If no precipitate forms when a few drops of sodium hydroxide solution are added to an ionic solid, and a pungent gas is evolved on warming, the solid possibly contains the NH_4^+ ion and the gas evolved would be ammonia. **I:** Ammonia is an alkaline gas which turns red litmus paper blue. **II:** Ammonia gas reacts with hydrogen chloride gas to form white fumes of ammonium chloride. **III:** Ammonia does not react with acidified potassium dichromate(VI) solution, so the solution would not change colour from orange to green.
7	B	Copper(II) sulfate W must contain the Cu^{2+} ion because, on adding hydrochloric acid, a blue-green solution forms that then reacts with aqueous ammonia to form a blue precipitate which would be copper(II) hydroxide. W must also contain the SO_4^{2-} ion because the SO_4^{2-} ion does not react with hydrochloric acid, so the ion remains when the acid is added and then forms a white precipitate of barium sulfate when a few drops of barium chloride solution are added.
8	D	
9	A	X: Magnesium nitrate Y: Sodium nitrate Nitrates of calcium and below in the reactivity series decompose when heated to form brown nitrogen dioxide gas, and oxygen gas which relights a glowing splint. Nitrates of sodium and above in the reactivity series decompose when heated to form oxygen gas only.

No.	Answers	Further explanations
10	C	II and III only **II:** The Br^- ion reacts with concentrated sulfuric acid to produce red-brown bromine vapour, whereas the I^- ion reacts with concentrated sulfuric acid to form grey-black solid iodine. **III:** The Br^- ion reacts with the Ag^+ ion in the silver nitrate solution to form a cream precipitate of silver bromide, whereas the I^- ion reacts with the Ag^+ ion to form a pale yellow precipitate of silver iodide. **I:** Neither the Br^- ion nor the I^- ion reacts with hydrochloric acid, so there would be no visible change which could be used to distinguish between them.
11	A	Acidified potassium manganate(VII) solution If T contained the sulfite ion, the ion would react with dilute hydrochloric acid to form sulfur dioxide. Sulfur dioxide causes acidified potassium manganate(VII) solution to turn from purple to colourless, so the solution can be used to detect the presence of the gas.
12	A	Sodium chloride The Cl^- ion reacted with the concentrated sulfuric acid to produce hydrogen chloride gas which reacted with the ammonia gas, given off by the drop of concentrated ammonia solution, to form white fumes of ammonium chloride.
13	B	
14	B	M: Hydrogen N: Water vapour Hydrogen reacts explosively with oxygen in the air to form steam or water vapour. The explosion makes the squeaky pop. The water vapour then causes the blue, anhydrous cobalt(II) chloride in the paper to form pink, hydrated cobalt(II) chloride.
15	D	