

## SUPPLEMENTARY INFORMATION

## Using HOTS-Based Chemistry National Exam Questions to Map the Analytical Abilities of Senior High School Students

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### Table Lists

**Table S1** Framework of HOTS items

Items	Content of HOTS	HOTS Level Measuring	Maximum Score
1	Periodicity Properties of Elements	C4	5
2	Acid-Base Titration	C4	5
3	Salt Hydrolysis and Solubility Product	C4	5
4	Voltaic Cell	C4	5
5	Polymer	C4	5

**Table S2** HOTS questions

Items	Content of HOTS	HOTS Questions
1	Periodicity Properties of Elements	Two elements, X and Y have electron affinity values of 240 kJ/mol and -349 kJ/mol, respectively. Based on this data, explain: a. comparison of the stability of the element X and its ions! b. the electronegativity of the elements X and Y!
2	Acid-Base Titration	Titration of 10 mL of 0.1 M nitric acid solution with NaOH solution was carried out and the endpoint of the titration was reached after adding 20 mL of titrant solution (Ar Na = 23, Ar O = 16, Ar H = 1). Determine the mass of NaOH dissolved in 20 mL of the NaOH solution!
3	Salt Hydrolysis and Solubility Product	A total of 100 mL 0.008 M NaOH solution is reacted with 100 mL 0.008 M CH <sub>3</sub> COOH solution into this mixture, drops of aqueous calcium chloride solution and terminated when the saturated solution settles as calcium hydroxide. Determine the concentration of calcium ions when fully saturated! ( $K_w = 10^{-14}$ , $K_a = 10^{-5}$ , $K_b = 10^{-5}$ , $K_{sp} \text{ Ca (OH)}_2 = 4 \times 10^{-16}$ )
4	Voltaic Cell	The following half-cell reaction is known: a. $\text{Mg}^{2+}_{(aq)} + 2e \longrightarrow \text{Mg}_{(s)}$ $E^0 = -2,37$ Volt b. $\text{Pb}^{2+}_{(aq)} + 2e \longrightarrow \text{Pb}_{(s)}$ $E^0 = -0,13$ Volt c. $\text{Cu}^{2+}_{(aq)} + 2e \longrightarrow \text{Cu}_{(s)}$ $E^0 = +0,34$ Volt d. $\text{Mn}^{2+}_{(aq)} + 2e \longrightarrow \text{Mn}_{(s)}$ $E^0 = -1,18$ Volt Based on these reactions, design and explain various possible cell notations that show spontaneous reactions!
5	Polymer	Similar and unequal monomers have potential to react with each other to form polymers. Explain the polymerization reaction between hexanediol dichloride and 1,6-diamino hexane!

**Table S3** Score of students at XII Natural Science 4, SMA A

Code of Students	Items					Total Score
	1	2	3	4	5	
A	2	0	0	1	0	3
B	1	3	1	5	0	10
C	2	5	1	4	0	12
D	1	1	1	5	1	9
E	0	3	5	5	0	13
F	2	2	1	5	1	11
G	2	2	1	1	1	7
H	1	0	0	5	2	8
I	0	1	1	5	0	7
J	0	0	1	1	0	2
K	2	1	1	5	1	10
L	1	3	2	5	1	12
M	0	1	0	4	0	5
N	2	1	1	5	0	9
O	0	0	0	5	0	5
P	2	4	0	4	0	10
Q	0	0	1	5	0	6
R	2	2	5	5	0	14
S	2	4	0	5	2	13
T	2	1	1	5	1	10
U	0	1	0	3	0	4
V	2	2	1	1	1	7
W	1	1	1	5	0	8
X	3	1	1	5	0	10
Y	2	4	0	5	0	11
Z	3	1	0	2	0	6
AB	2	4	1	5	3	15
AC	1	2	1	3	0	7
AD	0	1	2	3	0	6
AE	0	1	2	3	0	6
AF	2	4	2	1	1	10
AG	0	1	2	5	0	8
AH	0	0	1	4	0	5
AI	0	0	0	5	0	5

