Chemistry induction tasks 3: Quantitative Chemistry.

Quantitative chemistry is the 'layer' underpinning all experimental chemistry. Without it, other aspects of the subject could never have developed – for instance without quantitative approaches even the simplest formula of a substance would have remained elusive and chemistry would still be the pseudo-science of alchemy!

This induction exercise reviews, reinforces, and introduces new content to your quantitative work.

Hint: If you somehow got through GCSE chemistry hating this type of work, and unable to do it, you need to overcome this problem now. If you cannot, A-level is not an option you should consider as the subject is impenetrable without fluent grasp of these ideas.

Tasks part 1:

Aim to do about 2 hours work and then submit an image (or images) of what you accomplished in the time.

IMPORTANT: All work should be self-assessed according to the following rules:

- **Underline correct parts of work/responses in green; do NOT just tick somewhere on the page;**
- **Add essential words and phrases, also in green, to show development;**
- **Circle / cross out incorrect responses in red. Try to be specific about what was wrong and why.**

Work to complete:

1) Chemistry factsheet 02 – required for induction:
    a. Have a quick scan of the sheet – these approaches are not new. If you need to re-summarise the formulae used in quantitative chemistry then do it!
    b. If you are a more visual learner, these links could help:
        i. https://www.youtube.com/watch?v=jCynTWTwjpw
        ii. https://www.youtube.com/watch?v=yjoaLNx00Ps
    c. Next, try the relevant factsheet questions and self-assess them (using the guidance given above) as evidence of improvement.
    d. Now, lets try some 'real' exam questions – on the following page.
    e. Submit your IMPROVED, assessed answers to these questions (one page) as part of your evidence bundle.

Questions

Q1. Nickel is an element in the d-block of the Periodic Table.

(a) Complete the electronic configuration of a nickel atom using the s, p, d notation.

(1)

$1s^2$ .....

(b) A sample of nickel is made up of three isotopes. The percentage abundances are shown in the table below.

Isotope	Percentage abundance
^{58}Ni	69.02
^{60}Ni	27.32
^{62}Ni	3.66

Calculate the relative atomic mass of nickel. Give your answer to **two** decimal places.

(2)

(c) Nickel reacts with carbon monoxide, CO, to give the compound nickel carbonyl, $Ni(CO)_4$.

$$Ni(s) + 4CO(g) \rightarrow Ni(CO)_4(g)$$

(i) Calculate the volume of carbon monoxide, in dm^3, measured at room temperature and pressure, that is required to react completely with 5.87 g of nickel.

[Relative atomic mass: Ni = 58.7

Molar volume of a gas = 24 dm^3 mol^{-1} at room temperature and pressure.]

(3)

(ii) Calculate the **number** of carbon monoxide molecules present in the volume of gas you have calculated in (c)(i).

[The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}]

(1)

(d) Nickel(II) nitrate, $Ni(NO_3)_2$, can be made by several different methods.

Method 1

Nickel(II) oxide, NiO, was reacted with dilute nitric acid according to the equation

$$NiO(s) + 2HNO_3(aq) \rightarrow Ni(NO_3)_2(aq) + H_2O(l)$$

(i) Calculate the volume of 2.00 mol dm^{-3} dilute nitric acid, in cm^3, that was required to exactly neutralize 1.494 g of nickel(II) oxide.

Use the relative atomic masses: Ni = 58.7, O = 16.0

(3)

Method 2
A volume of 25.0 cm^3 of 2.00 mol dm^{-3} nitric acid, HNO_3, was transferred to a beaker. Solid nickel(II) carbonate, $NiCO_3$, was added until it was in excess.

(ii) Why was **excess** nickel(II) carbonate used?

(1)

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(iii) Why must the beaker be **much** larger than the volume of acid used?

(1)

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(iv) Write a balanced equation for the reaction between nickel(II) carbonate and dilute nitric acid, including state symbols.

(2)

*(v) For **Method 2**, describe the practical steps that you would take to obtain pure dry crystals of hydrated nickel(II) nitrate, $Ni(NO_3)_2.6H_2O$, from a mixture of nickel(II) nitrate solution and unreacted solid nickel(II) carbonate.

(4)

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(Total for question = 18 marks)

Mark Scheme

Q1.

