Appendix 2

Preliminary Survey Questionnaire (PSQ)

Respondent's Particulars

Name of School: ______________________________
Academic qualifications: ____________________________
Academic major(s): ____________________________
Professional qualifications: __________________________
Subject(s) taught: ______________________________
Level(s) taught: ________________________
No. of years teaching Chemistry: ____________________

Chemical Representations: ***What are Chemistry Teachers' Perceptions?***

1. Have you heard of or seen the term "chemical representations"?
   [ ] Yes
   [ ] No

   If *yes*, where did you come across the term "chemical representations"? (You can choose more than one)

   [ ] Curriculum Specifications by CDC
   [ ] Chemistry text book recommended by MOE, Malaysia
   [ ] Chemistry reference books (Local Publications)
   [ ] Chemistry reference books (International Editions)
   [ ] Chemistry teachers
   [ ] Chemistry teaching courseware by MOE, Malaysia
   [ ] Internet
   [ ] Other sources (please specify)

2. Are you familiar with the term "chemical representations"? [ ] Yes
   [ ] No

3. Do you know the meaning of the term "chemical representations"? [ ] Yes
   [ ] No

4. Are you aware of the existence of "the 3 levels of thinking" or "the 3 levels of representations of matter" in chemistry? [ ] Yes
   [ ] No

5. Do you have any difficulty teaching chemical representations to your students?
   [ ] Yes
   [ ] No

   If *yes*, what are some of your difficulties?

6. Is it important for chemistry students to know about chemical representations?

[ ] Yes
[ ] No

Why do you think so?

7. Is it important for chemistry teachers to know about chemical representations?

[ ] Yes
[ ] No

Why do you think so?

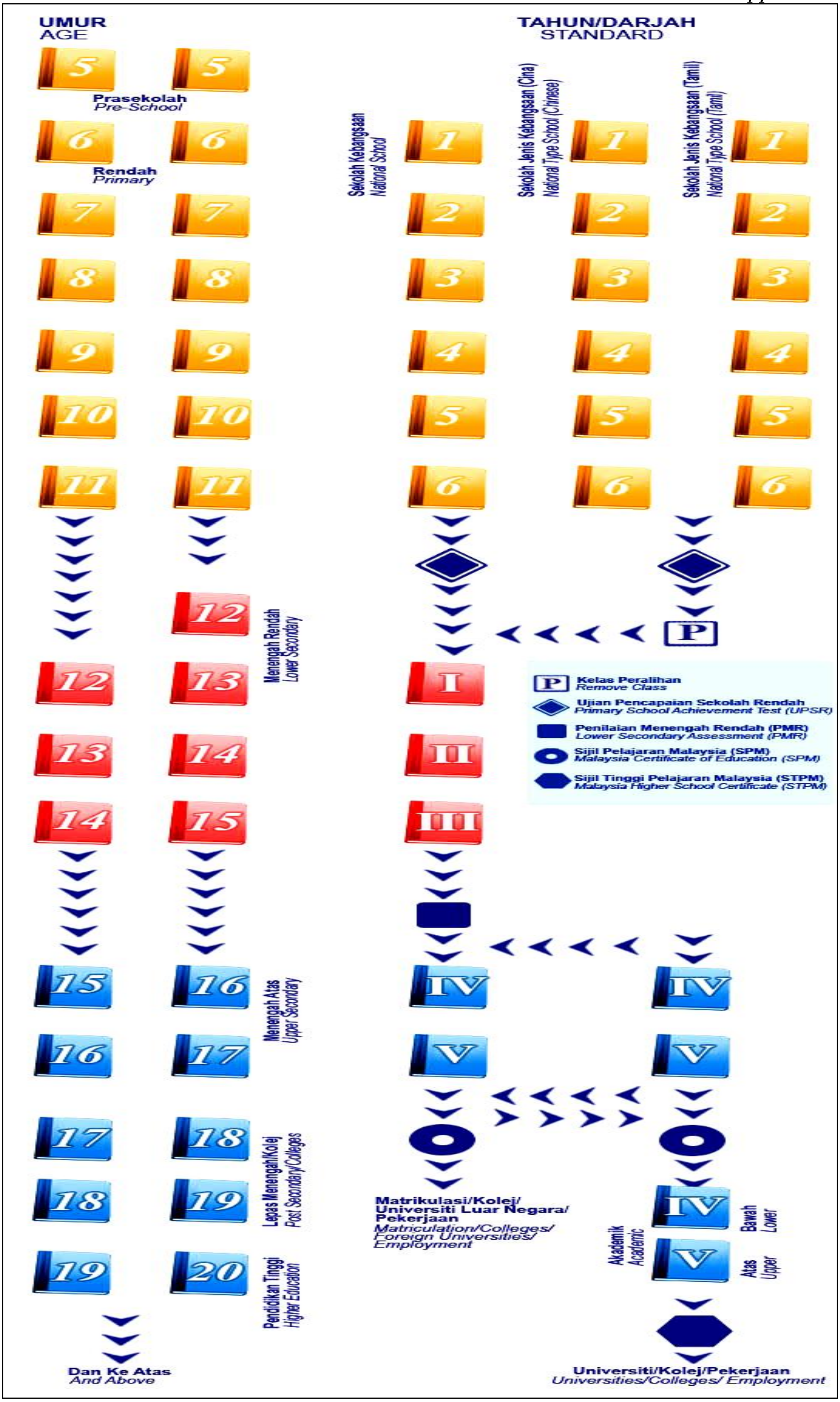
8. In what ways are chemical representations useful:

(a) to chemistry students?

(b) to chemistry teachers?

9. What do you think are the roles and purposes of representations in chemistry? Give examples.

THANK YOU FOR YOUR CO-OPERATION



National Education System Chart (Source: Ministry of Education, Malaysia, 2005)

Table of Specifications for the Test on Chemical Representations (TCR)
Actual Study

Content Domain	Propositional Statements	No. of Item	Item No.
1. The 3 levels of representation of matter (macroscopic, microscopic, symbolic)	Statements 1 to 4	6	*Part A* *4, 9, 10, 15, 16, 21*
2. Chemical symbols	Statements 5 & 6	6	*Part A* *1, 2, 5, 8* *Part B* *5, 6*
3. Chemical formulae (empirical, molecular, and structural)	Statements 7 to 13	14	*Part A* *3, 7, 11, 14, 17, 18, 20, 22, 23, 29, 30* *Part B* *1, 2, 3*
4. Models	Statements 15 to 17	4	*Part A* *13, 19, 24, 25*
5. Chemical equations	Statements 18 & 19	6	*Part A* *6, 12, 26, 27, 28* *Part B* *4*
Total	19	36	

Appendix 10

Table of Specifications for the Test on Chemical Representations (TCR)
Pilot Study

Content Domain	Propositional Statements	No. of Item (Percent)	Item No.
1. The 3 levels of representation of matter (macroscopic, microscopic, symbolic)	Statements 1 to 4	13 (26%)	*1, 5, 8, 15, 17, 20, 26, 27, 28, 29, 32, 37, 43*
2. Chemical symbols	Statements 5 & 6	5 (10%)	*2, 3, 6, 9, 14*
3. Chemical formulae (empirical, molecular, and structural)	Statements 7 to 14	20 (40%)	*4, 7, 10, 12, 16, 19, 22, 23, 24, 25, 30, 31, 33, 34, 36, 38, 39, 40, 42, 44*
4. Models	Statements 15 to 17	6 (12%)	*18, 21, 35, 41, 45, 50*
5. Chemical nomenclature	Statement 18	1 (2%)	*49*
6. Chemical equations	Statements 19 & 20	5 (10%)	*11, 13, 46, 47, 48*
Total	20	50 (100%)	

Test on Chemical Representations (TCR) – Actual Study

Instructions to candidates:

1. This test consists of TWO parts: Part A and Part B.
2. Answer ALL the questions in both parts.
3. For Part A, read each statement carefully and decide whether the statement is TRUE or FALSE. Then indicate your choice by **CIRCLING** T or F in the **Response Sheet** provided separately.
4. For Part B, choose the best answer for each item. Then mark your choice by **CIRCLING** the letter A, B, C or D in the **Response Sheet** provided separately.

THANK YOU FOR YOUR CO-OPERATION

NAME: ______________________________ CLASS: ________________

SCHOOL: ____________________________ GENDER: ______________

Test on Chemical Representations (TCR)

Instructions:

1. This test consists of TWO parts: Part A and Part B.
2. Answer ALL the questions in both parts.

Part A: True or False items

Item No.	Response		Item No.	Response		Item No.	Response	
1	T	F	11	T	F	21	T	F
2	T	F	12	T	F	22	T	F
3	T	F	13	T	F	23	T	F
4	T	F	14	T	F	24	T	F
5	T	F	15	T	F	25	T	F
6	T	F	16	T	F	26	T	F
7	T	F	17	T	F	27	T	F
8	T	F	18	T	F	28	T	F
9	T	F	19	T	F	29	T	F
10	T	F	20	T	F	30	T	F

Part B: Multiple Choice Questions

1	A	B	C	D	4	A	B	C	D
2	A	B	C	D	5	A	B	C	D
3	A	B	C	D	6	A	B	C	D

Test on Chemical Representations (TCR)

Instructions to candidates**:**

This test consists of TWO parts: Part A and Part B.
Answer all the questions in both parts.

Part A: True or False items.

Read each statement carefully and decide whether the statement is TRUE or FALSE. Indicate your choice by **CIRCLING** T or F in the **Response Sheet** provided separately.

Item No.	Statement
1	H_2 and O_2 are symbols of the elements hydrogen and oxygen respectively.
2	Chemists use symbols of one or two letters to represent the elements.
3	A hydrogen molecule can be represented either as H_2 or 2H.
4	Chlorine molecules are greenish-yellow.
5	The symbol for chlorine in chlorine gas is \`Cl_2'.
6	The statement "magnesium + oxygen → magnesium oxide" is a chemical equation.
7	Only compounds have chemical formulae.
8	The first letter of a chemical symbol is always capitalized, but any following letters are not.
9	Copper atoms are reddish brown.
10	Chlorine has 7 valence electrons.
11	In the water molecule (H_2O), a hydrogen molecule, H_2, is bonded to an oxygen atom, O.
12	A chemical equation is a representation of a chemical reaction using chemical formulae only.

13	In ball-and-stick models, sticks or springs are used to represent chemical bonds.
14	Structural formula shows how atoms are bonded to one another in a molecule.
15	Magnesium has a charge of +2.
16	Na=2.8.1, so sodium loses electron to form sodium ion.
17	Some molecules have the same molecular formula and empirical formula.
18	Co is the formula for carbon monoxide molecule.
19	In space-filling models, the bonds are not visible.
20	$C_6H_{12}O_6$ is glucose.
21	When hydrogen loses an electron, hydrogen ion, H^+, is formed.
22	The lines in structural formula represent the covalent bonds between atoms.
23	CH_4 represents the composition of a methane molecule.
24	Ball-and-stick model show the 3-D arrangement of atoms clearly.
25	Molecules have definite shapes that are best represented by molecular models.
26	The arrow sign (→) in a chemical equation is an equal sign.
27	Both molecular pictures and symbolic equations can be used to describe a chemical reaction.
28	The plus sign (+) on both sides of a chemical equation has the same meaning.
29	The formulae of ionic compounds are empirical formulae.
30	A carbon dioxide molecule, CO_2, is made up of 1 carbon atom and 1 oxygen molecule.

Part B: Multiple Choice Questions

Choose the best answer for each item. Then mark your choice by **CIRCLING** the letter A, B, C or D in the **Response Sheet** provided.

1. How many atoms of hydrogen are represented in the formula $(NH_4)_2HPO_4$?

   A. 5 B. 7 C. 8 D. 9

2. You are given the molecular formula of ethanol: $\mathbf{C_2H_5OH}$
   The molecular formula of ethanol shows the
   A. actual mass of ethanol
   B. formula of an ethanol molecule
   C. actual number of each atom of the elements in a molecule of ethanol
   D. ratio for the number of atoms of each type of element in a molecule of ethanol

3. Borax, $Na_2B_4O_7$, is used as a poison for ants and cockroaches.
   The number of atoms of boron represented by "$6Na_2B_4O_7$" is

   A. 4 B. 6 C. 10 D. 24

4. $CaCO_3 + HCl \longrightarrow CaCl_2 + H_2O + CO_2$
   What is (are) the reactant (s) for the above chemical equation?
   A $CaCO_3$ only
   B $CaCO_3$ and HCl
   C CO_2 and H_2O
   D $CaCl_2$, H_2O and CO_2

5. Which of the following compounds has the smallest number of different elements?
   A. Na_2SnCl_6
   B. $(NH_4)_2SO_4$
   C. $C_{18}H_{35}O_2K$
   D. $Cu(NH_3)_4SO_4$

6. The symbol of sodium atom can be written as $^{23}_{11}Na$
   The nucleus of this sodium atom contains
   A. 11 protons and 12 neutrons
   B. 11 neutrons and 12 protons
   C. 11 protons and 12 electrons
   D. 12 neutrons and 11 electrons

Test on Chemical Representations (TCR) – Pilot Study

Instructions to candidates:

This test consists of 50 items.

Read each statement carefully and decide whether the statement is ***TRUE*** *or* ***FALSE.***

Indicate your choice by ***CIRCLING*** *T or F on the* ***Response Sheet****.*

THANK YOU FOR YOUR CO-OPERATION

NAME: ________________________ CLASS: ________________

SCHOOL: ______________________ GENDER: ______________

Item No.	Response		Item No.	Response		Item No.	Response	
1	T	F	18	T	F	35	T	F
2	T	F	19	T	F	36	T	F
3	T	F	20	T	F	37	T	F
4	T	F	21	T	F	38	T	F
5	T	F	22	T	F	39	T	F
6	T	F	23	T	F	40	T	F
7	T	F	24	T	F	41	T	F
8	T	F	25	T	F	42	T	F
9	T	F	26	T	F	43	T	F
10	T	F	27	T	F	44	T	F
11	T	F	28	T	F	45	T	F
12	T	F	29	T	F	46	T	F
13	T	F	30	T	F	47	T	F
14	T	F	31	T	F	48	T	F
15	T	F	32	T	F	49	T	F
16	T	F	33	T	F	50	T	F
17	T	F	34	T	F			

Test on Chemical Representations (TCR) – Pilot Study

<u>Instructions to candidates</u>**:**

*This test consists of **50 items**.*

*Read each statement carefully and decide whether the statement is **TRUE** or **FALSE.***

*Indicate your choice by **CIRCLING** T or F in the **Response Sheet** provided separately.*

Item No.	Statement
1	Chemistry is just a science of symbols of elements, formulae of compounds and chemical equations.
2	H_2 and O_2 are symbols of the elements hydrogen and oxygen respectively.
3	Each chemical symbol is assigned to certain elements and indicates specific knowledge.
4	A chemical formula is an abbreviation for a mixture.
5	Chemical representations such as formulae, structures and symbols are used to represent chemical processes and conceptual entities such as atoms and molecules.
6	Chemists use symbols of one or two letters to represent the elements.
7	Hydrogen gas can be represented either as H_2 or 2H.
8	Chlorine molecules are greenish-yellow.
9	The symbol for magnesium in magnesium ribbon is \`Mg’.
10	Empirical formula is usually written for compounds which consist of molecules.
11	The statement “magnesium + oxygen → magnesium oxide” is a chemical equation.
12	The number in front of a chemical formula multiplies only the symbol which immediately follows it.

Item No.	Statement
13	A chemical equation is a representation of a chemical reaction using chemical formulae only.
14	The first letter of a symbol is always capitalized, but any following letters are not.
15	Copper atoms are reddish brown.
16	One mole of carbon monoxide molecule contains ½ mol of carbon atom and ½ mol of oxygen atom.
17	Chlorine has 7 valence electrons.
18	In chemistry, \`model’ refers to a physical or computational representation of the composition and structure of a molecule.
19	Only compounds have formulae.
20	The atoms in a molecule are arranged at random.
21	In ball-and-stick models, sticks or springs are used to represent chemical bonds.
22	Molecular formulae are the simplest chemical formulae.
23	In the water molecule (H_2O), a hydrogen molecule, H_2, is bonded to an O atom.
24	To get the total number of atoms in a chemical formula or ion, just add up the coefficient(s) and the subscript(s).
25	Structural formula shows how atoms are bonded to one another in a molecule.
26	Magnesium has a charge of +2.
27	Cu^{2+} ions in aqueous solution are blue.
28	Na=2.8.1, so sodium loses electron to form sodium ion.
29	The particles in magnesium ribbon are neutral atoms.
30	Formulae are abbreviations for names rather than a way to represent the composition or a structure.
31	Some molecules have the same molecular formula and empirical formula.

Item No.	Statement
32	A molecule of magnesium oxide, MgO, consists of one magnesium ion and one oxide ion.
33	Co is the formula for carbon monoxide molecule.
34	The structural formula of water can be either H—H—O or H—O—H.
35	In space-filling models, the bonds are not visible.
36	$C_6H_{12}O_6$ is glucose.
37	When hydrogen gains a proton, hydrogen ion, H^+, is formed.
38	The lines in structural formula represent the covalent bonds between atoms.
39	The formulae of ionic compounds are empirical formulae.
40	A carbon dioxide molecule, CO_2, is made up of 1 carbon atom and 1 oxygen molecule.
41	Ball-and-stick model show the 3-D arrangement of atoms clearly.
42	CH_4 represents the composition of a methane molecule.
43	The oxide ion, O^{2-}, is formed when oxygen gains 2 electrons.
44	The empirical formula for sodium chloride is Na^+Cl^-.
45	There is no real representation for a molecule, only models designed to bring out important features.
46	The arrow sign (→) in a chemical equation is an equal sign.
47	Both molecular pictures and symbolic equations can be used to describe a chemical reaction.
48	The plus sign (+) on both sides of a chemical equation has the same meaning.
49	Chemical nomenclature expresses the relationship between the names and formulae of chemical compounds.
50	Molecules have definite shapes that are best represented by molecular models.

Item Analysis of the TCR - Pilot Study

Item No.	R_U	R_M	R_L	R_T	Item Difficulty Index $p=R_T/57$	Item Discrimination Index $D=(R_U - R_L)/15$
1	14	25	12	51	0.89	0.13
2	4	12	2	18	0.32	0.13
3	10	24	7	41	0.72	0.20
4	11	17	5	33	0.58	0.40
5	14	25	11	50	0.88	0.20
6	12	19	8	39	0.68	0.27
7	15	20	9	44	0.77	0.40
8	6	8	6	20	0.35	0.00
9	15	22	14	51	0.89	0.07
10	6	11	4	21	0.37	0.13
11	9	13	10	32	0.56	-0.07
12	10	11	9	30	0.53	0.07
13	4	9	6	19	0.33	-0.13
14	9	18	4	31	0.54	0.33
15	2	7	6	15	0.26	-0.27
16	13	12	11	36	0.63	0.13
17	0	7	6	13	0.23	-0.40
18	12	23	9	44	0.77	0.20
19	15	36	9	50	0.88	0.40
20	13	16	7	36	0.63	0.40
21	14	24	8	46	0.81	0.40
22	10	20	6	36	0.63	0.27
23	4	6	4	14	0.25	0.00
24	11	15	6	32	0.56	0.33
25	14	22	5	41	0.72	0.60
26	5	5	4	14	0.25	0.07
27	3	7	6	16	0.28	-0.20
28	1	3	0	4	0.07	0.07
29	8	10	5	23	0.40	0.20
30	10	8	9	27	0.47	0.07
31	9	14	5	28	0.49	0.27
32	2	4	2	8	0.14	0.00
33	14	17	9	40	0.70	0.33
34	14	21	5	40	0.70	0.60
35	11	18	5	34	0.60	0.40

36	2	2	1	5	0.09	0.07
37	8	12	5	25	0.44	0.20
38	11	13	8	32	0.56	0.20
39	9	21	8	38	0.67	0.07
40	13	17	14	44	0.77	-0.07
41	15	27	12	54	0.95	0.20
42	15	23	8	46	0.81	0.47
43	4	4	3	11	0.19	0.07
44	11	19	7	37	0.65	0.27
45	7	13	3	23	0.40	0.27
46	10	14	3	27	0.47	0.47
47	14	22	11	47	0.82	0.20
48	9	9	6	24	0.42	0.20
49	9	15	5	29	0.51	0.27
50	13	25	8	46	0.81	0.33

Note:

R_U = Number of students choosing the correct answer in the upper 27%

R_M = Number of students choosing the correct answer in the middle group

R_L = Number of students choosing the correct answer in the lower 27%

R_T = Total number of students choosing the correct answer

T = Total number of students taking the test = 57

N = Number of students in the upper or lower group = 15

Test Score Reliability of the TCR – Pilot Study

Item No.	P value	q=1-p	Pq
1	0.89	0.11	0.10
2	0.32	0.68	0.22
3	0.72	0.28	0.20
4	0.58	0.42	0.24
5	0.88	0.12	0.11
6	0.68	0.32	0.22
7	0.77	0.23	0.18
8	0.35	0.65	0.23
9	0.89	0.11	0.10
10	0.37	0.63	0.23
11	0.56	0.44	0.25
12	0.53	0.47	0.25
13	0.33	0.67	0.22
14	0.54	0.46	0.25
15	0.26	0.74	0.19
16	0.63	0.37	0.23
17	0.23	0.77	0.18
18	0.77	0.23	0.18
19	0.88	0.12	0.11
20	0.63	0.37	0.23
21	0.81	0.19	0.15
22	0.63	0.37	0.23
23	0.25	0.75	0.19
24	0.56	0.44	0.25
25	0.72	0.28	0.20
26	0.25	0.75	0.19
27	0.28	0.72	0.20
28	0.07	0.93	0.07
29	0.40	0.60	0.24
30	0.47	0.53	0.25
31	0.49	0.51	0.25
32	0.14	0.86	0.12
33	0.70	0.30	0.21
34	0.70	0.30	0.21
35	0.60	0.40	0.24
36	0.09	0.91	0.08
37	0.44	0.56	0.25
38	0.56	0.44	0.25

(Table continued)

39	0.67	0.33	0.22
40	0.77	0.23	0.18
41	0.95	0.05	0.05
42	0.81	0.19	0.15
43	0.19	0.81	0.15
44	0.65	0.35	0.23
45	0.40	0.60	0.24
46	0.47	0.53	0.25
47	0.82	0.18	0.15
48	0.42	0.58	0.24
49	0.51	0.49	0.25
50	0.81	0.19	0.15
			∑pq=9.74

KR-20 shall be computed instead of KR-21 as the difficulty level of the items (p value) is different.

$$\text{K-R 20: } r = \frac{k}{k-1}\left[1 - \frac{\sum pq}{S^2}\right]$$

where r = estimated reliability of the whole test
k = number of items in test
p = proportion of correct responses to a particular item
q = proportion of incorrect responses to that item (so that p+q=1)
pq = variance of a single item scored dichotomously
∑ = summation sign indicating that pq is summed over all items
S^2 = variance of the total test

Test score reliability for the TCR (K-R 20) - Pilot study (n = 57)

$$\textbf{K-R 20}: r = \frac{50}{50-1}\left(1 - \frac{9.74}{13.87}\right) = \underline{\mathbf{0.31}}$$

Reliability of Test Score for TCR – (Test-Retest) - Pilot Study (n=33)

Pearson correlation coefficient

		TCR (Test)	TCR (Retest)
TCR (Test)	Pearson Correlation	1	.819**
	Sig. (2-tailed)	.	.000
	N	33	33
TCR (Retest)	Pearson Correlation	.819**	1
	Sig. (2-tailed)	.000	.
	N	33	33

**. Correlation is significant at the 0.01 level (2-tailed).

Reliability of Test Score for TCR (Test-Retest) – Actual Study

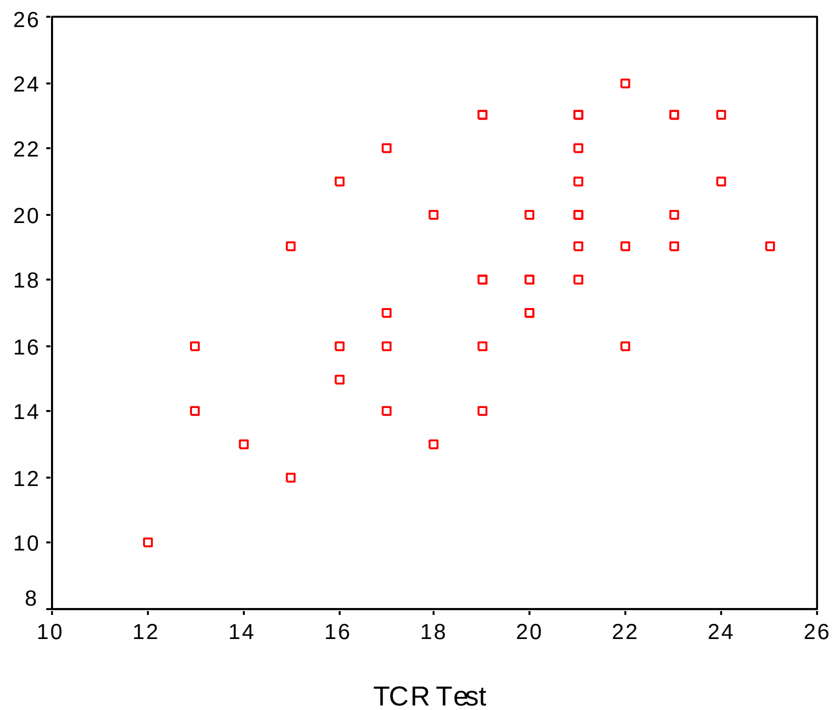
(i) Pearson correlation coefficient

Correlations

		TCR Test	TCR ReTest
TCR Test	Pearson Correlation	1	.642**
	Sig. (2-tailed)	.	.000
	N	379	45
TCR ReTest	Pearson Correlation	.642**	1
	Sig. (2-tailed)	.000	.
	N	45	45

**. Correlation is significant at the 0.01 level (2-tailed).

(ii) Scatter plot of TCR score (Test-Retest)



Appendix 14a

Table of Specifications for
Test on Representational Competence (TRC) – Actual Study

Representational Skills Assessed	Test points allocated and item no. (in italics)		Total Points (Percent)
	Part A MCQ	Part B Short-answer items	
1. The ability to interpret meanings of chemical representations.	4 *1, 3, 8, 18*	5 *5(i), (ii), (iii), 6(a), (b)*	9 (22.5%)
2. The ability to translate between different representations at the same level.	7 *2, 4, 5, 15, 16, 17, 20*	1 *1(a)*	8 (20.0%)
3. The ability to translate between different representations across levels.	7 *12, 14, 19, 21, 22, 23, 25*	1 *7(a)*	8 (20.0%)
4. The ability to use representations to generate explanations.	0	7 *2(a), (b) 3(a), (b), (c), 4, 7(b)*	7 (17.5%)
5. The ability to make connections between representations and concepts.	7 *6, 7, 9, 10, 11, 13, 24*	1 *1(b)*	8 (20.0%)
Total Test Points (Percent)	25 (62.5%)	15 (37.5%)	40 (100.0%)

Table of Specifications for Test on Representational Competence (TRC) -Pilot Study

Representational Skills Assessed	Test points allocated and item no. (in italics)		Total Points (Percent)
	Part A MCQ	Part B Short-answer items	
1. The ability to interpret meanings of chemical representations.	9 *1, 3, 6, 7, 8, 12, 13, 14, 18*	5 *5(i), (ii), (iii), 6(a), (b)*	14 (35.0%)
2. The ability to translate between different representations at the same level.	8 *2, 4, 5, 15, 16, 17, 20, 21*	1 *1(a)*	9 (22.5%)
3. The ability to translate between different representations across levels.	4 *19, 22, 23, 25*	1 *7(a)*	5 (12.5%)
4. The ability to use representations to generate explanations.	0	6 *2(a), (b)* *7(b)* *3(a), (b), (c)*	6 (15.0%)
5. The ability to make connections between representations and concepts.	4 *9, 10, 11, 24*	2 *1(b)* *4*	6 (15.0%)
Total Test Points (Percent)	25 (62.5%)	15 (37.5%)	40 (100.0%)

Test on Representational Competence (TRC)

Part A: Multiple choice questions

1. Which of the following groups represents only compounds?

   A. Co, Nb, HF, H_2S
   B. CO, BN, HI, NO_2
   C. VS, Os, Y_2O_3, CuO
   D. CO_2, P_4S_5, Mn, Mg

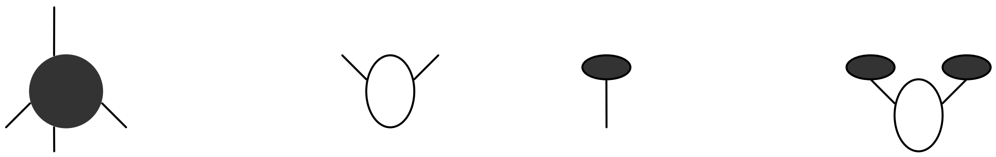
(ANCQ, 2001J, Q.2)R

2. Carbonates are compounds containing a *metallic element, carbon, and oxygen*. In a carbonate, there are always three oxygen atoms to every one carbon atom.
   Which one of the following formulae represents a carbonate?

   A. $CaCO_3$
   B. FeC_2O_4
   C. $CuH_2C_2O_4$
   D. $AgC_2H_3O_2$

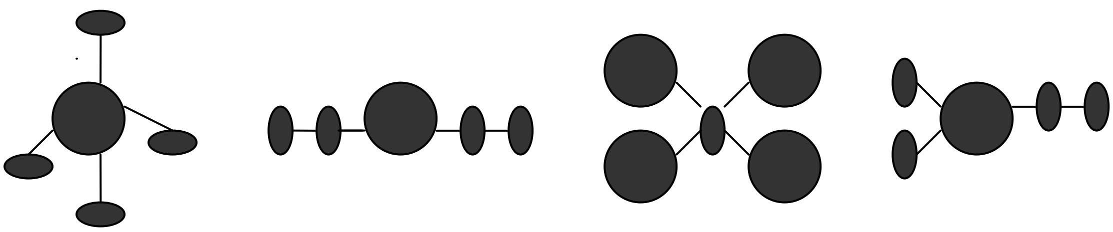
(ANCQ, 2001J, Q.17)R

3. The diagrams below represent atoms of carbon, oxygen, and hydrogen, and also a molecule of water, H_2O.



Carbon atom | Oxygen atom | Hydrogen atom | Water molecule

Which of the diagrams below correctly represents a molecule of methane, CH_4?