**Table S4** Score of students at XII Natural Science 6, SMA B

Code of Students	Items					Total Score
	1	2	3	4	5	
A	0	4	2	5	0	11
B	1	2	0	1	0	4
C	0	3	1	2	1	7
D	2	1	1	1	0	5
E	2	1	1	1	0	5
F	2	5	1	1	1	10
G	2	3	2	1	1	9
H	0	2	1	1	0	4
I	0	3	1	4	0	8
J	1	2	1	1	1	6
K	0	4	1	5	0	10
L	0	4	1	1	0	6
M	2	3	1	1	0	7
N	0	3	1	3	0	7
O	0	3	1	4	0	8
P	2	3	1	3	0	9
Q	0	3	1	2	0	6
R	0	3	1	5	1	10
S	2	1	1	1	0	5
T	2	3	1	4	1	11
U	0	5	1	5	0	11
V	2	1	1	0	0	4
W	1	0	1	1	0	3
X	0	1	0	1	1	3
Y	0	3	0	4	1	8
Z	1	3	0	1	0	5
AB	0	5	1	1	0	7
AC	0	3	0	1	0	4
AD	2	3	5	1	2	13
AE	2	3	5	1	2	13

## Figure Lists

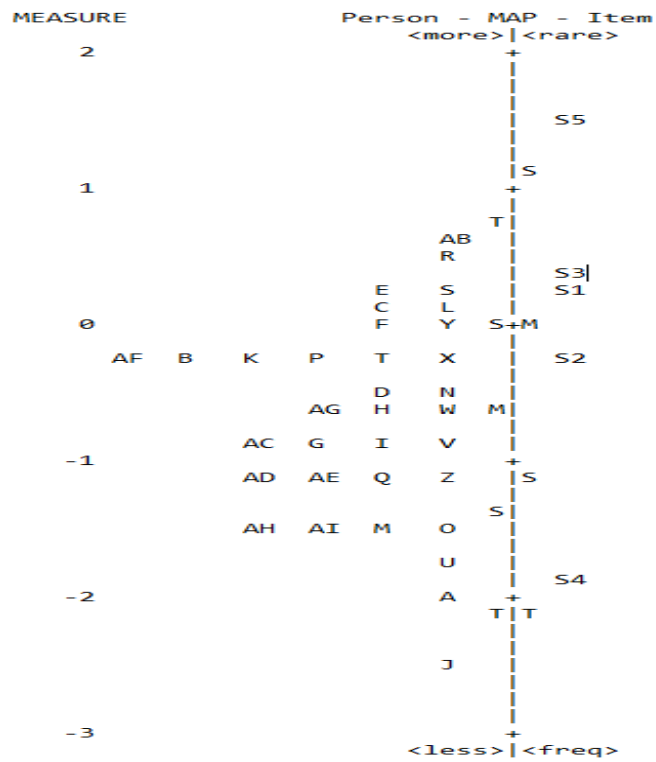


Figure S1 Variable map of XII Natural Science 4

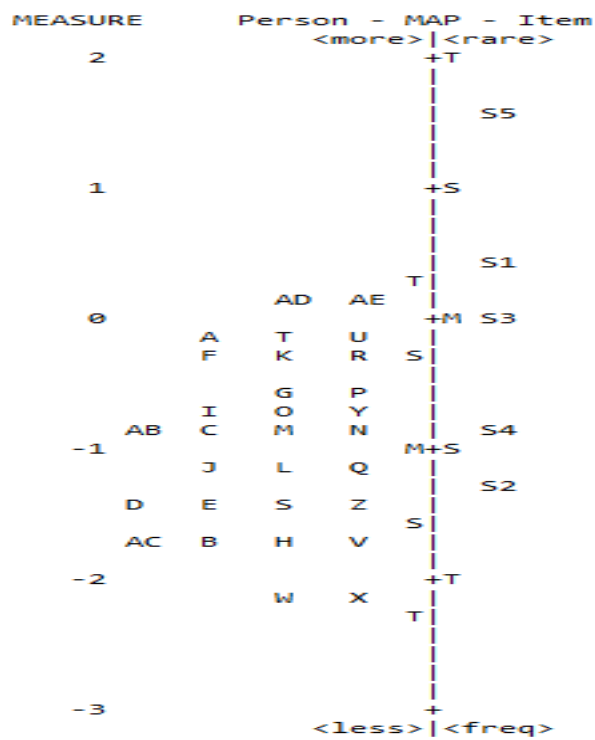


Figure S2 Variable map of XII Natural Science 6

SUMMARY OF 34 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	8.4	5.0	-.67	.48	1.04	.06	1.08	.11
SEM	.6	.0	.13	.01	.15	.18	.18	.17
P.SD	3.2	.0	.74	.07	.84	1.01	1.04	.96
S.SD	3.2	.0	.75	.07	.85	1.02	1.06	.98
MAX.	15.0	5.0	.59	.78	3.71	2.29	5.75	3.04
MIN.	2.0	5.0	-2.54	.38	.14	-1.74	.17	-1.26
REAL RMSE	.56	TRUE SD	.48	SEPARATION	.85	Person RELIABILITY	.42	
MODEL RMSE	.49	TRUE SD	.55	SEPARATION	1.13	Person RELIABILITY	.56	
S.E. OF Person MEAN = .13								

