

Practice Unit Test 1

Section A

- 1 The answer is D. Average mass refers to the relative atomic mass only. The mass is quoted relative to $\frac{1}{12}$ the mass of a carbon atom.
- 2 The answer is A. 'Parts per million' is a measure by mass. 1 dm^3 of water weighs 1000 g. Here, this contains $5.4 \times 10^{-6} \times 1000 \text{ g}$ of Al^{3+} . So there are $5.4 \times 10^3 \text{ g} = 5.4 \text{ mg}$ of Al^{3+} ions in the solution.
- 3 The answer is A.

$$\begin{aligned} \text{amount (moles)} &= \frac{\text{mass}}{\text{molar mass}} \\ &= \frac{10 \text{ g}}{100 \text{ g mol}^{-1}} = 0.1 \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{concentration} &= \frac{\text{moles}}{\text{volume}} \\ &= \frac{0.1 \text{ mol}}{0.250 \text{ dm}^3} = 0.40 \text{ mol dm}^{-3} \end{aligned}$$

- 4 The answer is B.

$$1 \text{ dm}^3 \text{ of gas} = \frac{1}{24} = 0.0417 \text{ mol}$$

butane forms carbon dioxide in a 1:4 molar ratio

$$\text{so amount (moles) of carbon dioxide produced} = 4 \times 0.0417 = 0.167 \text{ mol}$$

$$\text{mass} = \text{moles} \times \text{molar mass} = 0.167 \text{ mol} \times 44.0 \text{ g mol}^{-1} = 7.3 \text{ g}$$

- 5 The answer is A. Atom economy is the number of atoms in the desired product compared with the number of atoms in the starting materials, expressed as a percentage. In this example it is:

$$8 \times \frac{100}{15} = 53.3\%$$

- 6 The answer is C.

molar mass of ethanol = 46.0 g mol^{-1} ; molar mass of ethanoic acid = 60.0 g mol^{-1}

$$\begin{aligned} \text{amount (moles) of ethanol} &= \frac{\text{mass}}{\text{molar mass}} \\ &= \frac{23 \text{ g}}{46.0 \text{ g mol}^{-1}} = 0.50 \text{ mol} \end{aligned}$$

maximum theoretical yield of ethanoic acid = 0.5 mol as the reaction has a 1:1 ratio

$$\begin{aligned} \text{maximum theoretical mass of ethanoic acid} &= \text{moles} \times \text{molar mass} \\ &= 0.5 \text{ mol} \times 60.0 \text{ g mol}^{-1} = 30.0 \text{ g} \end{aligned}$$

$$\begin{aligned} \text{percentage yield} &= \frac{\text{actual yield}}{\text{maximum theoretical yield}} \times 100 \\ &= \frac{16 \text{ g}}{30.0 \text{ g}} \times 100 = 53.3\% \end{aligned}$$

- e The percentage yield is never equal to the actual mass of product $\times 100$ divided by the mass of reactant. In this instance, such a calculation would give the answer 69.6%, i.e. option D.

7 The answer is B.

$$\begin{aligned} \text{amount (moles) of calcium chloride} &= \frac{\text{mass}}{\text{molar mass}} \\ &= \frac{111.1 \text{ g}}{111.1 \text{ g mol}^{-1}} = 1.000 \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{number of formula units} &= \text{moles} \times \text{Avogadro constant} \\ &= 1.000 \times 6.02 \times 10^{23} = 6.02 \times 10^{23} \end{aligned}$$

$$\text{number of ions} = 3 \times 6.02 \times 10^{23} = 1.81 \times 10^{24}$$

- e Do not forget that calcium chloride has three ions per formula, one Ca^{2+} and two Cl^- .