A | B | C | D

(ANCQ, 2002J, Q.9)R

4. Compounds of carbon can contain exactly the same kinds and numbers of different atoms, but with the atoms in different arrangements. The diagrams below show how atoms are arranged in some compounds of carbon.
Which diagram represents two molecules that are the same?

```
          H   H                      H   H
          |   |                      |   |
A.    H—C—C—OH          and      HO—C—C—H
          |   |                      |   |
          H   H                      H   H


          H   H   H                 H  OH  H
          |   |   |                 |   |   |
B.    HO—C—C—C—H      and      H—C—C—C—H
          |   |   |                 |   |   |
          H   H   H                 H   H   H


          H   H   H                 H       H
          |   |   |                 |       |
C.    HO—C—C—C—H      and      H—C—O—C—H
          |   |   |                 |       |
          H   H   H                 H       H


        H   O                       H   O
        |   ‖                       |   ‖
D.    H—C— C —OH          and      H—C — C—H
        |                           |
        H                           H
```

(ANCQ, 2002J, Q.16)R

5. The main ingredient in vinegar is a substance called acetic acid. The arrangement of atoms in acetic acid may be represented as:

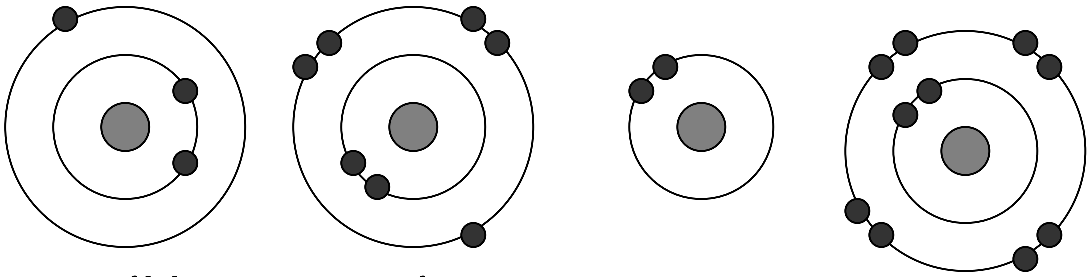
```
   H   O
   |   ‖
H—C—C—OH
   |
   H
```

Acetic acid can also be represented by the formula

A. HCO B. $H_3C_2O_2$ C. $C_2H_4O_2$ D. C_2H_4O

(ANCQ, 2002J, Q.20)R

6. The diagrams show separate lithium and nitrogen atoms, and the ions in the compound lithium nitride.



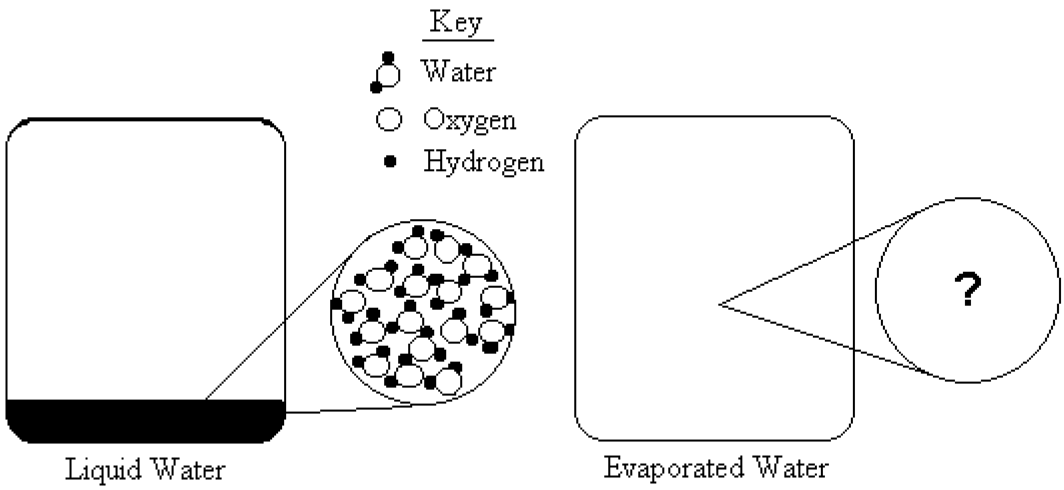
Atom of lithium | Atom of nitrogen | Ion of lithium in lithium nitride | Ion of nitrogen in lithium nitride

What is the correct formula for lithium nitride?

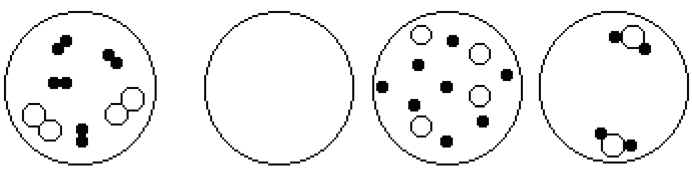
A. LiN B. LiN_3 C. Li_2N_3 D. Li_3N

(ANCQ, 2008, Q.10)

7. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water have evaporated?



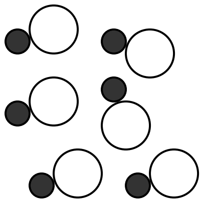
A B C D

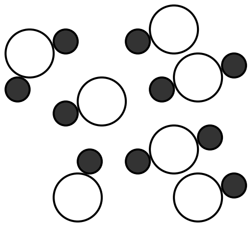
8. What is the relative formula mass of magnesium phosphate, $Mg_3(PO_4)_2$?
(RAM: Mg=24, O=16, P=31)

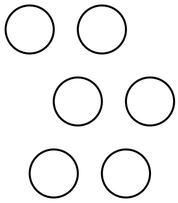
A. 190 B. 199 C. 231 D. 262

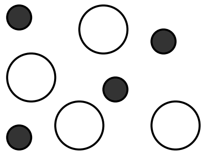
(ANCQ, 2000, Q.5)R

9. Which one of the following diagrams below represent, in order:
an element, a pure compound, a mixture of elements, and a mixture of compounds?


1


2


3


4

A. 4, 3, 2, 1 B. 3, 4, 1, 2 C. 3, 1, 4, 2 D. 1, 2, 3, 4

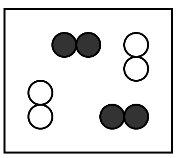
(ANCQ, 2001, Q.12)R

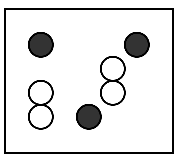
10. A charged particle with 28 protons, 29 electrons and 31 neutrons can be represented as:

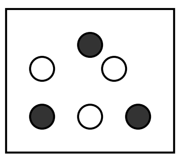
A. $^{59}_{28}X^{+}$ B. $^{59}_{27}X^{-}$ C. $^{59}_{28}X^{-}$ D. $^{59}_{29}X^{+}$

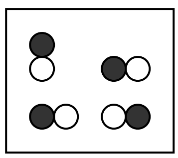
(ANCQ, 1998, Q.6)R

11. A mixture of gases contains only atoms of helium and molecules of hydrogen. Which of the following diagrams is the best representation of the mixture?


A


B


C


D

(ANCQ, 2000, Q.4)R

12. Chlorine gas (Cl_2) reacts with fluorine gas (F_2) to form chlorine trifluoride, according to the equilibrium reaction:

$$Cl_2(g) + 3F_2(g) \rightleftharpoons 2ClF_3(g)$$

10 molecules of Cl_2 gas and 30 molecules of F_2 gas were placed in a sealed container and allowed to react. After some time the mixture in the container was analyzed. It was found to contain 6 molecules of Cl_2 gas, and some F_2 and ClF_3.

How many molecules of F_2 and ClF_3 were present?

A. 18 molecules of F_2 and 6 molecules of ClF_3.
B. 24 molecules of F_2 and 6 molecules of ClF_3.
C. 18 molecules of F_2 and 8 molecules of ClF_3.
D. 24 molecules of F_2 and 8 molecules of ClF_3.

(ANCQ, 2008, Q.9)R

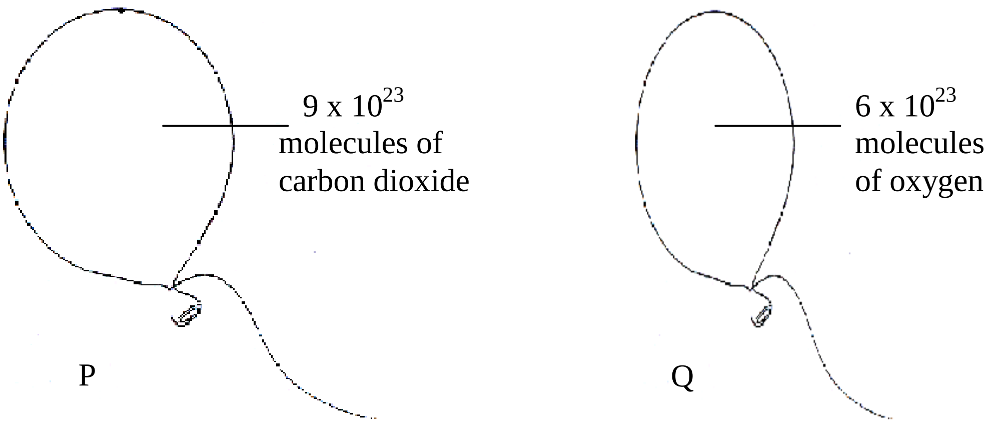
13. The table below shows the number of protons of four atoms W, X, Y and Z.

Atom	Number of protons
W	3
X	16
Y	17
Z	19

Which of the atoms have the same number of valence electrons?

A. W and Z
B. X and Z
C. X and Y
D. Y and Z

14. The diagram shows two balloons P and Q.

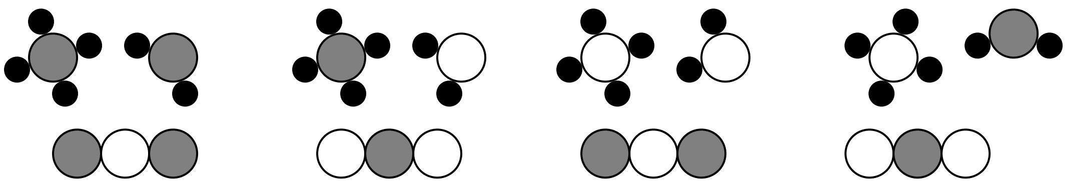


Balloon P is filled with 9 x 10^{23} molecules of carbon dioxide gas whereas balloon Q is filled with 6 x 10^{23} molecules of oxygen gas.

What is the mass of carbon dioxide and oxygen?
[Relative atomic mass: C,12; O,16; N_A = 6 x $10^{23}mol^{-1}$]

	carbon dioxide	Oxygen
A	22 g	16 g
B	44 g	32 g
C	66 g	32 g
D	None of the above	

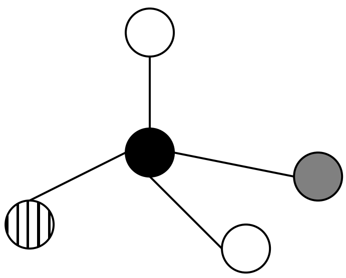
15. Which one of the following diagrams represents one molecule each of methane, CH_4, water, H_2O, and carbon dioxide, CO_2?



A B C D

(ANCQ, 2004, Q.3)R

16. A model of a compound was made using patterned balls. Each different pattern represents a different element.



Which of the following compounds is the most likely to be represented above?

A. dichloromethane, CH_2Cl_2
B. bromodichloromethane, $CHBrCl_2$
C. trichloromethane, $CHCl_3$
D. tetrachloromethane, CCl_4

(ANCQ, 1996, Q.28)R

17. Use the molecular diagrams and formulae in Figure 1 to determine the chemical formula for the molecule represented in Figure 2.

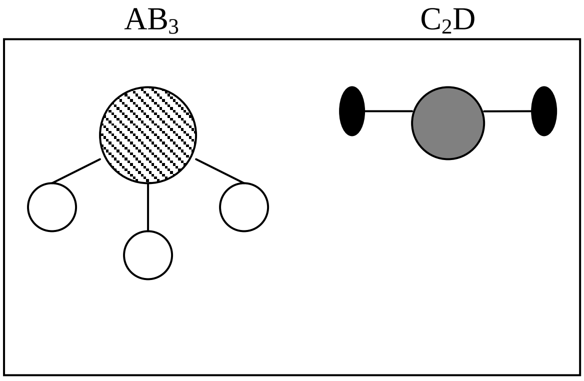


Figure 1

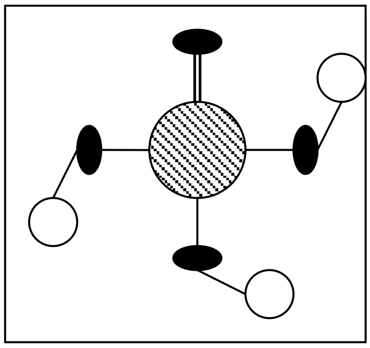


Figure 2

The correct formula for the molecule represented in Figure 2 is

A. BA_4C_3 B. CB_4A_3 C. AC_3B_4 D. C_4AB_3

(ANCQ, 2000, Q.13)R

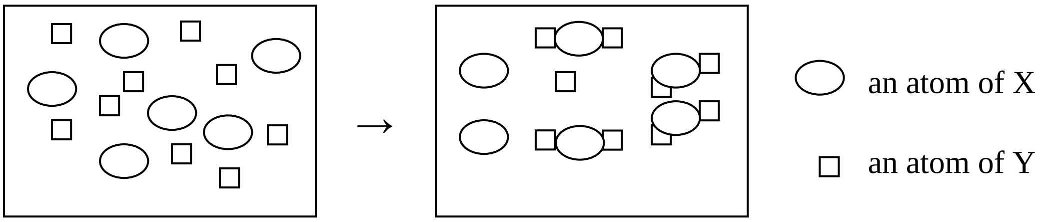
18. Xanthates are water-soluble chemicals that are used in the mining industry to separate valuable ore minerals from waste material called gangue. Potassium amyl xanthate (PAX) has the formula $CH_3CH_2CH_2CH_2CH_2OCSSK$.

A simplified formula and the number of elements present in PAX are

A. $C_6H_{11}OS_2K$ with 5 elements
B. $C_6H_{11}OS_2K$ with 21 elements
C. $C_5H_{11}OCSSK$ with 7 elements
D. $C_5H_{11}OCSSK$ with 20 elements

(ANCQ, 2008, Q.1)R

19. The elements X and Y react to give a product XY_2. The reaction is shown diagrammatically below.



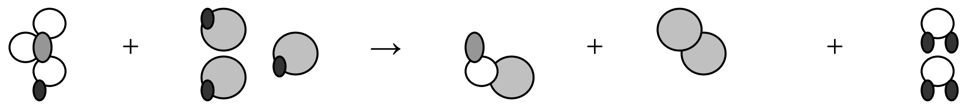
The simplest and correct chemical equation to describe the reaction taking place is:
A. $4X + 8Y \rightarrow 4XY_2$
B. $X + 2Y \rightarrow XY_2$
C. $6X + 9Y \rightarrow 4XY_2 + 2X + Y$
D. $X_4 + Y_8 \rightarrow 4XY_2$

(ANCQ, 1999, Q.8)R

20. A mixture of concentrated nitric acid and concentrated hydrochloric acid is one of the few solutions that can dissolve the metals gold and platinum. When mixed, the acids react as shown in the following equation:

$$HNO_{3\,(l)} + 3HCl_{(aq)} \rightarrow NOCl_{(aq)} + Cl_{2\,(aq)} + 2H_2O_{(l)}$$

The same reaction can be shown as a particulate drawing as follows:



Which element is represented by each symbol in the above diagram?

A. Chlorine	Hydrogen	Oxygen	Nitrogen
B. Oxygen	Chlorine	Hydrogen	Nitrogen
C. Chlorine	Hydrogen	Nitrogen	Oxygen
D. Oxygen	Hydrogen	Chlorine	Nitrogen

(ANCQ, 2003, Q.18)R

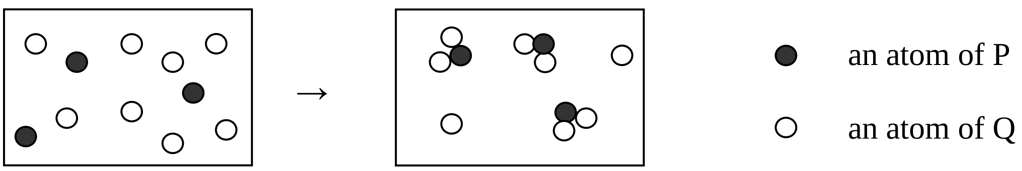
21. The equation shows the reaction between carbon and oxygen gas.

$$C\,(s) + O_2\,(g) \longrightarrow CO_2\,(g)$$

What is the mass of carbon dioxide gas released when 12 g of carbon reacts completely in the reaction? [Relative atomic mass: C, 12 : O, 16]

A 12 g
B 28 g
C 32 g
D 44 g

22. The reaction of element P with element Q is represented in the following diagram:



Which equation best describes this reaction?

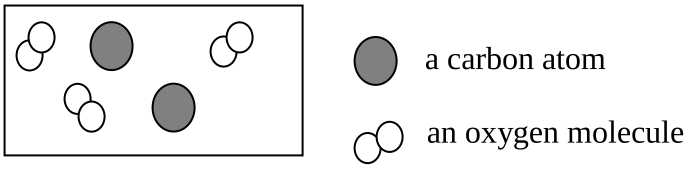
A. $3P + 8Q \rightarrow 3PQ_2 + 2Q$
B. $P_3 + Q_8 \rightarrow 3PQ_2 + Q_2$
C. $P + Q \rightarrow 3PQ_2 + 2Q$
D. $P + 2Q \rightarrow PQ_2$

(Nurrenberg & Pickering, 1987, JCE, p.509)R

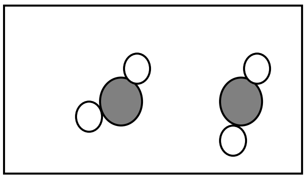
23. Carbon and oxygen react according to the following equation:

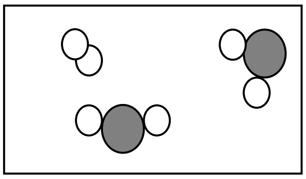
$C + O_2 \rightarrow CO_2$

Reactants



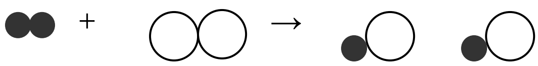
Which diagram correctly represents the molecules in the container after the reaction?

A. 

B. 

C. Both A or B are correct
D. Both A and B are incorrect

24. The following shows a chemical change. The symbol (○) represents one atom of a certain type. The symbol (●) represents a single atom of another type. If the symbols for atoms touch, they are part of a single molecule.



The reaction represented by these symbols can be

A. $2H_2 + O_2 \rightarrow 2H_2O$
B. $2Mg + O_2 \rightarrow 2MgO$
C. $C + O_2 \rightarrow CO_2$
D. $H_2 + Cl_2 \rightarrow 2HCl$

25. Ozone (O_3) is a gas found in the stratosphere. It absorbs ultra violet (UV) rays from the sun. The gas chlorofluorocarbon (CFC) released from aerosol tins can cause this ozone layer to decompose according to the following equation:

$2O_{3(g)} \rightarrow 3O_{2(g)}$

(RAM: O=16; 1 mole of gas occupies 24 dm^3 at room temperature and pressure of 1 atmosphere).
Which one of the following statements is true?

A. 3 moles of ozone produce 2 moles of oxygen
B. 1 mole of ozone produces 1 mole of oxygen
C. 48 g of ozone produce 48 g of oxygen
D. 24 dm^3 of ozone produce 24 dm^3 of oxygen

(IKM, 2002, Q.15)R

Note: ANCQ = The Australian National Chemistry Quiz
IKM = Institute of Chemistry, Malaysia
JCE = Journal of Chemical Education
R = Revised

NAME: ________________________ CLASS: ___________________

SCHOOL: ______________________ GENDER: _________________

TEST on REPRESENTATIONAL COMPETENCE (TRC) – Actual Study

Instructions:
1. This test consists of TWO parts: Part A and Part B.
2. Answer ALL the questions in both parts.
3. For Part A, choose the best answer for each item, then mark your choice by **CIRCLING** either A, B, C or D on the A**nswer Sheet** provided.
4. For Part B, write your answers in the spaces provided for each question.

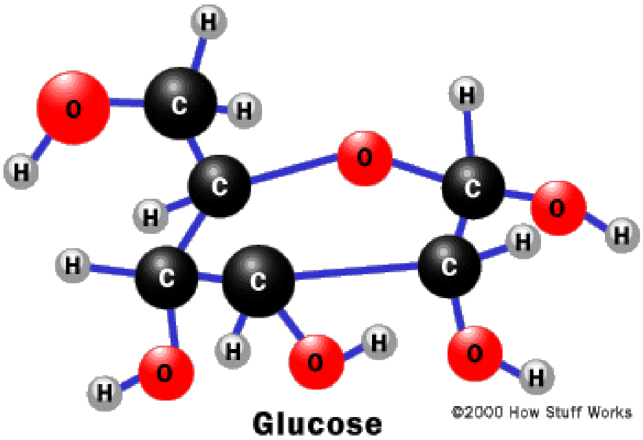
<u>Part A:</u> Multiple Choice Questions (25 marks)

For Questions 1 to 25, CIRCLE either A, B, C or D

1	A	B	C	D	14	A	B	C	D
2	A	B	C	D	15	A	B	C	D
3	A	B	C	D	16	A	B	C	D
4	A	B	C	D	17	A	B	C	D
5	A	B	C	D	18	A	B	C	D
6	A	B	C	D	19	A	B	C	D
7	A	B	C	D	20	A	B	C	D
8	A	B	C	D	21	A	B	C	D
9	A	B	C	D	22	A	B	C	D
10	A	B	C	D	23	A	B	C	D
11	A	B	C	D	24	A	B	C	D
12	A	B	C	D	25	A	B	C	D
13	A	B	C	D					

<u>Part B:</u> Short Free Response Format (15 marks)

1. The diagram below shows the structure of glucose.



(a) **Write** the molecular formula of glucose. _______________

(b) **Deduce** the empirical formula of glucose. ______________

2. When aluminium metal is exposed to air, a protective layer forms on its surface. This layer prevents further reaction between aluminium and oxygen.

(a) **Identify** this protective layer. _____________________________

(b) **Write** a balanced equation for the formation of this protective layer.

3. What do you know about: (a) an atom, (b) a molecule, (c) an element?
   Answer using **drawings** only.

4. **Draw** the Lewis structure of an oxygen molecule.

5. Magnesium reacts with an acidic solution to produce hydrogen. The following equation describes the reaction:

$$Mg(s) + 2H^{+}(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

In the above equation, the number "2" appears 3 times, with different meaning in each case. **Explain** the meaning of the number "2" in:

(i) $2H^{+}$ (aq)

(ii) Mg^{2+}(aq)

(iii) H_2(g)

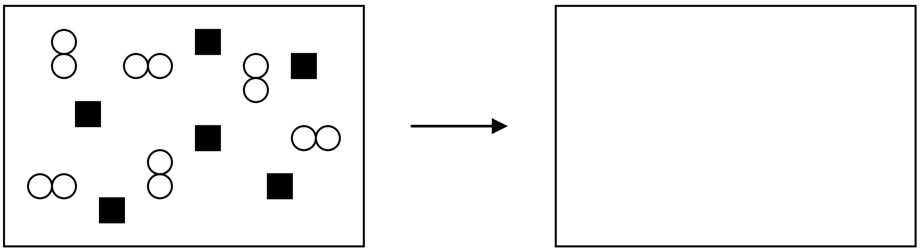
6. Consider the equation: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

(a) **Explain** its meaning at the molecular level.

(b) **Interpret** it in terms of moles.

(Hill & Petrucci, 2002, p.125)

7. The equation for a reaction is: $2S + 3O_2 \rightarrow 2SO_3$. Consider a mixture of S (■) and O_2 (○○) in a closed container as illustrated below:



Starting material   product mixture

Assuming complete reaction,

(a) **Draw** a molecular level representation of the product mixture in the box provided.

(b) **Explain** how you arrived at this representation.

(Arasasingham, Taagepera, Potter, & Lonjers, 2004, p.1523)R

Appendix 15

Test on Representational Competence (TRC) – Pilot Study

Part A: Multiple choice questions

1. Which of the following groups represents only compounds?

   A. CO, BN, HI, NO_2
   B. Co, Nb, HF, H_2S
   C. VS, Os, Y_2O_3, CuO
   D. CO_2, P_4S_5, Mn, Mg

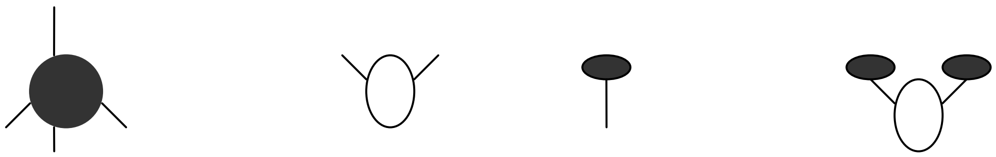
(ANCQ, 2001J, Q.2)R

2. Carbonates are compounds containing a *metallic element, carbon, and oxygen*. In a carbonate, there are always three oxygen atoms to every one carbon atom.
   Which one of the following formulae represents a carbonate?

   A. $CaCO_3$
   B. FeC_2O_4
   C. $CuH_2C_2O_4$
   D. $AgC_2H_3O_2$

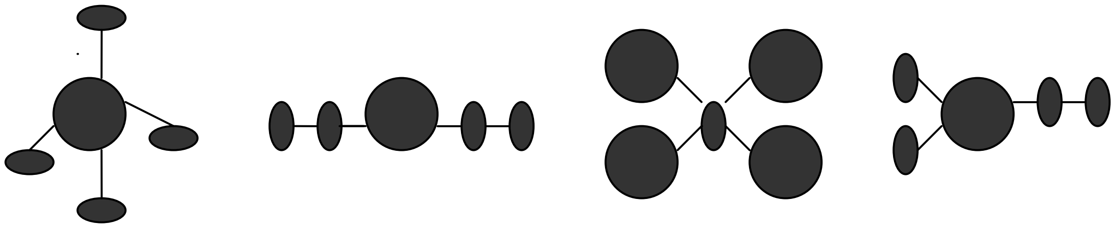
(ANCQ, 2000J, Q.17)R

3. The diagrams below represent atoms of carbon, oxygen, and hydrogen, and also a molecule of water, H_2O.



Carbon atom | Oxygen atom | Hydrogen atom | Water molecule

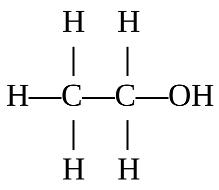
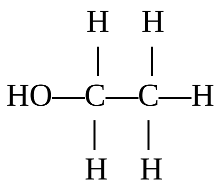
Which of the diagrams below correctly represents a molecule of methane, CH_4?

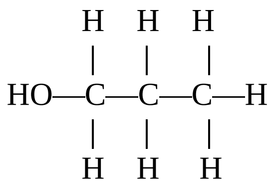
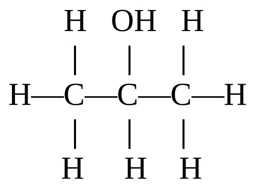


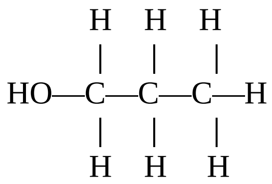
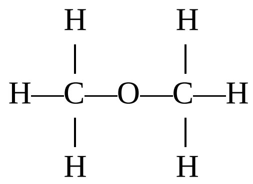
A | B | C | D

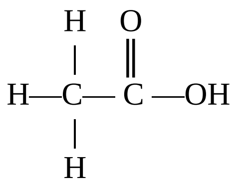
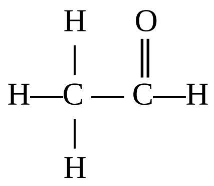
(ANCQ, 2002J, Q.9)R

4. Compounds of carbon can contain exactly the same kinds and numbers of different atoms, but with the atoms in different arrangements. The diagrams below show how atoms are arranged in some compounds of carbon.
Which diagram represents two molecules that are the same?

A.  and 

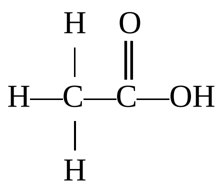
B.  and 

C.  and 

D.  and 

(ANCQ, 2002J, Q.16)R

5. The main ingredient in vinegar is a substance called acetic acid. The arrangement of atoms in acetic acid may be represented as:



Acetic acid can also be represented by the formula

A. HCO B. $H_3C_2O_2$ C. $C_2H_4O_2$ D. C_2H_4O

(ANCQ, 2002J, Q.20)R

6. The protective coating on our teeth is mostly calcium hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$. The total number of all kinds of atoms in this molecule is

   A. 18
   B. 22
   C. 37
   D. 44

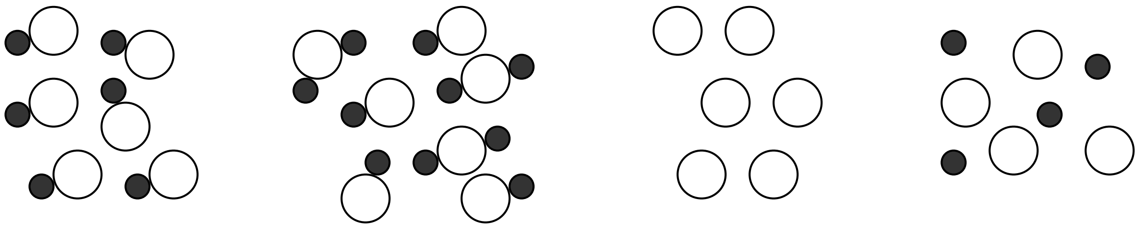
7. How many atoms of hydrogen are represented in the formula $(NH_4)_2HPO_4$?
   A. 5
   B. 7
   C. 8
   D. 9

8. Which of the following compounds has the largest number of different elements?

   A. Na_2SnCl_6
   B. $(NH_4)_2SO_4$
   C. $C_{18}H_{35}O_2K$
   D. $Cu(NH_3)_4SO_4$

(ANCQ, 2001, Q.1)R

9. Which one of the following diagrams below represent, in order:
   an element, a pure compound, a mixture of elements, and a mixture of compounds?