Person RAW SCORE-TO-MEASURE CORRELATION = .99  
 CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .37 SEM = 2.52

SUMMARY OF 5 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	56.8	34.0	.00	.19	1.08	.25	1.08	.18
SEM	20.7	.0	.54	.02	.13	.48	.15	.44
P.SD	41.3	.0	1.08	.05	.26	.96	.29	.88
S.SD	46.2	.0	1.21	.05	.29	1.07	.32	.99
MAX.	135.0	34.0	1.47	.28	1.41	1.46	1.54	1.26
MIN.	15.0	34.0	-1.86	.15	.72	-1.19	.66	-1.35
REAL RMSE	.21	TRUE SD	1.06	SEPARATION	4.95	Item RELIABILITY	.96	
MODEL RMSE	.20	TRUE SD	1.06	SEPARATION	5.37	Item RELIABILITY	.97	
S.E. OF Item MEAN = .54								

Item RAW SCORE-TO-MEASURE CORRELATION = -.98  
 Global statistics: please see Table 44.  
 UMEAN=.0000 USCALE=1.0000

Figure S3 Person and item reliability of XII Natural Science 4

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT		OUTFIT		PTMEASUR-AL		EXACT MATCH		Item
					MNSQ	ZSTD	MNSQ	ZSTD	CORR.	EXP.	OBS%	EXP%	
5	15	34	1.47	.28	1.17	.59	.93	-.08	.45	.36	61.8	61.5	S5
3	37	34	.35	.18	1.25	.87	1.07	.34	.40	.50	47.1	41.6	S3
1	40	34	.25	.18	.84	-.48	1.20	.73	.50	.52	35.3	41.6	S1
2	57	34	-.20	.15	.72	-1.19	.66	-1.35	.73	.59	41.2	36.9	S2
4	135	34	-1.86	.16	1.41	1.46	1.54	1.26	.54	.63	47.1	48.9	S4
MEAN	56.8	34.0	.00	.19	1.08	.3	1.08	.2			46.5	46.1	
P.SD	41.3	.0	1.08	.05	.26	1.0	.29	.9			8.8	8.6	

