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| **UNIT 3**  **AMOUNT OF SUBSTANCE AND MEASUREMENT**  **Answers** |

***Lesson 1 – Why are practicals important?***

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| https://image.freepik.com/free-icon/think-symbol-of-a-head-from-side-view-with-brain-shape-inside_318-61572.jpg **Activity 1.1: Understand risks and safety precautions in the laboratory** |
| Students should simply be encouraged to take time to discuss and present any of the laboratory safety precautions from the list above. It may be necessary to distribute colouring pencils and /or pens in order to motivate students to make an effort with their poster. The best posters should be displayed in the laboratory. |

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| **Summary Activity 1.2: units of temperature** |
| * Kelvin, degrees celsius (and degrees Farenheit) * 298 K, 373 K, 0 K * 72 oC, 327 oC, -173 oC |

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| Image result for test icon**Test your knowledge 1.3: Interconverting important units in Chemistry** |
| 1. (i) 25000 g; (ii) 3200 g; (iii) 340 g 2. (i) 2.5 x 10-5 m3; (ii) 3.2 x 10-3 m3; (iii) 3.4 x 10-4 m3, (d) 1.5 x 10-4 m3, (e) 0.12 m3 3. (i) 250 dm3; (ii) 3200 dm3; (iii) 0.025 dm3; (iv) 0.15 dm3; (v) 6.2 x 10-3 dm3 4. (i) 2.5 x 105 cm3, (b) 3.2 x 106 cm3, (c) 400 cm3, (d) 15 cm3, (e) 6200 cm3 |

***Lesson 2 – What is a base quantity and what is a derived quantity?***

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| Image result for test icon**Test your knowledge 2.1: Using base and derived quantities** |
| 1. Force (= mass x acceleration) kgms-2 2. Work done (= pressure x volume) kgm2s-2 3. Power (= voltage x current) kgm2s-3 4. Momentum (= mass x velocity) kgms-1 5. Rate of reaction (= concentration / time) molm-3s-1 |

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| Image result for test icon**Test your knowledge 2.2: Measuring Volumes** |
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***Lesson 3 – What is density and how can we measure it?***

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| cid:ii_jepnvfe00_1621fa54a497745d **Practical 3.1: Compare the densities of pure water and salt water** |
| Equipment needed per group: 100 cm3 measuring cylinder, funnel, access to a mass balance, access to tap water, access to brine (50 cm3 per group)   * Students should get a density close to 1.0 gcm-3 for pure water * The density of brine is close to 1.2 gcm-3; brine is more dense than pure water because the Na+ and Cl- ions occupy the spaces between the water molecules, providing extra mass without using any extra volume |

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| cid:ii_jepnvfe00_1621fa54a497745d **Practical 3.2: Measure the density of sand** |
| Equipment needed per group: 2 x 100 cm3 measuring cylinders, access to a mass balance, access to tap water, access to sand (around 20 g per group), access to a spoon   * students should get a density close to 1.5 gcm-3 * sand must be denser than water because it does not float on water * The error in the measurement of volume is the biggest error, as measuring cylinders are not very accurate |

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| Image result for test icon**Test your knowledge 3.3: Using Avogadro’s number** |
| (a) 0.0042 or 4.2 x 10-3 (b) 1.5 x 1023 (c) 0.05 (d) 1.2 x 1022 (e) 15 |

***Lesson 4 – How can we work out how many moles we have in a sample?***

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| Image result for test icon**Test your knowledge 4.1: Deducing relative molecular masses and relative formula masses** |
| (a) (i) 12.0; (ii) 16.0; (iii) 35.5; (iv) 23.0; (v) 1.0; (vi) 24.3  (b) (i) 32.0; (ii) 44.0; (iii) 71.0; (iv) 36.5; (v) 16.0; (vi) 18.0  (c) (i) 58.5; (iii) 106.0; (iv) 40.3; (v) 95.3; (v) 58.3 |

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| Image result for test icon**Test your knowledge 4.2: Using mass measurements to calculate moles** |
| a) (i) 0.1; (ii) 0.078; (iii) 5450; (iv) 0.16, (v) 0.022  b) (ii) 3.55 g; (ii) 14.9 g; (iii) 5.56 g; (iv) 39900 g or 39.9 kg; (v) 6.85 g  c) (i) 28 g/mol; (ii) 40 g/mol; (iii) 160 g/mol; (iv) 28 g/mol; (v) 249.6 g/mol |