1 2 3 4

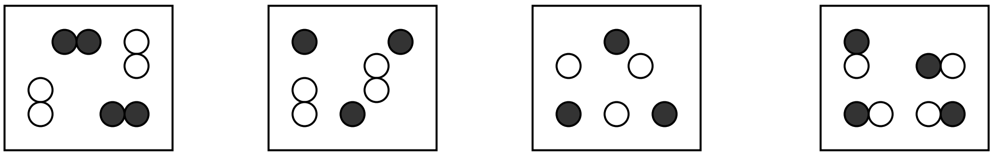
   A. 3, 1, 4, 2
   B..1, 2, 3, 4
   C. 4, 3, 2, 1
   D. 3, 4, 1, 2

(ANCQ, 2001, Q.12)R

10. A charged particle with 28 protons, 29 electrons and 31 neutrons can be represented as:
   A. $^{59}_{28}X^{+}$ B. $^{59}_{27}X^{-}$ C. $^{59}_{28}X^{-}$ D. $^{59}_{29}X^{+}$

(ANCQ, 1998, Q.6)R

11. A mixture of gases contains only atoms of helium and molecules of hydrogen. Which of the following diagrams is the best representation of the mixture?



A B C D

(ANCQ, 2000, Q.4)R

12. What is the relative formula mass of calcium phosphate, $Mg_3(PO_4)_2$?
(RAM: Mg=24, O=16, P=31)

A. 190 B. 199 C. 231 D. 262

(ANCQ, 2000, Q.5)R

13. Borax, $Na_2B_4O_7$, is used as a poison for ants and cockroaches.
The number of atoms of boron represented by "$6Na_2B_4O_7$" is

A. 4 B. 6 C. 10 D. 24

(ANCQ, 2000, Q.8)R

14. Hydrocarbons are substances made up of carbon and hydrogen only. Formulae for some hydrocarbons are given below. Which values below for x and y will make CxHy the next member of the series shown?

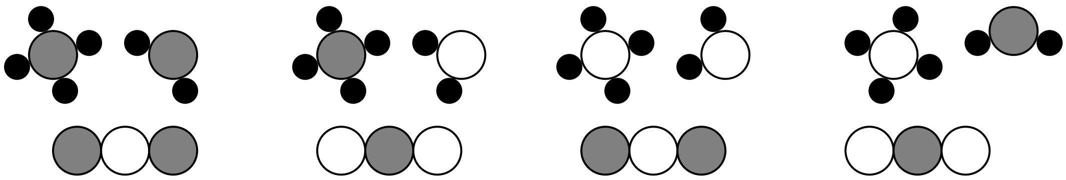
A. C_5H_{12} B. CxHy C. C_9H_{20} D. $C_{11}H_{24}$

x and y are respectively,

	x	y
A.	6	11
B.	7	16
C.	8	20
D.	16	7

(ANCQ, 1996, Q.12)R

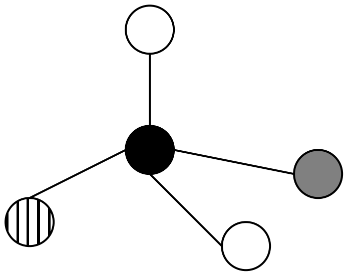
15. Which one of the following diagrams represents one molecule each of methane, CH_4, water, H_2O, and carbon dioxide, CO_2?



A B C D

(ANCQ, 2004, Q.3)R

16. A model of a compound was made using patterned balls. Each different pattern represents a different element.



Which of the following compounds is the most likely to be represented above?

A. dichloromethane, CH_2Cl_2
B. bromodichloromethane, $CHBrCl_2$
C. trichloromethane, $CHCl_3$
D. tetrachloromethane, CCl_4 (ANCQ, 1996, Q.28)R

17. Use the molecular diagrams and formulae in Figure 1 to determine the chemical formula for the molecule represented in Figure 2.

AB_3 C_2D

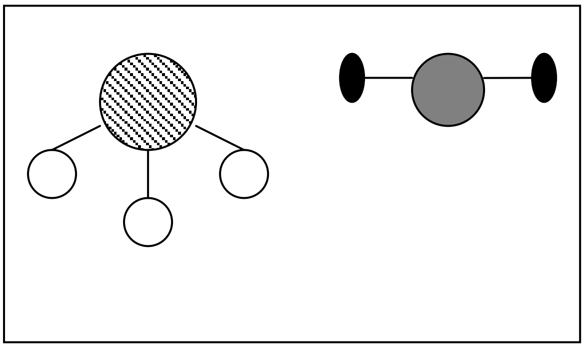


Figure 1

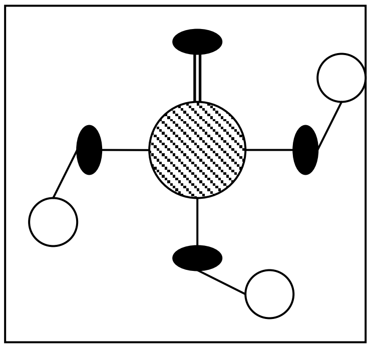


Figure 2

The correct formula for the molecule represented in Figure 2 is

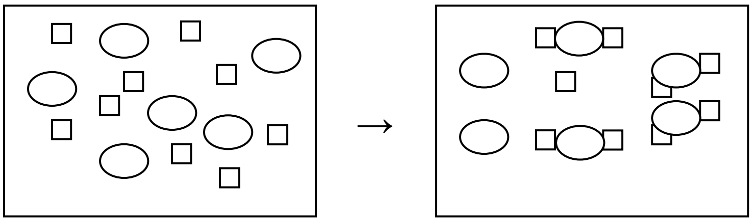
A. BA_4C_3 B. CB_4A_3 C. AC_3B_4 D. C_4AB_3

(ANCQ, 2000, Q.13)R

18. Which of the four molecules whose formulae are given below has the greatest mass? (RAMs: H=1, C=12, N=14, O=16)

    A. Propane, C_3H_8
    B. Ethylamine, $C_2H_5NH_2$
    C. Ethanol, C_2H_5OH
    D. Dimethylamine, $(CH_3)_2NH$

19. The elements X ( ) and Y ( ) react to give a product XY_2. The reaction is shown diagrammatically below.



The simplest and correct chemical equation to describe the reaction taking place is:

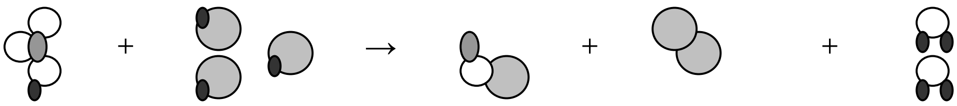
A. $4X + 8Y \rightarrow 4XY_2$
B. $X + 2Y \rightarrow XY_2$
C. $6X + 9Y \rightarrow 4XY_2 + 2X + Y$
D. $X_4 + Y_8 \rightarrow 4XY_2$

(ANCQ, 1999, Q.8)R

20. A mixture of concentrated nitric acid and concentrated hydrochloric acid is one of the few solutions that can dissolve the metals gold and platinum. When mixed, the acids react as shown in the following equation:

$HNO_{3\,(l)} + 3HCl_{(aq)} \rightarrow NOCl_{(aq)} + Cl_{2\,(aq)} + 2H_2O_{(l)}$

The same reaction can be shown as a particulate drawing as follows:



Which element is represented by each symbol in the above diagram?

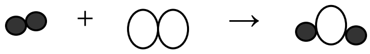
A. Chlorine	Hydrogen	Oxygen	Nitrogen
B. Oxygen	Chlorine	Hydrogen	Nitrogen
C. Chlorine	Hydrogen	Nitrogen	Oxygen
D. Oxygen	Hydrogen	Chlorine	Nitrogen

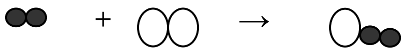
(ANCQ, 2003, Q.18)R

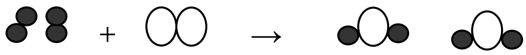
21. Hydrogen gas burns in air to form water according to the following equation:

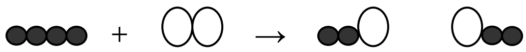
$$2H_2 + O_2 \rightarrow 2H_2O$$

A model of the above process is best represented by

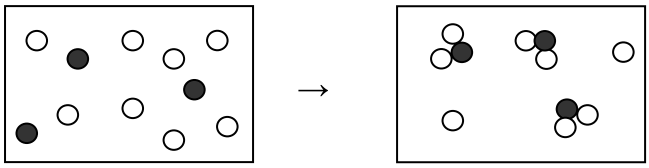
A. 

B. 

C. 

D. 

22. The reaction of element P (●) with element Q (○) is represented in the following diagram:



Which equation best describes this reaction?

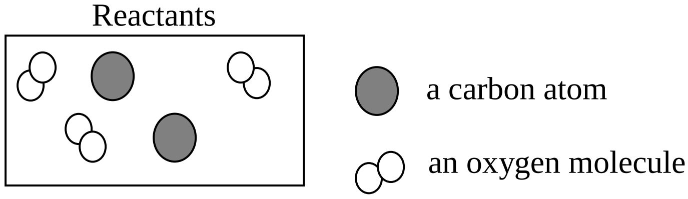
A. $P + Q \rightarrow 3PQ_2 + 2Q$
B. $P + 2Q \rightarrow PQ_2$
C. $3P + 8Q \rightarrow 3PQ_2 + 2Q$
D. $P_3 + Q_8 \rightarrow 3PQ_2 + Q_2$

(Nurrenbern & Pickering, JCE, 1987, p.509)R

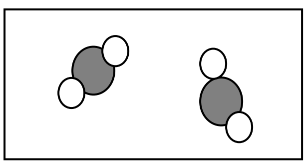
23. Carbon and oxygen react according to the following equation:

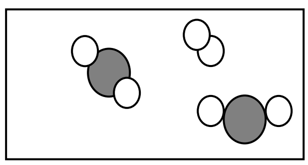
$C + O_2 \rightarrow CO_2$

Reactants



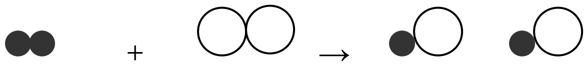
Which diagram correctly represents the molecules in the container after the reaction?

A. 

B. 

C. Both A or B are correct
D. Both A and B are incorrect

24. The following shows a chemical change. The symbol () represents one atom of a certain type. The symbol () represents a single atom of another type. If the symbols for atoms touch, they are part of a single molecule.



The reaction represented by these symbols can be

A. $2H_2 + O_2 \rightarrow 2H_2O$
B. $H_2 + Cl_2 \rightarrow 2HCl$
C. $2Mg + O_2 \rightarrow 2MgO$
D. $C + O_2 \rightarrow CO_2$

25. Ozone (O_3) is a gas found in the stratosphere. It absorbs ultra violet (UV) rays from the sun. The gas chlorofluorocarbon (CFC) released from aerosol tins can cause this ozone layer to decompose according to the following equation:

$$2O_{3(g)} \rightarrow 3O_{2(g)}$$

(RAM: O=16; 1 mole of gas occupies $24dm^3$ at room temperature and pressure of 1 atmosphere).

Which one of the following statements is true?

A. 3 moles of ozone produce 2 moles of oxygen
B. 1 mole of ozone produces 1 mole of oxygen
C. 48g of ozone produce 48g of oxygen
D. $24dm^3$ of ozone produce $24dm^3$ of oxygen

(IKM, 2002, Q.15)R

Note:		
	ANCQ	= The Australian National Chemistry Quiz
	IKM	= Institut Kimia Malaysia
	JCE	= Journal of Chemical Education
	J	= Junior Division
	R	= Revised

NAME: ________________________ CLASS: ___________________

SCHOOL: ______________________ GENDER: _________________

TEST on REPRESENTATIONAL COMPETENCE (TRC) – Pilot Study

Instructions:
1. This test consists of TWO parts: Part A and Part B.
2. Answer ALL the questions in both parts.
3. For Part A, choose the best answer for each item, then mark your choice by **CIRCLING** either A, B, C or D on the A**nswer Sheet** provided.
4. For Part B, write your answers in the spaces provided for each question.

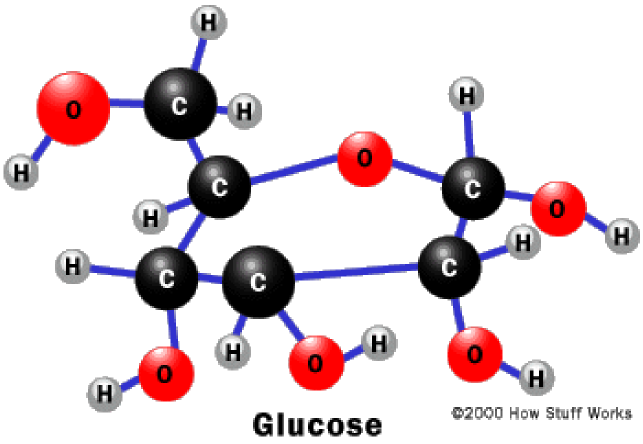
Part A: Multiple Choice Questions (25 marks)

For Questions 1 to 25, CIRCLE either A, B, C or D

1	A	B	C	D	14	A	B	C	D
2	A	B	C	D	15	A	B	C	D
3	A	B	C	D	16	A	B	C	D
4	A	B	C	D	17	A	B	C	D
5	A	B	C	D	18	A	B	C	D
6	A	B	C	D	19	A	B	C	D
7	A	B	C	D	20	A	B	C	D
8	A	B	C	D	21	A	B	C	D
9	A	B	C	D	22	A	B	C	D
10	A	B	C	D	23	A	B	C	D
11	A	B	C	D	24	A	B	C	D
12	A	B	C	D	25	A	B	C	D
13	A	B	C	D					

Part B: Short Free Response Format (15 marks)

1. The diagram below shows the structure of glucose.



(a) **Write** the molecular formula of glucose. _______________

(b) **Deduce** the empirical formula of glucose. ______________

2. When aluminium metal is exposed to air, a protective layer forms on its surface. This layer prevents further reaction between aluminium and oxygen.

(a) **Identify** this protective layer. ______________________________

(b) **Write** a balanced equation for the formation of this protective layer.

3. What do you know about: (a) an atom, (b) a molecule, (c) an element?
Answer using **drawings** only.

4. **Draw** the Lewis structure of an oxygen molecule.

5. Magnesium reacts with an acidic solution to produce hydrogen. The following equation describes the reaction:

$$Mg(s) + 2H^{+}(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

In the above equation, the number “2” appears 3 times, with different meaning in each case. **Explain** the meaning of the number “2” in:

(i) $2H^{+}(aq)$

(ii) $Mg^{2+}(aq)$

(iii) $H_2(g)$

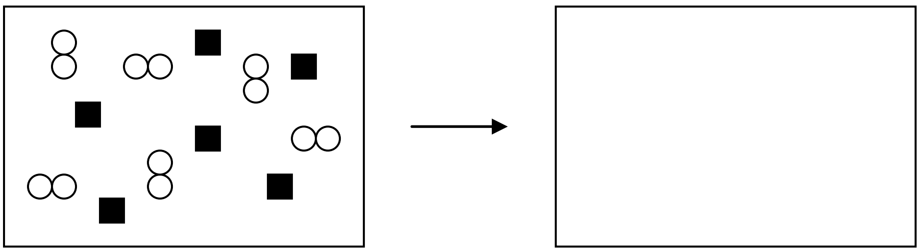
6. Consider the equation: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

(a) **Explain** its meaning at the molecular level.

(b) **Interpret** it in terms of moles.

(Hill & Petrucci, 2002, p.125)

7. The equation for a reaction is: $2S + 3O_2 \rightarrow 2SO_3$. Consider a mixture of S (■) and O_2 (○○) in a closed container as illustrated below:



Starting material | product mixture

Assuming complete reaction,
(a) **Draw** a molecular level representation of the product mixture in the box provided.
(b) **Explain** how you arrived at this representation.

(Arasasingham, Taagepera, Potter, & Lonjers, 2004, p.1523)R

Item Analysis of the TRC - Actual Study

Item No.	**R_U**	**R_M**	**R_L**	**R_T**	**Item Difficulty Index $P=R_T/384$**	**Item Discrimination Index $D=(R_U - R_L)/104$**
A1	80	83	32	195	.51	.46
A2	103	145	55	303	.79	.46
A3	98	136	52	286	.74	.44
A4	90	111	43	244	.64	.45
A5	96	133	56	285	.74	.38
A6	79	45	26	150	.39	.51
A7	52	62	16	130	.34	.35
A8	102	154	51	307	.80	.49
A9	97	73	17	187	.49	.77
A10	78	79	23	180	.47	.53
A11	80	46	16	142	.37	.62
A12	56	56	19	131	.34	.36
A13	103	138	46	287	.75	.55
A14	76	44	13	133	.35	.61
A15	85	117	44	246	.64	.39
A16	94	101	39	234	.61	.53
A17	92	122	37	251	.65	.53
A18	62	70	31	163	.42	.30
A19	20	12	20	52	.14	.00
A20	99	142	38	279	.73	.59
A21	89	84	26	199	.52	.61
A22	23	8	12	43	.11	.11
A23	79	77	24	180	.47	.53
A24	88	94	27	209	.54	.59
A25	59	44	21	124	.32	.37

B1(a)	100	119	29	248	.65	.68
B1(b)	96	104	19	219	.57	.74
B2(a)	76	19	6	101	.26	.67
B2(b)	35	5	0	40	.10	.34
B3(a)	93	96	28	217	.57	.63
B3(b)	88	90	27	205	.53	.59
B3(c)	76	54	7	137	.36	.66
B4	21	2	1	24	.06	.19
B5(i)	56	11	4	71	.18	.50
B5(ii)	22	4	0	26	.07	.21
B5(iii)	27	1	0	28	.07	.26
B6(a)	31	2	0	33	.09	.30
B6(b)	67	3	0	70	.18	.64
B7(a)	57	8	0	65	.17	.55
B7(b)	16	0	0	16	.04	.15

Note:

R_U = Number of students choosing the correct answer in the upper 27%
R_M = Number of students choosing the correct answer in the middle group
R_L = Number of students choosing the correct answer in the lower 27%

R_T = Total number of students choosing the correct answer
T = Total number of students taking the test = 384
N = Number of students in the upper or lower group = 104

Test on Representational Competence (TRC) – Actual Study

Table 16a(i): Interpretation of Difficulty Index
(Source: adapted from Macintosh & Morrison, 1969)

Difficulty Index (p)	Item Difficulty Level	Item No.
< 0.10	Too difficult	B4, B5(ii), B5(iii), B6(a), B7(b)
0.10 – 0.29	Difficult	A19, A22, B2(a), B2(b), B5(i), B6(b), B7(a)
0.30 – 0.70	Moderately difficult	A1, A4, A6, A7, A9, A10, A11, A12, A14, A15, A16, A17, A18, A21, A23, A24, A25 B1(a), B1(b), B3(a), B3(b), B3(c)
0.71 – 0.90	Easy	A2, A3, A5, A8, A13, A20
> 0.90	Too easy	-

Table 16a(ii): Interpretation of Discrimination Index
(Source: adapted from Stanley & Hopkins, 1981)

Discrimination Index (ID)	Interpretation of ID	Item No.
< 0.20	Poor (reject)	A19, A22, B4, B7(b)
0.20 – 0.29	Marginal (needs improvement)	B5(ii), B5(iii)
0.30 – 0.40	Quite good	A5, A7, A12, A15, A18, A25, B2(b), B6(a)
> 0.40	Discriminates well	A1, A2, A3, A4, A6, A8, A9, A10, A11, A13, A14, A16, A17, A20, A21, A23, A24, B1(a), B1(b), B2(a), B3(a), B3(b), B3(c), B5(i), B6(b), B7(a)

Item Analysis of the TRC (mcq only) - Pilot Study

Item No.	**R_U**	**R_M**	**R_L**	**R_T**	**Item Difficulty Index $p=R_T/60$**	**Item Discrimination Index $D=(R_U - R_L)/16$**
1	11	15	4	30	0.50	0.44
2	16	25	4	45	0.75	0.75
3	13	22	4	39	0.65	0.56
4	16	22	8	46	0.77	0.50
5	15	22	1	38	0.63	0.88
6	16	23	3	42	0.70	0.81
7	15	20	9	44	0.73	0.38
8	14	6	11	31	0.52	0.19
9	15	21	11	47	0.78	0.25
10	13	12	1	26	0.43	0.75
11	16	11	9	36	0.60	0.44
12	16	26	11	53	0.88	0.31
13	16	15	4	35	0.58	0.75
14	15	21	5	41	0.68	0.63
15	16	22	1	39	0.65	0.94
16	15	24	4	43	0.72	0.69
17	16	25	1	42	0.70	0.94
18	14	21	2	37	0.62	0.75
19	4	1	2	7	0.12	0.13
20	16	26	1	43	0.72	0.94
21	16	27	13	56	0.93	0.19
22	3	0	3	6	0.10	0.00
23	13	17	3	33	0.55	0.63
24	16	17	5	38	0.63	0.69
25	9	9	1	19	0.32	0.50

Note:

R_U = Number of students choosing the correct answer in the upper 27%
R_M = Number of students choosing the correct answer in the middle group
R_L = Number of students choosing the correct answer in the lower 27%
R_T = Total number of students choosing the correct answer
T = Total number of students taking the test = 60
N = Number of students in the upper or lower group = 16

Test on Representational Competence (mcq only) – Pilot Study

Table 16(i): Interpretation of Difficulty Index
(Source: adapted from Macintosh & Morrison, 1969)

Difficulty Index (p)	Item Difficulty Level	Item No.
< 0.10	Too difficult	-
0.10 – 0.30	Difficult	19, 22
0.30 – 0.70	Moderately difficult	1, 3, 5, 6, 8, 10, 11, 13, 14, 15, 17, 18, 23, 24, 25
0.70 – 0.90	Easy	2, 4, 7, 9, 12, 16, 20
> 0.90	Too easy	21

Table 16(ii): Interpretation of Discrimination Index
(Source: adapted from Stanley & Hopkins, 1981)

Discrimination Index (ID)	Interpretation of ID	Item No.
< 0.20	Poor (reject)	8, 19, 21, 22
0.20 – 0.30	Marginal (needs improvement)	9
0.30 – 0.40	Quite good	7, 12
> 0.40	Discriminates well	1, 2, 3, 4, 5, 6, 10, 11, 13, 14, 15, 16, 17, 18, 20, 23, 24, 25

Test Score Reliability of the TRC – Actual Study (n=384)

Item No.	Total no. of correct responses	P value	q=1-p	Pq
A1	195	.51	.49	.25
A2	303	.79	.21	.17
A3	286	.74	.26	.19
A4	244	.64	.36	.23
A5	285	.74	.26	.19
A6	150	.39	.61	.24
A7	130	.34	.66	.22
A8	307	.80	.20	.16
A9	187	.49	.51	.25
A10	180	.47	.53	.25
A11	142	.37	.63	.23
A12	131	.34	.66	.22
A13	287	.75	.25	.19
A14	133	.35	.65	.23
A15	246	.64	.36	.23
A16	234	.61	.39	.24
A17	251	.65	.35	.23
A18	163	.42	.58	.24
A19	52	.14	.86	.12
A20	279	.73	.27	.20
A21	199	.52	.48	.25
A22	43	.11	.89	.10
A23	180	.47	.53	.25
A24	209	.54	.46	.25
A25	124	.32	.68	.22
B1a	248	.65	.35	.23
B1b	219	.57	.43	.25
B2a	101	.26	.74	.19
B2b	40	.10	.90	.09
B3a	217	.57	.43	.25
B3b	205	.53	.47	.25
B3c	137	.36	.64	.23
B4	24	.06	.94	.06
B5i	71	.18	.82	.15
B5ii	26	.07	.93	.06
B5iii	28	.07	.93	.07

B6a	33	.09	.91	.08
B6b	70	.18	.82	.15
B7a	65	.17	.83	.14
B7b	16	.04	.96	.04
				∑pq=7.58

KR-20 was computed instead of KR-21 as the difficulty level of the items (p value) was different.

K-R 20: $$r = \frac{k}{k-1}\left[1 - \frac{\sum pq}{S^2}\right]$$

where r = estimated reliability of the whole test
k = number of items in test
p = proportion of correct responses to a particular item
q = proportion of incorrect responses to that item (so that p+q=1)
pq = variance of a single item scored dichotomously
∑ = summation sign indicating that pq is summed over all items
S^2 = variance of the total test

Test score reliability for the MCQ items of the TRC (Part A)

K-R 20: $$r = \frac{25}{25-1}\left(1 - \frac{5.35}{23.995}\right)$$

$$= 1.04\ (1- 0.22)$$

= **0.81**

Test score reliability for the Free Response item of the TRC (Part B)

K-R 20: $$r = \frac{15}{15-1}\left(1 - \frac{2.26}{12.483}\right)$$

$$= 1.07\ (1- 0.18)$$

= **0.88**

Test score reliability for the 40-item TRC

K-R 20: $$r = \frac{40}{40-1}\left(1 - \frac{7.61}{60.542}\right)$$

$$= 1.03\ (1- 0.13)$$

$$= \underline{\mathbf{0.90}}$$

Test Score Reliability of the TRC (Part B) – Actual Study

Rater1*Rater2

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.795	.043	26.110	.000
N of Valid Cases		96			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Rater1*Rater3

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.807	.042	26.482	.000
N of Valid Cases		96			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Rater2*Rater3

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.989	.011	31.963	.000
N of Valid Cases		96			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Average k value = (0.795 + 0.807 + 0.989)/3

= **0.864**

Test Score Reliability of the TRC (Part A) – Pilot Study

Item No.	P value	q=1-p	pq
1	0.50	0.50	0.25
2	0.75	0.25	0.19
3	0.65	0.35	0.23
4	0.77	0.23	0.18
5	0.63	0.37	0.23
6	0.70	0.30	0.21
7	0.73	0.27	0.20
8	0.52	0.48	0.25
9	0.78	0.22	0.17
10	0.43	0.57	0.25
11	0.60	0.40	0.24
12	0.88	0.12	0.11
13	0.58	0.42	0.24
14	0.68	0.32	0.22
15	0.65	0.35	0.23
16	0.72	0.28	0.20
17	0.70	0.30	0.21
18	0.62	0.38	0.24
19	0.12	0.88	0.11
20	0.72	0.28	0.20
21	0.93	0.07	0.07
22	0.10	0.90	0.09
23	0.55	0.45	0.25
24	0.63	0.37	0.23
25	0.32	0.68	0.22
			$\sum pq=4.99$

KR-20 was computed instead of KR-21 as the difficulty level of the items (p value) was different.

$$\textbf{K-R 20:} \quad \mathbf{r = \frac{k}{k-1}\left[1 - \frac{\sum pq}{S^2}\right]}$$

where r = estimated reliability of the whole test
k = number of items in test
p = proportion of correct responses to a particular item
q = proportion of incorrect responses to that item (so that p+q=1)
pq = variance of a single item scored dichotomously
$\sum$ = summation sign indicating that pq is summed over all items
S^2 = variance of the total test

<u>Test score reliability for the TRC pilot study (n = 60)</u>

$$\text{K-R 20:} \quad r = \frac{25}{25-1}\left(1 - \frac{4.99}{59.81}\right)$$

$$= 1.04\ (1- 0.08)$$

$$= \underline{\mathbf{0.96}}$$

Test Score Reliability of the TRC (Part B) – Pilot Study

Rater1*Rater2

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.845	.101	8.446	.000
N of Valid Cases		15			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Rater1*Rater3

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.769	.118	7.906	.000
N of Valid Cases		15			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Rater2*Rater3

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.920	.078	8.430	.000
N of Valid Cases		15			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Test Score Reliability of CTSR – Actual Study

Item No.	P value	q=1-p	Pq
1	.69	.31	.22
2	.63	.37	.23
3	.41	.59	.24
4	.37	.63	.23
5	.35	.65	.23
6	.36	.64	.23
7	.33	.67	.22
8	.39	.61	.24
9	.46	.54	.25
10	.40	.60	.24
11	.14	.86	.12
12	.19	.81	.15
13	.29	.71	.21
14	.20	.80	.16
15	.50	.50	.25
16	.71	.29	.21
17	.51	.49	.25
18	.40	.60	.24
19	.46	.54	.25
20	.36	.64	.23
21	.29	.71	.20
22	.36	.64	.23
23	.29	.71	.20
24	.47	.53	.25

$\sum pq=5.28$

KR-20 shall be computed instead of KR-21 as the difficulty level of the items (p value) is different.

$$\textbf{K-R 20:} \quad \mathbf{r = \frac{k}{k-1}\left[1 - \frac{\sum pq}{S^2}\right]}$$

where r = estimated reliability of the whole test
k = number of items in test
p = proportion of correct responses to a particular item
q = proportion of incorrect responses to that item (so that p+q=1)
pq = variance of a single item scored dichotomously
$\sum$ = summation sign indicating that pq is summed over all items
S^2 = variance of the total test

Test score reliability for the CTSR actual study (n = 214)

$$\text{K-R 20:} \quad r = \frac{24}{24-1}\left(1 - \frac{5.28}{24.57}\right)$$

$$= 1.04\ (1- 0.21)$$

$$= \underline{\mathbf{0.82}}$$

Appendix 18

NAME: ________________________ CLASS: ___________________

SCHOOL: ______________________ GENDER: _________________

CLASSROOM TEST of SCIENTIFIC REASONING (CTSR)

Instructions:

This test contains 24 items.
Choose the best answer for each item. Then make a dark mark on the answer sheet.