Figure S4 Ability of students of XII Natural Science 4

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL	INFIT		OUTFIT		PTMEASUR-	AL-	EXACT OBS%	MATCH EXP%	Person
				S.E.	MNSQ	ZSTD	MNSQ	ZSTD	CORR.	EXP.			
27	15	5	.59	.38	1.01	.20	1.29	.60	.64	.72	40.0	37.8	AB
18	14	5	.45	.38	1.53	.98	1.26	.57	.71	.73	40.0	42.6	R
5	13	5	.30	.39	2.19	1.65	1.80	1.01	.67	.75	40.0	42.7	E
19	13	5	.30	.39	.95	.13	1.00	.32	.71	.75	40.0	42.7	S
3	12	5	.14	.40	1.09	.36	1.17	.48	.76	.77	20.0	41.8	C
12	12	5	.14	.40	.17	-1.74	.17	-1.16	.93	.77	80.0	41.8	L
6	11	5	-.03	.43	.14	-1.69	.17	-1.21	.93	.79	80.0	42.9	F
25	11	5	-.03	.43	.99	.23	.84	.11	.87	.79	40.0	42.9	Y
2	10	5	-.22	.45	.33	-.88	.33	-.77	.96	.80	60.0	46.0	B
11	10	5	-.22	.45	.39	-.73	.35	-.74	.86	.80	60.0	46.0	K
16	10	5	-.22	.45	1.35	.65	1.12	.43	.80	.80	.0	46.0	P
20	10	5	-.22	.45	.39	-.73	.35	-.74	.86	.80	60.0	46.0	T
24	10	5	-.22	.45	.85	.08	.77	.00	.87	.80	40.0	46.0	X
31	10	5	-.22	.45	3.71	2.29	5.75	3.04	.00	.80	20.0	46.0	AF
4	9	5	-.44	.48	.25	-.99	.30	-.91	.86	.81	60.0	50.1	D
14	9	5	-.44	.48	.37	-.69	.39	-.70	.93	.81	60.0	50.1	N
8	8	5	-.68	.50	1.49	.79	2.33	1.49	.61	.80	20.0	43.6	H
23	8	5	-.68	.50	.20	-1.16	.21	-1.26	.95	.80	80.0	43.6	W
32	8	5	-.68	.50	.74	-.06	.80	-.01	.88	.80	40.0	43.6	AG
7	7	5	-.93	.50	2.84	1.87	2.07	1.33	-.02	.78	20.0	44.9	G
9	7	5	-.93	.50	.49	-.55	.45	-.67	.91	.78	60.0	44.9	I
22	7	5	-.93	.50	2.84	1.87	2.07	1.33	-.02	.78	20.0	44.9	V
28	7	5	-.93	.50	.45	-.65	.37	-.85	.98	.78	60.0	44.9	AC
17	6	5	-1.19	.50	.97	.18	.76	-.10	.85	.75	40.0	44.1	Q
26	6	5	-1.19	.50	2.02	1.40	2.45	1.63	.50	.75	40.0	44.1	Z
29	6	5	-1.19	.50	.66	-.34	1.00	.25	.81	.75	60.0	44.1	AD
30	6	5	-1.19	.50	.66	-.34	1.00	.25	.81	.75	60.0	44.1	AE
13	5	5	-1.44	.51	.46	-.84	.41	-.73	.91	.71	40.0	43.2	M
15	5	5	-1.44	.51	1.42	.78	.89	.11	.86	.71	20.0	43.2	O
33	5	5	-1.44	.51	.60	-.50	.60	-.36	.85	.71	40.0	43.2	AH
34	5	5	-1.44	.51	1.42	.78	.89	.11	.86	.71	20.0	43.2	AI
21	4	5	-1.72	.55	.27	-1.09	.32	-.86	.92	.66	80.0	56.9	U
1	3	5	-2.06	.63	1.48	.75	2.24	1.29	.32	.61	60.0	64.9	A
10	2	5	-2.54	.78	.51	-.13	.87	.27	.57	.55	80.0	74.2	J

Figure S5 The difficulty of items of XII Natural Science 4

SUMMARY OF 30 MEASURED Person									
	TOTAL		MEASURE	MODEL	INFIT		OUTFIT		
	SCORE	COUNT		S.E.	MNSQ	ZSTD	MNSQ	ZSTD	
MEAN	7.3	5.0	-.95	.49	.94	-.02	1.00	.10	
SEM	.5	.0	.12	.01	.13	.17	.12	.14	
P.SD	2.8	.0	.64	.08	.71	.92	.63	.77	
S.SD	2.9	.0	.65	.08	.72	.94	.65	.78	
MAX.	13.0	5.0	.18	.69	3.24	2.43	2.96	2.14	
MIN.	3.0	5.0	-2.14	.42	.21	-1.49	.27	-1.08	
REAL RMSE	.54	TRUE SD	.34	SEPARATION	.63	Person RELIABILITY	.29		
MODEL RMSE	.50	TRUE SD	.39	SEPARATION	.79	Person RELIABILITY	.39		
S.E. OF Person MEAN	= .12								
Person RAW SCORE-TO-MEASURE CORRELATION = .99									
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .24 SEM = 2.47									
SUMMARY OF 5 MEASURED Item									
	TOTAL		MEASURE	MODEL	INFIT		OUTFIT		
	SCORE	COUNT		S.E.	MNSQ	ZSTD	MNSQ	ZSTD	
MEAN	43.8	30.0	.00	.22	1.04	.05	1.00	-.11	
SEM	12.9	.0	.51	.03	.16	.63	.20	.65	
P.SD	25.7	.0	1.02	.07	.32	1.26	.40	1.30	
S.SD	28.8	.0	1.14	.07	.36	1.40	.44	1.45	
MAX.	83.0	30.0	1.59	.34	1.48	1.35	1.70	1.95	
MIN.	12.0	30.0	-1.31	.15	.58	-2.05	.62	-1.57	
REAL RMSE	.24	TRUE SD	.99	SEPARATION	4.06	Item RELIABILITY	.94		
MODEL RMSE	.23	TRUE SD	.99	SEPARATION	4.34	Item RELIABILITY	.95		
S.E. OF Item MEAN	= .51								