***Lesson 5 – How can we work out how many moles we have in a solution?***

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| Image result for test icon**Test your knowledge 5.1: Using moles, molarity and aqueous volume** |
| 1. (i) 0.0025; (ii) 0.008; (iii) 0.015; (iv) 0.0025; (v) 0.0052 2. (i) 2.5 moldm-3; (ii) 0.4 moldm-3; (iii) 0.12 moldm-3; (iv) 0.1 moldm-3; (v) 2 moldm-3 3. (i) 6.0 moldm-3; (ii) 0.63 moldm-3; (iii) 2.7 moldm-3 (iv) 0.8 moldm-3, (v) 2.9 moldm-3 |

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| Image result for test icon**Test your knowledge 5.2: Preparing Standard Solutions** |
| 1. moles needed = 250/1000 x 0.1 = 0.025; mr = 106 so mass needed = 0.025 x 106 = 2.65 g 2. moles needed = 250/1000 x 0.1 = 0.025; mr = 174 so mass needed = 0.025 x 174 = 4.35 g |

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| cid:ii_jepnvfe00_1621fa54a497745d **Practical 5.3: Prepare 250 cm3 of 0.1 moldm-3 standard solutions of sodium chloride (NaCl) and sugar (C12H22O11)** |
| Equipment needed per group: 250 cm3 beaker, distilled water bottle, spatula, stirring rod, funnel, 250 cm3 volumetric flask, weighing boat, access to 2 dp mass balance, access to NaCl, access fo sugar   * Mass of salt needed = 58.5 x 0.25 x 0.1 = 1.46 g * Mass of sugar needed = 342 x 0.25 x 0.1 = 8.55 g   It ma be advisable to prepare the standard solution of NaCl together, as a class, with the teacher leading from the front showing the key steps, before allowing the students to prepare the sugar solution independently |

***Lesson 6 – How can we prepare standard solutions by diluting concentrated solutions?***

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| cid:ii_jepnweck1_1621fa5f68bdf569 **Demonstration 6.1: Prepare 250 cm3 of a 0.1 moldm-3 standard solution of HCl from a sample of concentrated HCl**  **(CAUTION – concentrated HCl is highly corrosive)** |
| **Equipment needed: concentrated HCl (corrosive); distilled water; one weighing bottle, one larger beaker (250 cm3), one dropping pipette; one mass balance (2dp); one 250 cm3 volumetric flask, one funnel**   1. Weigh out 2.53 g of concentrated HCl (put one of the small beakers onto the bass balance; place some of the concentrated HCl into the other small beaker; use the dropping pipette to add HCl from the stock beaker to the beaker on the mass balance until 2.53 g has been added 2. Add 100 cm3 of water to a beaker, and then add the 2.53 g concentrated HCl and stir 3. Transfer the solution into a volumetric flask and add water until the base of the meniscus lies on the graduated mark on the volumetric flask, shaking well; use washings from the weighing bottle used to weigh the concentrated HCl and the empty beaker used for the initial dilution |

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| cid:ii_jepnvfe00_1621fa54a497745d **Practical 6.2: Prepare 250 cm3 of a 0.1 moldm-3 solution of hydrogen peroxide by diluting a**  **2.0 moldm-3 solution** |
| **Equipment needed per group: around 20 cm3 2.0 moldm-3 H2O2 or closest concentration available; one 25 cm3 measuring cylinder, one dropping pipette, beaker (250 cm3), one 250 cm3 volumetric flask, one funnel**   1. dilution factor = 2/0.1 = 20 so volume needed = 250/20 = 12.5 cm3 2. Use a dropping pipette for the final 2 – 3 cm3 of H2O2 3. Use washings from the measuring cylinder |

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| Image result for test icon**Test your knowledge 6.3: Preparing standard solutions by dilution** |
| 1. Moles needed = 250/1000 x 0.1 = 0.025; mass of pure HNO3 = 0.025 x 63 = 1.58 g; mass of conc. HNO3 = 100/65 x 1.58 = 2.42 g 2. Moles of NaOH = 5/1000 x 6 = 0.03; total volume of diluted solution = 0.03/0.1 = 0.3 dm3 = 300 cm3; So 300 – 5 = 295 cm3 of water must be added |

***Lesson 7 – How can calculate the moles present in a gaseous sample?***

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| **Summary Activity 7.1: The Gas Laws** |
| * Because the particles are far apart and there are no forces between the particles * The typical pressure exerted on the earth’y surface by its atmosphere; 100 kPa (also known as 1 atm) * P1V1/T1 = P2V2/T2 * Boyle’s Law, Charles’ Law and Gay-Lussac’s Law (any two of these can be used to derive the combined gas law) |