1.	=A=	=B=	=C=	=D=	=E=	13.	=A=	=B=	=C =	=D=	=E=
2.	=A=	=B=	=C=	=D=	=E=	14.	=A=	=B=	=C=	=D=	=E=
3.	=A=	=B=	=C=	=D=	=E=	15.	=A=	=B=	=C=	=D=	=E=
4.	=A=	=B=	=C=	=D=	=E=	16.	=A=	=B=	=C=	=D=	=E=
5.	=A=	=B=	=C=	=D=	=E=	17.	=A=	=B=	=C=	=D=	=E=
6.	=A=	=B=	=C=	=D=	=E=	18.	=A=	=B=	=C=	=D=	=E=
7.	=A=	=B=	=C=	=D=	=E=	19.	=A=	=B=	=C=	=D=	=E=
8.	=A=	=B=	=C=	=D=	=E=	20.	=A=	=B=	=C=	=D=	=E=
9.	=A=	=B=	=C=	=D=	=E=	21.	=A=	=B=	=C=	=D=	=E=
10	=A=	=B=	=C=	=D=	=E=	22.	=A=	=B=	=C=	=D=	=E=
11.	=A=	=B=	=C=	=D=	=E=	23.	=A=	=B=	=C=	=D=	=E=
12.	=A=	=B=	=C=	=D=	=E=	24.	=A=	=B=	=C=	=D=	=E=

Test Score Reliability LAQ

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

		Mean	Std Dev	Cases
1.	ITEM1	3.1991	.7159	211.0
2.	ITEM2	2.9526	.8151	211.0
3.	ITEM3	1.9810	.8835	211.0
4.	ITEM4	2.7062	.9304	211.0
5.	ITEM5	2.2464	.8596	211.0
6.	ITEM6	2.8578	.9753	211.0
7.	ITEM7	2.4313	.9506	211.0
8.	ITEM8	2.9431	.9888	211.0
9.	ITEM9	2.7109	.8601	211.0
10.	ITEM10	2.7536	.8485	211.0
11.	ITEM11	2.4929	1.0159	211.0
12.	ITEM12	3.1137	.9031	211.0
13.	ITEM13	2.8057	.8019	211.0
14.	ITEM14	2.8341	1.0583	211.0
15.	ITEM15	2.7536	.8706	211.0
16.	ITEM16	2.3412	.9842	211.0
17.	ITEM17	2.6493	.9662	211.0
18.	ITEM18	2.8389	.8851	211.0
19.	ITEM19	2.3744	.9140	211.0
20.	ITEM20	2.3412	.9088	211.0
21.	ITEM21	2.3791	.9848	211.0
22.	ITEM22	2.5687	.9605	211.0
23.	ITEM23	2.6540	.9801	211.0

N of Cases = 211.0

Statistics for	Mean	Variance	Std Dev	N of Variables
Scale	60.9289	47.7711	6.9117	23

Item Means	Mean	Minimum	Maximum	Range	Max/Min	Variance
	2.6491	1.9810	3.1991	1.2180	1.6148	.0859

Reliability Coefficients   23 items

Alpha = 0.6204   Standardized item alpha = .6266

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Reliability Coefficients

N of Cases =   212.0   N of Items = 13

Alpha =   0.7701

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Reliability Coefficients

N of Cases =   211.0   N of Items = 10

Alpha =   0.4725

Reliability LAQ

ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
S101	3	2	1	3	3	3	2	3	2	3	3	4	3	2	2	3	3	3	3	2	2	3	3	61
S102	4	3	2	2	3	4	3	3	3	4	3	3	4	2	2	3	3	2	2	2	3	2	2	64
S103	4	3	3	2	2	4	4	3	3	4	4	4	4	2	2	4	3	3	1	2	1	4	3	69
S104	4	2	2	2	1	3	3	2	2	3	1	2	2	2	3	3	3	3	2	3	2	2	2	54
S105	4	4	1	3	4	2	4	4	1	4	1	4	2	2	4	3	3	3	4	0	4	2	4	67
S106	2	3	2	3	3	3	4	3	2	4	2	4	3	2	2	3	2	3	3	2	3	3	2	63
S107	2	2	2	3	3	3	2	2	2	3	2	4	3	2	2	3	3	3	2	3	2	3	3	59
S108	3	4	2	1	2	3	1	2	3	3	3	2	3	3	3	1	3	3	2	2	1	2	3	55
S109	4	2	2	2	2	4	4	3	2	2	3	3	4	2	2	1	2	3	2	1	3	2	3	58
S110	2	2	2	2	3	2	3	3	2	3	2	4	2	1	3	3	3	2	3	1	3	2	3	56
S111	2	2	2	2	3	4	3	2	3	1	3	4	3	3	2	1	2	3	2	1	1	4	2	55
S112	2	2	2	3	2	2	1	2	2	3	2	4	3	3	2	1	4	3	2	2	2	2	4	55
S113	3	3	2	4	3	3	4	2	3	3	3	2	3	2	2	3	3	2	3	3	2	3	2	63
S114	3	2	2	2	2	2	1	2	2	3	3	4	2	2	2	3	3	2	2	2	2	2	3	53
S115	3	4	1	2	2	4	2	3	3	4	3	3	3	2	1	3	3	3	1	2	1	4	2	59
S116	4	2	2	3	3	2	3	3	2	3	2	3	3	2	2	2	3	3	3	2	2	2	3	59
S118	3	3	3	2	3	4	3	2	4	3	2	4	2	1	3	4	3	3	3	3	4	2	4	68
S119	3	4	2	2	2	4	3	4	2	4	3	4	4	3	1	2	2	3	1	4	2	4	2	65
S120	2	3	3	3	1	4	3	3	3	3	3	3	3	2	3	2	2	3	2	2	2	3	4	62
S121	4	4	2	4	3	4	4	4	4	4	2	4	4	1	4	2	4	4	3	4	4	4	3	80
S123	4	1	2	1	2	3	1	1	2	2	4	4	3	2	1	4	2	3	1	1	2	3	4	53
S124	4	3	1	4	3	3	4	2	2	4	2	2	2	3	2	1	4	2	4	1	1	2	2	58
S125	3	4	1	4	3	3	3	3	3	3	2	4	3	3	3	3	2	3	2	2	2	1	3	63
S126	3	2	3	2	2	4	3	2	2	2	2	3	2	3	2	3	1	3	2	1	1	2	2	52
S127	4	4	1	4	1	2	1	4	2	4	3	4	4	1	4	1	4	4	3	1	1	4	3	64
S128	3	3	3	2	3	4	3	2	2	4	1	4	2	3	3	3	3	3	3	2	2	4	3	65
S129	3	2	1	3	4	2	3	2	2	3	2	4	3	4	2	3	4	2	2	2	1	4	3	61
S130	3	3	3	2	2	4	3	4	2	3	2	4	2	2	3	3	4	2	2	2	2	4	2	63
S131	3	2	1	3	3	3	1	4	3	3	2	4	2	1	3	4	3	3	3	3	4	2	4	64
S132	4	4	2	2	1	4	4	3	3	4	4	3	4	3	2	3	3	3	2	4	3	4	4	73
S133	4	3	1	2	2	3	2	4	2	4	4	2	4	2	2	2	4	3	1	2	2	4	1	60
S134	2	4	2	1	2	2	1	2	3	4	1	1	2	1	2	1	4	1	4	2	1	1	1	45
S135	2	2	2	3	4	2	3	3	1	4	1	3	2	3	3	4	4	3	3	2	1	2	4	61
S136	4	3	3	3	3	3	1	4	1	3	4	4	3	4	3	3	3	4	2	3	2	4	4	71
S201	1	4	1	1	2	4	1	2	2	3	4	3	4	1	2	1	4	1	2	3	3	2	3	54
S202	4	4	1	4	1	4	1	4	3	3	3	1	3	2	4	3	4	4	1	4	3	3	1	65
S204	4	2	1	1	2	2	1	4	3	3	3	4	4	2	1	2	4	1	2	3	4	1	1	55
S205	3	3	3	2	3	3	1	4	3	3	3	4	2	3	2	3	4	3	2	2	3	1	2	62
S206	2	2	2	2	3	2	3	3	2	3	2	3	2	1	2	3	4	4	3	2	3	2	2	57
S207	4	3	2	3	1	4	2	3	3	3	3	3	2	2	1	2	2	3	1	4	4	2	4	61
S208	3	3	2	3	3	2	1	4	2	2	2	3	4	2	3	3	2	3	3	2	2	4	3	61
S209	4	4	2	4	1	4	3	4	4	4	4	4	3	2	4	4	3	4	2	3	3	2	3	75
S210	3	3	1	2	1	2	2	4	3	4	4	4	4	2	4	2	3	4	2	4	4	2	4	68
S212	4	3	1	2	2	3	3	4	3	4	4	4	3	1	4	1	3	3	2	3	2	2	2	63
S213	2	4	1	3	2	2	2	4	3	2	2	1	3	1	4	3	4	4	3	2	2	1	2	57
S214	3	2	1	4	4	4	3	3	4	4	1	4	2	4	1	1	4	4	2	2	3	4	3	67
S215	4	4	2	2	2	4	3	4	3	2	2	4	3	3	1	4	4	2	2	3	4	2	3	67
S216	3	3	1	4	1	3	3	3	4	3	4	3	3	2	2	2	3	2	1	2	3	2	3	60

S218	3	3	2	3	1	3	3	3	2	4	3	2	2	3	2	2	3	3	2	2	2	3	3	59
S219	3	2	1	1	3	4	2	1	4	3	4	3	4	4	3	4	3	2	1	2	3	4	1	62
S220	3	3	1	2	3	4	4	4	2	4	2	4	3	2	4	3	2	1	2	3	2	1	2	61
S221	4	2	1	3	1	3	4	4	4	3	4	3	3	1	3	1	3	1	3	4	3	1	2	61
S223	1	1	2	2	3	2	1	2	3	3	2	3	3	3	2	4	2	3	3	2	2	3	3	55
S224	1	1	1	1	1	3	1	4	2	3	1	4	2	1	2	3	3	2	4	2	1	2	3	48
S225	2	3	1	3	3	2	1	4	2	2	2	2	4	1	3	3	3	4	4	1	3	2	4	59
S226	3	3	4	2	3	4	1	3	1	2	4	3	1	3	2	1	2	2	2	4	1	4	3	58
S227	3	2	1	3	3	2	1	4	3	3	2	1	3	2	3	1	3	1	3	2	2	2	2	52
S228	3	3	2	3	2	3	2	4	2	4	4	4	4	2	4	2	1	4	1	2	2	4	4	66
S229	2	3	1	3	1	3	1	4	2	2	2	3	4	2	2	2	3	3	1	3	3	2	4	56
S230	3	2	3	4	4	1	1	2	2	2	1	1	3	3	3	3	4	2	2	4	3	1	1	55
S231	4	4	2	3	2	4	3	1	2	3	4	4	3	3	1	3	3	3	2	2	3	4	4	67
S232	4	3	2	3	2	2	3	3	3	3	3	3	2	3	3	2	3	3	1	4	4	2	3	64
S233	4	4	2	3	2	3	2	3	2	4	3	4	3	2	3	2	3	4	1	3	3	2	4	66
S301	3	4	1	4	3	3	4	4	3	4	3	3	4	4	3	2	4	2	3	2	4	3	3	73
S302	4	4	2	4	3	3	1	3	2	4	3	3	3	2	4	2	4	2	2	4	2	3	1	65
S303	2	2	3	2	3	1	3	1	2	2	2	2	2	3	2	3	2	3	3	1	2	3	3	52
S301	2	3	1	4	4	2	2	4	1	4	3	4	3	4	4	1	3	2	2	2	2	3	4	64
J38	2	3	3	3	2	2	3	2	3	3	2	4	3	2	3	1	3	4	3	2	3	2	3	61
J39	2	2	2	4	3	1	1	2	1	2	2	3	1	4	2	4	3	3	2	2	2	4	3	55
J40	4	4	2	3	2	4	3	3	3	4	3	3	3	1	3	2	3	3	1	3	3	2	2	64
K01	3	2	3	1	3	3	3	4	4	3	2	3	3	2	2	1	3	2	2	2	2	3	3	59
K02	3	2	1	2	3	3	3	4	2	3	2	4	3	3	3	4	2	3	3	1	2	2	3	61
K04	3	3	3	2	3	2	2	3	2	2	2	2	2	2	2	2	3	2	3	2	2	2	3	54
K05	1	3	2	1	3	3	1	2	2	3	2	3	3	3	3	4	3	2	4	2	3	3	2	58
K07	1	1	4	1	4	1	4	1	1	1	1	4	1	2	3	3	1	3	3	2	1	2	4	49
K08	4	4	1	4	1	4	3	4	3	4	4	4	3	3	4	2	3	4	2	3	4	2	4	74
K09	3	4	2	2	2	4	2	4	2	4	4	3	3	3	1	2	2	3	1	2	1	2	3	59
K10	3	2	2	2	3	3	2	4	2	4	4	3	3	3	2	3	4	2	3	1	2	3	2	62
K11	3	3	3	2	3	2	3	2	2	3	2	3	3	2	3	2	3	3	2	2	3	2	3	59
K12	3	4	3	2	2	4	4	4	2	3	2	4	2	2	3	2	2	3	2	2	2	1	2	60
K13	3	3	1	3	2	3	2	1	2	4	3	2	4	1	4	1	2	3	2	2	2	1	3	54
K14	3	2	2	2	2	4	2	4	2	3	2	4	4	2	1	3	3	3	1	2	2	3	3	59
K15	3	4	2	3	2	4	2	4	4	4	3	4	3	3	3	1	4	2	2	4	4	2	3	70
K16	3	2	2	1	1	3	4	4	4	3	2	4	2	1	2	4	4	4	2	2	1	2	4	61
K17	3	2	1	2	3	3	4	4	4	4	3	4	4	2	3	3	4	2	2	2	3	2	3	67
K18	3	1	1	2	1	4	1	4	2	3	2	4	2	1	1	4	4	4	2	2	4	3	4	59
K19	3	2	2	3	1	3	3	4	2	1	3	4	2	1	3	2	4	4	2	1	2	2	4	58
K20	3	4	1	2	2	4	1	1	2	4	3	3	2	1	1	2	1	3	3	3	4	3	2	55
K21	3	4	3	1	3	4	4	2	3	3	4	3	4	1	3	2	1	3	1	4	4	4	4	68
K22	3	3	1	3	3	3	1	4	3	3	3	3	4	1	3	3	3	2	2	2	3	3	3	62
K23	1	2	2	1	1	2	4	4	2	2	1	3	3	1	1	4	3	1	2	1	4	1	2	48
K24	2	2	2	3	3	1	2	4	3	3	2	2	2	2	1	1	4	2	4	3	1	2	2	53
K25	4	4	2	3	3	4	3	3	2	4	4	1	3	3	0	2	2	2	3	3	4	3	2	64
K26	3	4	1	4	3	3	1	3	4	4	3	3	4	2	4	1	3	3	1	4	3	3	3	67
K27	3	2	1	1	1	4	1	3	2	1	3	4	2	2	2	2	4	3	1	3	4	1	4	54
K28	2	3	2	1	4	4	2	4	4	3	1	2	4	3	3	3	4	2	3	1	3	4	3	65
K29	3	1	1	2	3	1	4	3	1	2	1	4	2	2	3	3	1	3	3	3	3	2	3	54
K30	1	3	3	1	3	1	1	2	2	2	2	2	3	3	1	2	3	4	3	1	4	1	4	52
K31	4	4	1	3	2	4	4	3	3	3	4	4	4	2	2	2	4	4	1	2	3	4	4	71
K32	3	2	3	1	2	3	1	3	2	4	3	3	3	2	1	3	3	3	1	2	2	2	3	55
K33	2	3	2	3	3	2	3	3	2	3	2	3	3	2	2	3	3	2	3	3	2	3	3	60
K34	4	4	2	2	4	3	2	4	3	3	3	3	4	3	3	3	3	4	3	3	4	2	3	72
K35	1	1	4	1	4	1	4	1	1	1	2	4	2	4	2	4	2	3	3	1	1	4	4	55
K37	4	3	2	4	2	4	4	4	3	4	4	4	4	2	3	2	4	4	1	3	4	4	4	77
K38	2	4	2	3	3	3	3	3	2	3	3	3	3	3	2	3	2	4	2	3	3	3	3	65

K39	3	4	1	4	2	3	3	3	4	1	2	4	2	3	3	3	3	3	2	3	4	4	3	67
K40	2	2	2	3	1	2	4	4	1	2	3	3	2	4	1	4	4	4	3	3	4	4	4	66
H01	3	3	1	3	2	4	3	4	3	3	3	2	4	2	1	3	4	4	1	2	2	4	4	65
H02	4	4	1	3	1	4	2	4	4	4	4	4	4	2	4	1	3	3	1	3	3	3	2	68
H03	3	3	1	3	1	4	4	4	3	3	3	4	3	2	3	3	4	4	2	3	3	3	4	70
H04	3	4	2	3	1	4	2	3	3	3	4	4	4	2	2	2	3	2	1	3	2	2	2	61
H05	3	4	2	3	1	3	2	4	2	4	3	3	3	2	3	1	4	2	1	3	3	2	3	61
H06	4	3	3	3	3	4	4	4	3	4	4	4	4	2	3	2	3	3	2	4	2	1	4	73
H07	3	3	1	3	2	2	3	3	4	3	3	3	3	2	3	2	2	3	3	2	1	3	2	59
H08	3	4	2	3	2	2	4	4	3	4	4	4	3	2	3	2	3	2	2	3	2	2	4	67
H09	4	4	2	4	1	4	2	3	4	4	4	4	3	2	3	3	2	3	2	3	3	3	4	71
H11	3	4	2	3	2	4	4	4	4	4	4	4	3	2	4	2	3	3	2	3	3	2	4	73
H12	4	4	2	4	1	4	3	4	4	4	4	2	4	1	2	1	3	4	1	4	3	1	1	65
H13	3	3	3	2	2	3	2	2	2	3	4	4	2	3	2	3	4	3	2	1	2	4	4	63
H14	3	3	3	3	2	4	3	3	3	4	3	3	1	2	2	2	4	3	2	3	4	2	4	66
H15	3	4	3	3	2	2	3	3	3	3	4	3	4	3	3	2	2	3	3	3	3	2	3	67
H16	3	3	1	4	1	3	3	3	4	3	4	3	3	2	4	2	4	2	1	3	4	3	2	65
H17	4	1	3	1	2	1	4	2	3	1	1	1	1	3	2	4	2	1	1	1	1	3	2	45
H18	3	2	3	2	3	2	3	2	2	2	1	3	2	1	2	1	3	2	3	1	2	3	3	51
H19	3	3	3	3	3	2	3	3	2	3	2	3	3	3	2	2	2	2	3	2	2	2	2	58
H20	4	4	1	3	1	3	3	4	2	3	3	3	4	2	2	3	3	3	2	2	4	2	3	64
H21	3	4	2	2	1	2	3	3	3	3	2	4	2	2	1	2	3	3	4	2	2	3	3	59
H22	3	4	2	3	1	3	3	4	3	3	3	3	3	1	3	3	3	2	1	3	4	1	3	62
H23	2	3	1	2	2	4	3	3	3	3	3	3	3	2	3	2	3	2	3	2	3	3	2	60
H24	2	4	3	2	2	1	4	4	2	3	2	2	1	3	3	3	2	3	1	1	2	3	2	55
H25	3	3	2	2	2	2	3	3	2	2	3	3	4	3	3	2	2	2	2	2	1	2	3	56
H26	3	2	3	1	3	3	4	2	2	3	1	4	4	1	1	2	3	3	3	2	1	1	3	55
H27	3	3	2	4	2	4	3	4	4	3	3	1	3	1	3	3	3	2	3	4	1	3	1	63
H28	3	3	4	2	2	3	1	2	2	2	1	2	3	3	4	3	2	1	3	2	1	2	3	54
H29	3	4	2	3	3	2	3	4	3	4	2	2	3	3	2	3	4	3	2	3	4	2	3	67
H30	3	2	2	4	3	3	1	4	3	2	3	1	4	3	2	2	1	2	2	2	3	1	2	55
H32	3	2	4	3	4	2	3	2	3	2	2	4	3	3	1	3	3	2	3	3	1	1	2	59
H33	3	4	2	4	2	2	3	3	2	2	2	3	3	3	3	2	3	3	2	2	3	2	3	61
B02	4	2	2	1	3	2	2	4	2	1	3	4	2	1	3	3	4	1	4	1	3	3	1	56
B03	2	2	1	1	3	3	2	4	2	4	4	3	2	1	2	1	3	1	3	2	1	3	3	53
B04	4	3	2	4	2	3	3	4	4	4	2	3	4	1	2	2	4	2	2	1	3	4	3	66
B05	3	3	3	2	2	2	2	4	2	3	2	3	2	3	2	3	3	3	4	2	1	3	2	59
B07	2	1	2	2	3	2	2	2	3	2	3	4	2	3	1	2	2	3	2	2	2	2	3	52
B08	2	3	1	2	1	4	2	3	2	3	4	4	2	1	3	1	4	2	1	2	2	3	3	55
B09	2	1	2	1	2	3	4	2	2	2	4	2	2	2	1	4	3	3	1	2	1	3	4	53
B10	2	4	2	2	2	3	2	3	2	2	2	4	3	3	3	3	3	3	0	3	2	3	2	58
B11	4	3	2	2	2	3	3	4	2	2	4	4	3	2	2	3	3	2	1	4	3	3	4	65
B12	3	3	1	3	3	2	2	3	2	4	3	4	3	1	1	2	2	2	3	2	3	2	2	56
B13	2	3	2	3	3	1	3	4	2	2	1	4	2	3	3	3	4	4	4	2	1	3	4	63
B14	1	3	3	4	2	3	3	4	3	4	2	1	3	1	3	3	4	3	2	3	4	2	4	65
B15	3	2	2	3	2	2	3	4	3	3	2	3	3	2	3	3	4	3	3	2	1	3	3	62
B16	2	2	2	1	1	2	4	4	2	1	2	2	1	3	1	3	3	3	3	1	1	2	3	49
B18	2	2	4	3	3	4	2	3	1	2	3	2	3	2	3	1	2	3	1	1	2	2	4	55
B19	2	2	3	2	3	2	3	2	2	2	2	3	2	3	2	3	2	3	3	2	2	3	3	56
B20	2	3	3	2	2	3	3	2	2	2	4	4	1	3	3	3	4	3	3	2	2	2	4	62
B21	2	2	4	1	2	1	4	2	2	3	2	2	4	3	2	1	2	2	1	1	1	3	3	50
B22	3	3	3	2	3	1	2	2	2	2	1	3	2	3	3	2	3	1	2	1	2	3	1	50
B23	3	4	1	3	3	4	2	3	3	4	4	4	4	1	2	2	3	4	2	4	3	3	3	69
B24	3	2	2	2	3	3	4	4	3	4	4	4	2	2	1	2	3	3	2	4	4	1	3	65
B25	4	1	3	1	4	1	2	4	2	1	1	4	3	3	4	2	1	3	4	2	1	2	4	57
B26	3	4	1	4	2	3	1	4	4	3	4	3	3	3	3	2	4	3	2	1	3	2	2	64
B27	1	1	1	1	4	1	3	1	1	2	1	2	4	4	1	3	2	1	4	1	1	4	3	47

B28	1	1	3	2	3	3	2	3	2	2	1	3	2	4	3	3	2	4	2	3	1	2	4	56
B29	2	2	2	1	3	2	3	1	1	2	3	4	3	2	3	2	3	1	2	2	3	2	1	50
B30	2	1	4	4	4	1	1	4	3	3	4	3	4	4	2	2	1	4	2	1	2	1	2	59
B31	1	2	3	2	2	1	2	2	1	4	1	3	2	3	1	3	2	4	2	1	2	2	4	50
B32	0	1	1	3	3	1	2	3	2	2	2	3	3	3	3	4	1	2	3	1	3	3	2	51
B33	3	3	2	3	1	3	3	3	4	3	2	4	2	4	2	4	4	4	3	3	2	2	4	68

Appendix 19

Learning Approach Questionnaire (LAQ): modified version

(Adapted from Boujoule, Salloum &Al-El-Khalick, 2004)

The following statements refer to your attitudes and processes in learning science, particularly **CHEMISTRY**.

For each statement there is a four-point scale ranging from “Always True” to “Never True”.

Read each statement carefully, then **CIRCLE** the letter (A, B, C or D) that best fits your IMMEDIATE reaction.

Do not spend a long time on each item; your first reaction is probably the best one.

Do not worry about projecting a good image. Your answers are confidential. The information is about your study attitude and learning style. There are no "right/wrong" answers.

A = Always True
B = More True Than Untrue
C = More Untrue Than True
D = Never True

1. I generally put in a lot of effort into trying to understand things that at the beginning seem difficult.	A	B	C	D
2. As I am reading new material in Chemistry, I try to relate it to what I already know on that topic.	A	B	C	D
3. I tend to remember things best if I concentrate on the order in which the teacher presented them.	A	B	C	D
4. While I am studying Chemistry, I often think of real life situations to which the material I am learning would be useful.	A	B	C	D
5. I tend to concentrate on memorizing a great deal of what I have to learn.	A	B	C	D
6. I go over important topics until I understand them completely.	A	B	C	D
7. Teachers should not expect students to spend a lot of time studying material everyone knows will not be tested.	A	B	C	D
8. I feel that any topic can be very interesting once I get into it.	A	B	C	D

A = Always True; B = More True Than Untrue; C = More Untrue Than True; D = Never True

9. I often find myself questioning things that I hear in lectures or read in books.	A	B	C	D
10. I find it useful to get an overview of a new topic for myself, by seeing how the ideas fit together.	A	B	C	D
11. After a lesson, I read my notes again to make sure they are clear and that I understand them.	A	B	C	D
12. I think reading outside material is a waste of time, so I only study seriously what is given in class.	A	B	C	D
13. I set out to understand very well the meaning of what I am asked to read.	A	B	C	D
14. I prefer subjects with a lot of facts (such as History) rather than theoretical kind of subjects (such as Chemistry).	A	B	C	D
15. I try to relate what I have learned in one subject to that in another.	A	B	C	D
16. The best way for me to understand the meaning of scientific words is to remember their text book definition.	A	B	C	D
17. I find puzzles and problems interesting, particularly where you have to work through the material to reach a logical conclusion.	A	B	C	D
18. I usually do not think about the relationship of what I learn to everyday life.	A	B	C	D
19. I tend to memorize things, going over and over them until I know them by heart.	A	B	C	D
20. When I am starting a new topic, I ask myself questions that the new information would answer.	A	B	C	D
21. I spend some of my free time finding out more about interesting topics that have been discussed in different classes.	A	B	C	D
22. I often read things without having the chance to understand them well.	A	B	C	D
23. I usually study what is specifically requested, because I think it is not necessary to do anything extra.	A	B	C	D

Appendix 2

Preliminary Survey Questionnaire (PSQ)

Respondent's Particulars

Name of School: ____________________________
Academic qualifications: __________________________
Academic major(s): __________________________
Professional qualifications: ________________________
Subject(s) taught: ____________________________
Level(s) taught: ______________________
No. of years teaching Chemistry: ___________________

Chemical Representations: *What are Chemistry Teachers' Perceptions?*

1. Have you heard of or seen the term "chemical representations"?
   [ ] Yes
   [ ] No

If *yes*, where did you come across the term "chemical representations"?
(You can choose more than one)

[ ] Curriculum Specifications by CDC
[ ] Chemistry text book recommended by MOE, Malaysia
[ ] Chemistry reference books (Local Publications)
[ ] Chemistry reference books (International Editions)
[ ] Chemistry teachers
[ ] Chemistry teaching courseware by MOE, Malaysia
[ ] Internet
[ ] Other sources (please specify)

2. Are you familiar with the term "chemical representations"? [ ] Yes
   [ ] No

3. Do you know the meaning of the term "chemical representations"? [ ] Yes
   [ ] No

4. Are you aware of the existence of "the 3 levels of thinking" or "the 3 levels of representations of matter" in chemistry? [ ] Yes
   [ ] No

5. Do you have any difficulty teaching chemical representations to your students?
   [ ] Yes
   [ ] No

   If *yes*, what are some of your difficulties?

6. Is it important for chemistry students to know about chemical representations?

[ ] Yes

[ ] No

Why do you think so?

7. Is it important for chemistry teachers to know about chemical representations?

[ ] Yes

[ ] No

Why do you think so?

8. In what ways are chemical representations useful:

(a) to chemistry students?

(b) to chemistry teachers?

9. What do you think are the roles and purposes of representations in chemistry? Give examples.

THANK YOU FOR YOUR CO-OPERATION

Test score reliability of the DSBT

Correlations

		DSBT	DSBTr
DSBT	Pearson Correlation	1	.862(**)
	Sig. (2-tailed)	.	.000
	N	56	56
DSBTr	Pearson Correlation	.862(**)	1
	Sig. (2-tailed)	.000	.
	N	56	56

** Correlation is significant at p< 0.01 (2-tailed).

Digit Span Backwards Test
(DSBT)

Instructions to candidates:

This is a test to measure your ability to hold, translate and rearrange information which is very similar to what happens during problem solving. The First Section of the test is for practice while the Second Section intends to measure the working memory capacity.

IN THE SECOND SECTION, YOU ARE NOT ALLOWED TO WRITE THE NUMBERS FROM RIGHT TO LEFT. LISTEN CAREFULLY, TURN THE NUMBER OVER IN YOUR MIND AND WRITE FROM LEFT TO RIGHT.

Alex H. Johnstone, May 2001, Digit Span Backwards Test, Centre for Science Education, University of Glasgow, United Kingdom.

Section ONE

Name: ____________________________

Gender: ___________________________ Date of Birth: __________________

You will hear a series of numbers read out. Listen carefully and when the test administrator has finished saying the numbers, write the numbers in the grid provided below.

Series	NUMBERS								
3									
4									
5									
6									
7									
8									
9									

Section TWO

Name: ______________________

Gender: _____________________ Date of Birth: __________________

A set of numbers will be read out. When the test administrator has finished saying them, write them down in reverse order. DO NOT WRITE FROM RIGHT TO LEFT. Turn the numbers over in your mind and WRITE FROM LEFT TO RIGHT in the grid provided below.

Series	NUMBERS								
3									
4									
5									
6									
7									
8									
9									

Digits used in Section ONE of the Digit Span Backwards Test

Series	Digits								
3	5	8	2						
	6	9	4						
4	6	4	3	9					
	7	2	8	6					
5	4	2	7	3	1				
	7	5	8	3	6				
6	6	1	9	4	7	3			
	3	9	2	4	8	7			
7	5	9	1	7	4	2	8		
	4	1	7	9	3	8	6		
8	5	8	1	9	2	6	4	7	
	3	8	2	9	5	1	7	4	
9	2	7	5	8	6	2	5	8	4
	7	1	3	9	4	2	5	6	8

Digits used in Section TWO of the Digit Span Backwards Test

Series	Digits								
2	2	4							
	5	8							
3	6	2	9						
	4	1	5						
4	3	2	7	9					
	4	9	6	8					
5	1	5	2	8	6				
	6	1	8	4	3				
6	5	3	9	4	1	8			
	7	2	4	8	5	6			
7	8	1	2	9	3	6	5		
	4	7	3	9	1	2	8		
8	9	4	3	7	6	2	5	8	
	7	2	8	1	9	6	5	3	

The Interview Protocol (1)

Semi-Structured Interview 1- Conceptions of Chemical Representations

Part 1: Recall without any specific prompts

1. What do you know or understand about chemical representations (or representations in chemistry)?
[You may use pictures/diagrams/words to describe/to represent/to explain your understanding].

