Supplementary Data

Appendix A

Solutions: showing the methods used by a 200 level male NCE chemistry major (M2M) with Serial Number 107 to solve the CPST items including retrospective interview questions and responses

CPST item1:

I: Explain to me all the steps in your answer to this question

S107: I used the formula, $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$, I sorted out data to find V_1 as $3.8cm^3$, $P_1 = 5$ atm, $V_2 = 1/3 \times 3.8cm^3 = 1.26cm^3$. It follows that $\frac{5atm \times 3.8cm^3}{273k} = \frac{P_2 \times 1.26cm^3}{819k}$, $P_2 = 45$atm. *(used Plug&ChugMethod)*

I: What made you to decide to solve the question the way you did?

S107: *Because the question involves Gas Laws*

I: Could you solve the question in another way?

S107: *There could be other ways, but I cannot remember*

CPST item2:

I: Explain to me all the steps in your answer to this question

S107: I sorted the values i.e. mass of copper anode (M_1) and mass of copper cathode (M_2), all before experiment. Mass of copper anode (Mr_1) and mass of copper cathode (Mr_2) all after the experiment. I used the equation.

$\frac{M_1}{M_2} = \frac{Mr_1}{Mr_2}$, $Mr_2 = \frac{M_1 M_2}{M_1}$, I substitute the values and got M_2 = 11.63g. *(used Ratio and Proportion Method)*

. **I: What made you to decide to solve the question the way you did?**

S107: *Because the question involves calculating mass from the given equation.*

I: Could you solve the question in another way?

S107: *There could be other ways but I cannot remember.*

CPST item3:

I: Explain to me all the steps in your answer to this question

S107: Using the stoichiometric equation, the mole ratio of N_2 to H_2 is 1:3 and Mass = Relative Molar mass x Concentration. Therefore, Mass = 31 x 1.5g = 46.5g. *(used Reaction Chemical Equivalence Method)*

. **I: What made you to decide to solve the question the way you did?**

S107: *Because the question involves mole ratios*

. **I: Could you solve the question in another way?**

S107: *There may be other ways, but I cannot remember.*

CPST item4:

I: Explain to me all the steps in your answer to this question

S107: I used the formula, $\frac{impure}{pure} \times \frac{100}{1}$, substituting the given data will give 125%. *(used Ratio and Proportion)*

. **I: What made you to decide to solve the question the way you did?**

S107: *The question involves calculating percentage composition.*

I: Could you solve the question in another way?

S107: *No.*

Appendix B

Solutions: showing the methods used by a 300 level NCE chemistry major with Serial Number 192 to solve the CPST items including retrospective interview questions and responses

CPST item1:

I: **Explain to me all the steps in your answer to this question**

S192: Using the general gas equation, i.e. $P_1T_1 = P_2T_2$,

$P_2 = \frac{P_1T_1}{T_2}$, substituting the values given into this formula, P_2 = 1.67atm. *(used Plug and Chug Method)*

I: **What made you to solve the question the way you did?**

S192: Because the question involves gas laws.

I: **Could you solve the question in another way?**

S192: No, this is the only way I can solve it.

CPST item2:

I: **Explain to me all the steps in your answer to this question**

S192: I sorted the data given. I used the formula $M_2 = \frac{M_1 \times M_{ii}}{M_i}$, and got a final answer of 11.88g. *(used Ratio and Proportion Method)*

I: **What made you to solve the question the way you did?**

S192: I just feel that, that is the way to do it.

I: **Could you solve the question in another way?**

S192M: No, I don't think so.

CPST item3:

I: **Explain to me all the steps in your answer to this question**

S192: I first of all calculated the relative molecular mass of ammonia as 34g, then I got stuck and could not proceed from there *(started but stucked)*

. **I:** **What made you to solve the question the way you did?**

S192: I did solve the question completely, I could not continue from I stopped.

I: **Could you solve the question in another way?**

S192: No.

CPST item4:

I: **Explain to me all the steps in your answer to this question**

S192: I sorted out given data. Using the percentage purity formula, i.e. $\frac{impure}{pure} \times \frac{100}{1}$, I substituted and got the answer as 79.9%. *(used Ratio and Proportion Method)*

I: **What made you to solve the question the way you did?**

S192: It involves calculating percentage purity.

I: **Could you solve the question in another way?**

S192: No.