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| Image result for test icon**Test your knowledge 7.2: Using Avogadro’s Law** |
| 1. 2.4 dm3, (b) 7.2 dm3, (c) 24 dm3, (d) 0.5, (e) 0.005   Note: it doesn’t matter what the gas is; the gas laws apply equally to all gases |

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| cid:ii_jepnweck1_1621fa5f68bdf569 **Demonstration 7.3: Measure the volume of a gas** |
| Equipment needed: conical flask, bung which fits conical flask and has delivery tube attached, gas syringe connectible to delivery tube (or trough of water and 100 cm3 measuring cylinder), 50 cm3 measuring cylinder, access to mass balance, access to 2.0 moldm-3 HCl and marble chips  Using the measuring cylinder, pour around 50 cm3 of 2.0 moldm-3 HCl into the conical flask; ensure that the delivery tube with the bung is connected to the syringe; add 0.25 g – 0.30 g of marble chips and quickly replace the bung; the plunger in the syringe will move and the volume of gas can be measured (expect 50 – 70 cm3 of gas)  Record the atmospheric temperature and inform the class  Moles of gas = n = PV/RT; Pressure = 100,000 Pa, R = 8.31; T = (eg) 20 oC = 293 K (use class measurement); V = (eg) 65 cm3 = 6.5 x 10-5 m3 (use class measurement); number of moles of gas produced = (100,000 x 6.5 x 10-5)/ (8.31 x 293) = 2.7 x 10-3 moles (this is an example using V = 65 cm3) and T = 20 oC) |

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| Image result for test icon**Test your knowledge 7.4: Using the ideal gas equation** |
| 1. (i) 1.9 mol; (ii) 0.048 mol; (iii) 0.0022 mol; (iv) 4.0 mol; (v) 0.0024 mol 2. (i) 1.2 dm3, (ii) 6.2 dm3, (iii) 9.1 dm3, (iv) 2.5 dm3, (v) 11 dm3 3. (i) 62 g, (ii) 2.1 g, (iii) 0.62 g, (iv) 280 g, (v) 0.11 g |

***Lesson 8 – What is an empirical formula and how is it different from a molecular formula or a unit formula?***

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| **Summary Activity 8.1: Unit formula and molecular formula** |
| * Molecular formula: number of atoms of each element in one molecule: eg C6H12O6 or CO2   Unit formula: simplest ratio of each particle in the compound: eg NaCl, Ca(OH)2 |

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| Image result for test icon**Test Your Knowledge 8.2: Empirical Formulae** |
| 1. ef: 62.08/12:10.34/1:27.58/16 = 5.17:10.34:1.72 = 3:6:1 so ef = C3H6O; efm = 58 and rmm = 58 so n = 58/58 2. ef: 22.02/12:4.59/1:27.73.39/79.9 = 1.84:4.59:0.92 = 2:5:1 so ef = C2H5Br 3. ef: 84.21/12: 15.79/1 = 7.01:15.79 = 1:2.25 = 4:9 so ef = C4H9; efm = 57 and rmm = 114 so n = 114/57 = 2 so mf = C8H18O 4. 7.8 – 0.6 = 7.2 g of C; ef: 72/12:6/1 = 6:6 = 1:1 so ef = CH; efm = 13 and rmm = 78 so n = 78/13 = 6 so mf = C6H6 5. ef: 3.36/55.8:1.44/16 = 0.06:0.09 = 1:1.5 = 2:3 so ef = Fe2O3 6. ef: 48.4/16:24.3/32.1:21.2/14:6/1/1 = 3.03:0.76:1.51:6.1 = 4:1:2:8 so ef = O4SN2H8; unit formula = (NH4)2SO4 |

***Lesson 9 – What are chemical equations and why are they useful?***

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| Image result for test icon**Test your knowledge 9.1: Using equations to calculate numbers of moles** |
| 1. (i) 0.01/2 = 0.005; (ii) 0.01/2 = 0.005 2. (i) 0.5 x 3/2 = 0.75; (ii) 0.5 x 1 = 0.5 3. (i) 0.05/4 = 0.0125; (ii) 0.05/2 = 0.025 |

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| **Online task 9.2: Illustrating the law of conservation of mass** |