2. Can you give some examples of chemical representations or representations in chemistry?

Part 2: Questions based on TCR
Part A (T/F): Item no. 9, 10, 11, 20, 22

Part 3: Symbolic representations

1. What does the symbol `Cu' mean to you?

2. Show three symbolic representations (see **Focus Card 1** – *Appendix 23*) to the respondent: O_2, $2O$, O^{2-}
Ask questions such as:
   (a) Does the number `2' in each of the representation above have the same meaning?
   (b) Can you distinguish or explain the meaning of the number `2' in each of the representation?

3. Show examples of representations at the symbolic level for some common molecules such as water, ammonia or methane (see **Focus Card 2** – *Appendix 24*) and ask questions such as:
   (a) What do the lines/sticks represent?
   (b) What do the circles/balls represent?
   (c) Why do the circle/balls have different colours and/or sizes?

   OR show actual ball-and-stick models of common molecules such as water, ammonia and methane and ask questions similar to those in a, b, and c above.

4. Show two symbolic representations: Cl_2 and Cl_2 (g).
Ask questions such as:
   (a) Do the symbols Cl_2 and Cl_2 (g) have the same meaning or mean the same thing to you? If not, what is the difference?
   (b) Can you use **drawing(s)** to show the difference in (a) above?

Part 4: Submicroscopic representations

1. Ask the respondent to work through the online quiz available at www.darvill.clara.net/hotpots/emc.htm (see Appendix ---) or another set of questions on particulate drawings (see Appendix ---).
   Check and record his/her score.
   Also review selected answers chosen by the respondent to find out how and why a particular answer was chosen.

2. Ask the respondent to work through **Worksheet 1** (see *Appendix 25*).

   For both 1 and 2, examine if there is a difference in the responses chosen by respondents with different overall levels of understanding of (i) basic chemical concepts and (ii) chemical representations.

The Interview Protocol (2)

Semi-Structured Interview 2 - Representational Competence

Part 1: Questions based on items in the TRC

Part A (MCQ): Item no. 19, 22
Part B (SRF): Item no. 3

Part 2: Student generated representations

1. Show a beaker/bottle of water.
   Ask the respondent to show, by **drawing**, how a beaker of water might appear when viewed through `a very powerful microscope'.
   Elicit further responses by asking the respondent to explain the drawing(s).

2. Show a copper wire or a copper foil.
   Ask question such as:
      Can you tell me what are inside this copper wire/foil or what is this copper wire/foil made up of?
      [Encourage the respondent to use **drawing** to show or describe their answer].

3. A gas jar contains a mixture of carbon dioxide and oxygen gas.
   What are you likely to `see' through a very powerful microscope?
   Use d**rawing** to show your answer.

4. Show, in as many ways as you could, how you would **represent** a molecule of water.
   a. Are all the representations similar?
   b. Which representation do you prefer to use and why?
   c. Why do you need to use/know so many ways to represent a molecule of water?

5. **Draw** the electron arrangement of: (i) a sodium atom, and (ii) a sodium ion.
   Can you describe the electron arrangement of the sodium atom and the sodium ion that you have drawn?
   What do you think is the difference between a sodium atom and a sodium ion?

Part 3: Multiple levels of representation

Ask the respondent to work through **Worksheet 2** (see *Appendix 26*).

For Question 1, examine the level(s) of descriptions (macroscopic or submicroscopic or symbolic) or a combination of these levels (i.e. multiple levels of description or multiple levels of representation) used by the respondents.

For Question 2, evaluate the level of representational competence using the scoring rubics as categorized by Kozma and Russell (2005).

Appendix 22a

Sample of the interview transcript from the Low group (L2)

SSI (1)

I: [Showing the term `CHEMICAL REPRESENTATIONS’ on a piece of paper to the participant]. What do you know or understand about chemical representations?
R: [No response].
I: Have you seen the words `Chemical Representations’?
R: No.
I: You never hear this term before?
R: Never.
I: Can you give any example of chemical representation? Maybe you can just tell me what you know about chemical representations, or you can also use pictures or diagrams to describe or to explain what you know about chemical representations. [Pieces of plain paper were given to the respondent]
R: Representations? [Respondent appeared blank and surprised to hear that]
I: Can you give some examples?
R: Forget already. [Pause] Like what ah???
I: Have you seen this term `CHEMICAL REPRESENTATIONS’? [Showing the term `CHEMICAL REPRESENTATIONS’ on a piece of paper to the participant again].
R: No, never see.

I: [Showing a copy of the Test on Chemical Representations, TCR, see *Appendix 11a*, to the participant]. Do you remember doing this test?
R: [Flipping through the test paper]. Yes.
I: Now let’s look at the test paper. Is the statement No. 9 true or false?
R: Copper atoms? [Pause] True.
I: Why do you think that the statement is true?
R: I’ve seen before.
I: What have you seen?
R: Copper only.
I: Have you seen copper atoms?
R: No.
I: Do you think copper and copper atoms mean the same thing?
R: No, different.
I: What is the difference?
R: The atoms.
I: What do you mean when you said `the atoms’?
R: The copper is mixed already.
I: What do you mean when you said “the copper is mixed already”?
R: The atoms are mixed, then get copper.

I: Ok, let’s look at some symbolic representations. [Showing the symbol `Cu’ written on a piece of paper to the participant] What does the symbol `Cu’ mean to you?
R: [Pause]
I: Have you seen this symbol before?
R: Yes.
I: So, what do you think is the meaning of `Cu’?
R: [Another long pause, then suddenly uttered a phrase] Carbon atom?
I: No.
R: [Participant appeared surprised his answer is wrong]
I: So you still think this symbol means carbon atom?
R: Yes.

I: [Showing three symbolic representations: O_2, 2O, O^{2-} (see Focus Card 1 – *Appendix 23*)
I: Have you seen these symbols before?
R: Yes.
I: Does the number `2’ in each of the representation above have the same meaning?
R: No.

I: Can you distinguish or explain the meaning of the number `2' in each of the representation?
R: [Looking at the symbolic representations]
I: What does the number `2' in O_2 mean?
R: [Long pause]
I: What is the meaning of `O'?
R: Oxygen.
I: So, O_2 means …
R: [No response but apparently thinking]
I: Is O_2 an atom?
R: No.
I: Is it a molecule?
R: Molecule? I think yes.
I: Can you draw to show how O_2 look like?
R: No.
I: Ok, now what is the meaning of the number `2' in 2O?
R: Don't know.
I: Can you draw to show how 2O look like?
R: Haa.. draw again?
I: Can you write down the symbols O_2 and 2O first?
R: [Writing down the symbols O_2 and 2O]
I: Now draw to show how O_2 look like.
R: [Participant drawing something on the plain paper provided but the drawing shows 1 big circle and 2 smaller circles]. See Figure 5.12.

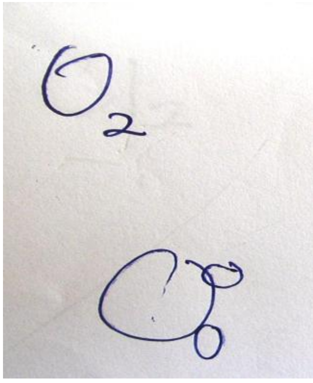


Figure 5.12: L2a

I: Can you draw to show 2O?
R: [Participant drawing shows something that looks like a molecule - 2 big circles joined together]. See Figure 5.13.

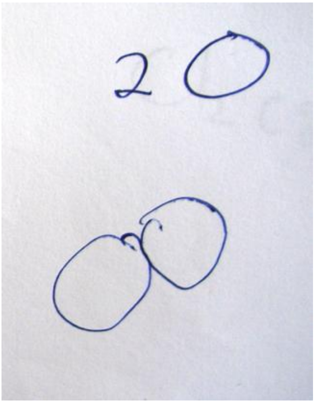


Figure 5.13: L2b

I: Ok. What about the number `2' in O^{2-}?
R: [Not responding]

I: [Show actual ball-and-stick models of common molecules such as water, ammonia and methane] (see Focus Card 2 – *Appendix 24*).
R: [Looking at the models with keen interest]
I: [Pointing to the ball-and-stick model of a water molecule]. What do the sticks represent?
R: [Pause]. Take it together.
I: What do you mean when you said "Take it together"?
R: Stick together, join together.
I: Now, what do the balls represent?
R: [Pointing at the smaller, white colour ball and said]. Atom (See Figure 5.19)
I: How about this? [Pointing at the larger, red colour ball] (See Figure 5.19)
R: Molecule.
I: So, what does the whole thing represent? [Showing a model of the water molecule]
R: Don't know.

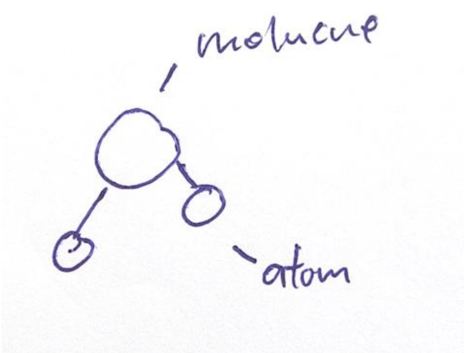


Figure 5.19: L2c

I: Why do the balls have different colours and or sizes?
R: Different meaning.
I: What do you mean when you said "have different meaning"?
R: Small ball is atom, big ball is molecule.

I: [Show two symbolic representations: Cl_2 and $Cl_2\,(g)$]
I: Do the symbols Cl_2 and $Cl_2\,(g)$ mean the same thing to you?
R: No.
I: So what is the difference between the symbols Cl_2 and $Cl_2\,(g)$?
R: Don't know.
I: Maybe you can use drawing(s) to show the difference.
[Helping the participant to write down the symbols Cl_2 and $Cl_2\,(g)$ on the paper].
R: [No response and nothing appeared on the paper provided]
I: What does `Cl' represent?
R: Don't know.
I: How about (g)?
R: `g' mean gram.
I: Have you seen the symbol (g)?
R: I forgot already.

I: Now work through the online quiz available at www.darvill.clara.net/hotpots/emc.htm (see *Appendix 25a*).
R: Working on the quiz.
I: Your score is 42%.

I: Now you can try to work through **Worksheet 1** (see *Appendix 25*).
R: [Working on Worksheet 1]. See Figure 5.27 in Chapter 5 for L2's responses.

SSI (2)

I: [Showing a copy of the TRC (*Appendix 15a*) to the participant]. Have you done this test before?
R: [Turning the pages and looking]. Yes.
I: Now, let's look at Questions 19 of Part A. What do you think is the correct answer for Question 19?
R: [Reading the question and looking at the diagram for a long time]. The answer is `C'.
I: Why do you choose `C' as the answer?
R: Because has 6 atoms of X and 9 atoms of Y.
I: What is $4XY_2$ in the equation? [Pointing at option `C']
R: [No response]
I: Can you identify $4XY_2$ in the diagram?
R: [Looking at the diagram but could not identify anything]
I: The correct answer is `B'.
R: ah? [Looking so surprised]

I: Now let's look at Question 3(c) of Part B.   Can you draw to show an atom and an element?
[No answer in test paper!]
R: [Drawing and labeling but both look similar]. See Figure 5.35.

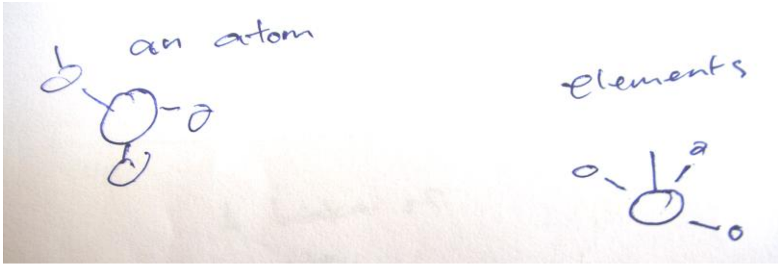


Figure 5.35: L2e

I: Why are you drawing the same thing? So what is the difference between an atom and an element?
R: Don't know.

I: [Showing a beaker of water to the participant]
I: Can you show, by drawing, how a beaker of water might appear when viewed through `a very powerful microscope'?
R: Draw ah? How to draw?
I: Just draw what you think you can `see'.
R: Hah! Draw a microscope ah?
I: No, just draw a beaker and what you think you can `see' inside the beaker.
R: [Busy drawing but drawing shows `atoms of water']. See Figure 5.44.

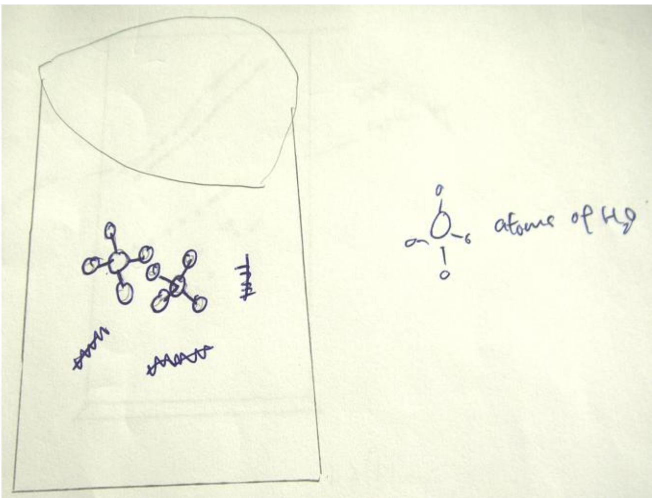


Figure 5.44: L2f

R: [Pointing at Figure 5.44 and asking]. Something like this??
I: [Pointing at the particles inside the beaker]. What are all these?
R: Atoms.
I: Atoms of what?
R: Atoms of water.
I: So you think water is made up of atoms?
R: [Participant appeared confused and unsure]
I: [Pointing at the wavy lines inside the beaker and asking]. What are all these?
R: Hah?
I: Do you want to explain your diagram to me or do you want to label anything?
R: [Draw one of the particles but writing down `atoms of water']. See Figure 5.44.
I: But you haven't explained to me what are those wavy lines inside the beaker.
R: Virus.
I: Why are you talking about virus?
R: The water is not pure, dirty water.

I: [Showing a piece of copper foil]. Can you tell me what is this copper foil made up of?
R: Hah!
I: Just draw what you think is inside this piece of copper.
R: [Drawing a piece of sand paper and a strip of copper instead]. See Figure 5.53.

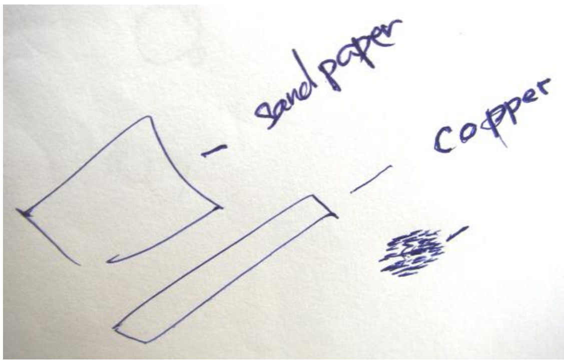


Figure 5.53: L2g

I: What do you think is inside the piece of copper?
R: Iron.
I: Iron inside the copper foil?? Is copper an element?
R: [No response]
I: Have you heard of the term `element'?
R: Yes.
I: Is copper an element?
R: No, [pause]. Not sure.
I: Do you want to label anything?
R: [Writing and labeling `sand paper' and `copper']. See Figure 5.53.
I: What is this? [Pointing at some dark shadings in Figure 5.53]
R: Something after cleaning the copper with sand paper, some dirty powder.
I: Anything else that you want to write or label?
R: No.

I: Ok, let's move on.
I: If I give you a closed gas jar containing a mixture of carbon dioxide and oxygen gas, what are you likely to `see' through a very powerful microscope?
R: What is gas jar?
I: [Showing a gas jar to the participant]. Can you draw a gas jar with a cover?
R: [Drawing a gas jar but no cover]. See Figure 5.61.

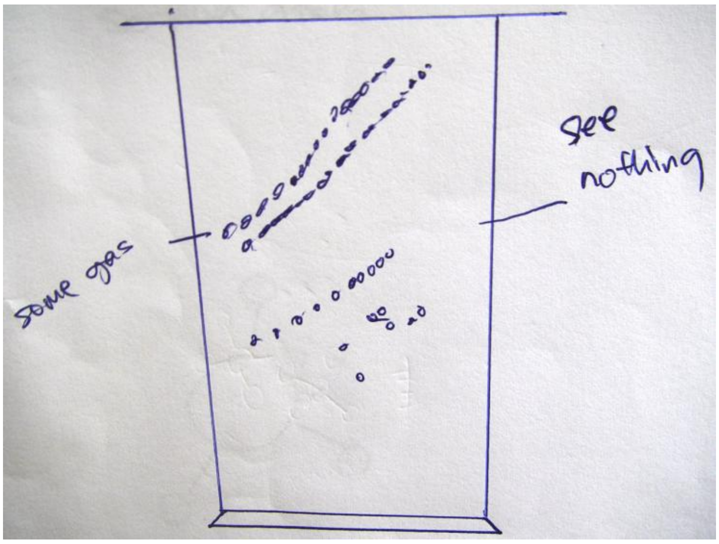


Figure 5.61: L2h

I: Now, draw what you can `see' inside the gas jar.
R: See nothinglah…
I: Why nothing?
R: Can't see gas.
I: Why see nothing? Imagine you see through a very powerful microscope.
R: Because gas go away already…
I: But the gas jar is closed.
R: Haa! Like that ah?
I: Just draw what you think you can `see' through the microscope.
R: I've seen leaf before. But I never see gas.
I: Can you just draw something that you think you may be able to `see'?
R: [Drawing something that look like tiny circles]. See Figure 5.61.
I: Do you want to label your drawing?
R: [Writing down `some gas' beside the tiny circles and another label `see nothing']. See Figure 5.61.

I: Ok. Let's continue.
I: Can you show me how you would represent a molecule of water?
R: [Drawing a space-filled model of a water molecule]. See Figure 5.73.

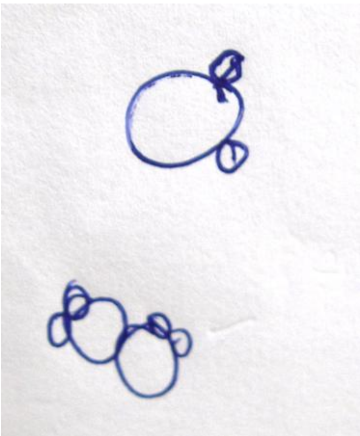


Figure 5.73: L2i

I: Only this one? Is there any other way to show a molecule of water?
R: No.
I: Are you sure there is no other way to represent a molecule of water?
R: Not sure.

I: Can you try drawing another one?
R: [Drawing 2 molecules of water joined together]. See Figure 5.73.
I: Why are you drawing the 2 water molecules joined together?
R: Don't know.

I: Ok, let's look at the next part.
I: Can you write down the words `a sodium atom' and `a sodium ion'?
R: [Writing]
I: Can you draw to show the electron arrangement of a sodium atom and a sodium ion?
R: Hah! Draw again ah?
I: Yes, drawing can show and tell more clearly than writing.
R: Cannot imagine lah.
I: Just draw what you think represents a sodium atom and then show the electron arrangement.
R: [Drawing, but drawing shows something that looks like a molecule]. See Figure 5.83.

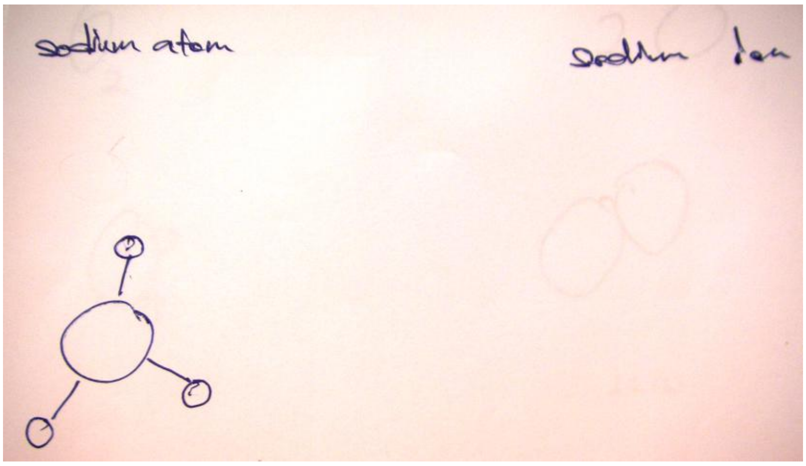


Figure 5.83: L2j

I: How about sodium ion? Can you draw to show the electron arrangement of a sodium ion?
R: Don't know. [Nothing appears on the paper for sodium ion]
I: Do you know the difference between a sodium atom and a sodium ion?
R: Don't know.

I: You can now work on the two questions on **Worksheet 2** (see *Appendix 26*)
R: [Looking at the Worksheet but does not seem to know what to do next. After a long time, R was seen scribbling something on the paper]. See Figure 5.92 and 5.101 in Chapter 5 for L2's responses.

Sample of interview transcript from the Medium group (M1)

SSI (1)

I: What do you know or understand about chemical representations or representations in chemistry? [Showing the words `chemical representations' written on a piece of paper]
R: Chemical representations? What ah?
I: [Repeat question to the participant]
R: Chemical representations show the… I think, chemical formula of an element…
I: Only chemical formula? Anything else?
R: [Silence…]
I: You can also use pictures or diagrams or words to describe or to explain what you know about chemical representations. [Pieces of plain paper were given to the participant]
R: Looking at the plain paper and thinking…
I: Can you give some examples of chemical representations or representations in chemistry? You can show your answers by either writing or drawing.
R: [Nothing written or drawn on the plain paper]
I: [Interviewer repeated the question above]
R: [Participant began writing on the plain paper and read out at the same time]. (see Figure M1a).
I: [Pointing at the above chemical equation written by the respondent on the paper]. Is this chemical formula?
R: [Silent and appearing confused]
I: Any other things that you consider are chemical representations?
R: [Continue thinking and writing then read out]. (see Figure 5.4).

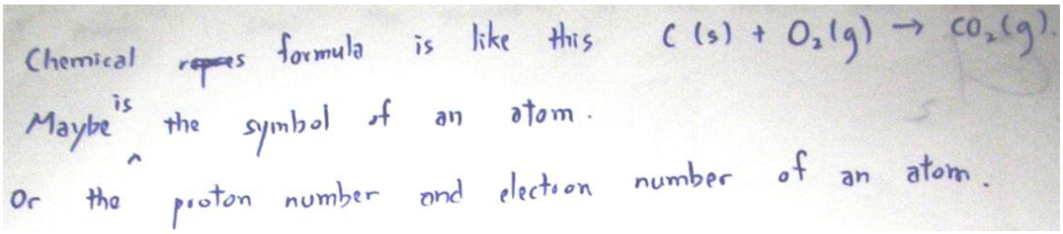


Figure 5.4: M1a

I: Ok. [Showing a copy of the Test on Chemical Representations, TCR, see *Appendix 11a*, to the participant]
I: Now look at the test paper. Do you think that statement No. 9 is true or false?
R: True.
I: Why do you think copper atoms are reddish brown?
R: [Started to recall an experiment on the displacement of copper metal from its salt solution] Teacher, last time we did an experiment before. When we put a piece of copper into a blue solution, a reddish brown solid was formed. Teacher you said the solid was copper.
I: Is copper atom the same as the element copper?
R: Copper atom is part of copper element. Copper element is …
I: What do you mean by `copper atom is part of copper element'?
R: [No response and looking very confused]

I: Ok, let's look at some symbolic representations. [Showing the symbol `Cu' written on a piece of paper to the participant] What does the symbol `Cu' mean to you?
R: Copper atom or copper.
I: Copper?
R: I mean copper element.
I: Ok, let's move on.

I: [Showing three symbolic representations: O_2, 2O, O^{2-} (see Focus Card 1 – *Appendix 23*)
I: Does the number `2' in each of the representation above have the same meaning?
R: Not the same.
I: Can you distinguish or explain the meaning of the number `2' in each of the representation?
R: [Looking at the symbolic representations and thinking]
I: What does the number `2' in O_2 mean?
R: O is atom. O_2 shows double atom of oxygen. O_2 is empirical formula of oxygen.
I: What do you mean when you said "double atom of oxygen"?
R: I mean 2 atoms of oxygen.
I: What about 2O?
R: 2 oxygen atoms.
I: But you mentioned earlier O_2 also means 2 atoms of oxygen??? Can you use drawing to show the difference between O2 and 2O?
R: [Drawing]. See Figure 5.16.
I: Ok. Good.

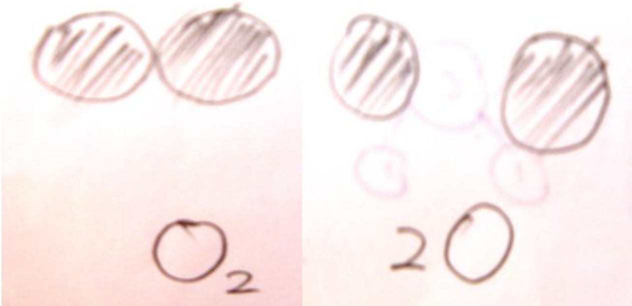


Figure 5.16: M1b

I: What about the number `2' in O^{2-}?
R: [Not responding]
I: What type of particle is this, atom or molecule or ion?
R: Ion.
I: Is this a positive or negative ion?
R: Positive ion.
I: Why do you say so?
R: Because it gave away 2 electrons.
I: So to you, this is a positive ion?
R: Yes.

I: [Show actual ball-and-stick models of common molecules such as water, ammonia and methane] (see **Focus Card 2** – *Appendix 24*).
I: What do the sticks represent?
R: Represent the bond.
I: What do the balls represent?
R: The balls represent the atoms.
I: Good.
I: Why do the balls have different colours and or sizes?
R: Because our world many types of atoms. Atoms are directly different from one another.
I: What do you mean when you said `atoms are directly different from one another'?
R: They are different atoms.

I: [Show two symbolic representations: Cl_2 and Cl_2 (g)]
I: Do the symbols Cl_2 and Cl_2 (g) mean the same thing to you?
R: First one is an atom. Second one is (g) represent atoms of a gas.
I: Can you use drawing(s) to show the difference?
R: How about writing?
I: It will be easier to see the difference if you use drawing(s).
R: [Drawing]. See Figure 5.20.

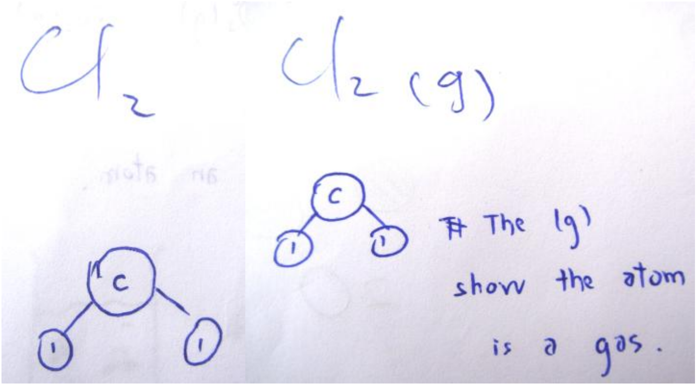


Figure 5.20: M1c

I: [Pointing at the drawing in Figure 5.20]. Why did you write the letter `C' in the bigger circle and the letter `l' in the 2 smaller circles?
R: I think 1 `C' combined with 2 `l' is Cl_2. Cl_2 is chlorine.
I: What does the letter `C' represent?
R: Maybe is carbon. `l', I …
I: So, Cl_2 has 3 atoms?
R: I think wrong already…

I: Now work through the online quiz available at www.darvill.clara.net/hotpots/emc.htm (*Appendix 25a*).
R: Working on the quiz.
I: Ok. You score is 57%.

I: Now you can try to work through **Worksheet 1** (see *Appendix 25*). See Figure 5.29 in Chapter 5 for M1's responses.

SSI (2)

I: [Showing a copy of the TRC (see *Appendix 15a*) to the participant]. Look at Questions 19 of Part A.
R: [Participant saw that his response was wrong]
I: Why did you choose `A' as your answer for question 19?
R: [Looking at the question and thinking]… Then said: I think the correct answer is `C', and changed the answer from `A' to `C'.
I: Why do you choose `C' this time?
R: I look at the number of atoms in the box. Number of atoms of X is 6. Number of atoms of Y is 9. Then the chemical equation is like this (pointing at option `C': $6X+9Y \rightarrow 4XY_2+2X+Y$). So I choose `C'.

I: Now let's look at Question 3(c) of Part B.
I: [Referring to Figure 5.37]. Why did you draw a lot of atoms? What does the drawing represent?
R: An element, atoms of an element.
I: Does oxygen exist as atoms? Your diagram is acceptable if you did not label as O_2.

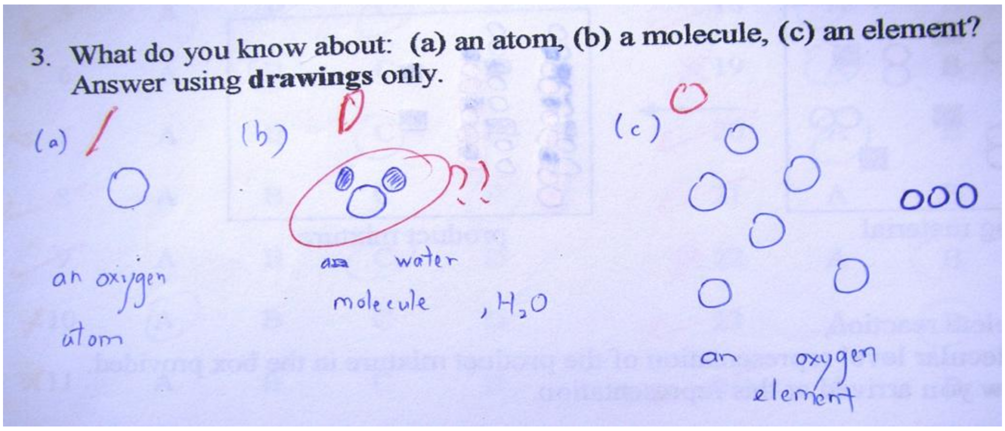


Figure 5.37: M1e

I: [Showing a beaker of water to the respondent]. Can you show, by drawing, how a beaker of water might appear when viewed through `a very powerful microscope'?
R: [Looking and listening, then drawing]. See Figure 5.37.