Question Number	Acceptable Answers	Reject	Mark
(a)	$(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ 4s^2$ OR $(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^8$ ALLOW capital S P D Allow subscripts (e.g. $(1s^2)\ 2s_2\ 2p_6\ 3s_2\ 3p_6\ 4s_2\ 3d_8$)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)	(A_r for Ni) = (58 x 0.6902) + (60 x 0.2732) + (62 x 0.0366) or a correct fraction using percentages **(1)** (= 58.6928) [calculator value] = 58.69 (**must be to 2 dp**) **(1)** 2nd mark CQ on numbers transcribed Correct answer with no working **(2)** IGNORE Units of any kind (e.g. 'g', 'g mol^{-1}', 'amu', etc.)	58.68 (as rounding error)	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	Moles of nickel = $\frac{5.87}{58.7}$ = 0.1(00) (mol) **(1)** Moles CO = 0.1(00) x 4 = 0.4(00) (mol) Answer CQ on 4 x mol Ni **(1)** Volume of CO = 0.4(00) x 24 (dm^3) = 9.6 (dm^3) ALLOW 9600 $\mathbf{cm^3}$ Answer CQ on 24 x mol CO **(1)** Correct answer with no working scores **(3)**	9.6 dm^3 $\mathbf{mol^{-1}}$ (no 3rd mark) 9.6 dm^{-3} (no 3rd mark) OR Any other incorrect units (no 3rd mark)	**3**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(Number of CO molecules = 0.400 x 6.02 x 10^{23}) = 2.408 x 10^{23} Answer CQ on moles / volume of CO in (c)(i) IGNORE sf except 1 sf IGNORE Any units, even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	Moles of NiO $= \frac{1.494}{74.7}$ $= 0.02(00)$ (mol) **(1)** Moles HNO_3 = 0.02(00) x 2 = 0.04(00) (mol) Answer CQ on 2 x mol NiO **(1)** Volume of HNO_3 = $\frac{0.04(00) \times 1000}{2.00}$ $= 20(.0)$ (cm^3) ALLOW 0.02(00) **dm^3** Answer CQ on mol HNO_3 **(1)** Correct answer with no working scores **(3)** Penalise wrong units ONCE only		**3**

Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	To ensure all the **acid** reacts / all the **acid** is used up / all the **acid** is neutralized IGNORE References to 'yield' / reaction going to completion / just 'acid is the limiting reagent'	To ensure all the **reactants** are used up	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(iii)	Fizzing / effervescence / frothing / bubbles / gas released IGNORE spilling (over) / spillage References to 'vigorous', 'exothermic', 'violent' / **just** 'safety'	(Mixture) **boils** Quantity of reagents / 'displacement' of solution on adding solid	**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(iv)	$NiCO_3$**(s)** + $2HNO_3$**(aq)** → $Ni(NO_3)_2$**(aq)** + H_2O**(l)** + CO_2**(g)** ALLOW correct ionic equation $NiCO_3$**(s)** + $2H^+$**(aq)** → Ni^{2+}**(aq)** + H_2O**(l)** + CO_2**(g)** All species correct **(1)** Balancing and all state symbols correct **(1)** 2nd mark is dependent on 1st mark (ie all species correct)	H_2CO_3(aq) scores **(0)** overall	**2**

Question Number	Acceptable Answers	Reject	Mark
* (d)(v)	**First mark:** **Filter** (off the excess nickel(II) carbonate / solid) **(1)** **Second mark:** **Boil / heat** (to drive off some of the water) **(1)** **IGNORE** just 'evaporation' (as the technique of boiling / heating is required here) **Third mark:** Leave to cool / leave to crystallize / evaporate (water) slowly / leave (for water) to evaporate **(1)** **Fourth mark:** **Dry** (the crystals) **(1)** IGNORE Any washing of the crystals immediately prior to drying them NOTE If heat **to dryness** in the second stage, award (1) mark if filtration is **first** stage If filtration is not the first stage, award (1) mark for **steps 2, 3 and 4 all correct**	**Just** "warm" the filtrate / solution OR 'heat the filtrate **to dryness**' (Adding to a) drying agent Use of Bunsen burner or direct heating to dry crystals	**4**

Further work (not required for induction but a very good idea to smooth your transition over the summer)

Tasks:

- Use a similar structure to the task I set out earlier in the document.
- There is no need to submit any of this to me.
- Base your further 'quantitative chemistry' work on the factsheets 3,7,107 (in that order)

Important:

- This work really shouldn't be a shock to you – calculations are here to stay!
- Although you can study calculation types in isolation, only exposure to real exam questions will train you to become an effective user of the techniques – you may be surprised by how hard you found the questions. This is because you did not practice in contextual situations – only abstract ones.
- However, to be clear, this IS the level you have to work at from September (though with a LOT more teacher guidance, of course!)
- In summary, the induction again shows the initial level of challenge, but without the support. This means if you can do it without guidance (or even just a proportion of it) then you have the 'right stuff'!