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| Image result for test icon**Test your knowledge 9.3: Balancing Chemical Equations** |
| 1. N2 + 3H2 🡪 2NH3 2. 4Na + O2 🡪 2Na2O 3. 2Al + 3Cl2 🡪 2AlCl3 4. CH4 + 2O2 🡪 CO2 + 2H2O 5. 4HCl + O2 🡪 2Cl2 + 2H2O |

***Lesson 10 – How can we use chemical equations to predict reacting quantities?***

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| Image result for test icon**Test your knowledge 10.1: Calculating Reacting Quantities** |
| 1. moles of Mg = 1.94/24.3 = 0.08; moles of HCl = 0.16; volume of HCl = 0.16/0.5 = 0.32 dm3 = 320 cm3 2. moles of H2S = 8.5/34.1 = 0.25; moles of O2 = 0.375;   volume of O2 = 0.375 x 8.31 x 298/100000 = 9.3 x 10-3 m3 = 9.3 dm3   1. moles of K = 7.8/39.1 = 0.2; moles of K2O = 0.1; mass of K2O = 0.1 x 94.2 = 9.4 g 2. moles of NH3 = 10/17 = 0.588; moles of O2 = 0.588 x 5/4 = 0.735;   volume of O2 = 0.735 x 8.31 x 298/100000 = 0.018 m3 = 18 dm3   1. moles of Al = 135/27 = 5; moles of Al2O3 = 2.5; mass of Al2O3 = 2.5 x 102 = 255 g 2. moles of Cl2 = 100000 x 0.0024 /(8.31 x 298) = 0.097; moles of I2 = 0.097; mass of I2 = 0.097 x 253.8 = 25 g 3. moles of CuO = 32/79.5 = 0.4; moles of H2 = 0.4;   volume of H2 = 0.4 x 8.31 x 298 / 1000000 = 10 x 10-3 m3 = 10 dm3   1. moles of KClO3 = 735/122.6 = 6; moles of O2 = 9;   volume of O2 = 9 x 8.31 x 298 / 1000000 = 0.222 m3 = 222 dm3   1. moles of K = 195/39.1 = 5; moles of H2 = 2.5; volume of H2 = 2.5 x 8.31 x 298 / 1000000 = 0.062 m3 = 62 dm3 2. moles of CO2 = 100000 x 0.0012 /(8.31 x 298) = 0.048; moles of CaCO3 = 0.048;   mass of CaCO3 = 0.048 x 100.1 = 4.9 g   1. moles of O2 = 0.006 x 100000 / (8.31 x 298) = 0.24; moles of MgO = 0.48; mass of MgO = 0.48 x 40.3 = 20 g 2. moles of C4H8 = 5.6/56 = 0.1; moles of CO2 = 0.4;   volume of CO2 = 0.4 x 8.31 x 298 / 100000 = 9.9 x 10-3 m3 = 9.9 dm3   1. moles of SO2 = 100000 x 0.48 / (8.31 x 298) = 19.4; moles of CaCO3 = 19.4;   mass of CaCO3 = 19.4 x 100.1 = 1940 g = 19 kg   1. moles of HCl = 0.015 x 0.1 = 0.0015; moles of NaOH = 0.0015;   molarity of NaOH = 0.0015/0.025 = 0.06 moldm-3   1. moles of SiCl4 = 5/170.1 = 0.029; moles of H2O = 0.059; mass of H2O = 0.059 x 18 = 1.06 g 2. moles of PH3 = 200/34 = 5.88; moles of P4 = 5.88; mass of P4 = 5.88 x 124 = 729 g 3. moles of PbO2 = 37/2/239.2 = 0.156; moles of PbCl2 = 0.156; mass of PbCl2 = 0.167 x 278.2 = 43.3 g 4. moles of Cu(NO3)2 = 20/187.5 = 0.107; moles of CuO = 0.107; mass of CuO = 0.107 x 79.5 = 8.5 g 5. moles of NaOH = 0.025 x 0.1 = 0.0025; moles of HCl = 0.0025; molarity of HCl = 0.0025/0.05 = 0.05 moldm-3 6. moles of NaOH = 0.025 x 0.1 = 0.0025; moles of HCl = 0.0025;   molarity of HCl = 0.0025/0.0273 = 0.092 moldm-3 |

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| https://image.freepik.com/free-icon/plus-sign_318-54005.jpg**Extension 10.2: Calculating Reacting Quantities** |
| 1. moles of AgNO3 = 0.015 x 0.02 = 3 x 10-4; moles of NaCl = 3 x 10-4; molarity of NaCl = 3 x 10-4 /0.01 = 0.03 moldm-3; mass concentration = 0.03 x 58.5 = 1.8 gdm-3 2. moles of HxA = 0.025 x 0.1 = 0.0025; moles of NaOH = 0.075 x 0.1 = 0.0075; 1:x = 0.0025:0.0075 so x = 0.0075/0.0025 = 3 3. moles of CaCO3 = 1.3/100.1 = 0.013; moles of HCl = 0.026; molarity of acid = 0.026/0.025 = 1.0 moldm-3 4. moles of CaCO3 = 2.3/100.1 = 0.023; moles of HCl = 0.046; Volume of HCl = 0.046/0.1 = 0.46 dm3 = 460 cm3 5. moles of HCl = 0.0089 x 2 = 0.0178; moles of X2CO3 = 0.0089; Molar mass of X2CO3 = 2.05/0.0089 = 225 so ram of X = (225 – 60)/2 = 82.6 so X = Rb 6. (Moles of Ca(NO3)2 = 10/164.1 = 0.061; moles of NO2 = 0.122; moles of O2 = 0.030; (i) Volume of NO2 = 0.122 x 8.31 x 298/100000 = 3.0 x 10-3 m3 = 3.0 dm3; (ii) volume of O2 = 0.030 x 8.31 x 298/100000 = 7.5 x 10-4 m3 = 0.75 dm3; (iii) Total volume of gas = 3.8 dm3 7. Moles of H2O2 = 0.1 x 0.03 = 0.003 so moles of O2 = 0.003/2 = 0.0015; Volume of O2 = 0.0015 x 8.31 x 298 / 100000 = 3.7 x 10-3 m3 = 37 cm3 8. moles of PbO2 = 37.2/239.2 = 0.156; moles of HCl = 0.311; moles of Cl2 = 0.156; moles of PbCl2 = 0.156; (i) volume of HCl = 0.311/12 = 0.026 dm3 = 26 cm3; (ii) mass of PbCl2 = 278.2 x 0.156 = 43 g; (iii) volume of Cl2 = 0.156 x 8.31 x 298/100000 = 3.9 x 10-3 m3 = 3.9 dm3 9. Moles of H2 = 100 x 10-6 x 100000 /(298 x 8.31) = 0.0040; moles of Mg = 0.0040; moles of HCl = 0.0081; Mass of Mg = 0.04 x 24.3 = 0.098 g; volume of HCl = 0.0081/2 = 0.004 dm3 = 4 cm3 10. Moles of Na = 0.52/23 = 0.023; moles of H2 = 0.011; moles of NaOH = 0.023; (ii) Volume of H2 = 0.011 x 8.31 x 298 / 100000 = 2.8 x 10-4 m3 = 0.28 dm3 = 280 cm3; (ii) Molarity of NaOH = 0.023/0.1 = 0.23 moldm-3 11. Moles of Ti = 2.5/47.9 = 0.0522; moles of Cl2 = PV/RT = (100000 x 0.00194)/(8.31 x 298) = 0.0783; mole ratio Cl2: Ti = 0.0783/0.0522 = 1.5:1 so Ti + 1.5Cl2 🡪 TiCl3 |

###### *Lesson 11 – What have I understood about Amount of Substance and Measurement?*

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| 11.1 END-OF-TOPIC QUIZ  UNIT 3 – AMOUNT OF SUBSTANCE AND MEASUREMENT  Image result for test icon |
| 1. Mass (kg); temperature (K); time (s); amount (mol) 2. Volume (m3, m3); molarity (molm-3, molm-3); pressure (Pa, kgm-1s-2) 3. Temperature – thermometer; time – stopclock; gas volume – gas syringe 4. ef = C2H5; mf = C4H10 5. ef = MgO2H2; mf = Mg(OH)2 6. Mass required = 100/65 x 63 x 0.25 x 0.1 = 2.42 g   Weigh out 2.42 g of the acid and add to 100 cm3 of water in a beaker, stir well, transfer into a volumetric flask, make up to 250 cm3 using washings from beaker   1. Dilution factor = 6/0.5 = 12 so volume needed = 250/12 = 20.8 cm3 2. N2 + 3H2 🡪 2NH3 3. 3 moles of H2 makes 2 moles of NH3 so 0.06 moles of H2 makes 0.04 moles of NH3 4. 1.08 dm3 5. 53.3 cm3 6. 1.49 dm3 |