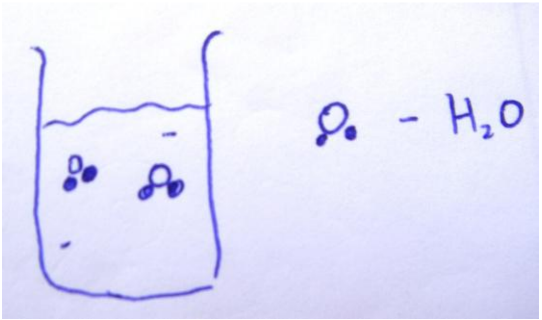


Figure 5.46: M1f

I: [Pointing at the drawing by the participant on the paper]. Is this what you will see?
R: I imagine seeing this.
I: Do you want to label anything on your diagram?
R: [Labeling] (see Figure 5.46)
I: [Pointing to the drawing and ask]. `What is this?' Can you explain the drawing(s)?
R: Water contains a lot of water molecules.

I: [Showing a piece of copper foil]. Can you tell me what is this copper foil made up of?
R: Many particles.
I: What type of particles do you think is inside the piece of copper?
R: I think is atom.
I: Can you use drawing to show or describe what you `see'?
R: [Drawing and saying]: `there are many copper atoms'. See Figure 5.55.
I: But you only draw one atom? So, do you think there is only one atom or many atoms?
R: Many atoms.
I: Then can you draw and show me?
R: Drawing more and more atoms (see Figure 5.46).
I: Do you want to label anything?
R: [Drawing an arrow pointing at an atom and writing down `Cu']

I-Interviewer; R=Interviewee

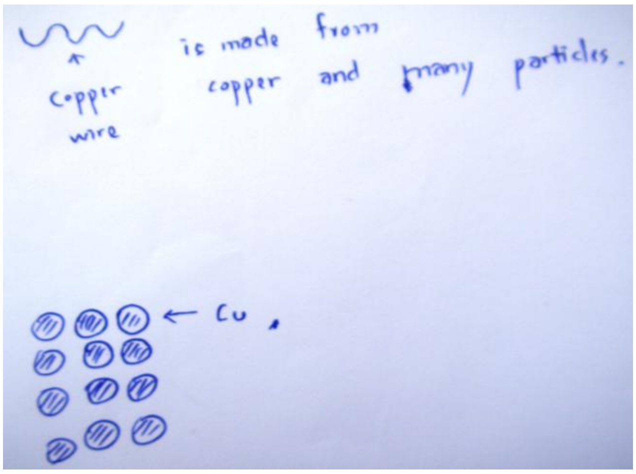


Figure 5.55: M1g

I: If I give you a closed gas jar containing a mixture of carbon dioxide and oxygen gas. What are you likely to `see' through a very powerful microscope?
R: [No response]
I: Can you use drawing to show your answer?
R: [Drawing on the plain paper provided]. Drawing shows only 1 molecule of oxygen and 1 molecule of carbon dioxide (labeled so), with the oxygen molecule looking like an atom. (See Figure 5.63)

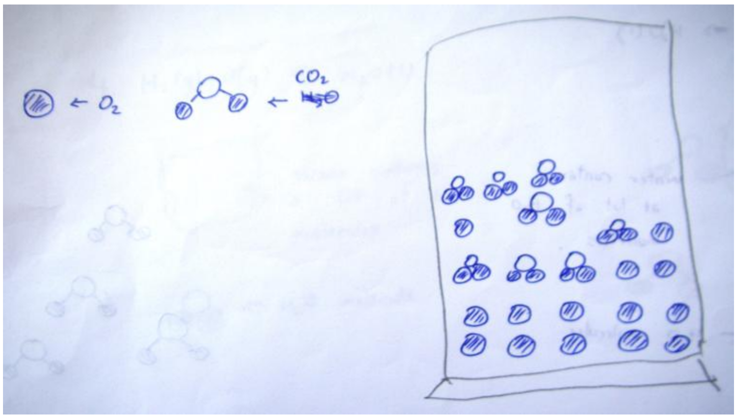


Figure 5.63: M1h

I: You only see this?
R: Continue to draw more and more such particles (see Figure 5.63)
I: [Pointing at the particles in Figure 5.63]. Why are you drawing the `oxygen molecules at the bottom of the gas jar and the molecules of carbon dioxide on top?
R: [No response]

I: Can you show, in as many ways as you could, how you would represent a molecule of water.
R: [Participant did not seem to get the question]
I: [Repeat the question to the participant and emphasize the term `a molecule of water']
R: [Show drawing, H_2O]. (See Figure 5.75)
I: Only this? Any other drawing that you want to show?
R: Still trying… but showing many molecules of water instead. (See Figure 5.76)
I: Why are you drawing a lot of water molecules? [Referring to Figure 5.76] Show me another way you would represent a molecule of water.
R: [Pointing to H_2O and the ball-and stick model of water] So many water molecules.

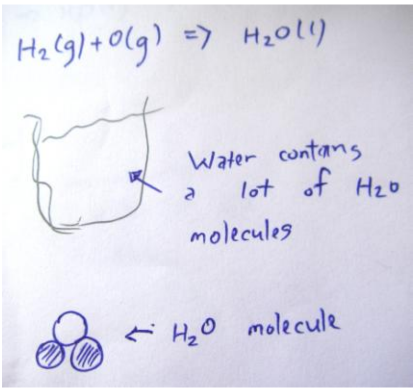


Figure 5.75: M1i

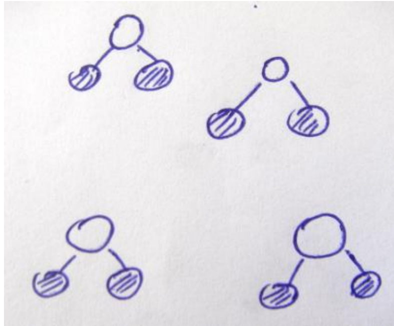


Figure 5.76: M1j

I: Are all the representations similar? Which one do you prefer to use?
R: This one, pointing at the symbol `H_2O'.
I: Why?
R: Easier to write or draw.
I: Why do you need to use or know so many ways to represent a molecule of water?
R: I don't know.

I: Can you draw the electron arrangement of a sodium atom and a sodium ion?
R: [Trying hard to draw something]. (See Figures 5.85)

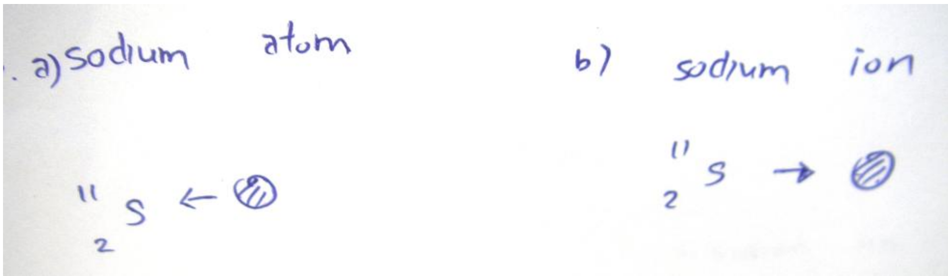


Figure 5.85: M1k

I: Why are the sodium atom and the sodium ion looking similar?
R: I think the size is different. I think one is smaller, one is bigger. Sodium ion is bigger.
I: Why do you think so?
R: I think many ions.
I: what do you mean when you wrote $^{11}_{2}S$?

R: 11 is proton, 2 is neutron, and `S' is sodium'.
I: How do you describe the electron arrangement of the sodium atom and the sodium ion that you have drawn?
R: [Participant did not seem to know what to do]
I: Do you know the meaning of electron arrangement?
R: [Not responding]
I: So, what do you think is the difference between a sodium atom and a sodium ion?
R: Sodium atom represents an element of sodium. Sodium ion represents the characteristic of an element. [Participant appeared unsure]
I: [Repeat the above question]. You can use drawing to show what you think is the difference between a sodium atom and a sodium ion.
R: I think the proton number… Not sure… I cannot answer.

I: You can now work on the two questions on **Worksheet 2** (see *Appendix 26*)
R: Reading through the questions and began writing. See Figures 5.94 and 5.103 in Chapter 5 for M1's responses.

Sample of interview transcript from the High group (H1)

SSI (1)

I: What do you know or understand about chemical representations or representations in chemistry?
R: Chemical representations?
I: You can also use pictures or diagrams or words to describe or to explain what you know about chemical representations. [Pieces of plain paper were given to the participant]
R: Any symbol used in chemistry will do?
I: You can say or write or draw anything that according to your understanding is chemical representation. If you find it difficult to describe in words, you can give some examples and show your answers by either writing or drawing.
R: [Participant began writing on the plain paper and read out at the same time]
Symbols like this means …

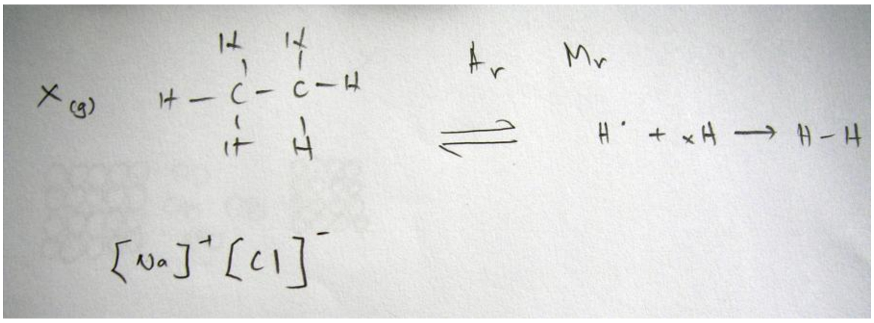


Figure 5.7: H1a

I: Anything else that you would like to add to the list?
R: [Continue writing and reading out]. M_r is relative molecular mass, A_r is relative atomic mass, … (see Figure 5.7: H1a).
I: Ok.
R: [Writing and drawing some more examples and explaining at the same time. This symbol means covalent bond…
I: Anything else?
R: Ionic bond [continue writing and drawing]
I: How about symbols of elements, chemical formulae, chemical equations, are they chemical representations?
R: Yes.

I: Ok. [Showing a copy of the Test on Chemical Representations, TCR, see *Appendix 11a,* to the participant]
I: Now look at the test paper. Is statement No. 9 true or false?
R: False.
I: Why do you think that the statement is false?
R: I think copper atom itself has no colour but when a lot of atoms make up the element copper, it is reddish brown.
I: Look at statement No. 20. Is it a true or a false statement?
R: False.
I: Why do you think it is a false statement?
R: It should be hexose generally. Glucose is only a subset of hexose.
I: Would you like to correct the statement to make it true?
R: [No response]

I: Now, let's look at some symbolic representations. What does the symbol `Cu' mean to you?
R: Copper atom.
I: Any other meaning?
R: I don't think so.
I: So it only mean copper atom to you?
R: [Not responding]
I: Does `Cu' refer to 1 Cu atom or 1 mole of Cu atom or N_A atoms of copper?
R: Both also can.
I: Why didn't you mention earlier?
R: I did not think of that.

I: [Showing three symbolic representations: O_2, 2O, O^{2-} (see **Focus Card 1** – *Appendix 23*)]
I: Does the number `2' in each of the representation above have the same meaning?
R: No.
I: Can you distinguish or explain the meaning of the number `2' in each of the representation?
R: [Looking at the symbolic representations and responding immediately]
I: What does the number `2' in O_2 mean?
R: The subscript `2' in O_2 means 2 atoms of oxygen and the whole thing is a molecule.
I: What about 2O?
R: `2' means 2 oxygen atoms or 2 moles of oxygen atoms.
I: Ok. Good.
I: What about the number `2' in O^{2-}?
R: Oxygen exists as an ion with a negative charge of 2.

I: [Show actual ball-and-stick models of common molecules such as water, ammonia and methane] (see **Focus Card 2** – *Appendix 24*).
I: What do the sticks represent?
R: Represent the bonds between atoms.
I: What do the balls represent?
R: The balls represent atoms.
I: Good.
I: Why do the balls have different colours and or sizes?
R: The different colours represent different atoms. The different sizes also represent different atoms. For example, hydrogen atom is smaller compared to carbon atom or oxygen atom.
I: Ok. Good.

I: [Show two symbolic representations: Cl_2 and Cl_2 (g)]
I: Do the symbols Cl_2 and Cl_2 (g) mean the same thing to you?
R: No, they mean different things.
I: So what is the difference between the symbols Cl_2 and Cl_2 (g)? Can you use drawing(s) to show the difference?
R: [Drawing]. See Figure 5.23.

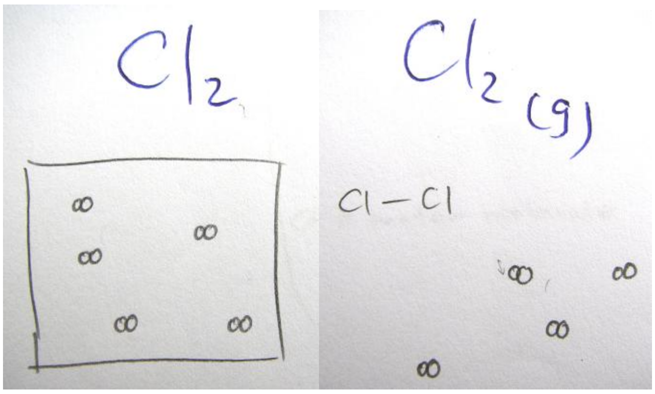


Figure 5.23: H1b

I: [Looking at the drawing (see Figure 5.23). Then pointing at the diagram and ask] `what is this'?
R: Cl_2 (g) is chlorine gas. Cl_2 is chlorine molecules but not necessarily in gaseous state.
I: [Pointing to Figure 5.23]. So, what is the difference between Cl_2 and Cl_2 (g)? Can you explain your drawing?
R: [Pointing to the figure and explaining]. This is Cl_2 molecule.
I: If Cl_2, how many molecules of Cl_2 are you going to draw?
R: [Still drawing more than 1 molecule of Cl_2]. There are a lot of molecules. Cl_2 (g) also show it is a gas.
I: Do you agree if I say ` Cl_2' refers to a molecule of chlorine?
R: Yes.
I: Would you like to change anything on the diagram?
R: No.

I: Now work through the online quiz available at www.darvill.clara.net/hotpots/emc.htm (see *Appendix 25a*).
R: [Working on the quiz].
I: Very good. You score is 100%.

I: Now you can try to work through **Worksheet 1** (see *Appendix 25*).
R: [Working on Worksheet 1].
I: [Participant's answers were all correct. Explanations were also given]. Refer to Figure 5.31 in Chapter 5.

SSI (2)

I: [Showing a copy of the TRC (*Appendix 15a*) to the participant]. Now, let's look at Questions 19 and Question 22 of Part A.
I: Ok. What answer would you give for Qu. 19?
R: [Working on Qu. 19 and responding fast]. The answer is `B'.
I: You also chose `B' in your test.
I: The most popular answer is `C'. Why didn't you choose `C'?
R: [Pointing to the diagram in Qu. 19 (*Appendix 15a*)]. These are the excess reagents. In chemical equation, only include the reactant and the products.
I: Why didn't you choose `A'?
R: Because `B' is the simplest.
I: Good. Shall we look at Qu. 22?
R: [Working on Qu.22]. The correct answer is `D'.
I: Very good. Both Qu.19 & Q.22 correct. You really understand the concept of a chemical equation.

I: Now let's look at Question 3(a) and (c) of Part B.
R: [Participant looking at his own answer script. His answers to both parts were correct] Figure 5.40.
I: What do you think is the difference between an atom and an element?
R: An element has only one kind of atom. An atom is a single particle.
I: Can you explain how element and atom are related?
R: An element is made up of one type of atom.
I: What is/are the type of particles found in an element?
R: Atoms.
I: Only atoms?
R: Atoms and molecules.
I: Ok, good.

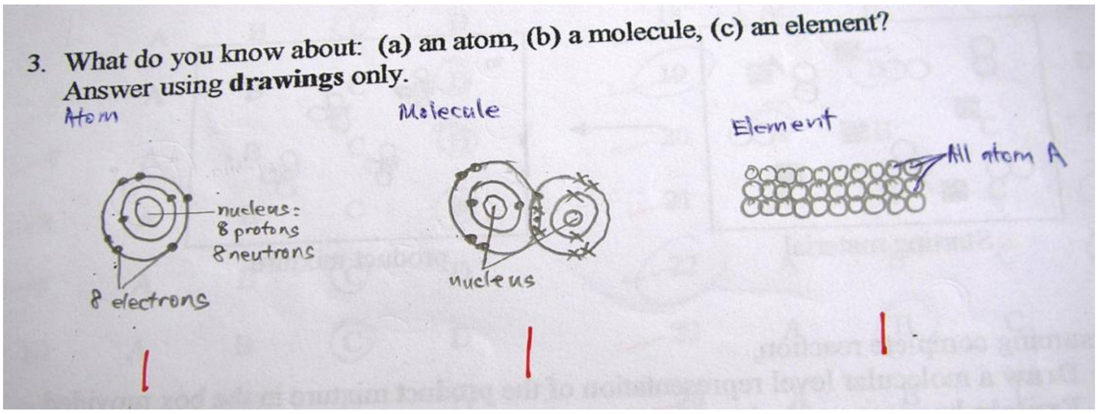


Figure 5.40: H1d

I: [Showing a beaker of water to the respondent]
I: Can you show, by drawing, how a beaker of water might appear when viewed through `a very powerful microscope'?
R: Powerful microscope means … at what level of magnification?
I: You can see at the particle level.
R: [Drawing]. Drawing shows wall of beaker as well! See Figure 5.49.

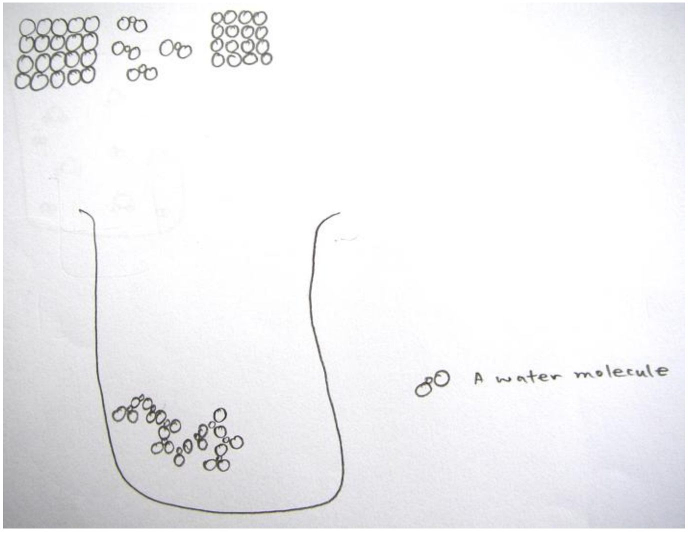


Figure 5.49: H1e

R: [Pointing at the diagram that was just drawn and explaining]. This is the wall of the beaker. It is a solid.
I: You can just focus on the content i.e. the water inside the beaker only.
R: [Appeared puzzled but said nothing]
I: [Repeat question to the participant]. Show, by drawing what you can see when a beaker of water is viewed through a very powerful microscope.
R: You mean what do the particles look like?
I: Yes. Just draw what you can `see' or visualize.
R: [Drawing and explaining while pointing to the diagram]. There are chains and chains of water molecules like this. There are separate water molecules but not really far apart as water is a liquid. This is the hydrogen bond. See Figure 5.49.
I: Anything else you want to add in?
R: Should I add in the hydrogen bond?
I: Just draw what you think is necessary.

I: [Showing a piece of copper foil]. Can you tell me what are inside this copper foil?
R: Copper atoms.
I: Can you use drawing to show or describe what you `see'?
R: [Drawing]. See Figure 5.58.

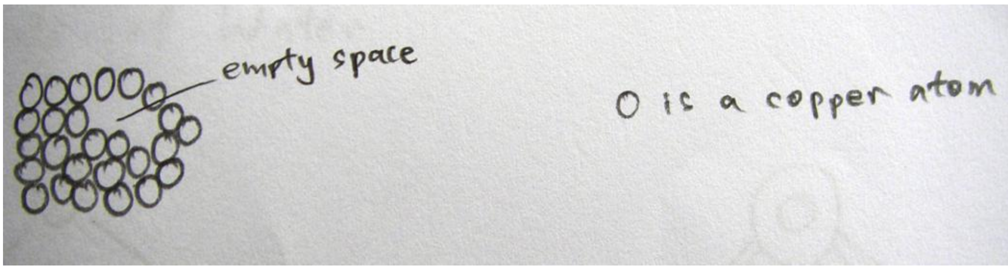


Figure 5.58: H1f

R: Do I need to show the electron?
I: You need only show at the atomic level.
I: [Pointing to Figure 5.58 and asking]. Why are you leaving a gap here?
R: Because it is one of the properties of metal. Metals are malleable, ductile, …

I: If I give you a closed gas jar containing a mixture of carbon dioxide and oxygen gas. What are you likely to `see' through a very powerful microscope?
R: [Busy drawing on the plain paper provided]. See Figure 5.66.

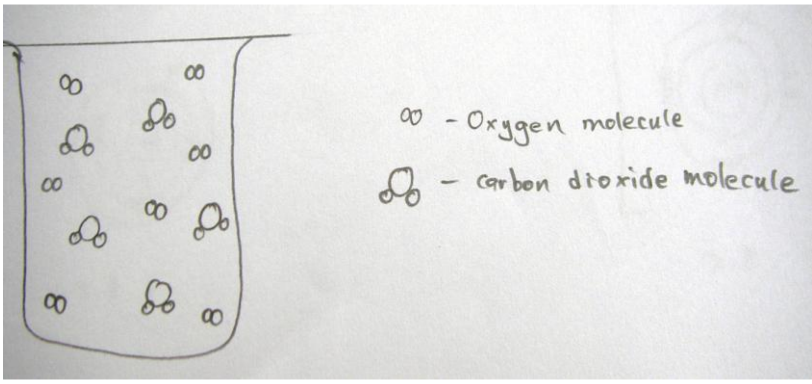


Figure 5.66: H1g

I: Can you explain your drawing?
R: Since it is a mixture, the particles are all thoroughly mixed. The particles are quite far apart as both are gases. They are moving at random. Carbon dioxide molecules are heavier compared to oxygen molecules so more are sinking or stay at the bottom.
R: Ok, good.
I: Shall we continue?
R: Ok.

I: Can you show, in as many ways as you could, how you would represent a molecule of water?
R: [Began drawing].
I: Ok. One… anymore?
R: Can I draw the whole molecule?
I: Yes, keep drawing.
R: [Continue drawing]. See Figure 5.79.
I: You always see water molecules in the teaching courseware. How do they look like?
R: Can't recall.

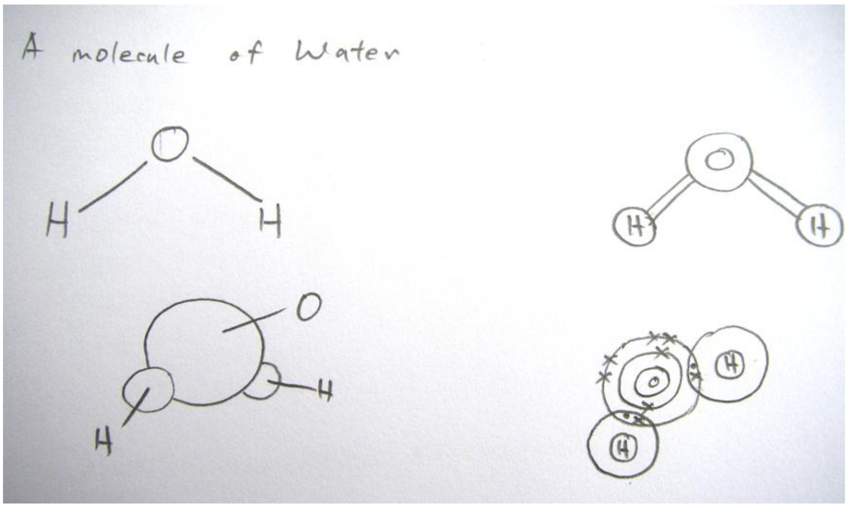


Figure 5.79: H1h

I: Any other way to represent a molecule of water?
R: [Drawing another one – the spaced-filled model, followed by another]. See Figure 5.79.
I: You are showing the whole covalent molecule?
R: Yes.
I: Anymore ways to represent a molecule of water?
R: [Pause]. I think that's all.
I: How about H_2O?
R: [Appeared surprised that he has missed out this one!]
I: Are all the representations similar? Which one do you prefer to use?
R: This one, pointing at H_2O
I: Why?
R: Easier to write and use, for example when writing chemical equation. .
I: Why do you need to use or know so many ways to represent a molecule of water?
R: Can use different representation for a different purpose?
I: Good. Let's go on.

I: Can you draw the electron arrangement of a sodium atom and a sodium ion?
R: [Completed the drawing within a short time]. See Figure 5.88.

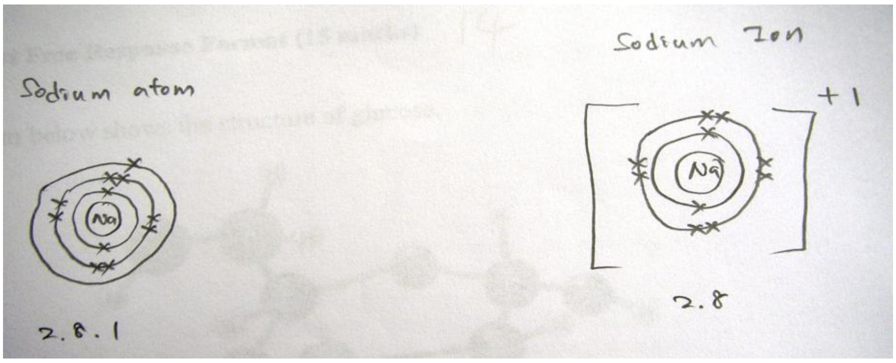


Figure 5.88: H1i

I: Can you describe the electron arrangement of a sodium atom and a sodium ion?
R: [Writing down 2.8.1 for sodium atom and 2.8 for sodium ion].
I: What do you think is the difference between a sodium atom and a sodium ion?
R: Sodium ion has a charge of 1+. It has 1 electron less than sodium atom.
I: How would you classify them according to the type of particle?
R: Sodium atom is an atom while sodium ion is an ion.
I: You can now work on the two questions on **Worksheet 2** (see *Appendix 26*)
R: [Reading through the questions and began writing]. See Figures 5.79 and 5.106 in Chapter 5 for H1's responses.

Focus Card 1: Symbolic Representations

$$O_2$$

$$2O$$

$$O^{2-}$$

(a) Does the number `2' in each of the representation above have the same meaning?

(b) Can you distinguish or explain the meaning of the number `2' in each of the representation?

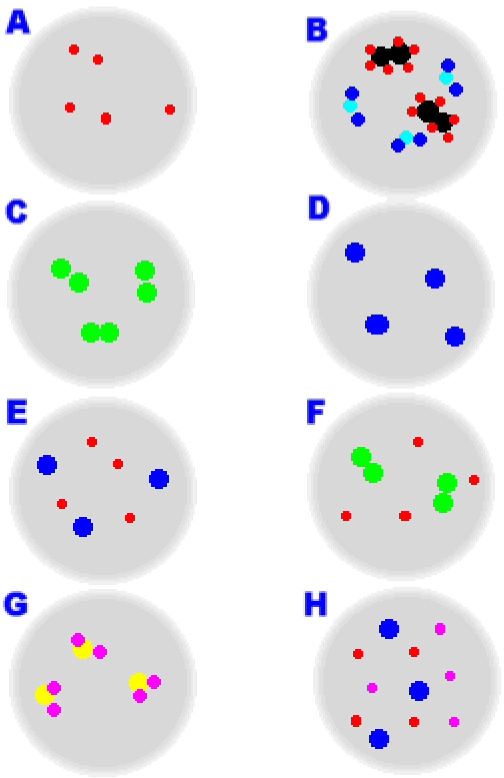
Focus Card 2: Symbolic Representations

Examples of representations at the symbolic level for some common molecules such as water, ammonia or methane are shown above.

(a) What do the sticks represent?
(b) What do the balls represent?
(c) Why do the balls have different colours and/or sizes?

Elements, Mixtures and Compounds

Here are pictures of some different particle arrangements. Choose the correct letters in the boxes on the right.



Pure elements	CHOOSE	
Elements made of SINGLE ATOMS	CHOOSE	
An element made of MOLECULES	CHOOSE	
Mixture of TWO elements	CHOOSE	
Mixture of THREE elements	CHOOSE	
Pure compounds	CHOOSE	
Mixture of TWO compounds	CHOOSE	

Your score is:

Worksheet 1: Submicroscopic Representations

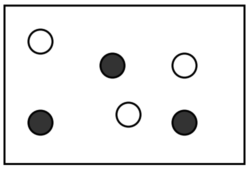


Figure 1

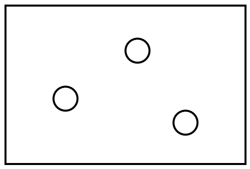


Figure 2

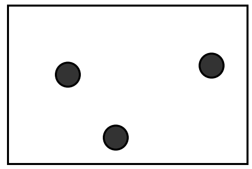


Figure 3

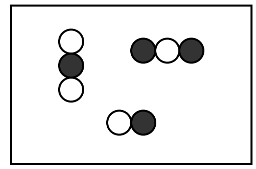


Figure 4

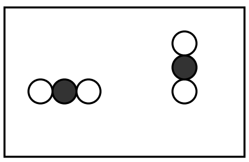


Figure 5

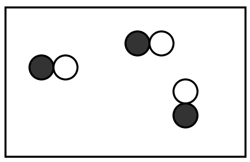


Figure 6

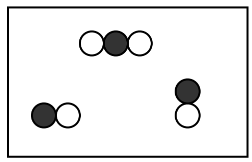


Figure 7

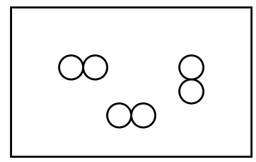


Figure 8

Note: In the figures, the symbol ○ represents atoms of one kind while the symbol ● represents atoms of another kind

1. Study Figures 1 to 8 carefully, then classify the diagrams into:

(a) Pure substances: ____

Mixtures: ____

What is/are the criteria you use to distinguish them? (or explain how you classify them).

(b) Elements: ____

Compounds: ____

What is/are the criteria you use to distinguish them? (or explain how you classify them).

A Formation of Compounds

Learning Outcomes

You should be able to:
- explain the stability of noble gases.
- explain the conditions for the formation of chemical bonds.
- state the types of chemical bonds.