8 The answer is B.

$$20 \text{ nmol of steroid per dm}^3 = 2.0 \text{ nmol of steroid per } 100 \text{ cm}^3 = 2.0 \times 10^{-9} \text{ mol per } 100 \text{ cm}^3$$

(1 nmol = 10^{-9} mol)

$$\text{number of molecules} = \text{moles} \times \text{Avogadro constant} = 2.0 \times 10^{-9} \times 6.02 \times 10^{23} = 1.204 \times 10^{15}$$

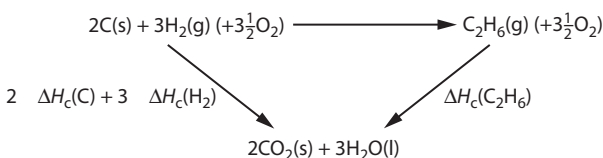
9 The answer is B.

$$\begin{aligned} \Delta H_r &= \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants}) \\ &= 2 \times -395 - (2 \times -297 + 0) = -196 \text{ kJ mol}^{-1} \end{aligned}$$

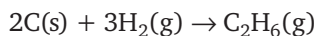
- 10 The answer is B. You cannot use 'products – reactants' here because you are not given enthalpy of formation data. The question has to be solved using a Hess's law cycle (direct ΔH = sum of indirect ΔH values).

The direct route is: elements \rightarrow ethane.

The indirect route is: elements (and oxygen) \rightarrow combustion products \rightarrow ethane (and oxygen):



The equation is:



$$\begin{aligned} \text{so, } \Delta H_f(\text{C}_2\text{H}_6) &= 2 \times \Delta H_c(\text{C}) + 3 \times \Delta H_c(\text{H}) - \Delta H_c(\text{C}_2\text{H}_6) \\ &= (2 \times -395) + (3 \times -286) - (-1560) = -88 \text{ kJ mol}^{-1} \end{aligned}$$

- 11 The answer is A. Beware! ΔH_f is for the formation of 1 mol. It is equal to one-half of ΔH_r because the equation has 2 moles of ammonia, NH_3 , on the right-hand side. ΔH_r is found from bond enthalpies. (Remember that bond breaking is endothermic and bond making is exothermic.)

$$\text{bonds broken} = 1 \times \text{N}\equiv\text{N} \text{ and } 3 \times \text{H}-\text{H} = +946 + (3 \times 436) = +2254 \text{ kJ}$$

$$\text{bonds made} = 6 \times \text{N}-\text{H} = 6 \times -391 = -2346 \text{ kJ}$$

$$\Delta H_r = +2254 + (-2346) = -92 \text{ kJ}$$

$$\text{so } \Delta H_f = 0.5 \times -92 = -46 \text{ kJ mol}^{-1}$$



12 The answer is D. The indirect route is:

$$2 \times \text{equation (i)} - \text{equation (ii)}$$

$$\text{so the enthalpy change} = 2 \times (-y) - (-z) = z - 2y$$

- e Since the equation relates to the decomposition of NaHCO_3 , the NaHCO_3 is on the left-hand side. Therefore, equation 1 must be in the direction given in the data. Na_2CO_3 is on the right-hand side, so you must reverse equation 2.

13 The answer is C.

$$\Delta T = 18.7 - 22.4 = -3.7^\circ\text{C}$$

$$\text{heat change, } Q = \text{mass} \times \text{specific heat capacity} \times \Delta T$$

$$= 100 \text{ g} \times 4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1} \times 3.7 = 1546.6 \text{ J} = 1550 \text{ J (3 s.f.)}$$

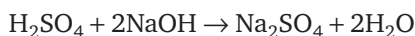
- e You must use the mass of the water being heated, *not* the mass of the solute. The latter gives option A as the answer.
- 14 The answer is A. A thermometer reading that is always 2° too high gives readings for both the starting and the final temperatures that are 2° too high. This has no effect on the value of ΔT , and so none on the accuracy of the experiment.
- e The reason that option D is incorrect is that it would result in not all the acid being neutralised, which would affect the value of ΔH .

15 The answer is D. The reaction is exothermic, so the value of ΔH is negative. Options A and C can, therefore, be ignored.

$$\text{amount (moles) of sulfuric acid} = \text{concentration} \times \text{volume in dm}^3$$

$$= 0.500 \text{ mol dm}^{-3} \times 0.025 \text{ dm}^3 = 0.0125 \text{ mol}$$

The data are for the equation:



$$\begin{aligned} \text{so } \Delta H \text{ per mole of } \text{H}_2\text{SO}_4 \text{ reacted} &= \frac{\text{-heat produced}}{\text{moles}} \\ &= \frac{-1.46 \text{ kJ}}{0.0125 \text{ mol}} = -116.8 \text{ kJ} \end{aligned}$$