Figure S6 Person and item reliability of XII Natural Science 6

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-CORR.	AL-EXP.	EXACT OBS%	MATCH EXP%	Person
29	13	5	.18	.42	3.24	2.43	2.96	2.14	.05	.77	20.0	28.5	AD
30	13	5	.18	.42	3.24	2.43	2.96	2.14	.05	.77	20.0	28.5	AE
1	11	5	-.17	.42	.93	.11	.93	.12	.89	.74	40.0	35.1	A
20	11	5	-.17	.42	.49	-.79	.48	-.77	.78	.74	20.0	35.1	T
21	11	5	-.17	.42	1.22	.54	1.19	.49	.90	.74	.0	35.1	U
6	10	5	-.35	.42	1.17	.46	.96	.16	.60	.72	20.0	34.6	F
11	10	5	-.35	.42	1.15	.43	1.06	.31	.87	.72	20.0	34.6	K
18	10	5	-.35	.42	1.21	.52	1.06	.31	.70	.72	20.0	34.6	R
7	9	5	-.53	.43	.80	-.14	.81	-.09	.55	.69	20.0	43.6	G
16	9	5	-.53	.43	.31	-1.33	.48	-.75	.91	.69	80.0	43.6	P
9	8	5	-.72	.44	.79	-.15	.77	-.13	.87	.67	60.0	44.4	I
15	8	5	-.72	.44	.79	-.15	.77	-.13	.87	.67	60.0	44.4	O
25	8	5	-.72	.44	1.09	.36	1.21	.51	.68	.67	20.0	44.4	Y
3	7	5	-.93	.46	.23	-1.49	.53	-.59	.76	.64	60.0	45.5	C
13	7	5	-.93	.46	.54	-.59	.78	-.11	.72	.64	60.0	45.5	M
14	7	5	-.93	.46	.40	-.95	.50	-.66	.92	.64	60.0	45.5	N
27	7	5	-.93	.46	1.42	.78	1.04	.29	.78	.64	40.0	45.5	AB
10	6	5	-1.15	.49	.28	-1.18	.52	-.59	.64	.60	60.0	44.5	J
12	6	5	-1.15	.49	.87	.06	.68	-.26	.80	.60	40.0	44.5	L
17	6	5	-1.15	.49	.26	-1.27	.35	-.99	.93	.60	60.0	44.5	Q
4	5	5	-1.41	.53	.92	.15	1.25	.56	.34	.57	60.0	49.5	D
5	5	5	-1.41	.53	.92	.15	1.25	.56	.34	.57	60.0	49.5	E
19	5	5	-1.41	.53	.92	.15	1.25	.56	.34	.57	60.0	49.5	S
26	5	5	-1.41	.53	.58	-.37	.56	-.45	.77	.57	60.0	49.5	Z
2	4	5	-1.73	.60	.33	-.80	.44	-.66	.78	.53	60.0	52.6	B
8	4	5	-1.73	.60	.21	-1.13	.27	-1.08	.89	.53	100.0	52.6	H
22	4	5	-1.73	.60	1.47	.76	1.89	1.17	.07	.53	40.0	52.6	V
28	4	5	-1.73	.60	.96	.24	.72	-.13	.80	.53	60.0	52.6	AC
23	3	5	-2.14	.69	1.03	.33	.87	.12	.11	.49	40.0	63.6	W
24	3	5	-2.14	.69	.55	-.30	1.47	.77	.22	.49	80.0	63.6	X
MEAN	7.3	5.0	-.95	.49	.94	.0	1.00	.1			46.7	44.6	
P.SD	2.8	.0	.64	.08	.71	.9	.63	.8			22.7	8.5	

Figure S7 Students' ability of XII Natural Science 6

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-CORR.	AL-EXP.	EXACT OBS%	MATCH EXP%	Item
5	12	30	1.59	.34	.95	-.05	.90	-.21	.49	.32	66.7	64.8	S5
1	26	30	.49	.24	1.48	1.35	1.70	1.95	.11	.42	23.3	51.2	S1
3	35	30	.05	.20	.88	-.32	.62	-1.34	.61	.47	56.7	44.7	S3
4	63	30	-.82	.16	1.34	1.33	1.14	.60	.56	.59	40.0	35.1	S4
2	83	30	-1.31	.15	.58	-2.05	.65	-1.57	.68	.62	46.7	27.1	S2
MEAN	43.8	30.0	.00	.22	1.04	.1	1.00	-.1			46.7	44.6	
P.SD	25.7	.0	1.02	.07	.32	1.3	.40	1.3			14.8	13.0	

Figure S8 Difficulty items of XII Natural Science