There is a total of 113 elements in the Periodic Table. However, the number of compounds that exist far exceeds this number. This is because atoms of various elements can chemically bond together to form compounds.

For example, the element sodium is a silver-coloured metal that reacts violently with water. The element chlorine is a greenish-yellow gas that is poisonous. When chemically bonded together, these two elements form the compound sodium chloride, NaCl which is the table salt that we eat every day.

***Photograph 5.1** The formation of sodium chloride, NaCl*

Work This Out 5.1 *Collecting and interpreting data*

Various naturally occurring compounds exist as a result of chemical bonding. Let us collect more information about these compounds from your school library or by surfing the Internet. Find out the following for each of the compounds.

(a) The constituent elements of the compound

(b) The differences in properties between the compound and its constituent elements

Formation of chemical bonds

You have learnt in Chapter 4 that noble gases have stable octet or duplet electron arrangements. Therefore, they exist as monoatomic gases and are chemically unreactive. Atoms of other elements tend to achieve the stable electron arrangement through the formation of **chemical bonds**.

Once Upon a Time

Gilbert Newton Lewis (1875 – 1946) established the basis of today's theory of chemical bonding.

Key Terms

- Chemical bond

Formation of ionic bonds

Ionic compounds are compounds that are formed through ionic bonds. Let us carry out Activity 5.1 to prepare these compounds in the laboratory.

Practical Book • Activity 5.1, page 52

Now, let us investigate the formation of the ionic bond in sodium chloride, NaCl. A sodium atom with an electron arrangement of 2.8.1 donates one electron to achieve the stable octet electron arrangement. This electron is transferred to a chlorine atom with an electron arrangement of 2.8.7.

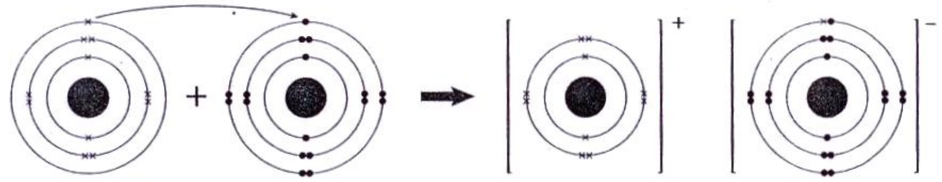


Figure 5.4 Formation of sodium chloride, NaCl

Web Link

View an animation on the formation of sodium chloride, NaCl. Go to http://www.beyondbooks.com/psc92/3b.asp

The sodium ion, Na^+ and chloride ion, Cl^- formed are attracted to one another to form a solid sodium chloride, NaCl compound. This is due to the existence of a strong electrostatic force between the oppositely-charged ions. The attractive force between the ions is called an **ionic bond** or **electrovalent bond**. Let us study Figure 5.5 below to see how the ionic bond is formed in magnesium fluoride, MgF_2.

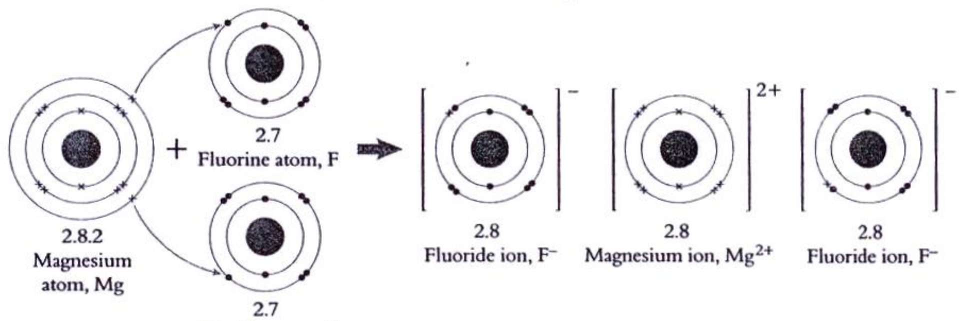


Figure 5.5 Formation of magnesium fluoride, MgF_2

Key Terms

- Electrovalent bond

Worksheet 2: Multiple Levels of Representation

1. You are given the chemical equation: $C(s) + O_2(g) \rightarrow CO_2(g)$.
   Describe in words what the equation tells you. You may describe in as many ways as you can.

2. The picture on the right shows the reaction between sodium metal and chlorine gas.
Draw and **explain** how sodium and chlorine react to form sodium chloride.

D R A W I N G	
E X P L A N A T I O N	

Appendix 27a

Permission to conduct the study
(from the Ministry of Education, Malaysia)

BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
KEMENTERIAN PELAJARAN MALAYSIA
ARAS 1-4, BLOK E-8
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA.

Telefon : 03-88846591
Faks : 03-88846579

Ruj. Kami : **KP(BPPDP)603/5/JLD.09(208)**
Tarikh : **10 September 2008**

Sim Joong Hiong
No.7, Persiaran Bekor 7
Taman Pertama
30100 Ipoh
Perak

Tuan/Puan,

Permohonan Untuk Menjalankan Kajian Di Sekolah, Institut Perguruan, Jabatan Pelajaran Negeri Dan Bahagian-Bahagian Di Bawah Kementerian Pelajaran Malaysia

Adalah saya dengan hormatnya diarah memaklumkan bahawa permohonan tuan /puan untuk menjalankan kajian bertajuk:

" Form Four Students' Understanding Of Chemical Representations And Their Representational Competence In Chemistry " diluluskan.

2. Kelulusan ini adalah berdasarkan kepada cadangan penyelidikan dan instrumen kajian yang tuan/puan kemukakan ke Bahagian ini. **Kebenaran bagi menggunakan sampel kajian perlu diperolehi dari Ketua Bahagian/Pengarah Pelajaran Negeri yang berkenaan.**

3. Sila tuan/puan kemukakan ke Bahagian ini senaskah laporan akhir kajian setelah selesai kelak. Tuan/Puan juga diingatkan supaya **mendapat kebenaran terlebih dahulu** daripada Bahagian ini sekiranya sebahagian atau sepenuhnya dapatan kajian tersebut hendak dibentangkan di mana-mana forum atau seminar atau diumumkan kepada media massa.

Sekian untuk makluman tuan/puan. Terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

(DR. SOON SENG THAH)
Ketua Sektor Penyelidikan Dan Penilaian
b.p. Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pelajaran Malaysia

s.k

Pengarah
Jabatan Pelajaran Negeri Perak

Prof. Dr. Siow Heng Loke
Jabatan Pendidikan Matematik & Sains
Fakulti Pendidikan
Universiti Malaya
50603 Kuala Lumpur

Appendix 27b

Permission to conduct the study
(from the State Education Department, Perak)

JABATAN PELAJARAN PERAK,
JALAN TUN ABDUL RAZAK,
30640 IPOH,
PERAK DARUL RIDZUAN.

Telefon : 05-501 5000
Faks : 05-527 7273

'KOMUNITI BERILMU PERAK TERBILANG'

J.Pel.Pk.Pend.S4757/Jld.32(78)
Tarikh : 19 September 2008

Sim Joong Hiong,
No. 7 Persiaran Bekor 7,
Taman Pertama,
30100 Ipoh,
Perak.

Tuan/Puan,

KEBENARAN UNTUK MENJALANKAN KAJIAN
<u>DI SEKOLAH-SEKOLAH MENENGAH / RENDAH NEGERI PERAK</u>

Saya diarahkan merujuk surat tuan bertarikh 2 September 2008 yang ada kaitannya dengan surat Kementerian Pelajaran Malaysia bilangan KP(BPPDP)603/5/JLD.09(208) bertarikh 10 September 2008 tentang perkara di atas.

2. Sukacita dimaklumkan bahawa pihak Jabatan Pelajaran Perak tiada halangan memberi kebenaran kepada tuan/puan untuk menjalankan kajian **" Form Four Students' Understanding of Chemical Representations and their Representational Competence in Chemistry "** di sekolah- sekolah menengah di negeri Perak.

3. Kehadiran tuan/puan membuat kajian di sekolah berkenaan tidak seharusnya menjejaskan proses pengajaran dan pembelajaran di sekolah berkenaan.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA'

Saya yang menurut perintah,

(ZAFIAN BIN HJ. KASIM)
Penolong Pendaftar Sekolah
b.p. Pendaftar Sekolah-Sekolah Perak.

s.k. 1. Pendaftar Sekolah dan Guru
Jabatan Pelajaran Perak
2. Penolong Pendaftar Sekolah dan Guru
Pejabat Pelajaran Daerah Negeri Perak.

Appendix 27c

Sim Joong Hiong
No. 7 Persiaran Bekor 7
Taman Pertama
30100 Ipoh
PERAK

Pengetua Kanan/Pengetua

SMK/SMJK/ST ……………………………

………………………………..................

………………………………………….....
(u.p.) 19 September 2008

Tuan/Puan,

Kebenaran untuk Menjalankan Kajian di Sekolah Tuan/Puan

Berkenaan dengan perkara tersebut, saya merupakan seorang guru yang sedang mengikuti Program Doktor Falsafah di Universiti Malaya.

2. Sempena memenuhi keperluan program dalam Pendidikan Sains melalui tesis, saya sedang menjalankan satu kajian bertajuk **"Form Four Students' Understanding of Chemical Representations and their Representational Competence in Chemistry"** dan ingin mengutip data dari sekolah tuan/puan.

3. Kebenaran untuk menjalankan kajian ini telahpun diluluskan oleh Jabatan Pelajaran Negeri Perak melalui surat Jabatan Pelajaran Perak bilangan J.Pel.Pk.Pend.S4757/Jld.32(78) bertarikh 19 September 2008. Bersama surat ini saya kepilkan salinan surat kebenaran dari Jabatan Pelajaran Negeri Perak untuk rujukan tuan/puan.

4. Semoga permohonan saya boleh diluluskan oleh pihak tuan/puan.

Sekian. Terima kasih.

Yang benar,

………………………..
(SIM JOONG HIONG)
No. Fail Peribadi: JPN 89169

Appendix 27d

Letter of Information and Consent

Request to participate in interview

I am a doctoral student of Science Education at the University of Malaya. At the moment I am working on the final PhD thesis. The title of the study is "*Form 4 Students' Representations of Basic Chemical Concepts*". To gain further insights into students' conceptions of chemical representations and their representational competence, I need to conduct interviews with selected Form 4 students.

I shall use a voice recorder and take notes while we talk. The interview will take approximately 60 to 90 minutes. We shall find the appropriate time and place for the interview.

It is voluntary to participate in the interview, and you may withdraw from the project without having to state a reason for doing so. If you withdraw all the data about you will be erased. Information collected shall be strictly confidential. The information will be made anonymous, and the recordings will be erased after the completion of the thesis at the end of 2010.

If you have any questions, please call me at 05-5276066 or 012-5606718, or email to me at: simjhjp@yahoo.com. You may also contact my project supervisor Associate Professor Dr. Esther Daniel at 03-79675210.

If you would to participate in the interview, please sign the attached letter of consent.

Yours sincerely,

………………………
SIM JOONG HIONG
Department of Mathematics & Science Education
Faculty of Education
University of Malaya
50603 KUALA LUMPUR

Letter of Consent

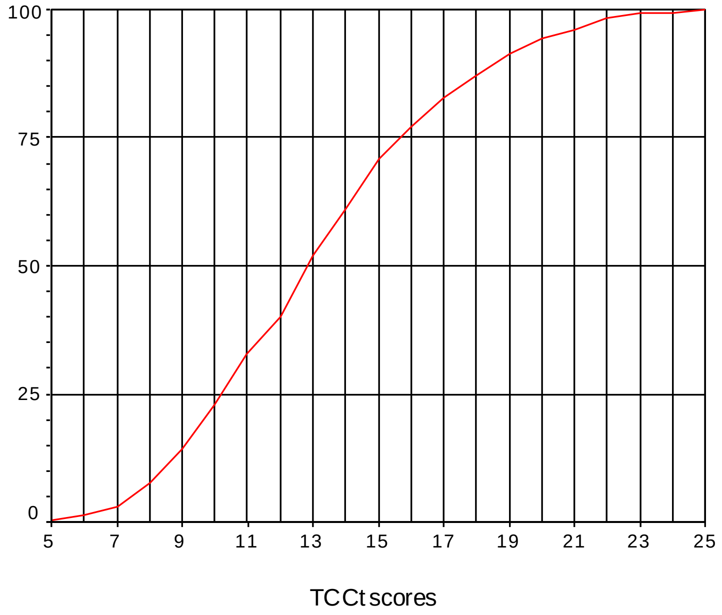
I have received information about the study and would like to participate in the interview.

Signature : …………………………………………

Phone number : …………………………………………

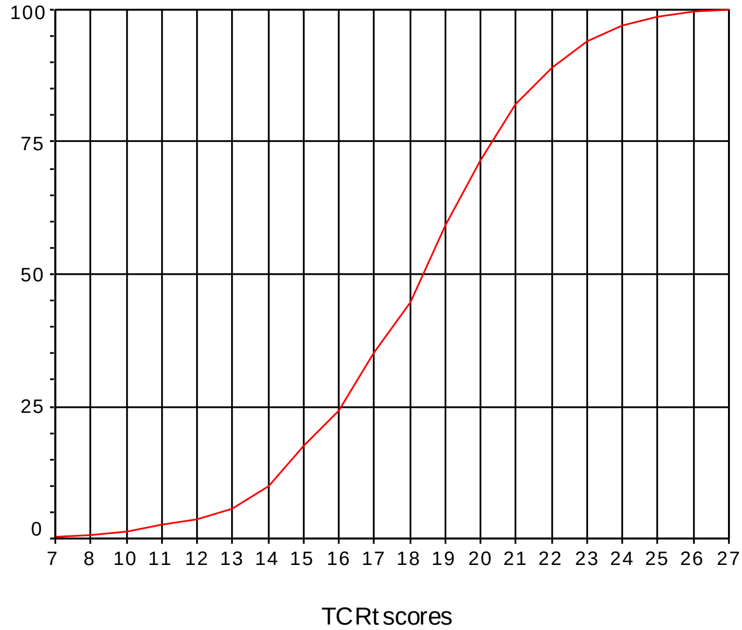
Date : …………………………………………

Cummulative frequency curves



<u>Categorization of TCC scores</u>

The lower 25% (L)	:	< 10
The middle 50% (M)	:	10 – 15
The higher 25% (H)	:	16 – 25



<u>Categorization of TCR scores</u>

The lower 25% (L)	:	< 16
The middle 50% (M)	:	16 – 20

The higher 25% (H) : 21 – 27

Appendix 2a

NAME: ____________________________ CLASS: ______________

SCHOOL: __________________________ GENDER: ____________

Preliminary Survey Questionnaire

Chemical Representations: ***What are Chemistry Students' Perceptions?***

1. Have you heard of or seen the term "chemical representations"?
   [ ] Yes
   [ ] No

If *yes*, where did you come across the term "chemical representations"?
(You can choose more than one)

[ ] Chemistry text book recommended by MOE, Malaysia
[ ] Chemistry reference books (Local Publications)
[ ] Chemistry reference books (International Editions)
[ ] Chemistry teachers
[ ] Chemistry teaching courseware by MOE, Malaysia
[ ] Internet
[ ] Other sources (please specify)

2. Are you familiar with the term "chemical representations"? [ ] Yes
   [ ] No

3. Do you know the meaning of the term "chemical representations"? [ ] Yes
   [ ] No

4. Are you aware of the existence of "the 3 levels of thinking" or "the 3 levels of representations of matter" in chemistry? [ ] Yes
   [ ] No

5. Do you have any difficulty learning about representations in chemistry?
   [ ] Yes
   [ ] No

   If *yes*, what are some of your difficulties?

6. Is it important for students to know about chemical representations?

[ ] Yes
[ ] No

Why do you think so?

7. Is it important for teachers to know about chemical representations?

[ ] Yes
[ ] No

Why do you think so?

8. In what ways are chemical representations useful to you:

(a) as a student?

(b) as a teacher?

9. What do you think are the roles and purposes of representations in chemistry? Give examples.

THANK YOU FOR YOUR CO-OPERATION

Content Area of the Test on Chemical Concept (TCC) – Pilot Study

<u>Chemical concepts tested in the TCC are</u>:

1. Matter
2. Pure substances and mixtures
3. Elements and compounds
4. Atoms, molecules and ions
5. Physical change and chemical change
6. The structure of the atom
7. Sub-atomic particles
8. Proton number and nucleon number
9. Isotopes
10. Electron arrangement
11. Valence electron

Content Area of the Test on Chemical Concepts (TCC) – Actual Study

Chemical concepts tested in the TCC are:

1. Matter and its properties
2. Pure substances and mixtures
3. Elements and compounds
4. Atoms, molecules and ions
5. Physical change and chemical change
6. Conservation of mass
7. Sub-atomic particles of an atom
8. Proton number and nucleon number
9. Isotopes
10. Electron arrangement and valence electron
11. The mole concept
12. Chemical bonds

Appendix 4

Table of Specifications for Test on Chemical Concepts (TCC) – Actual Study

Chemical Concepts Tested	Test points allocated and item no. (in brackets)		Total Test Points
	Part A True/False items	Part B MCQ	
1. Matter and its properties	-	1 (15)	1
2. Pure substances and mixtures	2 (1, 5)	1 (5)	3
3. Elements and compounds	3 (3, 8, 9)	1 (8)	4
4. Atoms, molecules and ions	4 (2, 4, 10,15)	4 (1, 2, 3, 11)	8
5. Physical change and chemical change	2 (6, 7)	2 (7, 12)	4
6. Conservation of mass	-	1 (13)	1
7. Sub-atomic particles of an atom	1 (13)	1 (9)	2
8. Proton number and nucleon number	-	1 (6)	1
9. Isotopes	1 (11)	-	1
10. Electron arrangement and valence electron	-	1 (4)	1
11. The mole concept	1 (14)	1 (14)	2
12. Chemical bonds	1 (12)	1 (10)	2
Total Test Points	15	15	30

NAME: ______________________________ CLASS: ____________________

SCHOOL: ____________________________ GENDER: __________________

TEST on CHEMICAL CONCEPTS (TCC) – Actual Study

Instructions

1. This test consists of TWO parts: Part A and Part B.
2. Answer ALL the questions in both parts.

Part A: True or False items

Item No.	Response		Item No.	Response		Item No.	Response	
1	T	F	6	T	F	11	T	F
2	T	F	7	T	F	12	T	F
3	T	F	8	T	F	13	T	F
4	T	F	9	T	F	14	T	F
5	T	F	10	T	F	15	T	F

Part B: Multiple Choice Questions

1	A	B	C	D	9	A	B	C	D
2	A	B	C	D	10	A	B	C	D
3	A	B	C	D	11	A	B	C	D
4	A	B	C	D	12	A	B	C	D
5	A	B	C	D	13	A	B	C	D
6	A	B	C	D	14	A	B	C	D
7	A	B	C	D	15	A	B	C	D
8	A	B	C	D					

THANK YOU FOR YOUR CO-OPERATION

Test on Chemical Concepts (TCC) - Actual Study

Part A: True or False items

Read each statement carefully and decide whether the statement is TRUE or FALSE. Indicate your choice by **CIRCLING** T or F on the **Answer Sheet**.

Item No.	Statement
1	The simplest substances in chemistry are atoms.
2	All molecules exist as compound.
3	The particles in an element can only be atoms.
4	Positive ions or cations are formed when neutral atoms gains protons.
5	Some familiar examples of mixtures are air, salt solution and petroleum.
6	When sugar dissolves in water, a chemical change takes place.
7	The statement “hydrogen gas burns in oxygen gas to form water” describes a chemical change.
8	The particles in a compound can be atoms, molecules, or ions.
9	Both water, H_2O and ozone, O_3 are molecular compounds.
10	A diatomic molecule can contain atoms of different elements.
11	Atoms of a given element all have the same mass.
12	Atoms take part in the formation of chemical bond to neutralize their charges.
13	All atoms can be identified by the number of protons they contain.
14	One mole of carbon monoxide molecule contains ½ mol of carbon atom and ½ mol of oxygen atom.
15	The particles in magnesium ribbon are neutral atoms.

Part B: Multiple choice questions

Choose the best answer for each item, then mark your choice by **CIRCLING** either A, B, C or D on the A**nswer Sheet** provided.

1. Atoms are electrically neutral. This statement is

   A. true, because an atom has no charge.
   B. true, because the number of protons is equal to the number of electrons.
   C. false, because an atom can be changed to an ion by gaining or losing electrons.
   D. false, because an atom has protons and electrons which are charged particles

2. Chlorine atom is different from chloride ion because chloride ion has

   A. a smaller size than chlorine atom.
   B. more protons than chlorine atom.
   C. more electrons than chlorine atom.
   D. more neutrons than chlorine atom.

3. An atom that donates an electron forms

   A. an ionic bond
   B. a positive ion
   C. a negative ion
   D. a new atom

4. What is the number of valence electron of an oxide ion, O^{2-}?

   A. -2 B. 4 C. 6 D. 8

5. Medals for the Olympic Games are usually made of gold, silver, or bronze. Which of these are pure substances?

   A. Gold and silver only
   B. Silver and bronze only
   C. Gold and bronze only
   D. All of them

6. An ion with 5 protons, 6 neutrons and a charge of 3+ has a proton number of

   A. 5 B. 6 C. 8 D. 11

7. Which of the following must be the same before and after a chemical reaction?

   A. The sum of the masses of all substances involved.
   B. The number of molecules of all substances involved.
   C. The number of atoms of each type involved.
   D. Both A and C must be the same.

8. When oxygen gas reacts with magnesium metal, what type of substance is formed?
   A. A compound
   B. A mixture
   C. A molecule
   D. An element

9. The identity of an element is determined by the number of which particle(s)?
   A. Protons
   B. Electrons
   C. Neutrons
   D. Protons and neutrons

10. In the formation of covalent bonds, the atoms of the elements involved

   A. accept electrons
   B. donate electrons
   C. share electrons
   D. exchange electrons

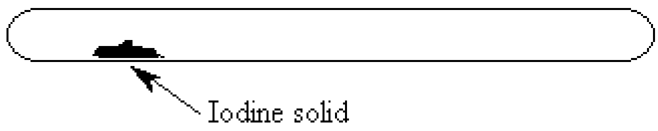
11. The type of particles in helium gas and hydrogen gas are the same. This statement is

   A. true, because both helium and hydrogen are very light gases.
   B. true, because both helium and hydrogen exist as diatomic molecules.
   C. false, because a helium atom is denser than a hydrogen atom.
   D. false, because the particles in helium gas are atoms whereas the particles in hydrogen gas are molecules.

12. Which of the following processes will make water molecules larger?

   A. Melting
   B. Evaporation
   C. Boiling
   D. None of the above

13. A 1.0-gram sample of solid iodine is placed in a tube and the tube is sealed after all of the air is removed. The tube and the solid iodine together weigh 27.0 grams.



The tube is then heated until all of the iodine evaporates and the tube is filled with iodine gas. The weight after heating will be:

A. less than 27.0 grams because iodine vapour is less dense than solid iodine.
B. less than 27.0 grams because iodine vapour is lighter than air.
C. 27.0 grams because mass is conserved.
D. more than 27.0 grams because when heated, the iodine molecules expand.

14. You are given this formu $\mathbf{X} = \dfrac{\textit{Number of Particles}}{\textit{Avogadro Cons}\tan t}$

What is **X** ?

A. Molar mass
B. Molar volume
C. Number of moles
D. None of the above

15. Following is a list of properties of a sample of solid sulfur:

i. Brittle, crystalline solid.
ii. Melting point of $113^{o}C$.
iii. Density of $2.1\ g\ cm^{-3}$.
iv. Combines with oxygen to form sulfur dioxide

Which, if any, of these properties would be the same for one single atom of sulfur obtained from the sample?

A. i only.
B. iv only.
C. i, ii and iii only.
D. All of these properties would be the same.

NAME: ________________________ CLASS: ___________________

SCHOOL: ______________________ GENDER: _________________

TEST on CHEMICAL CONCEPTS (TCC) – Pilot Study

Instructions

1. This test consists of TWO parts: Part A and Part B.
2. Answer ALL the questions in both parts.
3. For Part A, read each statement carefully and decide whether the statement is TRUE or FALSE. Indicate your choice by **CIRCLING** T or F on this **Response Sheet**.
4. For Part B, choose the best answer for each item, then mark your choice by **CIRCLING** either A, B, C or D on the A**nswer Sheet** provided.

Part A: True or False items

Item No.	Response		Item No.	Response		Item No.	Response	
1	T	F	9	T	F	17	T	F
2	T	F	10	T	F	18	T	F
3	T	F	11	T	F	19	T	F
4	T	F	12	T	F	20	T	F
5	T	F	13	T	F	21	T	F
6	T	F	14	T	F	22	T	F
7	T	F	15	T	F			
8	T	F	16	T	F			

Part B: Multiple Choice Questions

1	A	B	C	D	5	A	B	C	D
2	A	B	C	D	6	A	B	C	D
3	A	B	C	D	7	A	B	C	D
4	A	B	C	D	8	A	B	C	D

THANK YOU FOR YOUR CO-OPERATION

Test on Chemical Concepts (TCC) – Pilot Study

Part A: True or False items

Item No.	Statement
1	The simplest substances in chemistry are elements.
2	The particles in an element can only be atoms.
3	All molecules are compound.
4	Chemical elements have only one kind of atom.
5	An ion can be formed from an atom.
6	Mixtures have constant composition.
7	Substances can be either elements or compounds.
8	An atom is the smallest particle of an element.
9	All atoms can be identified by the number of protons they contain.
10	The proton number also indicates the number of electrons present in an atom.
11	Positive ions or cations are formed when neutral atoms gains protons.
12	Some familiar examples of mixtures are air, salt solution and petroleum.
13	When sugar dissolves in water, a chemical change takes place.
14	The proton number of an element is the number of protons in that element.
15	The statement “hydrogen gas burns in oxygen gas to form water” describes a chemical property of hydrogen.
16	Atoms of a given element all have the same mass.
17	Most matter is composed of molecules or ions.
18	Noble gases such as helium and neon exist in nature as single atoms.
19	The particles in a compound can be atoms, molecules, or ions.
20	Both water and ozone are molecular compounds.
21	A diatomic molecule can contain atoms of different elements.
22	The positively charged particles in the nucleus of an atom are called protons and neutrons.

Part B: Multiple choice questions

1. Atoms are electrically neutral. This statement is
   A. true, because an atom has no charge.
   B. true, because the number of protons is equal to the number of electrons.
   C. false, because an atom can be changed to an ion by gaining or losing electrons.
   D. false,because an atom has protons and electrons which are charged particles

2. Which of the following pairs are both elements?
   A. Nitrogen and water vapour
   B. Oxygen and carbon dioxide
   C. Carbon dioxide and water vapour
   D. Oxygen and nitrogen

3. Chlorine atom is different from chloride ion because chloride ion has
   A. a smaller size than chlorine atom.
   B. more protons than chlorine atom.
   C. more electrons than chlorine atom.
   D. more neutrons than chlorine atom.

4. An atom that donates an electron forms
   A. a cation
   B. an anion
   C. an ionic bond
   D. a covalent bond

5. Medals for the Olympic Games are usually made of gold, silver, or bronze. Which of these are pure substances?
   A. Gold and silver only   C. Gold and bronze only
   B. Bronze and silver only   D. All of them

6. What is the number of valence electron of an oxygen atom?
   A. 2   B. 4   C. 6   D. 8

7. How many types of elements are present in a molecule of ammonia?
   A. 1   B. 2   C. 3   D. 4

8. An aim of Chemistry is to study ***properties*** of substances. Which statement describes correctly one property of water?
   A. Water is H_2O.
   B. Water is needed by living things.
   C. Water is a very common substance.
   D. Water is a liquid at room temperature.

Item Analysis of the TCC - Pilot Study

Item No.	R_U	R_M	R_L	R_T	Item Difficulty Index $p=R_T/57$	Item Discrimination Index $D=(R_U - R_L)/15$
A1	11	11	1	23	0.40	0.67
A2	10	14	3	27	0.47	0.47
A3	12	13	9	34	0.60	0.20
A4	11	9	4	24	0.42	0.47
A5	15	22	8	45	0.79	0.47
A6	11	15	9	35	0.61	0.13
A7	10	22	9	41	0.72	0.07
A8	4	3	1	8	0.14	0.20
A9	2	9	1	12	0.21	0.07
A10	14	26	7	47	0.82	0.47
A11	9	13	6	28	0.49	0.20
A12	13	15	7	35	0.61	0.40
A13	11	13	2	26	0.46	0.60
A14	0	4	1	5	0.09	-0.07
A15	10	9	1	20	0.35	0.60
A16	5	18	7	30	0.53	-0.13
A17	8	18	5	31	0.54	0.20
A18	14	19	13	46	0.81	0.07
A19	2	5	4	11	0.19	-0.13
A20	4	10	4	18	0.32	0.00
A21	6	16	8	30	0.53	-0.13
A22	13	17	6	36	0.63	0.47
B1	8	8	2	18	0.32	0.40
B2	13	16	5	34	0.60	0.53
B3	15	15	8	38	0.67	0.47
B4	13	7	1	21	0.37	0.80
B5	11	7	5	23	0.40	0.40
B6	13	16	5	34	0.60	0.53
B7	11	16	3	30	0.53	0.53
B8	11	10	6	27	0.47	0.33

Note
R_U = Number of students choosing the correct answer in the upper 27%
R_M = Number of students choosing the correct answer in the middle group
R_L = Number of students choosing the correct answer in the lower 27%
R_T = Total number of students choosing the correct answer
T = Total number of students taking the test = 57
N = Number of students in the upper or lower group = 15

Test on Chemical Concepts (TCC)

Table 6(i)
Interpretation of Difficulty Index
(Source: adapted from Macintosh & Morrison, 1969)

Difficulty Index (p)	Item Difficulty Level	Item No.
< 0.10	Too difficult	(A) 14
0.10 – 0.30	Difficult	(A) 8, 9, 19
0.30 – 0.70	Moderately difficult	(A) 1, 2, 3, 4, 6, 11, 12, 13, 15, 16, 17, 20, 21, 22 (B) 1, 2, 3, 4, 5, 6, 7, 8
0.70 – 0.90	Easy	(A) 5, 7, 10, 18
> 0.90	Too easy	-

Table 6(ii)
Interpretation of Discrimination Index
(Source: adapted from Stanley & Hopkins, 1981)

Discrimination Index (ID)	Interpretation of ID	Item No.
< 0.20	Poor (reject)	(A) 6, 7, 9, 14, 16, 18, 19, 20, 21
0.20 – 0.30	Marginal (needs improvement)	(A) 3, 8, 11, 17
0.30 – 0.40	Quite good	(A) 12 (B) 8
> 0.40	Discriminates well	(A) 1, 2, 4, 5, 10, 13, 15, 22 (B) 1, 2, 3, 4, 5, 6, 7

Test Score Reliability of the TCC – Actual Study

Item No.	Total no. of correct responses	p value	q=1-p	pq
A1	64	.17	.83	.14
A2	251	.66	.34	.23
A3	262	.68	.32	.22
A4	182	.48	.52	.25
A5	206	.54	.46	.25
A6	122	.32	.68	.22
A7	266	.69	.31	.21
A8	77	.20	.80	.16
A9	111	.29	.71	.21
A10	211	.55	.45	.25
A11	268	.70	.30	.21
A12	116	.30	.70	.21
A13	87	.23	.77	.18
A14	238	.62	.38	.24
A15	174	.45	.55	.25
B1	143	.37	.63	.23
B2	239	.62	.38	.23
B3	217	.57	.43	.25
B4	107	.28	.72	.20
B5	172	.45	.55	.25
B6	184	.48	.52	.25
B7	73	.19	.81	.15
B8	266	.69	.31	.21
B9	162	.42	.58	.24
B10	282	.74	.26	.19
B11	105	.27	.73	.20
B12	172	.45	.55	.25
B13	118	.31	.69	.21
B14	239	.62	.38	.23
B15	108	.28	.72	.20
				$\sum pq = 6.52$

KR-20 was computed instead of KR-21 as the difficulty level of the items (p value) was different.