The definition of enthalpy of neutralisation is per mole of water produced *not* per mole of sulfuric acid reacted, so:

$$\text{enthalpy of neutralisation} = \frac{1}{2} \times -116.8 = -58.4 \text{ kJ mol}^{-1}$$

- 16 The answer is C. When determining the significant figures for numbers less than 1, the zero in front of the decimal point and zeros immediately after the decimal point are not counted, whereas zeros at the end of the number are counted. Written in scientific notation, the number is 2.10×10^{-2} , which is clearly to three significant figures.
- 17 The answer is A. Ionisation energy relates to a gaseous atom losing an electron and becoming a positive ion.
- 18 The answer is A. Oxygen has the electronic configuration $1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$. When an O^+ ion is formed the electron in the highest energy level is lost — one of the $2p_x$ electrons.
- 19 The answer is B. The chain is five carbon atoms long, so the stem name is pent-. The highest priority atoms attached to the $\text{C}=\text{C}$ group are the oxygen (atomic number 8) on the left-hand

carbon and the carbon (atomic number 6) on the right-hand carbon of the double bond. These are on opposite sides of the double bond and so the prefix *E* is given to the name.

- 20** The answer is B. A is wrong as there is always restricted rotation about a carbon dioxide bond. C and D are wrong as 2-methylbut-2-ene does not have geometric isomers.
- 21** The answer is C. The peak at 158 is caused by $(^{79}\text{X}-^{79}\text{X})^+$ and that at 162 by $(^{81}\text{X}-^{81}\text{X})^+$. Since there is no peak at 159, there cannot be an ^{80}X isotope ($^{79}\text{X}-^{80}\text{X}$ has a mass of 159). This cuts out options A, B and D. The double intensity of the peak at 160 is caused by the two ways of combining ^{79}X and ^{81}X — $(^{79}\text{X}-^{81}\text{X})^+$ and $(^{81}\text{X}-^{79}\text{X})^+$ (similar to the way that, when tossing two coins, the chances of the head–tail combination is twice as likely as either head–head or tail–tail).
- 22** The answer is B. The compound does not decolorise bromine water, so it cannot be an alkene. Therefore, option B is false and is the correct answer.
- 23 i** The answer is B. There is a big jump after the third ionisation energy when an electron is removed from an inner shell.
- ii** The answer is A. The ionisation energies decrease down a group as the atomic radius increases.
- iii** The answer is C. In a period, there is a general upward trend with a slight dip between the second and third elements. This is because the electron is being removed from a higher-energy *p*-orbital, rather than from an *s*-orbital, as is the case for the second element.

Section B

- 24 a i** Ionisation is achieved by the bombardment of the gaseous substance with a beam of high-energy (fast-moving) electrons ✓.
- ii** The ions formed are then accelerated by an electrical potential ✓.
- iii** They are then deflected by a magnetic field ✓. (Heavier ions are deflected less.)
- b** relative atomic mass = $\frac{(53.94 \times 5.94) + (55.93 \times 91.78) + (56.94 \times 2.28)}{100}$ ✓ = 55.83 ✓
- c** Rock dating ✓ — Use a mass spectrometer to measure the relative amounts of a radioactive isotope and its daughter isotope in the rock sample ✓. Assuming that there is no other source of the daughter element, the age of the rock can be calculated knowing the half-life of the radioactive isotope ✓.
- or
- Carbon-14 dating of organic materials ✓ — the relative amount of carbon-14 to carbon-12 is measured in a mass spectrometer ✓. If the approximate age is known, then the ratio of ^{14}C to ^{12}C when the organic material was grown can be estimated. Knowing the half-life ✓ of carbon-14, the age of the material can be calculated.
- or
- Catching drug cheats ✓ — a sample of the urine of an athlete is separated into component substances and placed in a mass spectrometer. The mass/charge ratio of the molecular ion ✓ is measured and compared with a data base ✓ of known performance-enhancing drugs.