Appendix C

Solutions: showing the methods used by a 200 level NCE non- major with Serial Number 16 to solve the CPST items including retrospective interview questions and responses

CPST item1:

I: **Explain to me all the steps in your answer to this question**

S16: I arranged the given data, $P_1 = 5.00atm$, $T_1 = 0^oC$, $T_2 = 546^oC$. I used $P_1T_1 = P_2T_2$, $P_2 = P_1T_1 \times T_2$, $P_2 = 5.00 \times 0^oC \times 546^oC$. *(used Plug and Chug Method)*

. **I:** **What made you to solve the question the way you did?**

S16: Because it involves gas laws, isn't it?

. **I:** **Could you solve the question in another way?**

S16: No.

CPST item2:

I: **Explain to me all the steps in your answer to this question**

S16: The given data were, mass anode before experiment was = 9.20g, that cathode was = 7.75g. After experiment anode was = 6.09g. Then cathode = $\frac{6.00g \times 7.75g}{9.20g}$.

(used Ratio and Proportion Method)

. **I:** **What made you to decide to solve the question the way you did?**

S16: It involves electrolysis.

I: **Could you solve the question in another way?**

S16: No.

CPST Item 3:

I: **Explain to me all the steps in your answer to this question**

S16: I wrote the given equation that $N_2 + 3H_2 \longrightarrow 2NH_3$ from the equation 1 mole of hydrogen would produce 2 moles of ammonia. *(started using Reaction Chemical Equivalence Method but could not complete the solution)*

I: **What made you to decide to solve the question the way you did?**

S16: I just guess the answer.

. **I:** **Could you solve the question in another way?**

S16: No.

CPST Item 4:

I: **Explain to me all the steps in your answer to this question**

S16: Mass of pure oxide was 3.978g = 100% purity.

Mass of black oxide was 3.178g = ?

% composition of black oxide = $\frac{3.178g}{3.978g} \times \frac{100}{1} = 79.88g$.

(used Ratio and Proportion Method)

I: **What made you to decide to solve the question the way you did?**

S16: The question involves calculating percentage composition of substances.

I: **Could you solve the question in another way?**

S16: No.

Appendix D

Solutions: showing the methods used by a 300 level NCE non- major with Serial Number 59 to solve the CPST items including retrospective interview questions and responses

CPST Item1:

I: Explain to me all the steps in your answer to this question

S59: I arranged the given data, $P_1 = 5.00atm$,

$T_1 = 0^oC + 273k = 273k$

$T_2 = 546^oC + 273k = 819k$

$P_2 = ?$

I used $\frac{P_1}{T_1} = \frac{P_2}{T_2}$, $P_2 = \frac{P_1 \times T_2}{T_1}$

$P_2 = \frac{5.00atm \ x \ 819k}{273k} = 15atm.$

$P_2 = 15atm.$ *(used Plug and Chug Method)*

I: What made you to solve the question the way you did?

S59: Because it involves the ideal gas equation.

I: Could you solve the question in another way?

S59: No.

CPST Item2:

I: Explain to me all the steps in your answer to this question

S59: I sorted out the given data, i.e. mass of anode before experiment = 9.20g, and that of cathode = 7.75g. Now the experiment mass of anode 6.00g, that of cathode = ?

Therefore, mass of cathode after the experiment = $\frac{6.00g \times 7.75g}{9.20g} = 5.05g$. *(used Ratio and Proportion Method)*

. **I: What made you to solve the question the way you did?**

S59: Because it was an electrolysis question.

I: Could you solve the question in another way?

S59: No.

CPST Item 3:

I: Explain to me all the steps in your answer to this question

S59: I used the formula

$\text{Mass} = \frac{Concentration\ of\ NH^3}{Molar\ mass\ of\ NH^3}$

Mole of hydrogen = 1.0

Concentration in gram of NH_3 = ?

Molar mass of NH_3 = 14 + (1 x 3)

= 17

Concentration in gram/of NH_3 = 17g. *(used Plug and Chug Method)*

. **I: What made you to solve the question the way you did?**

S59: The question involved calculating moles.

I: Could you solve the question in another way?

S59: No.

CPST Item 4:

I: Explain to me all the steps in your answer to this question

S59: I arranged the given data

Mass of Pure Cu = 3.178g = 100% purity

Mass of black oxide = 3.978g = ?

$$\% \text{ composition of black oxide} = \frac{Mass\ of\ Pure\ Cu}{Mass\ of\ black\ oxide} \times \frac{100}{1}$$

$\therefore \%$ composition of black oxide = 79.88g.

(used Ratio and Proportion Method)

N3F: Because I used the correct formula.

I: What made you to solve the question the way you did?

S59: Because it involves calculating percentage composition.

I: Could you solve the question in another way?

S59: No.