K-R 20: $$\mathbf{r = \frac{k}{k-1}\left[1 - \frac{\sum pq}{S^2}\right]}$$

where r = estimated reliability of the whole test
k = number of items in test
p = proportion of correct responses to a particular item
q = proportion of incorrect responses to that item (so that p+q=1)
pq = variance of a single item scored dichotomously
$\sum$ = summation sign indicating that pq is summed over all items
S^2 = variance of the total test

<u>Test score reliability for the TCC actual study (n = 383)</u>

K-R 20: $$r = \frac{30}{30-1}\left(1 - \frac{6.52}{15.244}\right)$$

$$= 1.03\ (1- 0.4277)$$

$$= \underline{\mathbf{0.59}}$$

Reliability of test scores (Test-Retest) for TCC – Actual study

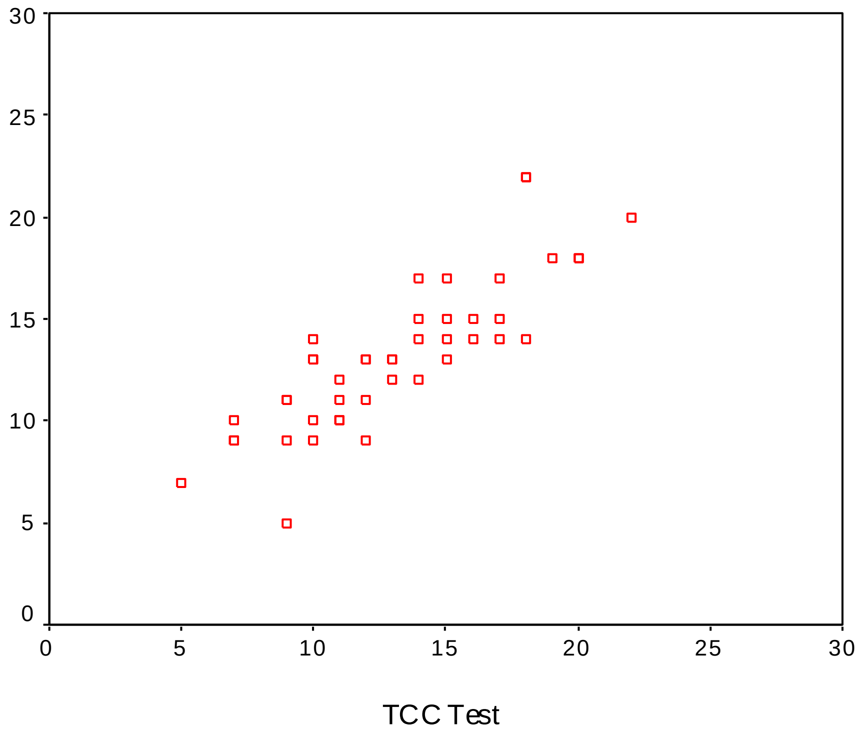
(i) Pearson correlation coefficient (actual study)

Correlations

		TCC Test	TCC ReTest
TCC Test	Pearson Correlation	1	.841**
	Sig. (2-tailed)	.	.000
	N	383	45
TCC ReTest	Pearson Correlation	.841**	1
	Sig. (2-tailed)	.000	.
	N	45	45

**. Correlation is significant at the 0.01 level (2-tailed).

(ii) Scatter plot for test-retest (TCC) – Actual study



Test Score Reliability of the TCC – Pilot Study

Item No.	p value	q=1-p	pq
A1	0.40	0.60	0.24
A2	0.47	0.53	0.25
A3	0.60	0.40	0.24
A4	0.42	0.58	0.24
A5	0.79	0.21	0.17
A6	0.61	0.39	0.24
A7	0.72	0.28	0.20
A8	0.14	0.86	0.12
A9	0.21	0.79	0.17
A10	0.82	0.18	0.15
A11	0.49	0.51	0.25
A12	0.61	0.39	0.24
A13	0.46	0.54	0.25
A14	0.09	0.91	0.08
A15	0.35	0.65	0.23
A16	0.53	0.47	0.25
A17	0.54	0.46	0.25
A18	0.81	0.19	0.15
A19	0.19	0.81	0.15
A20	0.32	0.68	0.22
A21	0.53	0.47	0.25
A22	0.63	0.37	0.23
B1	0.32	0.68	0.22
B2	0.60	0.40	0.24
B3	0.67	0.33	0.22
B4	0.37	0.63	0.23
B5	0.40	0.60	0.24
B6	0.60	0.40	0.24
B7	0.53	0.47	0.25
B8	0.47	0.53	0.25
			$\sum pq=6.45$

KR-20 shall be computed instead of KR-21 as the difficulty level of the items (p value) is different.

$$\textbf{K-R 20:} \qquad r = \frac{k}{k-1}\left[1 - \frac{\sum pq}{S^2}\right]$$

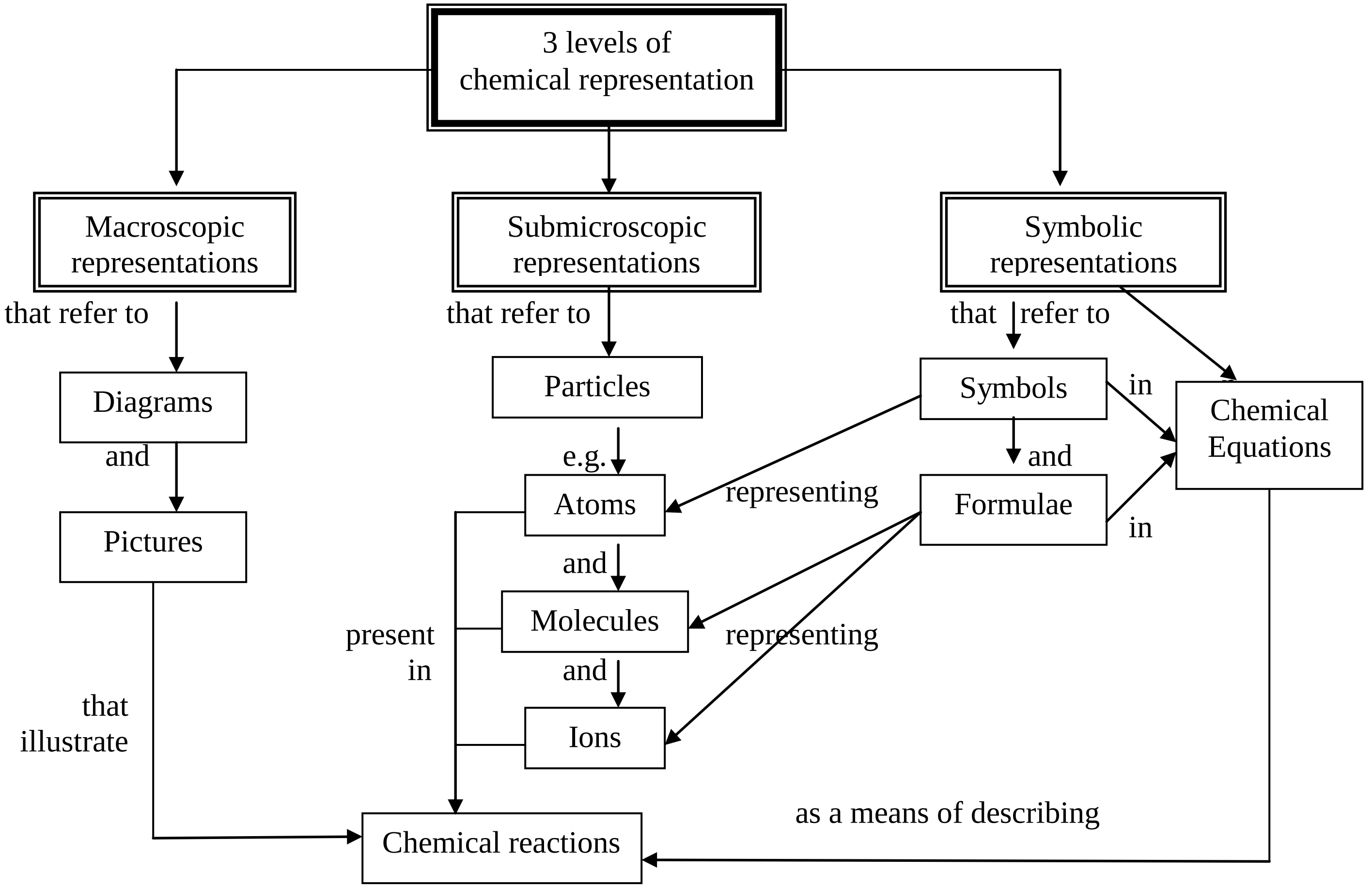
where r = estimated reliability of the whole test
k = number of items in test
p = proportion of correct responses to a particular item
q = proportion of incorrect responses to that item (so that p+q=1)
pq = variance of a single item scored dichotomously
$\sum$ = summation sign indicating that pq is summed over all items
S^2 = variance of the total test

<u>Test score reliability for the TCC pilot study (n = 57)</u>

$$\text{K-R 20:} \qquad r = \frac{30}{30-1}\left(1 - \frac{6.45}{13.95}\right)$$

$$= 1.03\,(1- 0.46)$$

$$= \underline{\mathbf{0.56}}$$



Concept map of the 3 levels of chemical representations
(adapted and simplified from: Chandrasegaran, Treagust & Mocerino, 2007, p.297)

Content Domain for the Test on Chemical Representations (TCR) –Actual Study

For the TCR, the content domain of interest is chemical representations, as defined by a separate list of 19 **propositions** related to: (1) the 3 levels of representation in chemistry (macroscopic, microscopic and symbolic representations), (2) chemical symbols, (3) chemical formulae, (4) models, (5) chemical equations.

These propositions are:

1. Three levels of representation in chemistry are the macroscopic, the submicroscopic, and the symbolic levels.
2. Chemical representations at the macroscopic level refer to pictures or diagrams that represent observable phenomena.
3. Submicroscopic representations of chemistry refer to models or other visual displays that depict the arrangement and motion of particles.
4. Chemical representations at the symbolic level refer to numbers, various types of symbols, formulae, structures and equations used to represent chemical processes and conceptual entities such as atoms and molecules.
5. Atoms of elements are represented by chemical symbols.
6. The first letter of a symbol is always capitalized, but any following letters are not.
7. A chemical formula uses symbols to indicate which elements are present, and it uses subscripts to indicate the relative number of atoms of the different elements present.
8. Both elements and compounds have chemical formulae.
9. Molecular formula shows the exact number of atoms of each element in the smallest unit of a substance.
10. Empirical formula lists the elements present and indicates the simplest whole number ratio in which their atoms are combined.
11. Empirical formulae are the simplest chemical formulae.

12. Structural formula is a chemical formula that shows how atoms are attached to one another.

13. The atoms in a molecule are attached in a definite order.

14. In structural formula, a line connecting two atomic symbols represents a chemical bond.

15. In chemistry, `model' refers to a physical or computational representation of the composition and structure of a molecule.

16. Models show the 3-D shape of molecules.

17. Two common types of molecular models are the ball-and-stick models and space-filling models.

18. A chemical equation is a representation of a chemical reaction using either symbols and chemical formulae or words.

19. The process symbols in a chemical equation are: (i) the plus sign (+), (ii) the arrow sign (→).

Content Domain for the Test on Chemical Representations (TCR) – Pilot Study

For the TCR, the content domain of interest is chemical representations, as defined by a separate list of **20 propositions** related to: (1) the 3 levels of representation in chemistry (macroscopic, microscopic and symbolic representations), (2) chemical symbols, (3) chemical formulae, (4) Models, (5) chemical nomenclature, (6) chemical equations.

These propositions are:

1. Three levels of representation in chemistry are the macroscopic, the submicroscopic, and the symbolic levels.

2. Chemical representations at the macroscopic level refer to pictures or diagrams that represent observable phenomena.

3. Submicroscopic representations of chemistry refer to models or other visual displays that depict the arrangement and motion of particles.

4. Chemical representations at the symbolic level refer to numbers, various types of symbols, formulae, structures and equations used to represent chemical processes and conceptual entities such as atoms and molecules.

5. Atoms of elements are represented by chemical symbols.
6. The first letter of a symbol is always capitalized, but any following letters are not.

7. A chemical formula uses symbols to indicate which elements are present, and it uses subscripts to indicate the relative number of atoms of the different elements present.

8. Both elements and compounds have chemical formulae.

9. Molecular formula shows the exact number of atoms of each element in the smallest unit of a substance.

10. Empirical formula lists the elements present and indicates the simplest whole number ratio in which their atoms are combined.

11. Empirical formulae are the simplest chemical formulae.

12. Structural formula is a chemical formula that shows how atoms are attached to one another.

13. The atoms in a molecule are attached in a definite order.

14. In structural formula, a line connecting two atomic symbols represents a chemical bond.

15. In chemistry, `model' refers to a physical or computational representation of the composition and structure of a molecule.

16. Models show the 3-D shape of molecules.

17. Two common types of molecular models are the ball-and-stick models and space-filling models.

18. Chemical nomenclature relates the names and formulae of chemical compounds.

19. A chemical equation is a representation of a chemical reaction using either symbols and chemical formulae or words.

20. The process symbols in a chemical equation are: (i) the plus sign (+), (ii) the arrow sign (→).

CLASSROOM TEST OF

SCIENTIFIC REASONING

Multiple Choice Version

Directions to Students:

This is a test of your ability to apply aspects of scientific and mathematical reasoning to analyze a situation to make a prediction or solve a problem. Make a dark mark on the answer sheet for the best answer for each item. If you do not fully understand what is being asked in an item, please ask the test administrator for clarification.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

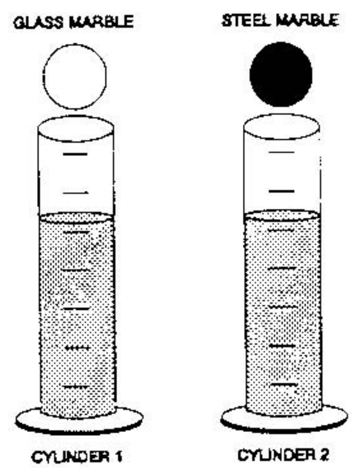
Revised Edition: August 2000 by Anton E. Lawson, Arizona State University. Based on: Lawson, A.E. 1978. Development and validation of the classroom test of formal reasoning. *Journal of Research in Science Teaching*, 15(1): 11-24.

1. Suppose you are given two clay balls of equal size and shape. The two clay balls also weigh the same. One ball is flattened into a pancake-shaped piece. *Which of these statements is correct?*

   a. The pancake-shaped piece weighs more than the ball
   b. The two pieces still weigh the same
   c. The ball weighs more than the pancake-shaped piece

2. *because*

   a. the flattened piece covers a larger area.
   b. the ball pushes down more on one spot.
   c. when something is flattened it loses weight.
   d. clay has not been added or taken away.
   e. when something is flattened it gains weight.



3. To the right are drawings of two cylinders filled to the same level with water. The cylinders are identical in size and shape.

   Also shown at the right are two marbles, one glass and one steel. The marbles are the same size but the steel one is much heavier than the glass one.

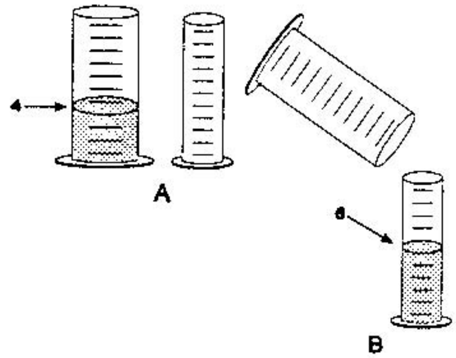
   When the glass marble is put into Cylinder 1 it sinks to the bottom and the water level rises to the 6th mark. *If we put the steel marble into Cylinder 2, the water will rise*

   a. to the same level as it did in Cylinder 1
   b. to a higher level than it did in Cylinder 1
   c. to a lower level than it did in Cylinder 1

4. *because*

   a. the steel marble will sink faster.
   b. the marbles are made of different materials.
   c. the steel marble is heavier than the glass marble.
   d. the glass marble creates less pressure.
   e. the marbles are the same size.

5. To the right are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).



Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. *How high would this water rise if it were poured into the empty narrow cylinder?*

a. to about 8
b. to about 9
c. to about 10
d. to about 12
e. none of these answers is correct

6. *because*

a. the answer can not be determined with the information given.
b. it went up 2 more before, so it will go up 2 more again.
c. it goes up 3 in the narrow for every 2 in the wide.
d. the second cylinder is narrower.
e. one must actually pour the water and observe to find out.

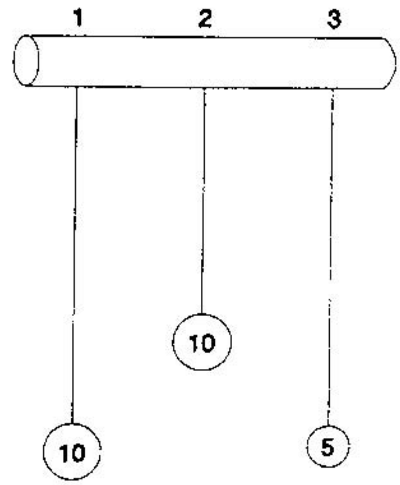
7. Water is now poured into the narrow cylinder (described in Item 5 above) up to the 11th mark. *How high would this water rise if it were poured into the empty wide cylinder?*

a. to about 7 1/2
b. to about 9
c. to about 8
d. to about 7 1/3
e. none of these answers is correct

8. *because*

a. the ratios must stay the same.
b. one must actually pour the water and observe to find out.
c. the answer can not be determined with the information given.
d. it was 2 less before so it will be 2 less again.
e. you subtract 2 from the wide for every 3 from the narrow.

9. At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10 unit weight is attached to the end of String 1. A 10 unit weight is also attached to the end of String 2. A 5 unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.



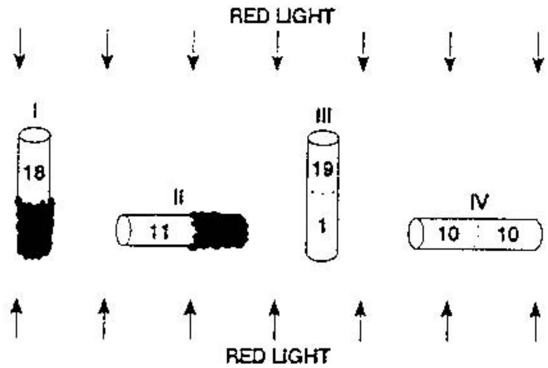
Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. *Which strings would you use to find out?*

a. only one string
b. all three strings
c. 2 and 3
d. 1 and 3
e. 1 and 2

10. *because*

a. you must use the longest strings.
b. you must compare strings with both light and heavy weights.
c. only the lengths differ.
d. to make all possible comparisons.
e. the weights differ.

11. Twenty fruit flies are placed in each of four glass tubes. The tubes are sealed. Tubes I and II are partially covered with black paper; Tubes III and IV are not covered. The tubes are placed as shown. Then they are exposed to red light for five minutes. The number of flies in the uncovered part of each tube is shown in the drawing.



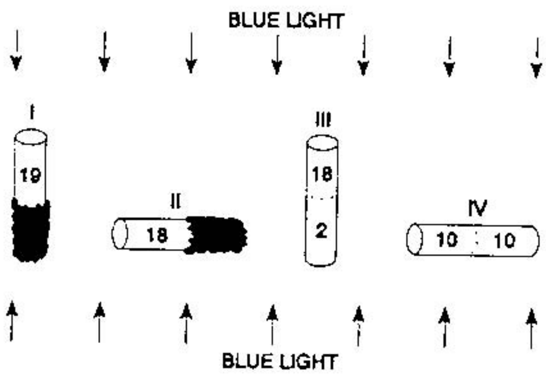
This experiment shows that flies respond to (respond means move to or away from):

a. red light but not gravity
b. gravity but not red light
c. both red light and gravity
d. neither red light nor gravity

12. *because*

a. most flies are in the upper end of Tube III but spread about evenly in Tube II.
b. most flies did not go to the bottom of Tubes I and III.
c. the flies need light to see and must fly against gravity.
d. the majority of flies are in the upper ends and in the lighted ends of the tubes.
e. some flies are in both ends of each tube.

13. In a second experiment, a different kind of fly and blue light was used. The results are shown in the drawing.



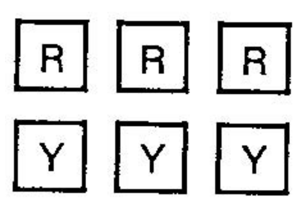
These data show that these flies respond to (respond means move to or away from):

a. blue light but not gravity
b. gravity but not blue light
c. both blue light and gravity
d. neither blue light nor gravity

14. *because*

a. some flies are in both ends of each tube.
b. the flies need light to see and must fly against gravity.
c. the flies are spread about evenly in Tube IV and in the upper end of Tube III.
d. most flies are in the lighted end of Tube II but do not go down in Tubes I and III.
e. most flies are in the upper end of Tube I and the lighted end of Tube II.

15. Six square pieces of wood are put into a cloth bag and mixed about. The six pieces are identical in size and shape, however, three pieces are red and three are yellow. Suppose someone reaches into the bag (without looking) and pulls out one piece. *What are the chances that the piece is red?*

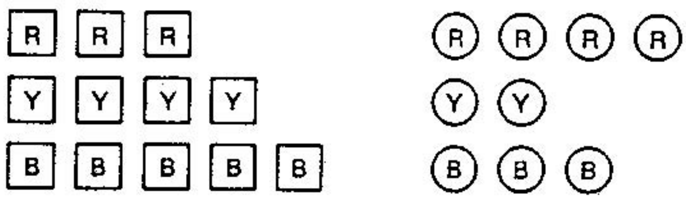


a. 1 chance out of 6
b. 1 chance out of 3
c. 1 chance out of 2
d. 1 chance out of 1
e. cannot be determined

16. *because*

a. 3 out of 6 pieces are red.
b. there is no way to tell which piece will be picked.
c. only 1 piece of the 6 in the bag is picked.
d. all 6 pieces are identical in size and shape.
e. only 1 red piece can be picked out of the 3 red pieces.

17. Three red square pieces of wood, four yellow square pieces, and five blue square pieces are put into a cloth bag. Four red round pieces, two yellow round pieces, and three blue round pieces are also put into the bag. All the pieces are then mixed about. Suppose someone reaches into the bag (without looking and without feeling for a particular shape piece) and pulls out one piece.



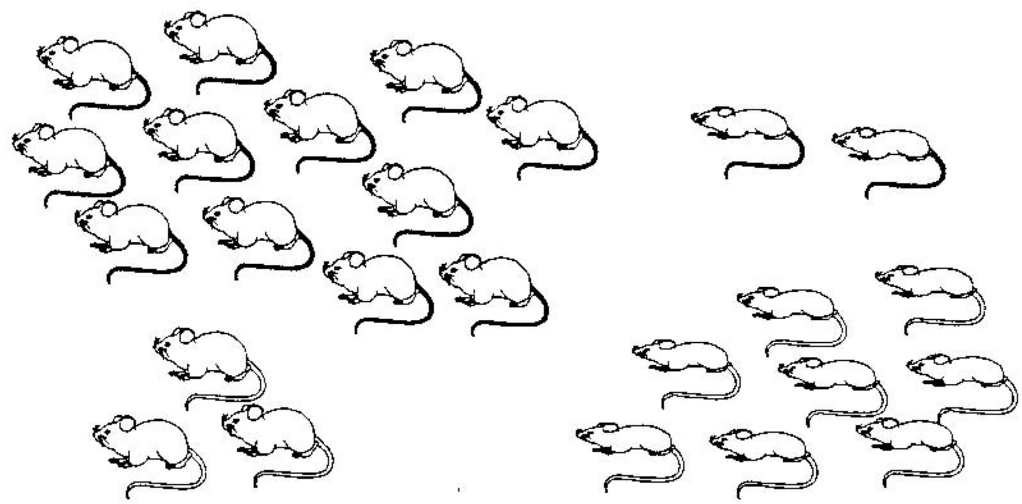
What are the chances that the piece is a red round or blue round piece?

a. cannot be determined
b. 1 chance out of 3
c. 1 chance out of 21
d. 15 chances out of 21
e. 1 chance out of 2

18. *because*

a. 1 of the 2 shapes is round.
b. 15 of the 21 pieces are red or blue.
c. there is no way to tell which piece will be picked.
d. only 1 of the 21 pieces is picked out of the bag.
e. 1 of every 3 pieces is a red or blue round piece.

19. Farmer Brown was observing the mice that live in his field. He discovered that all of them were either fat or thin. Also, all of them had either black tails or white tails. This made him wonder if there might be a link between the size of the mice and the color of their tails. So he captured all of the mice in one part of his field and observed them. Below are the mice that he captured.



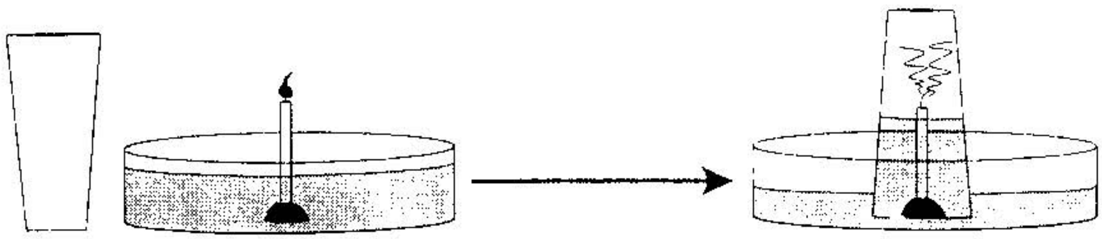
Do you think there is a link between the size of the mice and the color of their tails?

a. appears to be a link
b. appears not to be a link
c. cannot make a reasonable guess

20. *because*

a. there are some of each kind of mouse.
b. there may be a genetic link between mouse size and tail color.
c. there were not enough mice captured.
d. most of the fat mice have black tails while most of the thin mice have white tails.
e. as the mice grew fatter, their tails became darker.

21. The figure below at the left shows a drinking glass and a burning birthday candle stuck in a small piece of clay standing in a pan of water. When the glass is turned upside down, put over the candle, and placed in the water, the candle quickly goes out and water rushes up into the glass (as shown at the right).



This observation raises an interesting question: Why does the water rush up into the glass?

Here is a possible explanation. The flame converts oxygen into carbon dioxide. Because oxygen does not dissolve rapidly into water but carbon dioxide does, the newly formed carbon dioxide dissolves rapidly into the water, lowering the air pressure inside the glass.

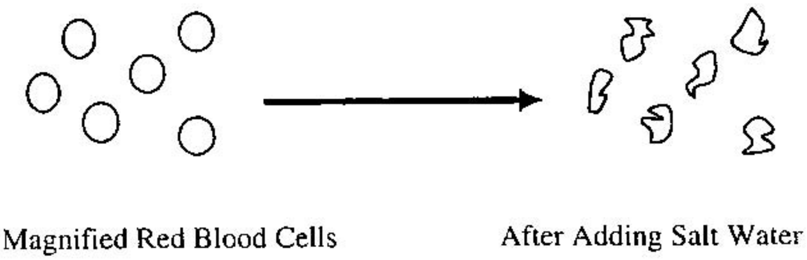
Suppose you have the materials mentioned above plus some matches and some dry ice (dry ice is frozen carbon dioxide). *Using some or all of the materials, how could you test this possible explanation?*

a. Saturate the water with carbon dioxide and redo the experiment noting the amount of water rise.
b. The water rises because oxygen is consumed, so redo the experiment in exactly the same way to show water rise due to oxygen loss.
c. Conduct a controlled experiment varying only the number of candles to see if that makes a difference.
d. Suction is responsible for the water rise, so put a balloon over the top of an open-ended cylinder and place the cylinder over the burning candle.
e. Redo the experiment, but make sure it is controlled by holding all independent variables constant; then measure the amount of water rise.

22. What result of your test (mentioned in #21 above) would show that your explanation is probably wrong?

a. The water rises the same as it did before.
b. The water rises less than it did before.
c. The balloon expands out.
d. The balloon is sucked in.

23. A student put a drop of blood on a microscope slide and then looked at the blood under a microscope. As you can see in the diagram below, the magnified red blood cells look like little round balls. After adding a few drops of salt water to the drop of blood, the student noticed that the cells appeared to become smaller.



This observation raises an interesting question: Why do the red blood cells appear smaller?

Here are two possible explanations: I. Salt ions (Na+ and Cl-) push on the cell membranes and make the cells appear smaller. II. Water molecules are attracted to the salt ions so the water molecules move out of the cells and leave the cells smaller.

To test these explanations, the student used some salt water, a very accurate weighing device, and some water-filled plastic bags, and assumed the plastic behaves just like red-blood-cell membranes. The experiment involved carefully weighing a water-filled bag, placing it in a salt solution for ten minutes and then reweighing the bag.

What result of the experiment would best show that explanation I is probably wrong?

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller

24. *What result of the experiment would best show that explanation II is probably wrong?*

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller