Appendix

A screenshot of the muddiest point prompt for Chapter 3 and examples of students' responses

Write the most confusing concept from Chapter 3.
NOTE: In Chapter 3, we discussed the Naming of ionic and molecular compounds, Mole concept of Compounds (determining moles, mass, and molecules of compounds), determining mass percent composition of elements in a compound, determining empirical and molecular formulas of compounds.

👤 Hidden

Determining the empirical and molecular formulas

Comments 🗨 0   👍 3

👤 Hidden

mass % composition of elements in conpound

Comments 🗨 0   👍 5

👤 Hidden

Determining mass percent compositions of a compound

Comments 🗨 0   👍 4

Table 1 Muddiest points reported by the participants from each chapter

Chapter	Muddiest Point Concept	Specific Muddiest Points	N	% Responses
Chapter 1- Matter, units and Measurements, Dimensional Analysis	Dimensional analysis	Unit conversions	125	40.3
		Exponents	4	1.3
	Significant figures	Applying sig figs rules in multistep calculations.	116	37.4
		Scientific notation	12	3.9
	Matter	Properties of matter	10	3.2
		Mixtures	8	2.6
		Compound/element	4	1.3
	Prefixes	-	16	5.2
	Others	Mass, volume, temperature, density, etc.	17	5.4
Chapter 2- Ions, Periodic Table, Atomic Mass	Mass and mole concept conversions	Converting between mass and moles	122	39.0
		Number of moles and number of atoms	102	32.6
	Atomic Mass	Calculating atomic mass of isotopes	52	16.6
	Subatomic Particles	Ions: Losing and gaining electrons	26	8.3
	Others	Law of conservation of mass, law of definite proportions e.tc	11	3.5
Chapter 3- Naming of ionic and molecular compounds, Mole concept of Compounds	The mole concept	Converting to moles/ mass	98	23.4
	Determination of empirical formula and molecular formula	Empirical formula	85	20.3
		Molecular formula	55	13.1
	Mass composition	Calculating mass % composition	78	18.6
	Compounds	Naming compounds	51	12.2
		Naming the compounds with transition metals	5	1.2
		Determining molecules of compounds	3	0.7
	Polyatomic ions	Naming polyatomic ions	20	4.8
	Others	Acid naming rules, charges, and cations	24	5.7

Table 1—Continued

Chapter	Muddiest Point Concept	Specific Muddiest Points	N	% Responses
Chapter 4-Balancing Chemical Reactions and Stoichiometry Reaction	Naming compounds/ Ions in a compound	Naming compounds: covalent compounds, oxyacids and/or writing chemical formulas	117	38.0
	Calculations	Theoretical yield	65	21.1
		Percent yield	41	13.3
		Actual yield	4	1.3
	Chemical reactions	Stoichiometry	24	7.8
		Balancing chemical reactions	9	2.9
		Products of a reaction	5	1.6
	Limiting reactant	Limiting reactant calculations	14	4.5
	Others	Chemical formulas, Polyatomic compounds.	29	9.5
Chapter 5-Introduction to solutions and aqueous reactions	Types of reactions	Redox reactions	100	46.3
		Acid base reactions	34	15.7
		Precipitation reactions and solubility	28	13
		Gas evolving reactions	22	10.2
	Solutions	Concentration/molarity	20	9.3
	Electrolytes	Strong/weak electrolytes	8	3.4
	Others	Molecular/ Net ionic equations	4	2.1
Chapter 6-Gases	Gases in a chemical reaction	Stoichiometry & molar volume	83	36.9
		Gas Mixture calculations/partial pressures	55	24.4
	Diffusion & Effusion of gases	Rates of effusion and diffusion, Graham's law	46	20.4
	Application of ideal gas law	Calculations involving ideal gas law: Pressure, density, mass, molar mass	37	16.4
	Others	Intermolecular forces, mean square velocity, Partial pressure.	4	1.8
Chapter 7-Thermochemistry	Hesse's law	Application of Hesse's law in calculations	65	28.0
	Calculations	Calculating enthalpies of reactions	58	25.0
	Quantifying heat& work	Thermal transfer/work/heat calculations	28	12.1
	Others	Exchanging energy between system and surrounding,	7	3.0

Table 1—Continued

Chapter	Muddiest Point Concept	Specific Muddiest Points	N	% Responses
Chapter 8- Quantum- Mechanical Model of Atom	Quantum numbers	n, l, m_l, m_s	120	40.8
	Calculations	Energy of a photon	80	27.2
		Calculations of wavelength given mass and speed	52	17.7
	Electronic transition levels of hydrogen atom	Calculations of wavelength of light for a transition in the Hydrogen atom	33	11.2
	Others	Orbitals (s, p, d, f)	9	3.1
Chapter 9- Periodic properties of elements	Orbitals	Filling orbitals	50	21.7
	Electron affinity	Electron affinity	50	21.7
	Ionization energies	Determining ionization energies of atoms	45	19.6
	Electron configuration	Electron configuration for ions	43	18.7
	Valence electrons	Valence electrons for transition elements	16	7
	Others	Trends of atomic Radii, Charge of the Nucleus, Para magnetism, etc.	26	11.3
Chapter 10- Chemical bonding/Lewis model	Resonance & formal charge	Drawing resonance structures and calculating formal charges	121	37.8
	Dot diagrams	Drawing Lewis structures of atoms	106	33.1
	Polarity	Determining polarity of molecules	70	21.9
	Bond energies & bond lengths	Bond energy calculations	13	4.1
	Others	Estimating enthalpy change of a reaction from bond energies	10	3.1

Table 2 Exam item number and assessed concepts in the three Midterm Exams and the Final Exam

Exam 1	
Exam Items	**Assessed Concepts**
M-1,2	Classification of matter- pure substances and mixtures
M-3,4,5,9	Properties of matter—physical change, separation of mixtures, chemical change, extensive versus intensive properties
M-6	Measurements—Precision and accuracy
M-7,8 S-24	Measurements—Significant figures
M-10,11 S-25,26,27	Dimensional analysis, Unit conversions, Derived Units—density & volume, Significant figures
M-12,17	Laws explained by the Atomic Theory of conservation of mass
M-13,14,15, 6,18,19,20 S-23	Periodic Table/Isotopes: Atom, elements, significant figures
S-21,22, 28	The mole concept, significant figures

Exam 2	
Exam Items	**Exam Concepts**
M-1,2	Bonding
M-3,4,5,7	Naming compounds
M-6,8	Chemical formula of compounds
M-9,12 S-26	Empirical formula/molecular formula
M-10,11	Mass percent composition
M-13 S-27	Balancing chemical reactions
M-14,15	Chemical reactions, moles, stoichiometry
M-16,17 S-28	Theoretical yield, Percent yield, Actual yield, Limiting reactants
M-18,21	Reaction types
M-19,22,23,24,25 S-29,30,31	Solutions and molarity

Exam 3	
Exam Items	**Exam Concepts**
M-1	Oxidation numbers
M-2,3	Types of reactions
M-4,5,6,7,9, 10,16,18	Gas laws, Ideal gas law
M-8	Grahams law of diffusion
M-11	Rates of effusion
M-12	Exchanging heat between system and surrounding.
M-13,14,15, 17,19,20,21	Enthalpy changes

Note: M and S denotes multiple-choice questions and short-answer questions, respectively.

Table 2—Continued

Final Exam	
Exam Items	**Exam Concepts**
M-1	Significant figures
M-2	Dimensional analysis/Unit conversions
M-3, 4	Elements, Isotopes
M-7, 8	Mole Concept, Stoichiometry: Limiting reactant, theoretical yield
M-5	Chemical formula of compounds
M-6	Empirical formula
M-9, 10	Oxidation states and redox reactions
M-11,12	Gas laws
M-13,14	Energy
M-15,16,17, 18	Quantum numbers and orbital
M-19, 20	Orbital diagrams, Paramagnetic/diamagnetic species
M-21	Electron Configuration
M-22	Trends of atomic Radii
M-23	Ionization energy
M-24	Electronegativity of elements
M-25	Polarity of molecules
M-26,27	Bond energies
M-28,29,30	Hybridization
S-31,32,33	Valence Bond Theory: Lewis dot structures, valence electrons, resonance structures, electron and molecular geometry, and formal charge
S-34	Stoichiometry: Titration calculations

Note: M and S denotes multiple-choice questions and short-answer questions, respectively.

Table 3 Reliability test results for Exam 1

	Multiple-Choice Questions Cronbach's Alpha=.767 Cronbach's Alpha Based on Standardized Items=.761 N of Items=20			
	Item Statistics			**Item-Total Statistics**
Exam items	**Mean**	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Exam 1 qn 1	.95	.223	326	.071
Exam 1 qn 2	.57	.496	326	.317
Exam 1 qn 3	.71	.457	326	.273
Exam 1 qn 4	.86	.345	326	.199
Exam 1 qn 5	.83	.372	326	.216
Exam 1 qn 6	.79	.411	326	.003
Exam 1 qn 7	.93	.256	326	.210
Exam 1 qn 8	.43	.496	326	.122
Exam 1 qn 9	.71	.452	326	.330
Exam 1 qn 10	.82	.388	326	.308
Exam 1 qn 11	.39	.488	326	.398
Exam 1 qn 12	.68	.467	326	.383
Exam 1 qn 13	.78	.418	326	.325
Exam 1 qn 14	.92	.276	326	.246
Exam 1 qn 15	.93	.262	326	.202
Exam 1 qn 16	.83	.372	326	.153
Exam 1 qn 17	.61	.488	326	.230
Exam 1 qn 18	.79	.405	326	.255
Exam 1 qn 19	.74	.438	326	.245
Exam 1 qn 20	.65	.479	326	.375

	Short-Answer Questions Cronbach's Alpha=.767 Cronbach's Alpha Based on Standardized Items=.761 N of Items=20			
	Item Statistics			**Item-Total Statistics**
Exam items	**Mean**	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Exam 1 qn 21	3.673	1.5105	330	.651
Exam 1 qn 22	3.776	1.6970	330	.616
Exam 1 qn 23	4.045	1.6053	330	.492
Exam 1 qn 24	3.558	1.4726	330	.386
Exam 1 qn 25	3.903	1.7757	330	.325
Exam 1 qn 26	2.923	1.2974	330	.558
Exam 1 qn 27	4.427	1.1057	330	.484
Exam 1 qn 28	3.212	1.8278	330	.587

Table 4 Reliability test results for Exam 2

Multiple-Choice Questions
Cronbach's Alpha=.820
Cronbach's Alpha Based on Standardized Items=.819
N of Items=25

Exam items	**Item Statistics**			**Item-Total Statistics**
	Mean	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Exam2 qn1	.68	.466	315	.389
Exam2 qn2	.65	.476	315	.317
Exam2 qn3	.47	.500	315	.453
Exam2 qn4	.49	.501	315	.312
Exam2 qn5	.29	.452	315	.346
Exam2 qn6	.58	.494	315	.406
Exam2 qn7	.56	.497	315	.260
Exam2 qn8	.71	.454	315	.465
Exam2 qn9	.81	.391	315	.354
Exam2 qn10	.71	.455	315	.365
Exam2 qn11	.54	.499	315	.389
Exam2 qn12	.76	.429	315	.317
Exam2 qn13	.85	.357	315	.453
Exam2 qn14	.65	.478	315	.312
Exam2 qn15	.60	.491	315	.346
Exam2 qn16	.61	.489	315	.406
Exam2 qn17	.92	.271	315	.260
Exam2 qn18	.73	.445	315	.465
Exam2 qn19	.41	.493	315	.354
Exam2 qn20	.59	.492	315	.365
Exam2 qn21	.41	.492	315	.389
Exam2 qn22	.41	.492	315	.317
Exam2 qn23	.89	.319	315	.453
Exam2 qn24	.74	.441	315	.312
Exam2 qn25	.48	.500	315	.346

Short-Answer Questions
Cronbach's Alpha=.769
Cronbach's Alpha Based on Standardized Items=.812
N of Items=6

Exam items	**Item Statistics**			**Item-Total Statistics**
	Mean	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Exam2 qn26	4.0136	1.72560	295	.370
Exam2 qn27	1.5492	1.28791	295	.602
Exam2 qn28	3.7763	2.42663	295	.632
Exam2 qn29	1.1788	.87653	295	.577
Exam2 qn30	.8178	1.02978	295	.634
Exam2 qn31	1.9975	1.35753	295	.579

Table 5 Reliability test results for Exam 3

Multiple-Choice Questions				
Cronbach's Alpha=.769				
Cronbach's Alpha Based on Standardized Items=.769				
N of Items=15				
Item Statistics				**Item-Total Statistics**
Exam items	**Mean**	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Exam 3 qn 1	.57	.496	317	.369
Exam 3 qn 2	.45	.498	317	.335
Exam 3 qn 3	.40	.491	317	.263
Exam 3 qn 4	.37	.484	317	.240
Exam 3 qn 5	.59	.493	317	.386
Exam 3 qn 6	.39	.489	317	.221
Exam 3 qn 7	.64	.482	317	.264
Exam 3 qn 8	.47	.500	317	.218
Exam 3 qn 9	.72	.449	317	.291
Exam 3 qn 10	.40	.491	317	.407
Exam 3 qn 11	.24	.430	317	.353
Exam 3 qn12	.69	.462	317	.352
Exam 3 qn 13	.60	.491	317	.253
Exam 3 qn 14	.50	.501	317	.405
Exam 3 qn 15	.28	.449	317	.244
Short-Answer Questions				
Cronbach's Alpha=.782				
Cronbach's Alpha Based on Standardized Items=.789				
N of Items=6				
Item Statistics				**Item-Total Statistics**
Exam items	**Mean**	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Exam3 qn 16	1.927	2.6942	315	.468
Exam3 qn17	1.590	1.8344	315	.574
Exam3 qn 18	2.930	2.2228	315	.556
Exam3 qn 19	2.514	2.3129	315	.519
Exam3 qn 20	4.300	3.3474	315	.674
Exam3 qn 21	2.841	2.2092	315	.467

Table 6 Reliability test results for the Final Exam

	Multiple-Choice Questions Cronbach's Alpha=.784 Cronbach's Alpha Based on Standardized Items=.716 N of Items=30			
	Item Statistics			**Item-Total Statistics**
Exam items	**Mean**	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Final qn1	.65	.477	308	.116
Final qn2	.79	.411	308	.252
Final qn3	.76	.428	308	.276
Final qn4	.01	.113	308	-.116
Final qn5	.52	.501	308	.392
Final qn6	.66	.476	308	.321
Final qn7	.16	.363	308	-.049
Final qn8	.56	.498	308	.552
Final qn9	.49	.501	308	.417
Final qn10	.44	.497	308	.244
Final qn11	.57	.496	308	.287
Final qn12	.42	.494	308	.244
Final qn13	.64	.480	308	.134
Final qn14	.48	.500	308	.321
Final qn15	.18	.384	308	.311
Final qn16	.24	.430	308	.331
Final qn17	.75	.432	308	.049
Final qn18	.57	.496	308	.370
Final qn19	.82	.386	308	.402
Final qn20	.22	.415	308	.308
Final qn21	.40	.491	308	.280
Final qn22	.08	.274	308	-.138
Final qn23	.42	.495	308	.258
Final qn24	.43	.496	308	.290
Final qn25	.21	.406	308	.244
Final qn26	.71	.456	308	.385
Final qn27	.38	.486	308	.032
Final qn28	.60	.490	308	.359
Final qn29	.36	.481	308	.315
Final qn30	.77	.422	308	.311
	Short-Answer Questions Cronbach's Alpha=.823 Cronbach's Alpha Based on Standardized Items=.827 N of Items=4			
	Item Statistics			**Item-Total Statistics**
Exam items	**Mean**	**Std. Deviation**	**N**	**Corrected Item-Total Correlation**
Final qn31	2.6076	2.13426	316	.670
Final qn 32	3.1155	2.28628	316	.666
Final qn 33	3.3244	2.14439	316	.721
Final qn 34	3.2666	2.46055	316	.546

Table 7 Results of multivariate tests (Multivariate Analysis of Covariance—MANCOVA)

Between-Subjects Factors		N	
FA type	Control group	173	
	Treatment group	100	
Gender	Male	94	
	Female	174	
Race/ ethnicity	Majority	194	
	Minority	79	
First Gen	Non-first-generation status	242	
	First-generation status	31	

Multivariate Tests[a]