- 25 a The first ionisation energy of an element is the energy required to remove one electron ✓ from each of a mole ✓ of gaseous atoms ✓ of that element.
- b i Sodium has a nuclear charge of +11 and the outer electron is shielded by ten inner electrons. The effective nuclear charge is therefore about +1. In magnesium, the nuclear charge of +12 is also shielded by ten inner electrons, so its effective nuclear charge is about +2 ✓. Also, the atomic radius of a magnesium atom is less than that of a sodium atom ✓. Together these factors result in it being harder to remove an electron from a magnesium atom than from a sodium atom ✓. Therefore, magnesium has a larger first ionisation energy.
- ii Aluminium has the electronic configuration [Ne] 3s² 3p¹ and that of magnesium is [Ne] 3s² ✓. The 3p-electron is at a higher energy level than a 3s-electron and so is slightly easier to remove. In addition, the 3s-electrons partially shield the 3p-electron ✓.

Element	Divide by r.a.m. ✓	Divide by smallest
Sodium	36.5/23.0 = 1.59	1.59/0.79 = 2.0
Sulfur	25.4/32.1 = 0.79	0.79/0.79 = 1
Oxygen	38.1/16.0 = 2.38	2.38/0.79 = 3.0

c The empirical formula is Na₂SO₃ ✓.

- e Make sure that you show all your working. The working for the second step (dividing by the smallest) is often omitted by candidates.

26 a i Free-radical substitution ✓

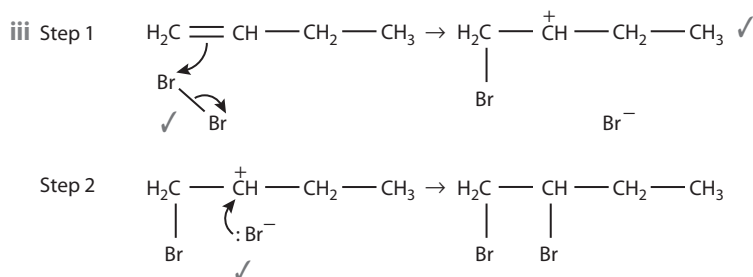
ii Electrophilic addition ✓

- e The equations are CH₃CH₃ + Cl₂ → CH₃CH₂Cl + HCl (substitution) and CH₂=CH₂ + Cl₂ → CH₂ClCH₂Cl (addition).

b i A homologous series is a series of compounds that all have the same general formula ✓. Each one differs from the next by CH₂ ✓ and either they have similar chemical properties or they show a trend in physical properties ✓.

ii CH₂=CHCH₂CH₃ + Br₂ → CH₂BrCHBrCH₂CH₃ ✓

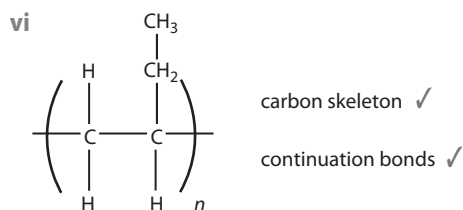
- e Do not use the 'added-up' formulae C₄H₈ and C₄H₈Br₂ as they are not specific.



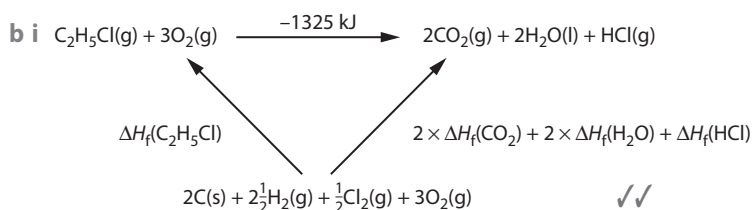
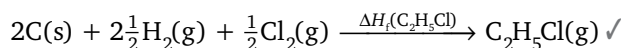
iv 1-bromobutan-2-ol/CH₃BrCH(OH)CH₂CH₃

v The purple ✓ potassium manganate(VII) solution turns to a brown precipitate ✓. The organic product is CH₂OHCH(OH)CH₂CH₃/butan-1,2-diol ✓.

- e Don't give the name *and* the formula in case one is wrong. +1 and -1 score 0.



- 27 a The standard enthalpy of formation, ΔH_f^\ominus , is the enthalpy change when 1 mol ✓ of a substance is formed from its elements ✓ in their standard states under standard conditions of 1 atm pressure and a stated temperature (usually 298 K) ✓.



- e The formulae in the Hess's law cycle are awarded 1 mark. Labelling with arrows in the correct directions gains the second mark. Make sure that you label the Hess's law diagram either with symbols or ΔH values.

Note that when chloroalkanes burn, hydrogen chloride gas is one of the products.

- ii $\Delta H_f(\text{C}_2\text{H}_5\text{Cl}) + (-1325) = [2 \times \Delta H_f(\text{CO}_2)] + [2 \times \Delta H_f(\text{H}_2\text{O})] + \Delta H_f(\text{HCl}) \checkmark$

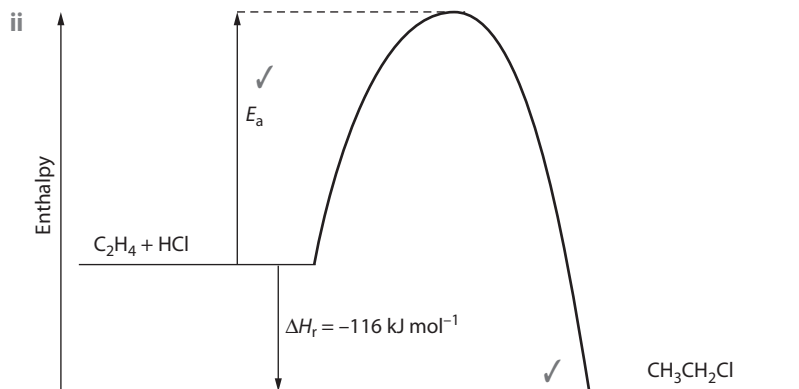
$$\Delta H_f(\text{C}_2\text{H}_5\text{Cl}) = [2 \times (-394)] + [2 \times (-286)] + (-92.3) + 1325 = -127.3 \text{ kJ mol}^{-1} \checkmark$$

c i

Bonds broken/kJ mol ⁻¹		Bonds made/kJ mol ⁻¹	
C=C	+612	C-C	-347
H-Cl	+432	C-H	-467
		C-Cl	-346
Total	+1044 ✓	Total	-1160 kJ ✓

$$\Delta H_r = +1044 - 1160 = -116 \text{ kJ mol}^{-1} \checkmark$$

- e Remember that bond breaking is always endothermic (+) and bond making is always exothermic (-). Another way of doing this calculation is to break all the bonds in the reactants. Broken 4 × C-H, 1 × C=C and 1 × H-Cl; made 5 × C-H, 1 × C-C and 1 × C-Cl.



- e 1 mark is for showing the energy level of products as lower than the energy level of reactants and for labelling ΔH_r . The hump with activation energy shown gains a second mark.



iii The bond enthalpies used in the calculation are the average of the enthalpies of the bonds in a range of different compounds ✓.

e The C–Cl bond enthalpy in C_2H_5Cl is slightly different from the C–Cl bond enthalpy in CH_3Cl .



e For parts (i) and (ii), there is 1 mark for both electronic configurations being correct and 1 mark for both charges being correct.

b i The difference between the two values in magnesium iodide is 383 kJ. For magnesium fluoride, it is 44 kJ. The iodide ion has the same charge as the fluoride ion (1–) but it has a much bigger radius ✓. This means that the anion is much more polarised ✓ by the Mg^{2+} ion, so magnesium iodide has more covalent character ✓ than magnesium fluoride. This causes its lattice energy obtained from the Born–Haber cycle to have a higher value than the theoretical value calculated on the basis of the compound being wholly ionic.

e The marks are for:

- size and charge of anions
- a comparison of polarisation of the anions
- comparison of covalent character

Do not confuse ions with atoms. This is a common error. To score the first mark, you must either state that the charges on the two anions are the same or give the charge. Do not say that magnesium iodide is covalent — say that it has ‘some covalent character’.

ii The main factors that determine lattice energy are ionic radius and charge. Calcium and magnesium ions are both 2+, but calcium ions have a smaller radius ✓ than magnesium ions and are, therefore, more strongly attracted ✓ to the fluoride ions. This means that the lattice energy of magnesium fluoride is more exothermic than that of calcium fluoride.