Effect	Wilks' Lambda	F	df	Error df	Sig.	η_p^2
Intercept	.653	33.656[b]	4.000	253.000	.000	.347
ACT Math	.590	44.039[b]	4.000	253.000	.000	.410
FA type	.963	2.423[b]	4.000	253.000	.049**	.037
Gender	.988	.759[b]	4.000	253.000	.553	.012
Race/ethnicity	.991	.572[b]	4.000	253.000	.683	.009
First-generation status	.991	.560[b]	4.000	253.000	.692	.009
FA type * Gender	.977	1.512[b]	4.000	253.000	.199	.023
FA type * Race/ethnicity	.967	2.170[b]	4.000	253.000	.073	.033
FA type * First-generation status	.980	1.324[b]	4.000	253.000	.262	.020
Gender* Race/ethnicity	.995	.305[b]	4.000	253.000	.874	.005
Gender * First-generation status	.986	.926[b]	4.000	253.000	.449	.014
Race/ethnicity* First-generation status	.992	.536[b]	4.000	253.000	.709	.008
FA type * Gender * Race/ethnicity	.992	.493[b]	4.000	253.000	.741	.008
FA type * Gender * First-generation	.975	1.617[b]	4.000	253.000	.170	.025
FA type * Race/ethnicity * First-generation status	.960	2.653[b]	4.000	253.000	.034**	.040
Gender * Race/ ethnicity* First-generation status	.993	.431[b]	4.000	253.000	.786	.007
FA type* Gender * Race/ ethnicity* First-generation	.980	1.293[b]	4.000	253.000	.273	.020

Note: Bolded independent variables and **indicates statistically significant interaction (p < .05).

a. Design: Intercept + ACT Math + FA type + Gender+ Race/ ethnicity + First-generation status + FA type * Gender+ FA type * Race/ ethnicity+ FA type * First-generation status + Gender* Race/ ethnicity + Gender * First-generation + Race/ethnicity * First-generation status + FA type * Gender * Race/ethnicity+ FA type * Gender * First-generation status + FA type * Race/ethnicity * First-generation status + Gender * Race/ethnicity* First-generation status + FA type * Gender * Race/ ethnicity* First-generation status.

b. Exact Statistic

Table 8 Descriptive statistics results showing the opportunity gap by demographics between the treatment group and the comparison group in the Midterms and the Final Exam

Demographics	Trt-Ctl	Demographic Groups	Statistic	Exam 1 (%)	Exam 2 (%)	Exam 3 (%)	Final Exam (%)
Race	Ctl	Majority	Mean	74.21	60.26	45.21	49.30
			N	138	137	136	135
			Std. Error	1.35	1.79	1.78	1.57
		Minority	Mean	67.38	52.66	39.40	45.21
			N	70	71	68	67
			Std. Error	1.97	2.32	2.35	1.90
			Opportunity gap (%)	**6.9**	**7.6**	**5.8**	**4.1**
	Trt	Majority	Mean	79.16	64.06	49.82	50.57
			N	86	87	86	87
			Std. Error	2.34	3.19	3.84	2.77
		Minority	Mean	75.62	58.30	46.47	48.16
			N	29	29	29	29
			Std. Error	2.34	3.19	3.84	2.77
			Opportunity gap (%)	**3.5**	**5.8**	**3.4**	**2.4**
First-gen status	Ctl	Non-first gen.	Mean	73.75	59.79	45.53	49.62
			N	188	189	185	183
			Std. Error	1.12	1.50	1.51	1.33
		First gen.	Mean	61.17	47.70	33.19	41.33
			N	33	32	32	31
			Std. Error	3.13	3.51	3.14	3.04
			Opportunity gap (%)	**12.6**	**22.1**	**12.3**	**8.3**
	Trt	Non-first gen.	Mean	79.12	63.63	50.12	51.08
			N	102	103	102	103
			Std. Error	1.21	1.76	1.87	1.50
		First gen.	Mean	73.32	56.48	42.50	42.47
			N	14	14	14	14
			Std. Error	3.88	4.20	5.74	3.68
			Opportunity gap (%)	**5.8**	**7.2**	**7.6**	**8.6**

Table 8—Continued

Demographics	Trt-Ctl	Demographic Groups	Statistic	Exam 1 (%)	Exam 2 (%)	Exam 3 (%)	Final Exam (%)
Gender	Ctl	Male	Mean	70.60	58.23	44.32	47.31
			N	77	77	78	75
			Std. Error	1.92	2.45	2.34	2.20
		Female	Mean	72.54	57.93	43.37	49.02
			N	144	144	139	139
			Std. Error	1.34	1.72	1.75	1.48
			Opportunity gap (%)	**1.94**	**0.3**	**0.95**	**1.71**
	Trt	Male	Mean	79.27	62.73	49.34	50.64
			N	42	42	41	42
			Std. Error	1.78	2.73	3.12	2.60
		Female	Mean	77.94	62.80	49.12	49.72
			N	74	75	75	75
			Std. Error	1.53	2.06	2.20	1.66
			Opportunity gap (%)	**1.33**	**0.07**	**0.22**	**0.92**